



Developing a managerial framework for handling radioactive material in South Africa's scrap metal industry

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The bottom of the cover features abstract, flowing wavy lines in shades of blue and teal, mirroring the design at the top.

DECLARATION

I, K V Mookodi, declare that the dissertation titled:

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is my original work, except where otherwise stated. Consulted sources are acknowledged by explicit referencing. A reference list is appended. Furthermore, I declare that I have not submitted this dissertation at any other institution before for degree purposes.

Signature

date

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ABSTRACT

The study is conducted to develop the managerial framework for handling radioactive material that can be adopted across the South African scrap metal industry to minimise risks and ensure proper handling and disposal of radioactive materials.

Exposure to high levels of radiation poses serious health risks; workers processing scrap material may be at greater risk if they handle radioactive materials, especially if materials are not properly managed. The risk is higher for scrap processors who may not have the necessary knowledge or resources to identify and handle radioactive materials, leading to potential mishandling and increased health risks. This gap in knowledge and lack of resources increases the likelihood of radioactive materials being mishandled. Therefore, a managerial framework for handling radioactive material that can be adopted across the scrap metal industry needs to be developed.

The study employed a qualitative research approach, chosen for its ability to provide the in-depth insights needed from managers and radiation protection officers and specialists of the scrap recyclers and processors to effectively address the research questions. Semi-structured interview questions were distributed to participants in advance, allowing them ample time to prepare for the interviews, which were conducted via Teams platform. The data collected was analysed using ATLAS.ti software to identify common codes, categories and themes across the dataset.

The study provided an in-depth analysis of the intersection between metal scrap recycling and radioactive material management, focusing on the South African context. It outlined the economic and environmental benefits of metal recycling and the growing global demand driven by sustainability and decarbonisation efforts. The study also explored the sources and risks of radioactive contamination in scrap, drawing on international case studies and IAEA guidelines. South Africa's regulatory frameworks, including the National Nuclear Regulator Act 47 of 1999, and Hazardous Substances Act 53 of 1973, were assessed alongside key guidance documents and authorisation conditions. The analysis revealed critical gaps in regulatory oversight, outdated standards, and limited industry awareness, especially among scrap dealers not authorised by the NNR, reinforcing the need for a more robust and inclusive approach to radiation protection in the scrap metal industry.

Interviews were conducted and participants provided detailed insights into the managerial and regulatory dynamics shaping the handling of radioactive material in the scrap metal industry, revealing key themes around governance, compliance behaviour, and stakeholder collaboration. Through rigorous thematic analysis, transcripts were coded and systematically examined to identify patterns in regulatory awareness, authorisation challenges, communication practices, and

operational risk management. The analysis illuminated how managerial decision-making, regulatory interpretation, and stakeholder engagement collectively influence safety and compliance outcomes within this scrap metal industry. The research adhered strictly to ethical principles, safeguarding participant confidentiality through informed consent, anonymisation, and secure data handling in line with institutional research ethics protocols.

The study provides a comprehensive exploration of the realities underpinning the regulation and safe handling of radioactive material within South Africa's scrap metal industry. This analytical foundation establishes the groundwork for the development of the proposed Managerial Framework, offering actionable insights and recommendations to streamline authorisation processes, enhance stakeholder communication, and strengthen regulatory coherence for sustainable compliance. The study synthesised the empirical findings and translated them into strategic recommendations for improving the management of radioactive materials within South Africa's scrap metal industry. It highlighted the need for regulatory simplification, stronger communication, and a more inclusive, participatory approach to compliance. By addressing the identified challenges, the proposed managerial framework seeks to establish a culture of safety and cooperation grounded in transparency, accountability, and shared value.

KEYWORDS

Radioactive material management; Scrap-metal industry; Radiation protection; Authorisation process; Managerial framework; Regulatory compliance, Radiation Protection Specialist, Communication, Awareness, Monitoring and measurement.

LIST OF ABBREVIATIONS

ARS	Acute Radiation Syndrome
BF	Blast Furnace
BOF	Basic Oxygen Furnace
EAF	Electric Arc Furnace
IAEA	International Atomic Energy Agency
ITDB	Incident and Trafficking Database
NNR	National Nuclear Regulator
NORM	Naturally Occurring Radioactive Material
SAHPRA	South African Health Products Regulatory Authority
The DTIC	The Department of Trade, Industry and Competition

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CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

Naturally occurring radioactive material (NORM) is defined by the International Atomic Energy Agency (IAEA) as radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides (International Atomic Energy Agency, 2021:1). The main radionuclides of interest are , Thorium-232, Potassium-40, and Uranium-238, and their radioactive decay products (International Atomic Energy Agency, 2024:9). These materials are typically sourced from mining and mineral processing facilities, industries such as oil and gas, zircon and zirconia, rare earth processing, and the phosphate industry.

Mines and mineral processing facilities produce large amounts of steel scrap, and during operations, some of this scrap gets contaminated with radioactivity due to uranium (National Nuclear Regulator, 2020a:165). Equipment and machinery used for handling or processing NORM, including pipes, valves, and pumps, can accumulate NORM residues over time. This contamination poses challenges and is a concern during facility operations and becomes particularly critical during decommissioning. Additionally, these residues are commonly found in scrap metals, necessitating proper management and disposal (International Atomic Energy Agency, 2021:11).

The scrap metal industry significantly contributes to value addition and employment generation. Furthermore, industries that process scrap metal produce intermediate products that support downstream sectors, ensuring further economic value and job creation (Chitaka *et al.*, 2018:2).

South Africa has a developed framework for the control of radioactive material. The NNR forms a legal basis for regulating scrap facilities and other mining and mineral processing facilities which also generate radioactive waste (Van der Westhuizen, 2022:29). Its primary role is to provide for the protection of workers, members of the public, the environment, and properties against potential harmful effects of radiation by developing regulations on Safety Standards and Regulatory Practices (National Nuclear Regulator, 2022a:11).

A Government's regulatory framework may be inadequately developed or prone to failure, leading to radioactive sources being lost from regulatory oversight and entering the environment. Consequently, regardless of how advanced the regulatory control infrastructure is, there is always

a risk that radioactive materials or radiation contaminated items could become mixed with scrap metal intended for recycling (International Atomic Energy Agency, 2012:1).

Several incidents have occurred in which orphan radioactive sources or other radioactive materials were accidentally gathered as scrap metal intended for recycling. If undetected, such materials pose a serious risk of harm to human health and the environment. This requires stringent regulatory oversight to minimise the occurrence of orphan sources and prevent radioactive contamination in scrap metal facilities (Costa *et al.*, 2019:2).

The IAEA developed an Incident and Trafficking Database (ITDB) where participating member states, of which South Africa is a member, report incidents involving nuclear or radioactive materials. In 2023, 168 incidents were reported, and most reported cases involved thefts and losses, primarily involving radioactive sources utilised in industrial, medical, or material analysis applications. Devices containing these sources are often targeted by thieves due to their perceived scrap metal or resale value, rather than their radioactive content. This highlights a risk of accidental exposure or environmental harm if mishandled. As of 31 December 2023, the ITDB recorded a total of 4243 confirmed incidents reported by participating states since 1993 (International Atomic Energy Agency, 2025a).

South Africa has a lot of scrap facilities, but the National Nuclear Regulator (NNR) has only 18 scrap processors issued with Certificates of Registration authorising them to handle radioactive material (National Nuclear Regulator, 2022b). This highlights the need for proper administrative processes, as the majority of scrap dealers are not authorized and may encounter radioactive materials and sources.

A gate monitor in the United Kingdom detected high radiation levels in a shipment of scrap from South Africa in 1993 (Van der Westhuizen, 2022:12). Recently in 2024, a source was found at a scrap yard in Cape Town, the City of Cape Town emergency services (firefighters), traffic police and the South Africa Police Services bomb squad were called to the scene (Swartz, 2024). There was no indication that the relevant authorities legally mandated to handle radioactive material were notified. This highlighted a lack of awareness and coordination regarding the process of handling radioactive material.

The current study intended to develop a managerial framework for handling radioactive material by the South African scrap metal industry. The developed framework outlined the authorisation process for handling radioactive material and ensuring proper implementation of safety measures.

This will ensure compliance with regulatory standards, thereby minimising radiation exposure risks to both workers and the public.

1.2 CONTEXT OF THIS STUDY

Recycling of scrap metals is an important component of a circular economy, as it helps reduce the depletion of natural resources by extending the lifespan of materials. By recovering and reprocessing metals from discarded products, industrial scrap, and other waste materials, recycling minimises environmental impact, reduces energy consumption, and supports sustainable resource management (DebRoy & Elmer, 2024:748). In South Africa, ferrous scrap metal comprises 90% of the total metal scrap traded, both for international export and local beneficiation processes (Chitaka *et al.*, 2018:2).

Radioactive materials can contaminate scrap metal through various means, and if undetected, they may be introduced into steel and non-ferrous metals during the melting process (Ministry of Health, 2024:1). The primary sources of radioactive material found in metal recycling facilities include orphan radioactive sources, NORM, and contaminated imported steel.

Orphan sources refer to radioactive materials that have fallen out of regulatory control, often due to the improper disposal of industrial gauges, medical waste, or radium-painted dials. These may contain isotopes such as caesium-137 (^{137}Cs), cobalt-60 (^{60}Co), americium-241 (^{241}Am), iridium-192 (^{192}Ir), or selenium-75 (^{75}Se), sometimes housed in depleted uranium-238 (^{238}U) containers. NORM enters the metal supply chain through industrial processes, where isotopes like uranium-238 (^{238}U), thorium-232 (^{232}Th), and radium-226 (^{226}Ra) accumulate in pipes or refractory materials, particularly in the mining, mineral processing facilities, and oil and gas industries. Imported steel can also become contaminated when an orphan source is unknowingly melted with scrap during steel production, leading to radiation exposure (Ministry of Health, 2024:1).

The steelmaking and foundry industries depend on scrap that is free from radiation, sourced from manufacturing processes and recycled products. Radioactively contaminated scrap poses significant risks to human health, the environment, and the economic stability of the steel industry. If such scrap enters the metal supply chain, it could expose and endanger steelworkers and potentially make its way into consumer products (United States Environmental Protection Agency, 2024c). The presence of radioactive materials in scrap raises critical issues for the metal industry, particularly concerning the reliability and safety of scrap as a fundamental resource for metal production.

The regulatory framework for the nuclear sector in South Africa primarily revolves around three key legislative frameworks: the Nuclear Energy Act 46 of 1999 and the National Nuclear Regulator Act 47 of 1999, which are administered by the Department of Mineral and Resources and Energy (Department of Mineral Resources and Energy, 2024a), and the South African Health Products Regulatory Authority, which obtains its mandate from the Hazardous Substances Act 15 of 1973 (South African Health Products Regulatory Authority, 2025).

The NNR in terms of Section 20 (3) of the National Nuclear Regulator Act 47 of 1999 requires that companies handling radioactive materials must have a Certificate of Registration (authorisation). In terms of section 23 (1) of the National Nuclear Regulator Act 47 of 1999, the Chief Executive Officer may impose specific conditions that authorised companies must adhere to. The conditions of the authorisations are derived from the Safety Standards and Regulatory Practices. In addition to the conditions, the Regulator prescribed the requirement documents which guide the authorisation holders on how they can achieve compliance (Van der Westhuizen, 2022:23). Authorisation holders, in terms of Section 28 of the National Nuclear Regulator Act 47 of 1999, are also required to pay an annual authorisation fee prescribed by the Minister of the Mineral Resources and Energy, in consultation with the NNR board and the Minister of Finance and gazetted by the Department of Mineral Resources and Energy (Department of Mineral Resources and Energy, 2024b:1).

In terms of Section 3A (1) of the Hazardous Substances Act 15 of 1973, no person shall produce or acquire, or dispose of, or import into the Republic or export from there, or be in possession of, or use, or convey or cause to be conveyed, any Group IV hazardous substance, except in terms of written authority. The applicant is also required to pay a fee prescribed by the Director-General. The Hazardous Substances Act 15 of 1973 categorises electronic generators of ionising radiation as Group III, and radioactive sources as Group IV hazardous substances. Unlike the National Nuclear Regulator, the South African Health Products Regulatory Authority does not regulate the scrap facilities, however the radioactive sources which are at times discovered at the scrap facilities.

The primary objective of the Regulator is to oversee and control the nuclear industry. This regulatory oversight also includes industries such as mining and mineral processing, where radiation exposure is incidental to their operations (Van der Westhuizen, 2022:23).

The NNR has made progress in managing radiation risks associated with sources of natural origin. However, there are currently no established guidelines to direct the scrap metal industry on the proper handling of radioactive materials. To address this gap, a regulatory framework will be developed to ensure that scrap metal dealers are fully informed of the necessary requirements. This initiative aims to enhance compliance, thereby protecting workers and the public from potential radiation exposure. By establishing clear guidelines, the framework will contribute to improved safety standards and responsible management of radioactive materials within the industry.

1.3 CAUSAL FACTORS

South Africa's mining industry generates NORM such as uranium and thorium, posing health risks if not properly managed (National Nuclear Regulator, 2020a:164). Orphan sources that fall out of regulatory control and imported scrap containing radioactive materials also pose health risks if found in the scrap facilities and not properly managed. The NNR has issued Certificates of Registration to only 18 scrap facilities authorising them to handle radioactive materials. Many others may still encounter radioactive material on their sites, creating regulatory and safety gaps. This highlights the need for stricter enforcement, increased awareness, and an improved regulatory framework.

1.4 PRELIMINARY LITERATURE STUDY

Scrap metal recycling is a crucial part of global sustainability efforts, turning discarded metals into valuable raw materials for new products while conserving resources. It offers environmental, economic, and energy-saving benefits, as metals can be recycled repeatedly without degrading their properties, making them a sustainable resource for manufacturing. By reducing the need for mining and processing new metals, recycling assists lower greenhouse gas emissions and preserves natural resources, supporting global environmental goals. As demand for sustainable construction and manufacturing materials grows due to urbanisation and infrastructure development, recycled metals provide a cost-effective and eco-friendly solution (Fortune Business Insights, 2025).

Scrap metal recycling offers a significant environmental benefit; however, the inadvertent inclusion of radioactive materials poses serious challenges. Public acceptance issues also arise due to concerns about safety and regulatory compliance (International Atomic Energy Agency, 2009a:353). This issue has gained attention as the metal recycling and production industries have

raised concerns about its impact. To mitigate these risks, many countries have strengthened regulations over the handling of radioactive materials, including implementing strict monitoring procedures at the borders, scrapyards, and melting facilities. They have also developed emergency response plans to manage potential incidents effectively. Given the international movement of scrap metal, this issue requires global cooperation and is ideally addressed through discussions at international forums to establish best practices and coordination (International Atomic Energy Agency, 2009a:270).

Radioactive materials should not be disposed of in the same manner as normal waste as they require specific handling and disposal procedures to prevent contamination. At times, items with radioactive sources are disposed of incorrectly. Even though they are typically small, various types of radioactive materials emit different levels of radioactivity. Improper disposal of items containing radioactive sources, including scrap material and equipment from mining activities, can occur when materials are not correctly labelled or when proper disposal guidelines are not followed and are ignored. These are often referred to as abandoned or orphaned sources (United States Environmental Protection Agency, 2024c). Orphan sources and other radioactive materials are occasionally inadvertently included in scrap metal intended for recycling. Over the years, several incidents have occurred involving these materials, resulting in radiation exposure to individuals and causing significant environmental, social, and economic consequences (Tomek *et al.*, 2022:2549)

If radioactive materials are not disposed of properly or sent to recycling facilities as scrap metal, they may end up at sites that are not authorised to handle them. Should a scrap yard or recycling facility unknowingly melt down radioactive items, it could lead to contamination of the metal, the machinery, and the entire facility (United States Environmental Protection Agency, 2024c). Furthermore, processing radioactive materials at unauthorised locations exposes workers to harmful radiation as they may not be aware of safe ways to handle radioactive materials (United States Environmental Protection Agency, 2024c). Recycling facilities should be equipped with portal monitors that detect radiation as they scan incoming scrap metal loads to detect material that should not be processed. It is essential to identify radioactive materials before they are processed at a scrap metal yard because radioactively contaminated sites pose a health risk to workers and it can also be costly to clean up processing equipment and processing sites (United States Environmental Protection Agency, 2024c).

According to International Atomic Energy Agency (2009a:1) the presence of radioactive materials in scrap metal poses substantial environmental and health risks, particularly when undetected materials enter the recycling process. Globally, scrap metal recycling operations face difficulties in maintaining compliance with safety regulations due to the complex nature of sorting, identifying, and disposing of radioactive materials. In the absence of detailed procedures, these materials can be inadvertently incorporated into manufacturing processes, leading to widespread contamination and severe health implications.

The IAEA further recommends that the regulatory body should prioritise raising awareness among scrap metal facilities about the risks associated with radioactive materials. This includes developing and distributing information leaflets and posters that describe common radioactive sources, their containers, and the devices they might be found in to help facilities identify potential threats. The regulatory body should also collaborate with the metal recycling industry to provide clear guidelines on the initial actions operators should take if radioactive material is detected, alongside basic radiation protection advice. They should also share lessons learned from past incidents and promote training programme to ensure workers are prepared to respond effectively (International Atomic Energy Agency, 2012:12).

In South Africa, mining and industrial processes frequently yield high levels of naturally occurring radioactive materials. The presence of NORM in significant quantities raises critical safety concerns due to the potential for radiation exposure among workers who handle these materials and the broader public who might encounter these waste products (International Atomic Energy Agency, 2009a:143). Dose limits are established to ensure that the total effective dose from authorised practices does not exceed levels considered safe, thereby preventing "unacceptable" risks. The primary objectives of dose limitation are to avoid deterministic effects by keeping doses below harmful thresholds and to minimise the risk of stochastic effects, such as long-term health impacts, to tolerable levels (International Atomic Energy Agency, 2018a:11). The prescribed dose limits are summarised below:

Table 1.1: Dose limits

Type of limit	Occupational	Public
Effective dose	20 mSv per year, averaged over five consecutive years; 50 mSv in any single year	1 mSv in a year ^a
Equivalent dose		
Eye lens	150 mSv in a year	15 mSv in a year
Skin	500 mSv in a year	50 mSv in a year
Hands and feet	500 mSv in a year	—

^a In special circumstances, an effective dose of 5 mSv, provided that the average dose over five consecutive years does not exceed 1 mSv per year.

Source: (International Atomic Energy Agency, 2018a:33)

The NNR oversees handling of radioactive material and mandates that scrap processors handling radioactive materials be issued Certificates of Registration to ensure compliance with the safety standards. However, only 18 scrap facilities have been issued such certifications (National Nuclear Regulator, 2023:80), leaving a large portion of the industry potentially exposed to radioactive materials without the necessary oversight.

International Atomic Energy Agency (2016:2) highlights that the international standards set by the IAEA provide a foundation for national regulatory frameworks. The practical application of these standards in South Africa has been limited. South Africa's regulatory framework, particularly the National Nuclear Regulator Act 47 of 1999, does provide clear guidelines for authorised processors, but the process for addressing inadvertent encounters with radioactive material by those not authorised do not exist. The need for improved administrative processes to address this issue is emphasised by recent incidents, such as the discovery of radioactive material in a Cape Town scrap facility (Swartz, 2024).

The NNR should consider adopting a more streamlined regulatory processes that make it easier for smaller scrap processors to understand and follow safety regulations. These align with the objectives of the current study, which aims to ensure safe handling of radioactive material for all scrap processors in South Africa through clear, accessible and standardised regulatory process. The study seeks to bridge the current regulatory gaps, ensuring that all stakeholders understand their responsibilities and the regulatory requirements.

Given the existing regulatory framework and international guidelines, this study's focus on developing a managerial framework for handling radioactive material by the South African scrap

metal industry is not only feasible, but urgently necessary. The literature suggests that while the foundational regulations are in place, practical gaps in implementation, particularly for scrap facilities not under regulatory control, continue to pose risks to workers, the public, and the environment. The study will build on existing research and frameworks, providing a targeted solution that addresses the specific needs of the South African context.

By drawing on both local and international best practices, the study can contribute to the development of a comprehensive managerial framework for handling radioactive material enhancing safety, compliance, and accountability in the scrap metal industry.

1.5 Importance of the study

Scrap metal can be associated with radioactive substances in several ways, and if they are not detected, they can be integrated into steel and non-ferrous metals during the melting process. This can result in significant commercial implications, as well as environmental and health hazards (International Atomic Energy Agency, 2009a:1). The study aimed to develop a managerial framework for handling radioactive material by the South African scrap metal industry, providing documented guidance on the arrangements that should be put in place. The process will also assist in the identification and control of radioactive material and sources that might be found within the metal recycling industries. A key aspect of this study was to provide clear and accessible information about the regulatory frameworks that govern radioactive scrap management and ensure that all stakeholders understand their responsibilities. It also aimed to facilitate effective compliance and implementation of prescribed safety measures.

1.6 Problem statement

The health implications resulting from exposure to elevated levels of radiation as long term exposure to low doses are significant e.g. long-term exposure to low doses of radiation can increase the risks of cancer and develop genetic effects in future generations (International Atomic Energy Agency, 2010:22). Workers engaged in processing scrap material may be at higher risk of exposure to high level of radiation, depending on the types and concentrations of materials that they may be exposed to. Considering the number of authorised scrap processors and those that are not authorised, the chances of radioactive material inadvertently landing on scrap processors not under regulatory control are relatively high. The gap in knowledge and lack of resources increases the likelihood of radioactive materials being mishandled, potentially leading to safety hazards, environmental contamination, and health risks to workers and the

public. The problem can be defined as the absence of a comprehensive managerial framework for handling radioactive material that can be adopted across the scrap metal industry.

1.7 Research objectives

1.7.1 Primary Objective

To develop a managerial framework for handling radioactive material that can be adopted across the scrap metal industry to improve regulatory frameworks, streamline authorisation processes and ensure proper handling and disposal of radioactive materials.

1.7.2 Secondary objectives

- i. To analyse the existing administrative procedures and protocols for handling radioactive materials recommended by IAEA and compare with those used by the South African regulators.
- ii. To identify and document the challenges, gaps, and inefficiencies in the current regulatory processes related to radioactive material management experience by scrap processors.
- iii. To provide clear and accessible information on the legal and regulatory frameworks governing radioactive scrap management ensuring that all stakeholders understand their roles and responsibilities.

1.8 Scope of the study/Delineation

1.8.1 Field of the study

The field of the study is within the radioactive waste management and regulatory framework within the context of the scrap metal recycling industry. This encompasses the enhancement of the regulatory administrative process for handling radioactive material where management of radioactive material in both authorised and non-authorised scrap facilities will be investigated.

1.8.2 Sector under investigation

The sector investigated is the scrap metal industry, specifically focusing on the recycling and processing of scrap metal that may knowingly or unknowingly contain radioactive materials. The

focus is primarily on the authorised scrap recyclers and processors as they can present valuable insights into current practices, challenges, and adherence to regulatory requirements.

1.8.3 Geographical demarcation

The study focused on 18 authorised scrap facilities across South Africa, specifically authorised to handle radioactive scrap materials that often arise from gold and uranium mining operations. These facilities are strategically located in key provinces such as Gauteng, the Free State, Kwa Zulu Natal and the North West Province, where they operate under regulations control authorised by the NNR to ensure the safety of people, property and the environment.

The study did not include unauthorised scrap facilities, although it is crucial to note that there is a significant number of unauthorised scrap facilities operating outside regulatory frameworks. This disparity presented considerable challenges, as these facilities may inadvertently expose workers to potential radiation. By focusing solely on the 18 authorised scrap facilities, the research aimed to identify best practices and challenges in managing processes for handling naturally occurring radioactive materials which will inform the development of guidelines that are grounded in compliance with regulatory standards and best practices, ensuring that the findings and recommendations are relevant and applicable to the scrap industry in general.

1.9 Research methodology

Research methodology is a systematic approach to solving the research problem. It involves exploring different steps typically taken by a researcher to study the research problem, along with the reasoning behind each step (Khan *et al.*, 2023:1).

1.9.1 Literature review

An extensive literature review formed the basis of this study, offering an in-depth overview of the current state of radioactive material management within the scrap metal industry. This review included various sources, such as international guidelines from the IAEA, which sets global standards for the safe handling and disposal of radioactive materials. Regulations and procedures from South Africa's NNR were critically examined to understand the specific legislative and regulatory framework in South Africa. These documents provided crucial insights into the formalised processes that scrap metal facilities are expected to adhere to while handling radioactive materials.

In addition to regulatory documents, academic journals and publications were sourced from platforms such as Google Scholar, ScienceDirect, and EBSCOhost. The literature review established a theoretical foundation for the study and assisted in identifying gaps in the current knowledge, such as areas where existing regulations may be insufficient or where industry practices may diverge from regulatory requirements.

1.9.2 Empirical study

Empirical research is a methodological approach that relies on observable, concrete evidence to draw conclusions and generate knowledge. It involves collecting and analysing data through direct or indirect observation and experimentation, rather than relying solely on theoretical or speculative reasoning (Khan *et al.*, 2023:42). Empirical research can be conducted using both quantitative methods (such as surveys, experiments, and statistical analyses) and qualitative methods (such as interviews, focus groups, and case studies). Qualitative methods are used to collect non-numerical data, aiming to explore meanings, opinions, or the fundamental reasons behind certain behaviours or phenomena (Ugwu & Eze Val, 2023:20).

1.9.2.1 Research Paradigm

According to Rehman and Alharthi (2016:51) a paradigm is a fundamental belief system and conceptual framework that includes beliefs about four key aspects: ontology, epistemology, methodology and methods. it defines how we interpret reality and explore it through research. According to Leavy (2022:12) there are several paradigms that direct social research such as post positivism, interpretive/constructivist, critical, transformative, pragmatic, and arts-based/aesthetic intersubjective. This varies based on ontology (the nature of reality), epistemology (the nature of knowledge), methodology (the study and critical analysis of data production techniques), and methods (means for obtaining, collecting, and analysing data) (Rehman & Alharthi, 2016:52) . This study aligns with an interpretivist paradigm, which submits that knowledge is actively developed by individuals through their own experiences, interactions, and interpretations of reality (Bryman *et al.*, 2021:93).

The study adopted an interpretivist philosophy to obtain a thorough understanding of how stakeholders in scrap metal recycling and processing facilities perceive and manage radioactive materials. This approach emphasised the importance of exploring the subjective experiences and interpretations of individuals directly involved in handling these materials.

1.9.2.2 Research approach

The research approach to inquiry for this study was primarily inductive, an approach where data was collected and theory was developed as a result of data analysis, the researcher generated concepts, meaning and insights from the patterns in the data collected in the field (Taylor *et al.*, 2016:8). The approach was employed to develop a managerial framework based on the experiences and perceptions of stakeholders in scrap metal recycling and processing facilities. This approach started with collecting detailed qualitative data through interviews and then used open coding to identify and organise emerging themes. Theories were then developed based on patterns and relationships within the data, reflecting participants' experiences rather than existing theoretical frameworks.

1.9.2.3 Research strategy

The research approach was qualitative. Qualitative research is distinguished by its inductive approach to knowledge generation, focusing on uncovering and interpreting meaning. It is particularly suitable when the primary aim is to explore, describe, or explain phenomena comprehensively (Leavy, 2022:9). In this research study, open-ended questions were used in semi-structured interviews to gather detailed information about the phenomenon being investigated.

1.9.2.4 Study methodology

Data saturation is important in qualitative research methodology (Hennink & Kaiser, 2022:1). It refers to the point at which no new information, themes, or patterns emerge from the data. It also indicates that the researcher has thoroughly examined and explored the study's phenomenon ensuring that no critical information is overlooked. This concept is important in determining sample size and in strengthening the credibility and validity of qualitative research (Ahmed, 2025:2). In qualitative research, the sample size should be large enough to ensure data or theoretical saturation is reached, but not so extensive that it becomes challenging to conduct a detailed, case-focused analysis. (Bryman *et al.*, 2021:411).

The research mainly focused on 18 scrap metal companies authorised by the NNR to handle radioactive material. These companies possess the necessary expertise and safety protocols for managing naturally occurring radioactive materials (NORM), making them the most appropriate participants for the study.

The researcher used purposive sampling, a strategy where participants were chosen based on knowledge applicable to the study (Taherdoost, 2016:23), it was used to select participants who possess specialised knowledge, skills and experiences. Managers and radiation protection officers and specialists within the nuclear material scrap processing environment were selected to ensure that the sample included individuals who can provide comprehensive and insightful information on the research topic.

1.9.2.5 Designing the measuring instrument

A semi-structured interview involves using a flexible set of prepared questions, allowing the interviewer to adjust the order and ask follow-up questions based on the interviewee's responses. This approach encourages deeper exploration of key topics and deeper exploration of important points during the interview (Bryman *et al.*, 2021:178). Therefore, qualitative semi-structured interview questions were utilised to collect data for this research study. This allowed for open-ended responses that revealed insights into their experiences and challenges.

1.9.2.6 Collection of data

The researcher contacted all prospective participants through emails and telephonically and invited them to take part in the study. Informed consent forms were emailed to everyone. This communication included information about the importance of the study while emphasising that participation was totally voluntary.

Once participants confirmed their willingness and availability to participate, they received the interview questions in advance of the scheduled interview date. This advance notice allowed participants enough time to review and prepare for the questions. The interviews were conducted through Microsoft Teams Meeting Virtual platform, based on the questions provided beforehand. Each interview was recorded with the participants' consent, and the recordings were transcribed into written scripts for further analysis.

1.9.2.7 Qualitative analysis

The data collected via interviews was analysed using ATLAS.ti, a supporting tool for the qualitative data analysis process, enabling efficient coding, categorisation, and thematic interpretation of transcripts, field notes, documents, etc., (Friese, 2019:1). It provides tools for coding, annotating, and visualising data, enabling researchers to uncover patterns and insights.

Thematic analysis was utilised to identify common themes and patterns within the data gathered through interviews. This analysis helped in understanding the perceptions of stakeholders regarding regulatory compliance, safety measures, and the effectiveness of current administrative processes. This assisted in developing a guideline for implementing the administrative process of managing radioactive material by the scrap metal industry.

1.9.2.8 Trustworthiness

According to Bryman *et al.* (2021:177), in qualitative research, the traditional concepts of reliability and validity are often replaced by the criteria of trustworthiness and authenticity. Bryman *et al.* (2021:177) indicated that Guba and Lincoln introduced four key criteria for assessing qualitative studies as follows; credibility, which ensures the accuracy of the findings; transferability, which considers the extent to which results can be applied in other contexts dependability which emphasises the consistency and reliability of the research process; and confirmability which ensures that the outcomes are derived from the data rather than the researcher's subjective influence. These criteria aim to provide a more contextually appropriate framework for evaluating qualitative research.

In this study, establishing credibility was crucial, since multiple interpretations of the industry's practices and regulatory compliance may exist, the credibility of the research findings will determine their acceptance by others. To ensure credibility, the study adhered to well-established research practices and standards throughout the research process.

1.9.3 Ethical considerations

Ethical standards were upheld by obtaining informed consent from all participants and also obtaining the required ethical clearance from the North-West University Business School ethics committee, ensuring compliance with ethical principles and the protection of participants' privacy throughout the study. The informed consent form, together with the permission to conduct the study, and the confidentiality agreement, were drafted and sent to the participants prior to the commencement of the research. Confidentiality was maintained throughout the research process, in alignment with the Protection of Personal Information Act 4 of 2013, which protects participants' personal data and privacy.

1.10 Contribution to the study

The study will significantly benefit the industry by offering comprehensive guidance on managing radioactive materials in scrap metal processing. Through documenting effective procedures and providing clear information on regulatory frameworks, it will enhance the industry's ability to detect, identify, and control radioactive material. This will lead to improved safety and ensure protection of people and the environment and better compliance with regulations. The study will also help the scrap industry understand their responsibilities, facilitating more effective implementation of safety measures and ultimately promoting safer and more efficient recycling practices. The study will also identify gaps in NNR regulations if there are any.

1.11 Layout of the study

CHAPTER 1: INTRODUCTION

The primary aim of this first chapter is to provide an overview of the research topic. It outlines the introduction and background of the study. This chapter also details the study's goals, objectives, and overall significance.

CHAPTER 2: LITERATURE REVIEW

This chapter will present the literature review underpinning the study. This chapter will discuss the administrative process of handling radioactive material by the scrap metal industry in South Africa.

CHAPTER 3: EMPIRICAL STUDY

In this chapter, the process of executing the research study is thoroughly outlined, including the methods used for collecting data and the rationale behind the chosen approach. The gathered data will be presented, detailed, interpreted, and analysed in relation to the research question and existing literature.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

The last chapter will conclude the research study by summarising the findings and addressing the research questions outlined in the introduction. It will also discuss the implications of the study and acknowledge its limitations. This chapter also presents the recommendations of the study.

1.12 Conclusion

The present study aimed to develop guidelines for managing the administrative processes involved in handling radioactive material within the scrap metal industry. By establishing a standardised framework, the study sought to minimise risks, enhance safety, and promote responsible practices for handling and disposal of radioactive materials. The current lack of predefined processes and clear protocols poses significant challenges, particularly for facilities that may inadvertently encounter radioactive materials. This gap in regulation and guidance increases the potential for unsafe handling, exposure, and environmental contamination.

To address these issues, the study created practical and accessible guidelines that are designed to be adopted industry-wide, ensuring consistency in approach and promoting the best practices for radiation safety. The guidelines emphasise key aspects such as the identification, segregation, storage, and disposal of radioactive materials, as well as training for employees to recognise and manage these materials safely. The study also recognises the unique challenges faced by non-authorised facilities, which may not have the expertise or resources to effectively handle radioactive materials. Therefore, the guidelines were particularly tailored to provide clear, step-by-step processes that such facilities can implement to manage radioactive materials responsibly and in compliance with legal and safety requirements.

The study also advocates for improved communication and collaboration between the NNR and the scrap metal industry. By establishing open channels for dialogue, it aimed to facilitate the dissemination of knowledge, enhance compliance, and build a culture of safety across all facilities. Ultimately, the developed framework will provide the resource to streamline administrative processes, promote adherence to regulatory requirements, and reduce the risks associated with the existence of radioactive materials in the scrap metal industry.

1.13 Summary

The study aimed to develop the managerial framework for handling radioactive material that can be adopted across the scrap metal industry to minimise risks and ensure proper handling and disposal of radioactive materials.

Exposure to high levels of radiation poses serious health risks, workers processing scrap material may be at greater risk if they handle radioactive materials, especially if materials are not properly managed. The risk is higher for scrap processors who may not have the necessary knowledge or

resources to identify and handle radioactive materials, leading to potential mishandling and increased health risks. This gap in knowledge and lack of resources increases the likelihood of radioactive materials being mishandled. Therefore, the managerial framework for handling radioactive material that can be adopted across the scrap metal industry needs to be developed.

The study employed a qualitative research approach, chosen for its ability to provide the in-depth insights needed from managers and radiation protection officers of the scrap recyclers and processors to effectively address the research questions. Semi-structured interview questions were distributed to participants in advance, allowing them ample time to prepare for the interviews, which were conducted via Microsoft Teams platform. The data collected was analysed using ATLAS.ti software to identify common codes, categories and themes across the dataset. Conclusions and recommendations were based on the patterns identified through the ATLAS.ti analysis.

CHAPTER 2 : LITERATURE REVIEW

2.1 INTRODUCTION

Metal scrap recycling is environmentally beneficial and therefore significant to sustainable resource management and circular economy (Tan *et al.*, 2021:2). Recycling enables the industry to transform waste into valuable resources thereby reducing environmental impact and preserving natural resources (Jain, 2011:3). However, the inadvertent incorporation of NORM and orphan sources into scrap streams poses significant risks to human health, environmental safety, and industrial integrity (United States Environmental Protection Agency, 2024c). The government of South Africa through the Department of Trade, Industry and Competition (the DTIC) introduced the Steel and Metal Fabrication Master Plan as part of a broader strategy to rebuild the economy and revive key industries. The plan aims to strengthen the steel industry, support local manufacturing, and create jobs through coordinated efforts with industry stakeholders (Department of Trade Industry and Competition, 2021). This will create bigger demand for scrap.

This chapter critically examines existing research and regulatory frameworks related to the handling and management of radioactive materials in the scrap metal industry, with emphasis on South Africa's context. It explores best practices from the IAEA and other international organisations, analyses South Africa's current regulatory framework under the National Nuclear Regulator Act 47 of 1999 and Hazardous Substances Act 53 of 1973. It will further identify key gaps in enforcement, detection technologies, and industry compliance. By combining academic literature, case studies, and policy documents, this review establishes the theoretical foundation for developing a managerial framework that addresses radiation concerns and risks while considering economic and operational realities of scrap metal recycling in South Africa.

2.2 THEORITICAL FRAMEWORK ON SCRAP MATERIAL

2.2.1 Recycling of metal scraps

Scrap metal is the mixture of waste metal, such as metallic material and any product that contains metal that can be recycled from previous consumption or product manufacturing (Parker, 2024). Recycling, an essential part of sustainable resource management, is the process of collecting, processing, and reintroducing waste materials into the manufacturing cycle to develop new products. This procedure reduces the quantity of waste that ends up in landfills while also minimising the use of natural resources (Fischer, 2024). Society generally acknowledges the

expectation for activities that minimise reliance on natural resources and promote the recycling and reuse of materials. The rationale for this position is that consumption of natural resources by our society is significantly higher than any level that can be considered sustainable. These are essential aspects of the circular economy (International Atomic Energy Agency, 2020:13).

Metal recycling results in significant energy savings, addresses raw material deficits, enhances the use of minerals and metals efficiently, and lowers the environmental pressure and financial burdens associated with primary metal production (Fischer, 2024; Raghupathy & Chaturvedi, 2013:1). When compared to the manufacturing of steel from virgin iron ore (primary steel), the production of new steel through recycling takes up to ten times less energy than the production of primary steel (Harvey, 2021:1). According to Jain (2011:3), the commonly recycled metals include steel, aluminium, copper, and lead, which can be reused repeatedly without quality loss. The process preserves mineral resources, minimises the ecological damage caused by mining, and significantly reduces production costs.

Recycling metals is not only environmentally advantageous but also economically and socially beneficial. It avoids the high costs of exploration, land acquisition, and infrastructure development required in mining, and accordingly, their harmful consequences globally (Azizi, 2022:91). Socially, it supports employment generation across various stages, including collection, segregation, processing, and manufacturing, producing a satisfactory and reliable income for many informal collectors (Jain, 2011:3)

Metal recycling can be classified into physical and chemical processes. Physical recycling involves re-melting or re-rolling scrap into new metal forms such as ingots or sheets, commonly used for materials like steel, aluminium, and copper. Chemical recycling processes, on the other hand, involve extracting metals like lead from compounds, typically from used automotive batteries (Tawonezvi *et al.*, 2023:4). In steel manufacturing, primary production refers to converting iron ore into steel via the blast furnace (BF) and basic oxygen furnace (BOF) route, which is energy intensive but benefits from reusing by-product gases. Secondary production, or recycling, typically involves the electric arc furnace (EAF) process, which melts scrap into new steel. Both BOF and EAF processes can involve mixed feedstocks, with BOF often incorporating 10–30% scrap, and EAF sometimes using pre-reduced iron, demonstrating the flexibility of production methods as demonstrated in Figure 2.1 (Broadbent, 2016:1660).

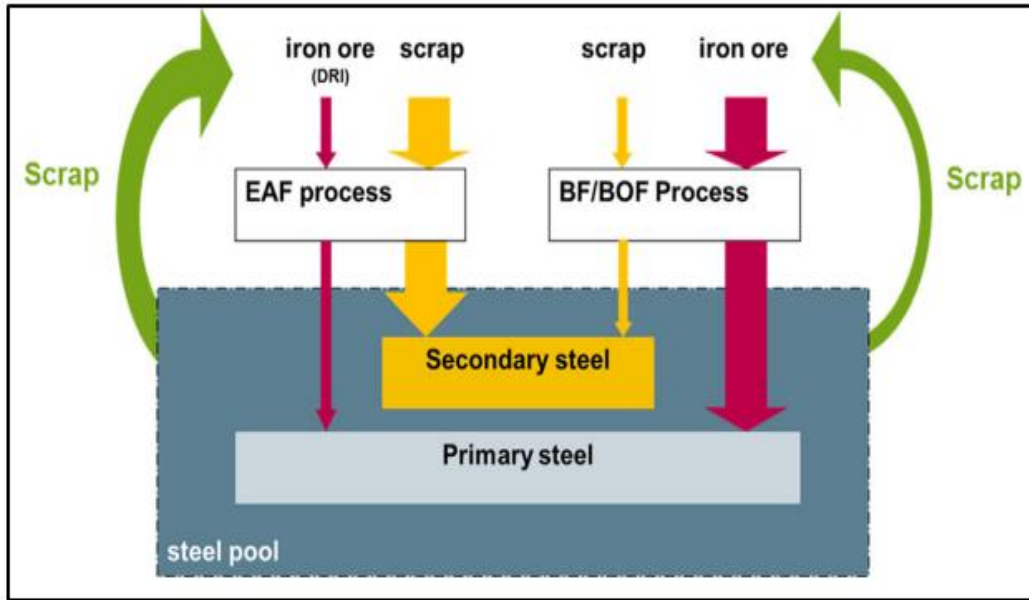


Figure 2.1: Connection between primary and secondary steel production.

Source: (Broadbent, 2016:1661).

The substantial decrease in CO₂ emissions is the biggest environmental advantages of recycling in the steel sector. The production of steel from recycled waste in electric arc furnaces produces significantly less CO₂ than the production of new steel in blast furnaces that utilise iron ore and coking coal. This plays an important role in reducing the greenhouse effect and advancing global climate objectives (Fischer, 2024). Recycling within the metal industry exemplifies not only efficient resource utilisation but also serves as a critical component in promoting sustainable industrial practices. (Fischer, 2024).

2.2.2 Global importance of scrap metal recycling

The demand for recycled metals is being driven by the increasing global infrastructure development, which is resulting in a substantial transition to sustainable practices in construction and manufacturing. The demand for infrastructure and construction materials is on the rise as urbanisation and economic growth persist. Recycled metals provide a sustainable solution to address this demand (Fortune Business Insights, 2025). Scrap metal is a valuable resource for creating low-carbon steel and is anticipated to play a critical role in the steel industry's decarbonisation efforts. According to Corneille and Agrawal (2024:5), the proportion of scrap utilised in steel manufacturing is expected to increase globally to 45-50% by 2050, in line with the

Paris Agreement's aims of limiting global warming to 1.5 °C. This presents scrap as an increasingly important commodity in the transition to a more sustainable steel production process.

Fortune Business Insights (2025) indicated that in 2023, the global scrap metal recycling market was valued at USD 407.02 billion. The market is projected to experience steady growth, reaching approximately USD 420.83 billion in 2024 and expanding further to USD 568.76 billion by 2032. This represents a compound annual growth rate (CAGR) of 3.8% over the forecast period, reflecting a sustained increase in global demand for recycled metal.

Global EAF steel production is projected to increase from 510 million metric tons (mmt) in 2019 to 1,340 mmt by 2050, raising its share of global steel production from 27% to 50%. As illustrated in Figure 2.2, EAF scrap consumption more than doubles from 360 mmt to 820 mmt.

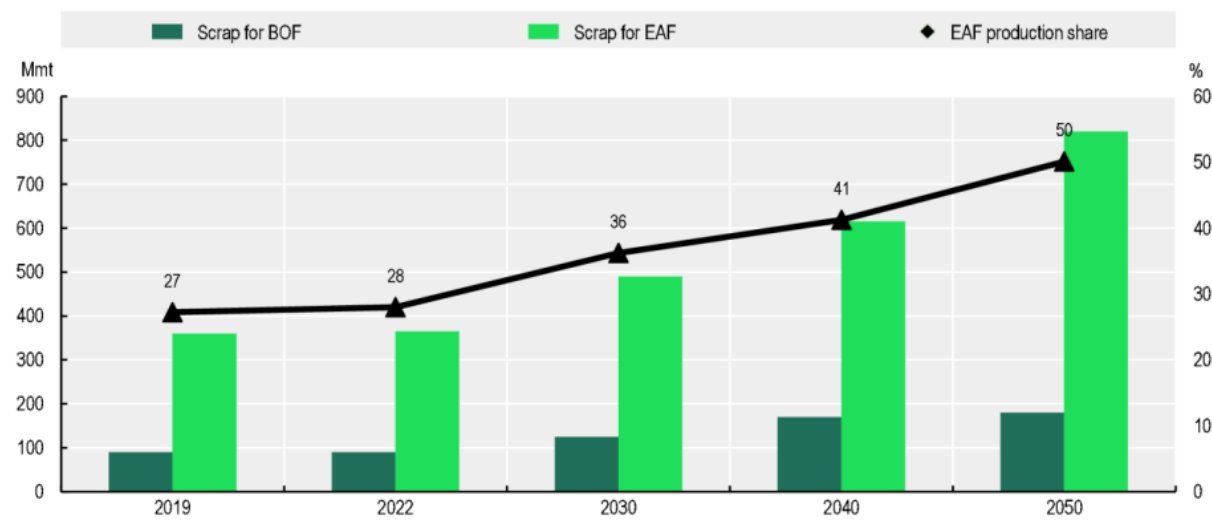


Figure 2.2: Global consumption of scrap and share of EAF production.

Source: (Corneille & Agrawal, 2024).

An assessment of future iron supplies was conducted and revealed a potential global shortage by 2060, highlighting the growing necessity to enhance metal recovery through recycling (Chitaka *et al.*, 2018:2), this implies a need for the scrap metal recycling industry to meet rising global demand for sustainable resource use and industrial growth. In addition to that, as industries continue to adopt circular economy principles and governments enforce stricter environmental regulations, the role of the scrap industry in supplying secondary materials will only grow more critical, ensuring its long-term relevance and necessity in both emerging and advanced economies, the demand for recycled metals will persist across generations.

2.2.3 South Africa's scrap metal industry

According to (Chitaka *et al.*, 2018:5) the South African government has recognised iron and steel as one of the five mineral resource-based value chains offering significant opportunities for value addition through beneficiation. As a result, supporting and expanding this industry through the sustainable development of downstream beneficiation has become a major focus area for government policy.

Copper, aluminium, steel, and lead are among the most valuable scrap metals in South Africa owing to their excessive demand, limited availability and strong economic value (Parker, 2024). Ferrous scrap metals, those that contain steel, account for 90% of all metal scrap traded, both for export and local beneficiation (Chitaka *et al.*, 2018:7). Over 60% of scrap metal revenue is generated from the mining, manufacturing and construction industries (Parker, 2024).

The scrap metal industry plays a crucial role in supporting the country's manufacturing and industrial sectors by supplying recycled materials essential to manufacturing processes. According to Ngwenya (2024); Parker (2024), industry data suggests that in 2023 this sector contributed over R15 billion to the national GDP and provided employment to around 300,000 individuals, highlighting its economic significance. The scrap metal industry also promotes environmental sustainability by conserving natural resources and minimising ecological degradation through metal recycling (Ngwenya, 2024) .

The government through the DTIC initiated the efforts to improve South Africa's steel industry as part of its bigger plan to rebuild the economy. This plan, known as the Re-imagined Industrial Strategy and Economic Reconstruction and Recovery Plan, started in October 2020. The Master Plan was officially launched on 11 June 2021, marking the start of the government's focused plan to support and grow the steel industry in the country (Department of Trade Industry and Competition, 2021:3).

The implementation of the Steel and Metal Fabrication Master Plan, aims to revitalise the country's struggling steel industry by increasing domestic production, promoting value addition, and enhancing global competitiveness. The strategy focuses on reducing reliance on raw material exports, stimulating local beneficiation, and enforcing local content compliance to retain more value within the country. It also seeks to support small and medium enterprises (SMEs), create jobs across the steel value chain, and align with global sustainability goals by transitioning

towards low-carbon/green steel production (Department of Trade Industry and Competition, 2021).

The implementation of the Steel and Metal Fabrication Master Plan, along with supporting government interventions, is expected to significantly shape the future of the scrap metal industry in South Africa by increasing domestic demand and unlocking new value-added opportunities. As the country shifts focus towards local beneficiation, infrastructure development, and green steel production, the demand for scrap metal, especially as a feedstock for electric arc furnaces and lower carbon steelmaking, will rise substantially. This presents growth opportunities for recyclers, especially those able to invest in advanced processing and move up the value chain.

2.3 RADIOACTIVITY IN SCRAP METAL RECYCLING

2.3.1 Sources of Radioactive Contamination

While scrap metal recycling plays an essential role in advancing circular economy goals and job creation, it is not without risks, and one of the most serious but often overlooked hazards is the presence of radioactive materials in scrap metal streams. Radioactivity is a natural phenomenon, and natural sources of radiation are elements of the environment. Radioactive materials have numerous beneficial applications, including electricity generation and various uses in medicine, industry, and agriculture (International Atomic Energy Agency, 2014a:1).

Radiation can be broadly categorised as ionising or non-ionising, according to the effects it produces on matter. Non-ionising radiation encompasses forms such as ultraviolet light, radiant heat, radio waves, and microwaves. In medical settings, procedures like ultrasound and magnetic resonance imaging utilise non-ionising radiation. (International Atomic Energy Agency, 2009b). Ionising radiation carries enough energy to alter atomic structures and damage living cells, it affects the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes, making it a significant concern in industries where radioactive materials may be inadvertently handled (United States Environmental Protection Agency, 2024a). Ionising radiation comes from cosmic rays, X rays and the radiation from radioactive materials (International Atomic Energy Agency, 2009b). The potential radiation risk to individuals and the environment resulting from the use of radiation and radioactive materials must be evaluated and regulated through the implementation of safety standards (International Atomic Energy Agency, 2014a:1).

The widespread use of radioactive materials demands careful oversight, as exposure risks to workers, the public, and the environment must be continuously assessed and controlled. Failures in applying or enforcing adequate controls have resulted in radioactive sources, presenting risks of significant radiological accidents as well as detrimental environmental, social, and economic impacts (Souza *et al.*, 2021:1).

There are several ways that scrap metal can become contaminated with radioactive material and, if not checked, they could enter ferrous and nonferrous materials through the melting process. In such cases, cost-intensive cleanup operations may be needed. If contaminated material is not detected at metal recycling or production facilities, workers may be exposed to radiation, and radionuclides could become incorporated into finished products and waste materials, potentially exposing end users to harmful radiation (International Atomic Energy Agency, 2009a:1).

Radioactive materials can enter the scrap facilities through NORM, abandoned or orphan sources, and contaminated imported metals. Unsealed radioactive and NORM-bearing materials can enter scrap due to insufficient control during the decommissioning of a nuclear installation or other facility or from equipment in the mining, oil, gas and other industries that contain naturally occurring radionuclides (International Atomic Energy Agency, 2012:2). NORM contamination presents a more systemic challenge, particularly in regions with extensive mining and mineral processing activities. Equipment used in uranium, phosphate, and rare earth element extraction often becomes contaminated with uranium-238, thorium-232, and their decay products. This issue is particularly acute in South Africa's gold and uranium mining regions, where processing machinery and pipes accumulate radioactive scale over time. The oil and gas industry also contributes significantly to NORM contamination, with pipes and separation vessels accumulating radium-226 deposits that may exceed regulatory limits.

Orphan sources are man-made radioactive materials that are no longer under regulatory control because they may have been lost, stolen, abandoned, or were never authorised properly. They often originate from medical equipment, industrial gauges, or research devices (International Atomic Energy Agency, 2012:2). These sources at times are dismantled and sold as scrap by individuals unaware of the risks, ending up in recycling facilities and smelters. Orphan sources are of significant concern as they pose an acute radiation hazard, exposure to very high levels of radiation delivered over a short period of time, especially if broken or melted in smelting operations, where radioactive materials can spread and contaminate entire production lines.

There is significant international trade in scrap metal and recycled metal products, creating a risk of radioactive material accidentally being transported across national borders when mixed with this scrap (International Atomic Energy Agency, 2012:1). Without proper detection systems at the ports and recycling facilities, contaminated imports can enter the domestic recycling chain unnoticed, exposing workers and the public to radiation hazards.

2.4 GLOBAL PERSPECTIVES ON RADIOACTIVE SCRAP METAL CONTAMINATION

The globalisation of scrap metal trade has introduced additional complexity, with radioactive materials frequently crossing international borders undetected. The global scrap metal industry faces persistent challenges from radioactive contamination, with documented cases occurring across all continents. Incidents involving orphan sources and other radioactive materials within the metal recycling and production industries have led to severe radiological accidents, along with significant environmental, social, and economic consequences (Dojcanova, 2020).

The IAEA established the Incident and Trafficking Database (ITDB) in 1995, in collaboration with its Member States. This initiative aimed to enable the prompt exchange of reliable information among States concerning incidents of illicit trafficking and other unauthorised activities involving nuclear and radioactive materials. It also sought to collect and analyse reported data to identify recurring threats and trends, thereby supporting States in developing effective policies and response strategies. The ITDB also serves as a reliable source of information for public communication regarding such incidents when necessary (International Atomic Energy Agency, 2025a).

The ITDB has recorded over 4,390 confirmed cases since 1993. Most materials reported as stolen or missing under unclear circumstances in the ITDB are radioactive sources used in industry, research, or medicine. These devices are often targeted due to their perceived resale or scrap metal value (International Atomic Energy Agency, 2025a). The reported incidents include 53% involving radioactive sources, about 10% involved nuclear materials, including 20 cases of high enriched uranium and a few involving plutonium and neutron sources. The remaining 37% related to contaminated items such as scrap metal, consumer goods, and NORM (International Atomic Energy Agency, 2025a).

In 2024 alone, 147 incidents involving nuclear or radioactive materials were recorded on the ITDB. An increase in incidents involving manufactured goods like used pipes contaminated with

radioactive material has been noted. This highlights challenges in controlling and preventing improper disposal of radioactive material (International Atomic Energy Agency, 2025b) .

The IAEA's Global Nuclear Safety and Security Network reported on several scrap metal case studies highlighting various incidents and critical lessons around the unauthorised inclusion of orphan sources and radioactive material in scrap metal shipments. The reported cases happened at ports, borders, steel mills, foundries, metal workshops and scrap facilities. Some radioactive sources were only discovered after being inadvertently melted in smelting processes, leading to contamination of equipment and production of by-products. In certain cases, workers were unknowingly exposed to radiation, resulting in significant doses and highlighting the significance of continuous safety training and awareness in the metal recycling industries. Contaminated manufactured goods, such as used pipes, also contributed to incidents, reflecting challenges in the proper disposal and tracking of radioactive material. Contaminated materials were detected through radiation portal monitors or handheld devices, demonstrating the effectiveness of properly deployed detection infrastructure in preventing potential exposure and environmental contamination (International Atomic Energy Agency, 2025c).

There have been several cases where accidents involving radioactive sources in the scrap metal supply chain resulted in death of workers at the scrap yard as indicated in Table 2.1:

Table 2.1: Summary of accidents that occurred at scrap metal facilities.

Location and date	Device	Radioactive source	Cause	Consequences	Ref.
Goiânia, Brazil, 1987	Teletherapy unit	Cs-137 (50 TBq)	Lack of regulatory control Theft from unsecured building for reprocessing as scrap metal	Substantial contamination 21 people with doses above 1 Gy; 4 people died Buildings demolished 3500 m ³ of radioactive waste	[1–2]
Istanbul, Turkey, 1998	Three teletherapy units	Co-60 (3.3 TBq; 23.5 TBq; 21.3 TBq)	Lack of regulatory control Sold as scrap metal	18 people hospitalized; 5 with doses of about 3 Gy; 1 with a dose of about 2 Gy; others with doses below 1 Gy Only two sources recovered intact	[1–3]
Samut Prakarn, Thailand, 2000	One teletherapy unit	Co-60 (15.7 TBq)	Lack of regulatory control Theft from unsecured site for reprocessing as scrap metal	10 people received high doses; 3 (all workers at a scrapyard) died Source recovered intact	[1–4]
Nigeria, 2002	Two well-logging sources	Am-241/Be (721 GBq; 18 GBq)	Theft from a company truck	Sources detected in a scrap metal shipment in Europe	[1–5]

Source: International Atomic Energy Agency, (2012:52).

These incidents underscore several key lessons for improving safety such as effective radiation monitoring systems which are important for early detection. Trained personnel, clear procedures, and appropriate personal protective equipment are important for managing risks during operations. Reporting incidents to the regulatory authorities is important for traceability of the sources, containment and safe keeping. The incidents emphasise the need for strong regulatory oversight, international cooperation, and continued investment in detection and response capabilities to protect public and occupational health within the global scrap metal industry.

2.5 HEALTH RISKS ASSOCIATED WITH RADIATION

The effects of radiation on personnel health are significant and depend on the type, duration, and amount of radiation exposure. Radiation exposure can damage human tissues or organs by killing enough cells to disrupt their normal function. This type of effects are called "deterministic effects," and they become clinically apparent in a person only when the radiation dose exceeds a specific minimum level (International Atomic Energy Agency, 2014a:1). The health risk associated with acute high dose radiation exposure could lead to Acute Radiation Syndrome (ARS). Noted symptoms of ARS are nausea, vomiting, diarrhoea, loss of appetite, fatigue, and, in severe cases, neurological damage or death. Such cases of ARS would typically occur in scenarios such as nuclear accidents, or accidents involving radioactive sources that are not handled properly (United States Environmental Protection Agency, 2024b).

Radiation exposure can cause non-lethal changes in cells that still divide. While the immune system often eliminates these abnormal cells, some may survive and later cause cancer or hereditary effects. Radioactivity exposure can also give rise to several diseases such as cancer and result in hereditary effects (Romano *et al.*, 2021:8) These outcomes are known as stochastic effects (International Atomic Energy Agency, 2014a:2)

Dose limits are established to ensure that the total effective dose from authorised practices does not exceed levels considered safe, thereby preventing "unacceptable" risks. The primary objectives of dose limitation are to avoid deterministic effects by keeping doses below harmful thresholds and to reduce the risk of stochastic effects, such as long-term health impacts, to tolerable levels (International Atomic Energy Agency, 2018a:11).

2.6 INTERNATIONAL GUIDANCE ON RADIOACTIVE SCRAP MANAGEMENT

2.6.1 The International Atomic Energy Agency

The IAEA is an international body that sets safety standards aimed at protecting health and reducing the risks associated with exposure to radioactive materials. As a member state, South Africa adopts and incorporates these IAEA standards into its regulatory framework for nuclear and radiation safety (Joubert, 2016:31).

2.6.2 Key IAEA Publication on Radioactive scrap management

The IAEA has developed comprehensive safety standards and guidelines to manage radioactive material inadvertently incorporated into scrap metal. Although the IAEA's guidance is typically non-prescriptive and not legally binding like national legislation, it often serves as the foundational framework upon which national procedures and regulations are developed (Van der Westhuizen, 2022:12). These documents, as presented in Table 2.2, are essential for regulators, scrap processors, and metal recyclers to ensure the safe handling, detection, and prevention of radioactive contamination in the recycling industry.

Table 2.2: Key IAEA publications on radioactive scrap management

KEY IAEA PUBLICATIONS ON RADIOACTIVE SCRAP MANAGEMENT	
Control and Management of Radioactive Material Inadvertently Incorporated into Scrap Metal.	A compilation of proceedings from an international conference addressing the growing global concern over the unintentional inclusion of radioactive materials such as orphan sources and naturally occurring radioactive material in the scrap metal industry. The document highlights the health, environmental, and economic risks posed by such occurrences, and the challenges faced by the metal recycling and nuclear industries in managing them. Emphasis was placed on the need to harmonise international strategies, stakeholder communication, effective monitoring, and regulatory control to minimise the recurrence of these incidents and to rebuild public trust in recycled metal products (International Atomic Energy Agency, 2009a).

Control of Orphan Sources and Other Radioactive Material in the Metal Recycling and Production Industries (IAEA Safety Standards Series No. SSG-17)	The document provides internationally recognised guidance for managing the inadvertent presence of radioactive materials within the metal recycling industry. The guide addresses the risks associated with radioactive contamination in scrap metal, which can lead to serious health, environmental, and economic consequences if not properly managed. It outlines a graded approach based on the size and capacity of facilities, and assigns responsibilities to key actors, including governments, regulatory bodies, and industry stakeholders (International Atomic Energy Agency, 2012)
Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (IAEA Safety Standards Series No. GSR Part 3)	The document establishes a global framework for protecting people and the environment from the harmful effects of ionising radiation. These standards set out general safety requirements applicable to all activities involving radiation sources. The standards encompass principles of radiation protection, dose limits, regulatory responsibilities, and emergency preparedness. They are designed for adoption by national governments to harmonise safety practices and form the basis for legal and regulatory infrastructure (International Atomic Energy Agency, 2014a).
Control of Transboundary Movement of Radioactive Material Inadvertently Incorporated into Scrap Metal and Semi-finished Products of the Metal Recycling Industries	It is a non-binding Code of Conduct intended to assist Member States in regulating the transboundary movement of scrap metal and semi-finished metal products that may inadvertently contain radioactive material. The Code aims to harmonise national policies and regulatory approaches, ensuring that any radioactive material discovered in consignments is promptly brought under regulatory control. It outlines the responsibilities of states, regulatory bodies, industry stakeholders, and the IAEA in detecting, reporting, and safely managing such material (International Atomic Energy Agency, 2014b).

Source: (International Atomic Energy Agency, 2025d)

The IAEA Safety Standards Series No. GSR Part 3: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, was published in 2014, this implies that this safety standard contains the most recent international requirements. In addition to this safety standard, the Code of Conduct, Control of Transboundary Movement of Radioactive Material Inadvertently Incorporated into Scrap Metal and Semi-finished Products of the Metal Recycling Industries was also published in the same year. These two documents are crucial to establish a regulatory framework as applicable to this study.

The Code of Conduct (International Atomic Energy Agency, 2014b), outlines a shared responsibility among the government, the regulatory body, and the metal recycling industry to prevent and manage the presence of radioactive material in scrap metal. Government is expected to establish national policies, legal and emergency frameworks, ensure radiation monitoring, allocate adequate resources, and promote cooperation between authorities and industry, including international coordination. The regulatory body's responsibility is to enforce regulatory oversight, verify contamination, develop relevant guidance, facilitate stakeholder training, and enhance international information exchange. The metal recycling industry is required to implement radiation safety measures, conduct inspections and monitoring, report findings to the regulator, and respond promptly when radioactive materials are detected, thereby supporting efforts to protect the public, persons and the environment.

Many of the above-mentioned documents emphasise the importance of detecting radioactive contamination in scrap metal before it enters recycling processes. They provide for the guidelines on ensuring the safety of workers in environments where scrap metal is handled and processed, they also include protective measures and best practices to minimise radiation exposure. The documents stress the need to apply radiation protection principles to minimise risks to the employees, public and the environment from radioactive contamination in scrap metal. Generally, the IAEA's safety standards form a solid international framework to guide the safe management of radioactive materials in the scrap metal industry (International Atomic Energy Agency, 2014a:6).

2.7 SOUTH AFRICA'S SCRAP METAL REGULATORY FRAMEWORK

The regulation of the scrap metal trade is primarily governed by the Second-Hand Goods Act 6 of 2009 which aims to handle metal theft, improve traceability, and promote responsible and ethical trade practices. This legislation requires all dealers involved in buying or selling scrap

metal to register with the South African Police Service (SAPS), ensuring that only authorised individuals or businesses participate in the sector. The Act also mandates comprehensive record-keeping, whereby dealers must document each transaction with details such as the type and quantity of goods, seller identification, and dates of purchase or sale. To further enhance oversight, monthly reports must be submitted by registered dealers, outlining all acquisitions and disposals of scrap metal.

In terms of radiation control and management, South Africa has established a robust legal framework to regulate radioactive materials and ensure public, workers and environmental safety including facilities where radioactive material may inadvertently enter processes such as scrap metal recycling. Key legislation includes the National Nuclear Regulator Act 47 of 1999 which mandates the oversight of radiation protection and nuclear safety and the Hazardous Substances Act, Act 15 of 1973 which governs radioactive sources.

2.7.1 The National Nuclear Regulator Act (Act 47 of 1999)

The NNR's Regulatory Framework is composed of legally binding obligations derived from international safety conventions, national legislation enacted by Parliament to oversee South Africa's nuclear industry, as well as specific regulations, authorisations, regulatory requirements, and guidance documents. These instruments are used by the NNR to oversee and control the nuclear industry. The regulatory requirements are aligned with the nature of the authorised activity and comprehensively address all responsibilities of the authorisation holder (National Nuclear Regulator, 2022a).

In terms of Section 20 (3) of the National Nuclear Regulator Act 47 of 1999, companies handling radioactive materials more than the exclusion level in terms of Section 2 must have a Certificate of Registration (authorisation). In terms of section 23 (1) of the Act, the Chief Executive Officer may impose specific conditions that authorised companies must adhere to. The conditions of the authorisations are derived from the Safety Standards and Regulatory Practices which were promulgated in accordance with Section 36 of the National Nuclear Regulator Act (Department of Mineral and Energy, 2006). In addition to the conditions, the Regulator prescribed the regulatory requirement documents which guide the authorisation holders on how they can achieve compliance (Van der Westhuizen, 2022:23). Authorisation holders, in terms of Section 28 of the National Nuclear Regulator Act 47 of 1999, are also required to pay an annual authorisation fee prescribed by the Minister of the Mineral Resources and Energy, in consultation with the NNR

board and the Minister of Finance and gazetted by the Department of Mineral Resources and Energy (Department of Mineral Resources and Energy, 2024b:1).

2.7.2 Conditions of Certificate of Registration and related regulatory guidance documents

A company that engages in activities that involve naturally occurring radioactive material more than the exclusion levels is required to have an authorisation called a Certificate of Registration (COR). Such a Certificate of Registration is a “licence to operate” and sets the holder’s authorisation conditions. The NNR has established guidance documents to control the release of NORM-contaminated materials, particularly from mining activities. These measures aim to prevent the inadvertent inclusion of radioactive materials in the scrap metal stream, thereby protecting workers and the public from potential radiation exposure. (Van der Westhuizen, 2022:24). Table 2.3 summarises these conditions and their related guidance documents and provides comments with regards to alignment.

Table 2.3: Guidance documents

SECTION	TITLE	DESCRIPTION	RELATED GUIDE DOCUMENTS
1.1	Scope	Provide the scope or practices authorised	N/A
1.2	Hazard assessment	All activities and operations that involve radioactive material must be subjected to radiological assessments.	Safety assessments for all practices
1.3	Operational limitations	Sets specific limitations in terms of activities that is allowed or not.	No demolition or disposal without prior approval by the NNR, supported by a hazard assessment.
1.4	Operational radiation protection: Workforce processing.	Sets the requirements for radiation protection of the workforce.	Guidance provided in: RD-006: Requirements for the control of radiation hazards: Mining and minerals processing (National Nuclear Regulator, 2002d) and RD-

			011: Requirements for medical surveillance and control of persons occupationally exposed to radiation: Mining and minerals processing. Radiation protection procedure (National Nuclear Regulator, 2002e)
1.5	Radioactive waste	Sets the requirements for waste management. Waste management procedure. The document provides limited guidance for broader waste management.	RD-004: Requirements for Radioactive Waste Management: Mining and Mineral Processing
1.6	Transportation	Sets the requirements for the transportation of radioactive materials	Regulations for the Safe Transport of Radioactive Material 2018 Edition
1.7	Physical security.	Sets expectation for a physical security system that will prevent access to areas containing radioactive materials.	The authorisation holder to provide a description of the physical security measures in place
1.8	Occurrences	Reference occurrence reporting mechanisms and emergency plans.	Guidance provided in: RD-012: notification requirements for occurrences: Mining and minerals processing (National Nuclear Regulator, 2002c). RD-008: Requirements for emergency preparedness: Mining and minerals processing (National Nuclear Regulator, 2002b)

1.9	Quality management	Quality management requirements are set.	Guidance provided in RD-005: Quality management requirements for activities involving radioactive materials (National Nuclear Regulator, 2002a)
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Source: Compiled from various requirement documents

There are 18 scrap processors issued with Certificates of Registration authorising them to handle radioactive material by the NNR (National Nuclear Regulator, 2022b). This highlights a need to have a proper administrative process, as most of the scrap dealers are not authorised, but may encounter radioactive material and sources, so they need to be aware of these requirements.

2.7.3 Guidance documents relevant to scrap facilities during operation

RD-005 sets out the requirements and conditions for the safe management of radioactive waste generated from the mining and minerals processing industry. It requires the authorisation holder to implement a radioactive waste management programme that includes waste minimisation and segregation, characterisation and classification, operational control, and monitoring. The document requires that radioactive waste must be managed in a manner that ensures safety and protection of workers, the public, and the environment. It requires proper identification, labelling, and record-keeping for traceability.

RD 006: requires employees working in mining and minerals processing operations where radiation is present to be adequately trained in radiation protection, to undergo radiation safety training, use personal protective equipment, and comply with established safety procedures. They must participate in regular medical surveillance, including pre-employment, periodic, and exit medical examinations to monitor potential health effects from radiation exposure as required by RD-011: Workers are obligated to wear personal dosimeters in designated areas. These measures aim to ensure employee safety, regulatory compliance, and effective control of occupational radiation exposure.

RD 008 and RD 012: provide the foundational regulatory guidance for managing radiological incidents within the scrap metal operations. RD-012 outlines how to report occurrences involving radioactive materials, ensuring timely notification and corrective action. RD-008 focuses on

emergency preparedness, requiring facilities to have response plans, training, and coordination measures.

Authorisation holders are further required to ensure that all radioactive materials are transported in approved containers with appropriate labelling and radiation shielding. Vehicles must be properly equipped, routes planned to minimise risk, and trained personnel assigned to oversee safe handling and emergency response during transit.

Scrap dealers must ensure that their premises are protected against unauthorised access, theft, and potential misuse of radioactive sources. This involves maintaining secure perimeter fencing, access control systems, CCTV surveillance, restricted entry to designated areas, and secure storage zones for any detected radioactive materials.

2.7.4 Hazardous substances Act (Act No. 15 of 1973)

The Department of Health (DOH) administers the Hazardous Substances Act, 1973, (Act No 15 of 1973). The DOH regulates radioactive materials that are outside a nuclear installation and are used for medical, scientific, agricultural, commercial, or industrial purposes, and any radioactive waste arising from the use of such radioactive material.

2.8 GAPS IN THE LITERATURE

The regulatory framework governing radioactive material within South Africa's scrap metal industry exhibits several critical gaps that may compromise public safety, environmental protection, and regulatory effectiveness. There is a lack of comprehensive guidelines that may assist facilities not authorised by the NNR, that may unknowingly come into contact with radioactive sources material, on what measures to take should they be in contact with radioactive material.

The existing guidance documentation remains outdated, failing to reflect recent technological, operational, and regulatory developments. For example, according to Joubert (2016:14), the Safety Standard and Regulatory Practices (SSRP) was promulgated in 2006 and was based on the 1996 IAEA Basic Safety Standards. The IAEA has since published new requirements in the General Safety Requirement Series on Radiation Protection and Safety of Radiation Sources, IAEA Safety Standards Series No. GSR Part 3, which makes the SSRP out-dated. Since the

conditions of authorisation were derived from the SSRP, there is a need to assess the SSRP to ensure that they are in line with the current IAEA Safety Standards Series No. GSR Part 3.

The 2024 Cape Town scrap yard incident, where a radioactive source was discovered, yet emergency responders lacked established protocols for notifying the NNR, demonstrated a critical failure in inter-agency communication and emergency preparedness (Swartz, 2024). This case indicates systemic weaknesses, including poor enforcement mechanisms, limited collaboration between key stakeholders such as the NNR, the South African Police Service (SAPS), and the Department of Health (DoH), as well as inadequate public awareness.

On a global scale, over 4,900 radioactive incidents have been reported since 1993, many involving orphan sources from industrial and medical applications (IAEA, 2024b). In South Africa, only 18 scrap metal facilities are currently authorised to handle radioactive material, leaving hundreds of informal and unauthorised operators unregulated with a potential risk of exposure to those handling scrap material. These gaps collectively reveal a regulatory system that requires urgent modification to address the risks posed by unmonitored radioactive sources and material within the scrap metal supply chain.

2.9 CONCLUSION

The combined risks from NORM, orphan sources, and imported contaminated scrap highlight the need for integrated radiation protection strategies in the recycling industry. While South Africa has a developed regulatory framework grounded in national and international standards through the National Nuclear Regulator Act 47 of 1999 and the Hazardous Substances Act 15 of 1973, the literature reveals significant implementation gaps, particularly among scrap facilities not authorised by the NNR who may unknowingly encounter radioactive material and sources. These include outdated regulatory guidance documents, insufficient monitoring infrastructure within scrap facilities, and poor coordination between key institutions such as the NNR, SAPS, and the Department of Health. Furthermore, only a limited number of facilities are authorised to handle radioactive materials, leaving the majority of scrap yards unregulated and vulnerable to potential contamination. The absence of formal guidelines and the lack of public awareness amplify these risks. An incident such as the 2024 Cape Town case illustrates the consequences of these regulatory shortcomings.

2.10 CHAPTER SUMMARY

This chapter provided an in-depth analysis of the intersection between metal scrap recycling and radioactive material management, focusing on the South African context. It outlined the economic and environmental benefits of metal recycling and the growing global demand driven by sustainability and decarbonisation efforts. The chapter also explored the sources and risks of radioactive contamination in scrap, drawing on international case studies and IAEA guidelines. South Africa's regulatory framework, including the NNR Act 47 of 1999, and Hazardous Substances Act 53 of 1973, was assessed alongside key guidance documents and authorisation conditions. The analysis revealed critical gaps in regulatory oversight, outdated standards, and limited industry awareness, especially among scrap dealers not authorised by the NNR, reinforcing the need for a more robust and inclusive approach to radiation protection in the scrap metal industry.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

The previous chapter gave a critical analysis of existing literature and regulatory frameworks governing the handling and management of radioactive materials within the scrap metal industry, particularly focusing on the South African context. This comprehensive review enabled the researcher to acquire an in-depth understanding of the regulatory and operational dimensions of radioactive material management in the scrap metal sector. This chapter details the research methodology employed in the study. Swarooprani (2022:537) defines research methodology as a systematic and structured approach used to address the research problem, a collective term for the process of conducting research. Research methodology outlines how a study is conducted, justifying the chosen quantitative and qualitative methods. It explains how data will be collected and analysed, while ensuring ethical standards such as participant privacy, confidentiality, and data integrity are maintained (Bryman *et al.*, 2021:312). It entails analysing the sequential steps a researcher follows to investigate the research problem, as well as the rationale guiding each stage of the process (Khan *et al.*, 2023:1).

This chapter describes the approach to empirical investigation, including the research paradigm, approach, and strategy. The chapter also elaborates on the qualitative methodology adopted, data collection techniques, sampling methods, the development and application of research instruments, and the procedures followed in data analysis. Emphasis is placed on ensuring the trustworthiness of findings and upholding ethical standards throughout the research process.

3.2 EMPIRICAL STUDY

Empirical research is a methodological approach that relies on observable, concrete evidence to draw conclusions and generate knowledge. It involves collecting and analysing data through direct or indirect observation and experimentation, rather than relying solely on theoretical or speculative reasoning (Khan *et al.*, 2023:42). Empirical research can be conducted using both quantitative methods and qualitative methods. To ensure methodological coherence and transparency, the design of the study is informed by the Research Onion model developed by Saunders, Lewis, and Thornhill as depicted in Figure 3.1 (Saunders *et al.*, 2023:131). This model provides a systematic framework for making informed methodological decisions, from the research philosophy through to data collection and analysis techniques. Each layer of the onion represents a critical element of the research design, including the philosophical stance, research

approach, strategy, methodological choice, time horizon, and the specific techniques and procedures used. This structured approach ensures that all aspects of the study are aligned with its interpretivist paradigm and inductive logic, allowing for the generation of in-depth, contextually grounded insights into the handling of radioactive materials in the scrap metal sector. The chapter proceeds by unpacking each layer of the research onion to justify and explain the choices made throughout the research process.

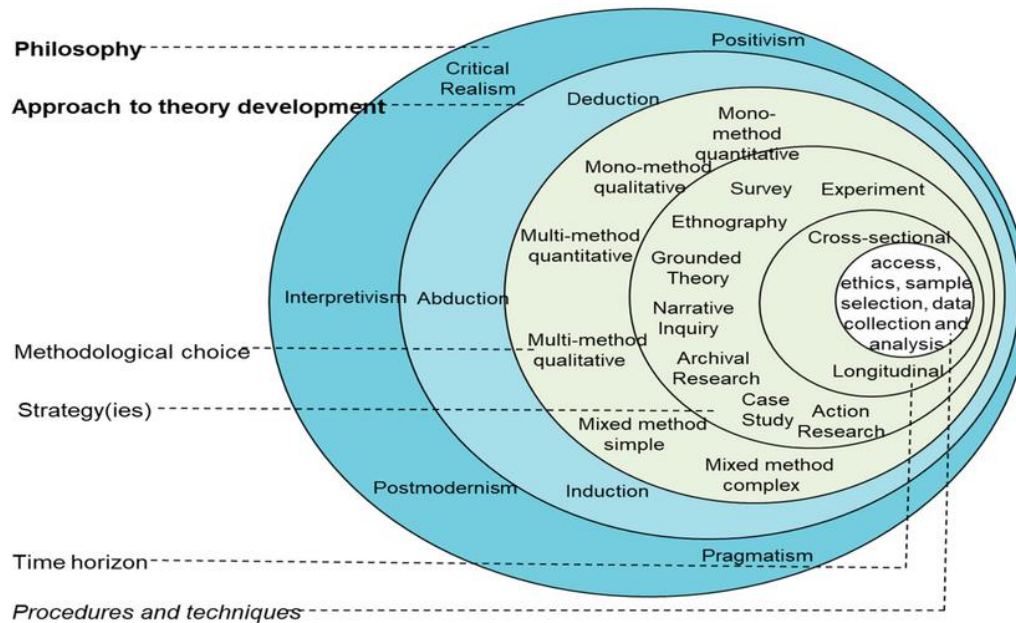


Figure 3.1: The research onion.

Source: (Saunders *et al.*, 2023:131)

3.2.1 Research Paradigm

A paradigm is a fundamental belief system and conceptual framework that includes assumptions about four key aspects: ontology, epistemology, methodology, and methods. it defines how we interpret reality and explore it through research (Husam Helmi Alharahsheh & Pius, 2020:40; Rehman & Alharthi, 2016:51). Paradigms guide how scientific inquiry is conducted, encompassing a researcher's beliefs based on ontology, epistemology, Methodology, and methods (Rehman & Alharthi, 2016:52) .

According to (Husam Helmi Alharahsheh & Pius, 2020:39) the key philosophical underpinnings of fundamental research paradigms are Positivism and Interpretivism. Rehman and Alharthi (2016:53) state that positivism is based on the belief that reality is objective and exists

independently of human interpretation. It follows an objectivist epistemology and a deductive research approach. Researchers use a scientific approach by forming hypotheses, collecting data, and using statistics to test whether the results support or reject the hypothesis, ultimately leading to theory development explaining the effect of independent variables on dependent variables (Rehman & Alharthi, 2016:54). Positivist research often generates numerical data employing quantitative methods.

Conversely, the interpretivist paradigm asserts that knowledge is actively created by individuals through their personal experiences, social interactions, and subjective interpretations of reality (Bryman *et al.*, 2021:93). Truth and reality are not discovered but created (Rehman & Alharthi, 2016:55) and according to Bryman *et al.* (2021:93), reality is viewed as subjective within this paradigm. Interpretive researchers employ methods that generate qualitative data. The selected paradigm also influences whether the researcher uses a qualitative or quantitative approach in designing the research and collecting data (Bryman *et al.*, 2021:136).

Due to the objectives of the study, an interpretivist philosophy was adopted to uncover insights into regulatory processes and compliance, communication effectiveness, and operational challenges through participants' lived experiences. This approach emphasised the importance of exploring the subjective experiences and interpretations of individuals directly involved in handling these materials.

3.2.2 Research approach

The concept of research approach involves structured plans that guide the entire research process, from general assumptions to specific methods for collecting, analysing, and interpreting data (Creswell & Creswell, 2018:50). According to Saunders *et al.* (2023:155), there are two different approaches to reasoning: deduction and induction approaches. Deductive reasoning is central to the positivist paradigm. Research within this paradigm follows a structured process that starts with the formulation of hypotheses, which are subsequently tested through empirical investigation using operational definitions, mathematical formulations, calculations, extrapolations, and quantitative analyses to draw conclusions (Kivunja & Kuyini, 2017:30). Conversely, with induction, data are collected and a theory is developed as a result of the data analysis (Creswell & Creswell, 2018:50). Inductive research is rooted in the humanities and prioritises the importance of subjective interpretation, therefore it is typically informed by the interpretivist philosophy (Saunders *et al.*, 2023:154).

This study adopted an interpretivist research paradigm because it enables an in-depth understanding of the experiences, perceptions, and practices of participants involved in managing radioactive materials. Given the complexity and contextual nature of the regulatory, operational, and safety challenges in this industry, an interpretivist approach enables the exploration of real-world phenomena without being limited by predefined theories. By employing inductive reasoning, the study aims to generate insights and develop a theory based on the analysis of qualitative data collected directly from participants within the industry.

3.2.3 Research strategy

A research strategy implies a general orientation to conduct a study, reflecting its methodological assumptions and outlining how data will be collected, analysed, and interpreted to address the research questions (Bryman *et al.*, 2021:139). Saunders *et al.* (2023:206) defines a case study as an in-depth study which explores issues, present and past, as they affect one or more units (organisation, group, department, or person). A case study strategy may involve investigating more than one case. The use of multiple cases strengthens the research by enabling comparisons across different contexts to determine whether the findings observed in one case are consistent in others (Coombs, 2022:3; Creswell & Creswell, 2018:35). This approach enhances the reliability of the results and allows for a broader generalisation of the insights, increasing their relevance and applicability across the industry.

This study adopts a multiple-case study strategy, which is well-suited for exploring complex phenomena within a real-life context. By adopting a case study approach, the researcher draws on insights from various scrap facilities to examine how radioactive materials are handled in practice, identify systemic gaps, and explore differences across various operational settings. This allows for cross-case comparisons, helping to determine whether observed challenges are widespread or context-specific. Furthermore, the case study strategy aligns with the study's interpretivist paradigm and inductive reasoning, supporting the goal of developing a practical managerial framework that reflects the realities and needs of stakeholders in the industry.

3.2.4 Methodological choice

Qualitative research is defined as a research strategy that typically prioritises words over numerical quantification in data collection and analysis, adopting an inductive approach to the relationship between theory and research, with a focus on theory generation (Saunders *et al.*, 2023:186). Qualitative methods aim to explore meanings, opinions, or the underlying reasons

behind certain behaviours or phenomena (Ugwu & Eze Val, 2023:20). On the other hand, quantitative research can be defined as a research strategy that emphasises quantification in data collection and analysis, employing a deductive approach to the relationship between theory and research, with a focus on the validation of ideas (Saunders *et al.*, 2023:182).

For this study a mono-method qualitative methodological choice, which is consistent with the interpretivist paradigm and inductive reasoning underpinning the research was used. A qualitative approach is particularly suitable for exploring complex, context-specific issues that require a deep understanding of participants perspectives, institutional practices, and regulatory processes. A qualitative method allowed the researcher to collect rich, descriptive data through semi-structured interviews complemented by document analysis.

3.2.5 Time Horizon

According to Saunders *et al.* (2023:212), a key consideration when designing a research study is whether the investigation aims to capture a single point in time, similar to a snapshot, or whether it intends to observe developments over a longer period. The choice between these two depends on the nature of the research question. A cross-sectional time horizon reflects the snapshot approach, providing insights into a phenomenon at a specific moment, whereas a longitudinal time horizon involves repeated observations to track changes and trends over time. For this study, a cross-sectional design is appropriate, as it seeks to explore current practices and challenges in radioactive material management within the scrap metal industry, rather than monitoring changes over an extended duration.

3.3 POPULATION AND SAMPLES

The first step in the sampling process is to define and specify the target population clearly (Taherdoost, 2016:19). The study population is the complete set of cases or elements from which a sample is taken that you are interested in researching (Saunders *et al.*, 2023:289). In this research, the study population is all the South African scrap facilities authorised by the NNR to handle radioactive material. Although the NNR authorised 18 facilities as scrap processors, 3 of these facilities are not handling scrap metal but other types of waste material, such as plastic and rubber, etc. These entities were identified as refurbishers or handlers of plastic materials and, therefore, were excluded from the sample. The study population is as indicated below:

Table 3.1: Distribution of authorised scrap facilities in South Africa

Province	Number of authorised scrap facilities
Northwest	4
Kwa Zulu Natal	1
Free State	1
Western Cape	0
Eastern Cape	0
Limpopo	0
Gauteng	9
Northern Cape	0
Mpumalanga	0

Source: Own Source

3.3.1 Accessibility of participants

The certificates of registration for authorised facilities are published on the NNR official website, and the company details were found on the NNR database. The NNR CEO awarded permission to contact the participants. Companies were contacted via email and telephone, requesting their participation. The study also considered the POPI Act 4 of 2013.

3.3.2 Inclusion and exclusion criteria

The study included all the scrap facilities in South Africa authorised by the NNR. The study participants included employees with a minimum of one year of experience in radiation protection, specifically in the roles of radiation protection officer, specialist, and managers directly involved in handling radioactive material and ensuring compliance with NNR regulations.

Table 3.2: Inclusion and exclusion criteria for the population

Inclusion Criteria	Exclusion Criteria
Scrap facilities authorised by the NNR	Scrap facilities not authorised by the NNR

The human participants should have a minimum of 1 year of experience working as radiation protection officers, specialists, and managers within the scrap facilities.	Employees with less than 1 year experience as a radiation protection officer, specialist and managers
Scrap facilities that are located in South Africa	Scrap facilities that are not located in South Africa
Authorised scrap facilities handling scrap metals	Authorised scrap facilities that do not handle scrap metals.

Source: Own

3.3.3 Sample selection

The research population for this study comprised all South African scrap facilities authorised by the NNR to manage radioactive material. Authorised facilities are published on the official NNR website, and company details were obtained from the NNR database as permission to approach participants was formally granted by the NNR Chief Executive Officer.

The researcher employed purposive sampling, a strategy where participants who possess specialised knowledge, skills, and experiences relevant to the study (Taherdoost, 2016:23). The sample selection process for this study was carefully structured to ensure the inclusion of participants with sufficient organisational experience and are directly involved in radioactive material management. Participants were required to have been employed in their current organisation for a minimum of one year, thereby guaranteeing familiarity with institutional processes and practices.

Participants with specialised knowledge and expertise in radioactive material management, such as facility Managers, Radiation Protection Officers, and Specialists within the scrap processing environment, were selected to ensure that the sample included individuals who could provide comprehensive and insightful information on the authorisation applications process, compliance, and the operational handling of radioactive material. Formal permission letters were issued to the managing directors of 15 facilities to request participation (**Annexure A**).

Of the facilities contacted, 12 participants, 4 Managers, 5 Radiation Protection Officers, and 3 Radiation Protection Specialists provided written informed consent to take part in the study (**Annexure B**). These participants are the most experienced role players in the South African

scrap processing industry, bringing expertise in regulatory engagement, safety management, and radiation protection. Data collection continued until saturation was reached, where no new themes or substantive insights emerged (Hennink & Kaiser, 2022:1).

Data saturation is crucial in qualitative research methodology (Hennink & Kaiser, 2022:1). It refers to the point at which no new information, themes, or patterns emerge from the data. It also indicates that the researcher has thoroughly examined and explored the study's phenomenon, ensuring that no critical information is overlooked. This concept is essential in determining sample size and in strengthening the credibility and validity of qualitative research (Ahmed, 2025:2). In qualitative research, the sample size should be large enough to ensure data or theoretical saturation is reached, but not so extensive that it becomes challenging to conduct a detailed, case-focused analysis. (Bryman *et al.*, 2021:411). In line with Bryman *et al.* (2021:411), the sample was of sufficient size to achieve depth without compromising case-oriented analysis.

By focusing on participants actively engaged in radioactive scrap management, the study captured diverse yet specialised perspectives. This enriched the findings and provided a comprehensive understanding of the administrative and operational challenges associated with handling radioactive materials. Similar to other qualitative studies in highly regulated industries, purposive sampling combined with the principle of saturation ensured both methodological rigor and practical relevance.

3.4 DATA COLLECTION PROCESS

A semi-structured interview involves using a flexible set of prepared questions, allowing the interviewer to adjust the order and ask follow-up questions based on the interviewee's responses. This approach encourages more profound exploration of key topics and deeper exploration of important points during the interview. (Bryman *et al.*, 2021:178). According to Bhalla *et al.* (2023:12), this format allows the interviewer to explore key themes while also encouraging follow-up questions and prompts based on the participant's responses.

To identify potential problems and establish possible solutions before the actual data collection, a pretest of the interview schedule was conducted on two participants. According to (Bhalla *et al.*, 2023:12), pre-testing is considered necessary in certain qualitative research studies that use questionnaires, as it helps enhance the construct validity and reliability of the data collection instrument. To avoid duplication, the pretest results were not used in the final analysis. The researcher recorded actual interviews to retain the words from the participants.

Therefore, qualitative semi-structured interview questions (**Annexure C**) were utilised to collect data for this research study. This allowed for open-ended responses that revealed insights into their experiences and challenges.

3.4.1 Collection of data

Upon receipt of the ethical clearance certificate, prospective participants were contacted via email and telephonically, as per the inclusion criteria, and were invited to participate in the study. This communication included information about the importance of the study while emphasising that participation is totally voluntary. The interview questions were sent in advance of the scheduled interview date. This advance notice allowed participants enough time to review and prepare for the questions. All participants provided written informed consent, and the study complied with the ethical standards of the North-West University's Economic and Management Sciences Research Ethics Committee (EMS-REC), under the approved ethics clearance number: NWU-00669-25-A4 (**ANNEXURE E**). Interviews were scheduled with voluntary participants at their convenient time, mainly in August 2025. The interviews were conducted via the Microsoft Teams Meeting Virtual platform, using the questions provided beforehand. The researcher conducted each interview, recorded with the participants' consent, and the interviews ranged from thirty minutes to not more than an hour. The participants were also encouraged to share further insights into the topic under the general feedback section of the interview. The researcher listened attentively to the participants without interruption and also took supplementary notes during the interview process.

3.4.2 Qualitative data analysis

All interviews were transcribed using Turboscribe, a transcription tool that ensured accurate, consistent, and efficient conversion of participant responses into text. This streamlined the data preparation process, saving time and supporting reliable qualitative analysis. Transcription was conducted immediately after each interview to preserve accuracy and capture subtle details such as tone, emphasis, and context while still fresh in the researcher's memory. To further ensure reliability, transcriptions were verified by re-listening to the recordings while reviewing the text, a process that both safeguarded authenticity and enhanced the researcher's familiarity with the data. This facilitated effective coding and ensured rigor in the subsequent analysis. An example of an interview transcription is included. For coding purposes, the researcher assigned clear identifiers to questions and responses, using "Interviewer" and "Participant" titles, respectively (**Annexure D**).

Ahmed *et al.* (2025:1) indicated that a widely used method in qualitative research is thematic analysis, which is utilised to identify and analyse themes of the empirical data. In line with Saunders *et al.* (2023:664) multi-level interactive approach, coding played a critical role in managing and interpreting the large volume of data. The six-phase thematic analysis outlined by Braun and Clarke (2006:79) as depicted in Figure 3.2, was then used to identify common codes and themes within the interview responses. This study adopted both a top-down (theoretical) approach, guided by the research objectives, and a bottom-up (inductive) approach, driven by the evidence itself, to ensure that all relevant themes were captured.



Figure 3.2 : Six phases in thematic analysis.

Source: (Ahmed *et al.*, 2025:2)

The transcribed data were analysed using ATLAS.ti 25. The software enabled the researcher to systematically uncover patterns and insights, thereby strengthening the credibility of the findings.

This analytical process utilised from Atlas.ti provided a deeper understanding of stakeholder perceptions regarding regulatory compliance, safety measures, and the effectiveness of current administrative processes. The insights generated ultimately informed the development of a guideline for implementing administrative process for managing radioactive material within the scrap metal industry. The thematic analysis yielded the following results and findings as discussed in the next section.

3.5 DISCUSSION OF THE RESULTS OF THE QUALITATIVE ANALYSIS

3.5.1 Analysis and concepts

As indicated, a total of twelve participants agreed to take part in this study through semi-structured interviews. The participants consisted of scrap metal facility managers, radiation protection officers (RPOs), and radiation protection specialists (RPSs), each with varying years of experience in radiation protection and scrap metal operations. This provided a broad and practical perspective on the NNR authorisation process, experienced across small and large facilities, and operational sides of the industry.

Figure 3.3 presents the biographical information of participants with regard to number of years of experience.



Figure 3.3: Participants Biographical information.

The participants' experience in radiation protection and scrap metal handling ranges from 5 to 30 years, with the majority being highly experienced RPOs and RPSs. Collectively, RPOs and specialists contribute the largest share of expertise, while managers at smaller facilities generally have less exposure, focusing more on operational aspects than technical compliance. This highlights the industry's reliance on seasoned specialists to guide smaller operators through regulatory requirements.

The next section outlines the research findings, structured according to the themes that emerged from the data.

3.5.2 Presentation of findings

The twelve interview transcripts were imported into ATLAS.ti Version 25 for analysis. From the analysis, a total of 365 codes emerged. A combination of AI-assisted coding and researcher-led refinement was then used to structure the data. After multiple rounds of data interrogation, 12 codes were identified and subsequently consolidated into four overarching themes: *Awareness & Access to Information*; *Application Process, Timelines & Bottlenecks*; *Costs & Capacity*; and *Measurement, Monitoring & Operations*. These themes were directly linked to the study's research objectives and informed by evidence from multiple participant perspectives.

Given the large volume of coded material, it was not possible to include every quotation in the report. A rigorous selection process was therefore applied to ensure that only the most analytically significant and representative quotations were included. This allowed for balanced reporting of both common patterns and unique insights across participants.

To complement the coding results, the Concepts Cloud function of ATLAS.ti was used to identify frequently recurring terms and phrases across the interviews. This visual highlighted the key words that appeared most often, helping to confirm the main themes identified in the analysis. The biggest words are those that are identified the most as presented in Figure 3.4.

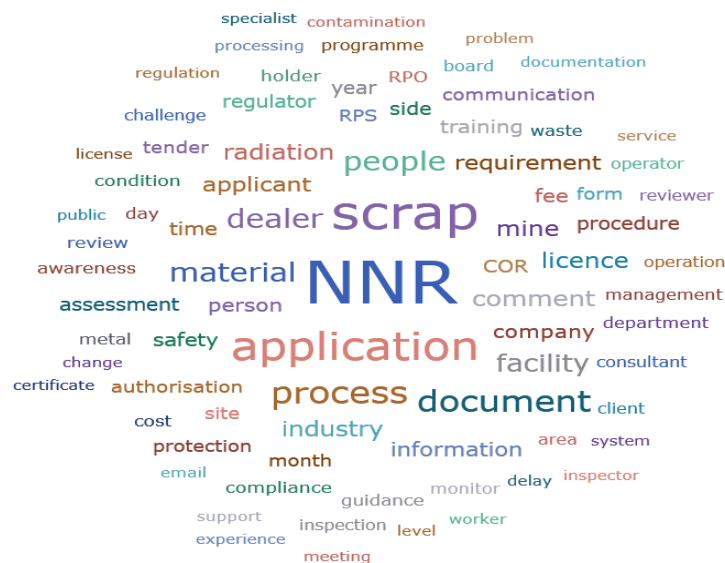


Figure 3.4: ATLAS.ti Concepts Cloud

Source: ATLAS.ti 25

3.5.2.1 Thematic analysis

Using ATLAS.ti, networks were generated for each theme, and the associated codes and quotations were reviewed for relevance. Related codes were merged into subthemes, resulting in four overarching themes to be discussed:

3.5.2.2 Theme 1: Awareness & Access to Information

Theme 1 consists of 3 subthemes as shown in Figure 3.5:

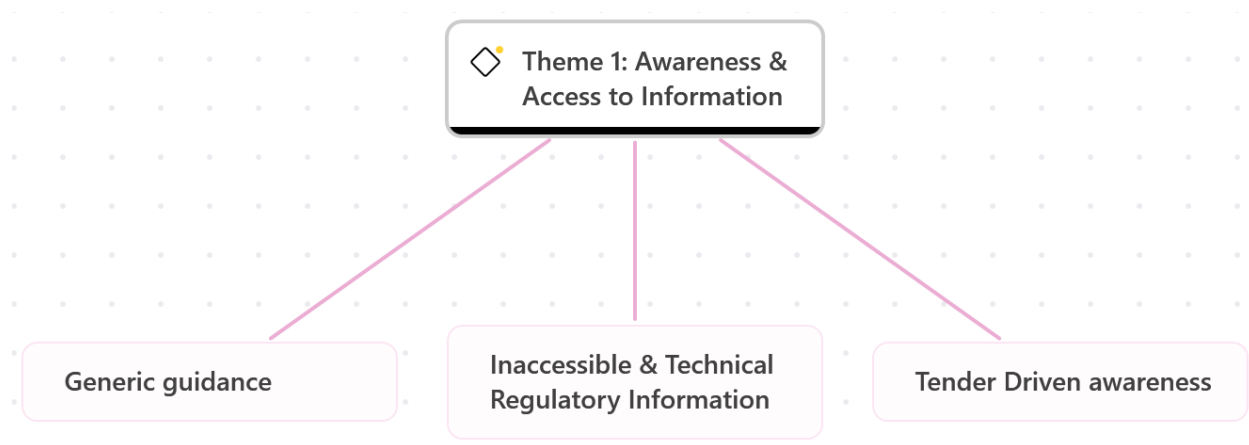


Figure 3.5: ATLAS.ti category code network: Awareness & Access to Information

The Awareness and Access to Information theme illustrates the critical role of knowledge, communication, and regulatory transparency in ensuring radiation safety within scrap-metal operations.

3.5.2.2.1 Generic guidance

Participants explained that the available guidance documents from the NNR were too broad, generic, and not tailored to the specific realities of scrap metal operations.

Participant 5: *“Maybe an application template with dropdowns and checkboxes would help, something practical for scrap yards. Right now, it feels like the forms are designed for big nuclear facilities, and everyone must use the same one, even if it doesn’t apply to your context.”*

Participant 9: *“Simplifying processes for scrap dealers, would make compliance possible. At the moment, the guidance is too generic and does not explain what is expected specifically from scrap yards, so they end up paying consultants to interpret it.”*

Participant 11: *“The NNR provided guidelines and documents, but they were very technical and not easy for someone without a radiation background to understand. Most of the practical guidance came from the consultants we hired.”*

Participant 10: *“I think it’s very clear from the NNR side, when you apply for a COR, they provide all the relevant documentation. Their documentation clearly outlines all the requirements. From my perspective as an RPO, and from the RPS side as well, it is set out very well in a structured document. There is nothing unusual or out of the ordinary, if I can put it that way. The assistance provided by the NNR during applications is brilliant”.*

Participants 5, 9 and 11’s insights reveal that while the NNR provides guidance, its generic and technical nature limits accessibility for scrap metal operators, who often lack the expertise of large nuclear facilities. As Neba (2018:36) stresses, information must be communicated in forms appropriate to different stakeholder groups, while the International Atomic Energy Agency (2018a) highlights the need for clarity, transparency, and accessibility. This indicates that the challenge lies not in the existence of regulation, but in how it is presented and operationalised for different contexts, particularly the scrap metal sector. International Atomic Energy Agency (2020:16) indicated, that communication about NORM should be framed in terms of risk, helping stakeholders compare and contextualise NORM-related hazards against other common risks. Participant 10 however, has a different view particularly because he is a Radiation Protection Officer with technical expertise.

3.5.2.2.2 Inaccessible and Technical Regulatory Information

Participants described how information about the NNR and the authorisation process was difficult to find and highly technical. For smaller facilities, this lack of accessible resources meant that they have to rely on external consultants to interpret requirements.

Participant 1 indicated the following:

“Information about the NNR is not easily accessible. You don’t find brochures, posters, or clear instructions anywhere. Unless you know someone at the NNR or have worked in radiation industry before, you can’t just access the information. That is why most of the time people only find out when it is too late.”

Participant 3 said:

“They are not easily accessible. If you go onto the website, the information is scattered and very technical. For a small scrapyards operator, it is impossible to understand what is required without hiring an RPS”.

Participant 8 stated:

“People start looking to find out what’s needed and then realise the information isn’t straightforward. There is no simple step-by-step guide or checklist. The regulations are there, but they are not written in a way that an ordinary scrap dealer can understand.

These insights illustrate that the problem is not a lack of regulations, but rather how information is presented and disseminated. Regulatory knowledge exists, yet it is inaccessible in practice to those without specialised expertise. Neba (2018:36) emphasises that stakeholders must be able to understand the information provided, which requires tailoring both content and format to each stakeholder group. This includes using appropriate concepts, language, and familiar communication media, and ensuring that translations or adaptations are accurate and accessible.

International Atomic Energy Agency (2020:16) emphasises that communication and education efforts must use clear, concise, and consistent language that can be easily understood by non-specialists. It recommends leveraging social media platforms to effectively share information with a wider audience. Similarly, International Atomic Energy Agency (2018a:11) highlights that regulatory information must be transparent, understandable, and available to all stakeholders. Where this does not occur, compliance is weakened, inclusivity is limited, and smaller scrapyards risk being excluded from the regulatory system

3.5.2.2.3 Tender-driven awareness.

Several participants explained that awareness of the NNR authorisation requirement was usually triggered externally, most often through contractual conditions such as tenders from mines. This shows that compliance was not the result of proactive regulator-led outreach but of stakeholder pressure exerted by large corporate clients. In practice, companies complied because meeting mine requirements was essential to securing business.

Participants 3 and 5 indicated that they became aware of NNR authorisation only when applying for a mine tender.

Participant 3: “We were first made aware of the NNR authorisation requirement when applying for a tender at a mine. Until then, we did not even know there was such a requirement. It was not communicated anywhere before that.”

Participant 5: “Usually, the mine will add it as a requirement in the RFQ or tender documents, and that’s when people start asking about NNR licensing. Before that, nobody talks about it, and you wouldn’t know it exists if you are a small scrapyard.”

Participant 7 stressed that without these contractual conditions, many facilities would remain unaware of regulatory obligations.

Participants 7: “That’s usually when they come to us when a tender needs it. Not because they knew about it before, but because it is in contract conditions. If there was no tender requirement, they would never even apply.”

Participant 11: I only became aware of the need for NNR authorisation when applying for a tender with a mine. Until then, I had not encountered any information suggesting that scrap could contain radioactive material. The requirement was not something that was clearly communicated in industry networks or by regulators beforehand, so the information came as a surprise and was not very accessible.

Participant 11’s insight reflects what Zhang (2024:183) calls information asymmetry, where one party holds more or better information than another, leading to imbalances in decision-making and efficiency. Applied to regulatory communication, this means that when regulators do not effectively share critical knowledge with all industry stakeholders, compliance becomes uneven and dependent on indirect information channels.

Overall, the participant’s quotations align closely with the concept of stakeholder engagement. Gutterman (2023:1) defines stakeholder engagement as both formal and informal dialogue with parties who influence, or are influenced by, an organisation’s operations. He emphasises that businesses cannot exist in isolation but rely on relationships with their stakeholders. In this study, mines acted as particularly powerful stakeholders by embedding NNR authorisation requirements into tender conditions, thereby compelling compliance in the absence of proactive regulator communication.

While this form of stakeholder driven enforcement ensures that regulatory standards are met in practice, it creates a reactive and potentially fragile compliance culture. Companies respond primarily when pressured by external demands, rather than internalising regulatory obligations as part of their strategic and operational values. This suggests that unless regulator and industry dialogue is strengthened, authorisation may be treated as a transactional requirement for market access rather than a sustained commitment to safety and responsible operations

3.5.2.3 Theme 2: Application Process, Timelines & Bottlenecks

Theme 2 consists of 3 subthemes as shown in Figure 3.6 below:

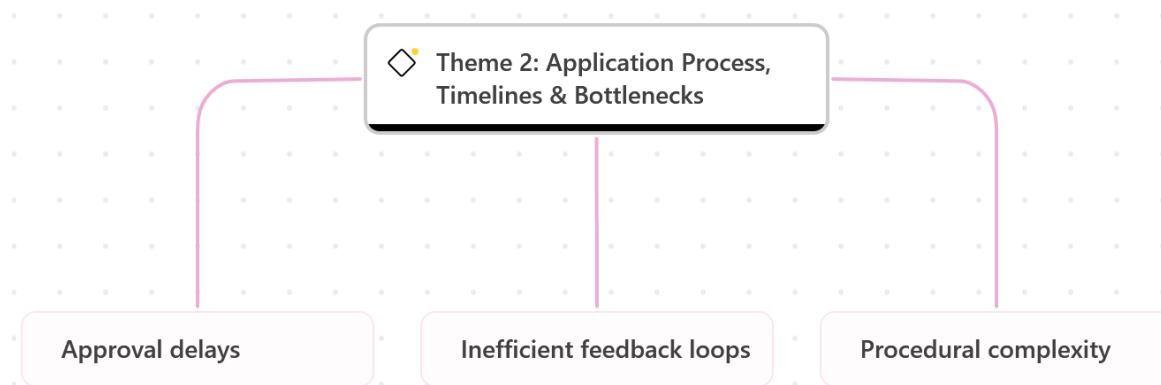


Figure 3.6: ATLAS.ti category code network: Application Process, Timelines & Bottlenecks

The Application Process, Timelines and Bottlenecks theme highlights the procedural and administrative challenges experienced by scrap-metal operators when seeking authorisation from the NNR.

3.5.2.3.1 Approval delays

Participants reported significant and unpredictable waiting times for authorisations approvals. Delays ranged from several months to multiple years, with the availability of the board highlighted as a key bottleneck in the process.

Participant 1: *“It took about a year. After submitting documents, the NNR often came back asking for additional documents, which created delays”. It would help if applicants knew exactly what was required and the expected turnaround times for each step. That way, we would not have to constantly probe the regulator for updates”.*

This insight shows how unclear requirements and lack of defined timelines create inefficiencies in the licensing process. The absence of upfront clarity means operators face repeated requests for additional documents, lengthening the process and creating uncertainty. This is in line with Ilesanmi (2025:2) who defined permitting as a formal procedure through which government agencies grant legal authorisation for proposed activities. Its primary goal is to ensure compliance with legal and regulatory standards; however, overlapping mandates and procedural inefficiencies frequently result in significant delays and unpredictability. Ye *et al.* (2023:2) shows that regulatory delays have the greatest impact on companies operating in competitive markets in comparatively disadvantaged positions, since they are less able to manage the added costs and uncertainties involved.

Participant 4: *“In earlier years, turnaround time was about 60 days, then extended to 90, 120, 150 days, and in some cases up to two years. The delay occurs partly because applications must now go through board approval, which only happens four times a year, adding significant delays.” The long turnaround times and trivial comments were major challenges. For example, being told a table of contents was not numbered or a board resolution was not certified. Such issues are not technical and unrelated to risk but delay licensing. Meanwhile, truly material issues, like not measuring specific activity, are legitimate. The current process also places too much weight on legal and financial conditions, which discourages entrepreneurs and small operators who lack financial history.*

Participant 8: *“It varies, but in my 21 years of being a consultant, I’ve only been pleasantly surprised once where in the application process took about two months. Other than that, it takes anything from four months to two years, depending on the review of the documents. And at some point, there was an introduction of all applications needed to go to the board, and this was not communicated. So even if technically, it has been approved, then the application has to wait for the NNR board to sit and sort of approve and then the COR is issued”.*

Participant 4 and 8’s views reflect two structural challenges, delays linked to the board’s quarterly meeting cycle, and misplaced emphasis on administrative formalities over substantive safety concerns. For small operators, strict financial requirements become barriers to entry. In terms of Section 21 (7) of the NNR Amendment Act 26 of 2024, the Chief Executive Officer may grant or refuse an application subject to the approval of the Board. While this provision enhances governance and accountability, it has also introduced systemic bottlenecks, as the limited

frequency of board meetings often contributes to significant delays in the finalisation of licence approvals

Udo (2023:17) highlights that lengthy application processes also deter some companies, especially those needing quicker funding turnarounds. These findings align with international best practice literature, which stresses that effective regulation should be both rigorous and timely to maintain stakeholder trust (International Atomic Energy Agency, 2018b:82). Addressing this issue may require process re-engineering, such as delegating routine approvals to technical committees or increasing the board meeting frequency, introducing service-level turnaround standards, or leveraging digital platforms for application tracking. Such reforms would improve predictability and increase efficiency in the regulatory processes.

3.5.2.3.2 Inefficient feedback loops

Participants highlighted that once applications were submitted, communication from the NNR was often slow and focused on administrative details rather than substantive safety issues. This created unnecessary delays and frustration.

Participant 1: *“Normally, one has to send an email request, and then the NNR responds by providing the required forms and information. The main difficulty was lack of communication and limited updates on the progress of the application. After submitting documents, the NNR often came back asking for additional documents, which created delays. Some comments were not clearly explained, making them difficult to address.”*

Participant 1 highlights the lack of structured and proactive communication in the licensing process. Rather than providing applicants with timely updates and clear guidance, the NNR relies on a reactive approach, leaving operators to chase progress and navigate vague instructions. This results in delays, repeated document submissions, and significant frustration for applicants.

The IAEA (2016) emphasises that regulators must ensure clarity and timeliness in communication to maintain efficiency and stakeholder trust. Meinam *et al.* (2023:10) stress that feedback must be both timely and valid to be effective. Ilesanmi (2025:2) further identifies poor communication as a key contributor to procedural delays, reinforcing how regulatory inefficiency emerges from fragmented feedback practices.

Participant 2: *“The NNR should not wait three months before giving feedback. They should send comments as they review the application, so issues can be addressed earlier. Timing and prioritisation are important, especially since some applications are linked to tenders with strict deadlines.*

Participant 2 stressed that the NNR’s feedback often takes up to three months, which creates unnecessary delays. This account reflects two key challenges, delayed feedback and the absence of clear process timelines. Without defined service standards, applicants cannot predict how long approvals will take or align them with business requirements such as tender submissions. Timely feedback is critical because the faster it is provided, the greater the chance that the receiver will understand the sender’s intent and be able to respond appropriately. Validity, on the other hand, refers to feedback being accurate, dependable, and meaningful for decision-making.

Participant 9: *“What we come across is most of the comments that we get from the NNR I don’t want to lie to you most of them are administrative related issues... instead of you receiving the comment saying your application is not approved because of risk issues, it will be that you forgot to attach the RPS qualifications. You would expect technical feedback, but instead you get administrative issues.”*

Here the problem is not just timing, but the content of feedback. Participants expected comments addressing technical safety or compliance matters but instead received administrative corrections. This creates the perception that attention is focused on procedural details rather than substantive safety risks. Benson et al. (2024) argue that effective regulatory oversight should balance administrative compliance with a focus on material health, safety, and environmental (HSE) risks. Excessive focus on non-material issues reduces regulatory legitimacy. The IAEA (2016) similarly advises that regulatory comments should be risk-informed, ensuring that applicants prioritise safety-critical requirements over minor administrative lapses.

3.5.2.3.3 Procedural complexity

Participants described the NNR application process as highly technical and difficult to manage without external support. They highlighted reliance on Radiation Protection Specialists (RPSs), the need for detailed safety assessments, and the generally complex documentation required.

Participant 2: *“Applicants must also submit a hazard assessment, a baseline survey, and consult a Radiation Protection Specialist. Most facilities cannot complete these requirements without external help.”*

Participant 6: *“The documentation is very complicated. The terminology is nuclear-industry level, not scrap-industry level. That complexity pushes people to outsource the process.”*

Participant 11: *“I only became aware of the requirements when I had to apply, and then I saw that they wanted a safety assessment and specialist input. There is no way a small scrap operator can handle that without paying someone.”*

The participants’ views show that the NNR’s application process is overly technical, requiring hazard assessments, baseline surveys, and specialist input that most scrap operators cannot manage independently. This complexity is intensified by the radiological environment in which scrap facilities operate, involving the handling of potential radioactive scrap material and the need for ongoing radiation monitoring. Neba (2018:36) however, points that regulatory information must be tailored to the capacities of different stakeholder groups. Safety requirements should be communicated in a transparent and understandable manner to avoid creating unnecessary barriers (International Atomic Energy Agency, 2018a).

3.5.2.4 Theme 3: Costs & Capacity

Theme 3 consists of 3 subthemes as shown in Figure 3.7:

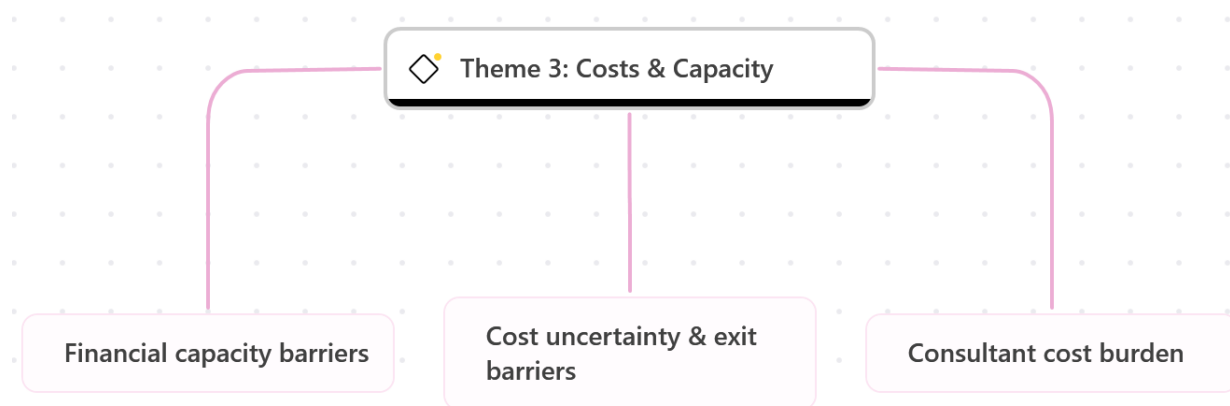


Figure 3.7: ATLAS.ti category code network: Costs & Capacity

This theme highlights how financial limitations and inadequate technical expertise constrain compliance within the scrap-metal industry.

3.5.2.4.1 Financial capacity barriers

Participants noted that demonstrating financial capacity was a requirement of the authorisation process. They highlighted that the requirement to provide financial statements and the broader costs of compliance created barriers, particularly for smaller facilities with limited resources.

Participant 2: “You must demonstrate financial capacity to pay authorisation fees.”

Participant 3: “The major challenge was the cost of application and compliance.”

Participant 4: “Some requirements, such as submitting three years of financial statements, create barriers for small facilities.”

These accounts illustrate how documentary requirements (multi-year financial statements) and affordability challenges (fees and compliance costs) act as structural barriers in the licensing process. Minimum capital requirements, though intended to safeguard economic stability, can exclude small startups with limited financial capacity (Udo, 2023). For larger operators, meeting these conditions may be routine, but for smaller scrapyards or new entrants, they create disproportionate strain. From a managerial perspective, these requirements limit inclusivity, as financial strength becomes a precondition for compliance rather than safety performance. Strategically, this favours well capitalised firms, entrenches market inequalities, and risks discouraging smaller players from pursuing authorisation, even when they intend to comply.

3.5.2.4.2 Cost uncertainty and exit barriers.

Participants highlighted that while the NNR’s hourly fee rate is known, the number of hours billed per application is unpredictable, making the total cost difficult to anticipate. In addition, annual license fees continue to apply during the surrender process, forcing operators to absorb costs even when facilities are inactive.

- **Participant 4:** *“The hourly rate charged by the NNR is known, but you don’t know how many hours will be billed or what exactly is covered in those hours.”*

This highlights a lack of transparency and predictability in fee calculations. While the rate is published, the absence of clear guidance on how hours are allocated leaves operators unable to estimate the total cost of compliance. This uncertainty complicates budgeting and planning, effective regulatory systems must ensure transparency in fee structures and provide clear, predictable costing mechanisms. Lack of clarity undermines trust and raises the perceived cost of compliance.

- **Participant 5:** *“There is a gap when it comes to surrendering a license. You still pay fees until the process is finalised, which can take months, even if you are not working anymore.”*
- **Participant 7:** *“The challenge is that annual fees keep recurring. If you want to exit, there is no immediate way to stop the charges, so you pay until the surrender is approved.”*

Participants 5 and 7 highlighted that annual licence fees continue to accrue during the surrender process, even when facilities are no longer operational. They viewed this as particularly unfair, since surrender processes can take months, leaving operators liable for recurring costs without generating revenue. Collectively, these views illustrate a perceived gap in transparency and fairness within the fee structure.

3.5.2.4.3 Consultant cost burden

Participants described having to involve Radiation Protection Specialists (RPSs)/consultants to navigate the NNR application process and technical assessments, which increases the cost of compliance. Larger operators were better able to absorb these costs, though they still described them as substantial.

- **Participant 1:** *“The NNR advised us to consult Radiation Protection Specialists and provided a list of accredited specialists, which helped but was costly.”*

This highlights that while external expertise supports compliance, it comes at a substantial cost. Reliance on accredited Radiation Protection Specialists (RPSs) creates a trade-off between ensuring technical quality and imposing financial strain, especially for small operators.

Participant 3: *“The Radiation Protection Specialist recommended by the NNR charged high consultation fees. On top of that, we had to pay a non-refundable fee to the NNR. For facilities like ours, this combined cost is a significant burden.*

This illustrates the cumulative nature of compliance costs, where high specialist fees are compounded by regulatory charges. For smaller facilities, these upfront, often non-refundable, costs create significant financial barriers to licensing. Udo (2023) observes that when compliance systems impose high upfront costs and non-refundable fees, smaller operators are disproportionately excluded, even when their risk profile is lower. This dynamic contributes to structural inequities within regulated industries.

- **Participant 11:** *“The main difficulty was the cost — both the licensing fees and the consultant charges were very high for a small facility like ours.”*

Here, the emphasis is on the disproportionate impact of regulatory costs on small facilities, which lack the financial reserves of larger operators. For these entities, compliance becomes a significant barrier to entry and sustainability. Ye (2023: 5) shows that the negative effects of regulatory burdens are most pronounced for firms in disadvantaged positions or competitive industries, since they are least able to absorb the costs of compliance. This aligns with participant concerns about the financial sustainability of smaller facilities under the current regime.

3.5.2.5 Theme 4: Measurement, Monitoring & Operations

This theme focuses on the practical safety measures implemented by facilities to detect, monitor, and control radiation risks in daily operations. Three subthemes were identified as indicated in Figure: 3.8:

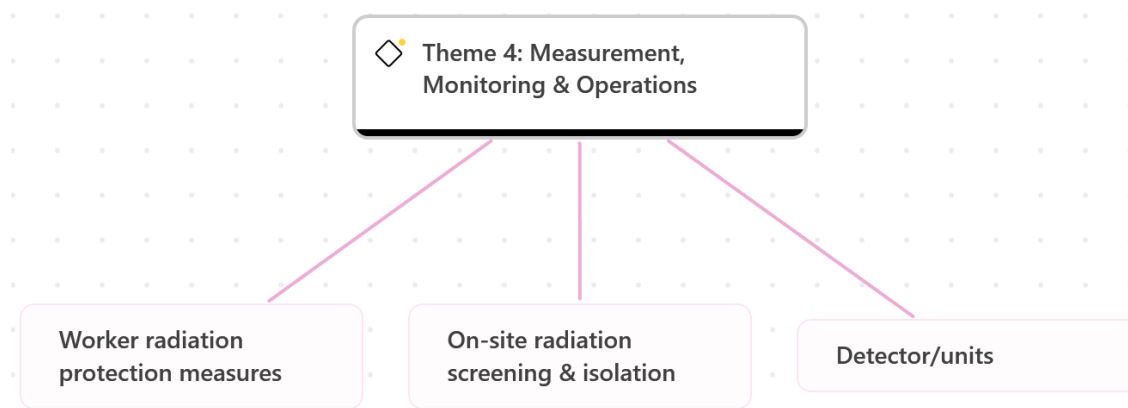


Figure 3.8: ATLAS.ti category code network: Measurement, Monitoring & Operations

The Measurement, Monitoring and Operations category highlights how scrap-metal facilities put radiation safety into practice through consistent monitoring, accurate record-keeping, and operational discipline.

3.5.2.5.1 Worker radiation protection measures

All participants highlighted that worker safety is a cornerstone of NNR authorisation, supported by a combination of PPE, structured training, and medical surveillance. PPE such as gloves, protective clothing, and dosimeter badges provide frontline defence. Training ensures workers understand procedures, while medical checks monitor their long-term fitness and exposure levels. According to Costa *et al.* (2019:6) the operator bears responsibility for ensuring the health and safety of its workers, as well as any other individuals who may be impacted by its operations and activities. The primary means of identifying radioactive material in scrap facilities is by means of radiation detectors (International Atomic Energy Agency, 2012:25).

Participant 1: *“We use monitoring systems such as drive through radiation monitors and handheld detectors to detect radioactive material, provide PPE and establish safety programmes to educate employees on handling contaminated scrap.”*

This response shows a focus on preventive safety culture by combining detection technology (drive-through monitors and handheld detectors) with protective measures (PPE) and employee education. It reflects an integrated approach: technology for early detection, and training programmes to ensure workers understand and apply safety practices. Scrap yard safety should integrate detection systems, protective equipment, and staff education, this is consistent with the IAEA Scrap Metal Toolkit and e-learning modules (Dojcanova, 2020). Similarly, (Benson *et al.*, 2024) show that training interventions combined with monitoring systems improve health, safety, and environmental outcomes in high-risk industries.

Participant 3: *“New employees receive induction training, and we conduct refresher toolbox talks every quarter. The RPO and key supervisors receive more in-depth external training.”*

Here the emphasis is on structured training programmes: induction for new staff, regular refresher sessions (quarterly toolbox talks), and specialised external training for supervisory staff such as Radiation Protection Officers (RPOs). This reflects a tiered training model, where training intensity is matched to responsibility level. It further highlights that tiered, role-specific training with supervisors receiving in-depth instruction and workers receiving operational training is critical to embedding safety culture. Al-Bayati and Chellappa (2025:9) affirm that well-trained supervisors can assess risks effectively and act as role models, shaping a stronger safety culture.

Participant 4: *“Training and awareness are critical. Facilities should ensure at least one person is trained as an RPM, with alternatives needed. Annual awareness training is essential due to high staff turnover in scrapyards. Continuous training ensures employees know how to respond when alarms are triggered.”*

This highlights the importance of continuity in training given high staff turnover in scrap facilities. The participant stresses the need for redundancy (at least one trained Radiation Protection Monitor, with alternates) and annual awareness training. The focus is on building resilience in safety systems so that knowledge is not lost when staff leave. Shiri *et al.* (2023:2) confirm that continuing professional training is strongly linked to knowledge retention and employee commitment in high-turnover environments. International Atomic Energy Agency (2012:32) also emphasises that operators of scrap facilities should ensure that employees who utilise radiation monitoring equipment are properly trained in its operation and fully understand the implication of their measurements and any related uncertainties.

3.5.2.5.2 On-site radiation screening & isolation

Participants highlighted that authorised facilities rely on portal monitors and handheld detectors as the first line of defence against contaminated scrap. Alarms from these devices trigger immediate isolation procedures to ensure suspect loads are segregated and not processed until further checks are completed.

Participant 3: *“When the detector picks up something suspicious, the load is pulled aside. We mark the area, cordon it off, and take readings before we decide if it can be processed or must be returned.”*

Participant 10: *“The portal monitor will alarm if something comes through, and then we have to stop the truck, isolate it, and notify the responsible person. The material is not allowed into the main yard until it has been checked.”*

The insights from Participant 3 and 10 represent a standard containment response in line with (International Atomic Energy Agency, 2012:39) which advises that if radiation levels in scrap exceed regulatory limits, the load should be moved to a pre-identified secure storage area, cordoned off with restricted access. The operator, together with the on-site radiation safety officer and regulator, must then arrange further investigation to ensure proper handling and safety.

Participant 7: *“If the RadCom portal monitor shows that the material is above the set limit, the facility will either refuse the load or hold it separately until the COR holder or regulator gives direction.”*

This reflects a compliance-based escalation process, once levels exceed the set threshold, facilities must halt processing and either refuse the load or store it securely pending regulator guidance. It demonstrates both risk aversion and reliance on regulatory oversight.

3.5.2.5.3 Detector/units misalignment

Participants described a practical mismatch between regulatory limits expressed in activity concentration (Bq/g) and the instruments commonly used on site (portal/RPMs measuring dose rate, e.g., $\mu\text{Sv/h}$). This creates confusion about what an alarm or dose-rate reading means relative to clearance/acceptance limits for scrap.

Participant 4: *“For example, the requirement is less than 10 becquerels per gram ... such as drive-through monitors cannot measure that directly. This creates a misalignment between regulatory requirements and practical implementation. I raised this with NNR officials, but the issue remains unresolved”.*

Participant 5: *“Scrap release both from the requirements document and the guidance documents that are at our disposal, the release limits are based on surface contamination and activity concentration (Bq per gram), but processors on site look at the dose rate ... like micro-sieverts per hour.”*

As participants 4 and 5 observed, while the NNR specifies limits in terms of activity concentration and contamination levels, site-level equipment, radiation portal monitors, cannot measure these directly, leaving operators uncertain about compliance. This highlights the need for clearer regulatory interpretation tools such as conversion guidelines or standardised reference tables to bridge the gap between regulatory language and operational practice. This gap also highlights a pressing need for greater regulatory and operational alignment. Benson *et al.* (2024:12) emphasise that collaboration between regulators and industry is critical to bridging such gaps. Active industry participation in dialogue, workshops, and policy discussions ensures that operational realities are understood and incorporated, facilitating the creation of practical, effective, and risk-based health and safety legislation that balances regulatory requirements with the constraints of scrap metal operations.

Participant 7: *“Most of the scrap metal dealers do have their RadCom drive-through monitors ... if something is above the limit, the drive-through monitor will indicate, and then according to internal processes they can safely handle whatever is being transported to the facility.”*

Participant 12: *“We have a drive through monitor that detect consignments if they contain radioactive material. If the cargo triggers an alarm, we set it aside and our employees use hand-held monitors to detect the source and once found, we store it in a secured area way from employees”.*

Participant 7 and 12's feedback demonstrates that facilities are equipped with monitoring infrastructure which is in line with International Atomic Energy Agency (2012:25) which stipulates that the primary means of identifying radioactive material in scrap facilities is by means of radiation detectors.

3.6 RELIABILITY AND VALIDITY OF THE MEASURING INSTRUMENT

Saunders *et al.* (2009:156) define reliability as the degree to which the data collection methods or analytical procedures produce consistent and repeatable results. Validity, on the other hand, is the extent to which the findings accurately represent the phenomena they are intending to describe or explain (Saunders *et al.*, 2009). The use of valid and reliable measurement instruments is fundamental to ensuring the integrity and quality of research findings. In qualitative research, validity and reliability are demonstrated through well-structured interview guides,

observation protocols, and document review checklists that accurately capture the phenomena under investigation.

3.7 TRUSTWORTHINESS

According to Bryman *et al.* (2021:177), in qualitative research, the traditional concepts of reliability and validity are often replaced by the criteria of trustworthiness and authenticity as the key criterion for assessing a qualitative study (Bryman *et al.*, 2021:177). The authors indicated that Guba and Lincoln introduced four key criteria for assessing qualitative studies as follows: credibility, which ensures the accuracy of the findings; transferability, which addresses the applicability of results to other contexts; dependability, which focuses on the consistency of the research process; and confirmability, which ensures that findings are based on the data rather than researcher bias. These criteria aim to provide a more contextually appropriate framework for evaluating qualitative research.

In this study, establishing credibility was crucial, since multiple interpretations of the industry's practices and regulatory compliance may exist; the credibility of the research findings will determine their acceptance by others. To ensure credibility, the study adhered to well-established research practices and standards throughout the research process. Additionally, the findings were shared with the participants, to confirm that the research accurately reflects their experiences and perspectives.

3.8 ETHICAL CONSIDERATIONS

Saunders *et al.* (2023:234) emphasised that ethical considerations are crucial, especially in cases involving individuals or human participants. The researcher demonstrated a steadfast commitment to protecting participants' confidentiality and ensuring that their privacy was fully respected throughout the study. Ethical guidelines were strictly followed, including obtaining informed consent from participants and obtaining necessary ethical approvals from North-West University Business School ethics committee to ensure that the study complies with ethical standards and protects participants' privacy throughout the process. The informed consent form, together with the permission to conduct the study indicating the confidentiality of the participants, were drafted and sent to the participants prior to the commencement of the research. Consent forms clearly articulated participants' rights, including options to withdraw at any moment without facing any repercussions. Participation was entirely voluntary, ensuring that no participants felt pressured to engage in the research.

Throughout the semi-structured interviews, participants were fully briefed on their unrestricted right to withdraw from the study at any moment, without repercussion, should they experience any discomfort. Each interview was conducted with a respectful, inclusive approach, empowering participants to openly share their experiences and perspectives without restraint.

Confidentiality was maintained throughout the research process, in alignment with the Protection of Personal Information Act 4 of 2013, which protects participants personal data and privacy.

3.9 CONCLUSION

This chapter outlined the research methodology followed to explore the handling of radioactive material within South Africa's scrap metal industry. Guided by an interpretivist paradigm and inductive reasoning, a qualitative research approach was employed to gather rich, contextual data through semi-structured interviews. The motivation behind methodological choices was grounded in the need to explore complex regulatory and operational realities through the lived experiences of relevant participants. Key elements such as the research paradigm, approach, strategy, sampling techniques, data collection methods, and ethical considerations were carefully designed to ensure methodological rigour, trustworthiness, and ethical compliance. This comprehensive approach forms the foundation for the empirical findings that follow in the next chapter.

This study adopted an interpretivist paradigm and an inductive, qualitative design to explain how radioactive material is managed within South Africa's scrap metal industry. Guided by the Saunders "research onion," the methodological choices, mono-method qualitative, multiple-case strategy, and a cross-sectional time horizon, were aligned deliberately with the research aim of generating rich, context-grounded insights. Purposive sampling targeted Managers, Radiation Protection Officers, and Radiation Protection Specialists across authorised facilities to ensure informed, practice-based perspectives. Semi-structured interviews enabled flexible probing of regulatory processes, operational practices, and stakeholder experiences, while document review added descriptive clarity around frameworks and roles.

Data was transcribed promptly, verified for accuracy, and analysed thematically in ATLAS.ti 25, combining top-down (objective-driven) and bottom-up (inductive) coding. The analysis yielded four overarching themes: *Awareness & Access to Information*; *Application Process, Timelines & Bottlenecks*; *Costs & Capacity*; and *Measurement, Monitoring & Operations*, capturing both systemic and operational realities. Trustworthiness was addressed through credibility (adherence

to good practice and member checking), transferability (thick description of context), dependability (clear audit trail of procedures), and confirmability (evidence-led findings). Ethical safeguards, ethics approval, informed consent, voluntariness, and confidentiality in line with POPI Act 4 of 2013 were observed throughout.

Overall, the methodology is fit-for-purpose: it privileges lived experience, surfaces procedural and operational points, and builds an empirically grounded platform for a managerial framework. While the cross-sectional design limits temporal inference and the purposive sample constrain statistical generalisation, data saturation enhance the robustness of insights. This chapter presented the results, illustrating how the identified themes cohere into practical recommendations for streamlining authorisation, improving communication, strengthening operational alignment, and advancing safety culture.

3.10 CHAPTER SUMMARY

The research design for this study is guided by the Research Onion model developed by (Saunders *et al.*, 2023), which provides a systematic framework for designing and articulating methodological choices. The model comprises six interconnected layers that researchers peel through to make coherent and justified decisions about their research process. At the outermost layer is the research philosophy, and this study adopts an interpretivist stance to gain a deep understanding of stakeholder experiences within the scrap metal industry. Aligned with this philosophy, the study employs an inductive approach, allowing themes and insights to emerge from the data rather than being imposed by existing theories. The research strategy employed a qualitative, multiple-case study design, focusing on 12 scrap metal facilities to explore practices related to the management of radioactive materials. A mono-method qualitative choice was adopted, using semi-structured interviews as the primary data collection method. Given the nature of the study, a cross-sectional time horizon was applied, capturing data at a single point in time. Finally, the innermost layer of the onion involves data collection and analysis techniques, which in this case include manual transcription and thematic analysis to interpret emerging patterns and experiences across different facilities. This layered approach ensures methodological coherence and alignment with the study's overarching aim of developing a practical managerial framework.

During the interviews, participants provided detailed insights into the managerial and regulatory dynamics that shape the handling of radioactive material in the scrap metal industry, revealing key themes related to governance, compliance behaviour, and stakeholder collaboration.

Through rigorous thematic analysis, transcripts were coded and systematically examined to identify patterns in regulatory awareness, authorisation challenges, communication practices, and operational risk management.

Data saturation was achieved after ten interviews, confirming both the consistency and depth of the collected perspectives. The analysis illuminated how managerial decision-making, regulatory interpretation, and stakeholder engagement collectively influence safety and compliance outcomes within this scrap metal industry. The research adhered strictly to ethical principles, safeguarding participant confidentiality through informed consent, anonymisation, and secure data handling in line with institutional research ethics protocols.

Chapter 3 provides a comprehensive exploration of the managerial realities underpinning the regulation and safe handling of radioactive material within South Africa's scrap metal industry. This analytical foundation establishes the groundwork for the development of the proposed Managerial Framework, offering actionable insights and recommendations to streamline authorisation processes, enhance stakeholder communication, and strengthen regulatory coherence for sustainable compliance.

CHAPTER 4 DISCUSSIONS, CONCLUSION, AND RECOMMENDATIONS

4.1 INTRODUCTION

The primary aim of this study was to explore and develop a managerial framework for the safe handling of radioactive material in South Africa's scrap metal industry. Chapter 2 provided a comprehensive literature review that examined both international and national regulatory contexts, identifying gaps in authorisation procedures, communication mechanisms, and compliance support. The review further illuminated how effective stakeholder engagement and transparent regulatory systems are critical to promoting safety and accountability in high-risk industries.

Chapter 3 transitioned into the empirical phase, presenting findings drawn from semi-structured interviews conducted with authorisation holders of CORs, Radiation Protection Officers and Specialists. Thematic analysis uncovered recurring patterns related to the accessibility of regulatory information, procedural bottlenecks in licensing, and the financial and operational challenges faced by industry participants.

This chapter now integrates the findings into a cohesive narrative, aligning them with the study's objectives and theoretical foundations. It discusses the practical and strategic challenges encountered during the research process, draws key conclusions from the empirical evidence, and proposes actionable recommendations to guide both regulators and industry stakeholders. Collectively, these insights form the basis for the Managerial Framework presented in Section 4.5

4.2 DISCUSSION OF CHALLENGES

The research process presented several methodological and contextual challenges, requiring constant adaptation and reflection. The design demanded the acquisition of advanced qualitative research competencies, including the development of in-depth interview techniques, data coding, and thematic analysis. The interview process itself was intensive, requiring significant coordination to accommodate participant's availability and ensure data saturation. Despite these challenges, the process yielded valuable insights that deepened understanding of how regulatory frameworks operate in practice.

A significant difficulty emerged in accessing scrapyards operators due to concerns about confidentiality and fear of regulatory repercussions. To overcome this, the researcher placed

strong emphasis on building trust, maintaining transparency, and clarifying the study's academic purpose. Ethical rigor was upheld throughout, ensuring anonymity and voluntary participation.

On an operational level, the diversity of scrapyard structures created difficulties in comparative analysis. Unlike standardised industrial facilities, scrapyards differ vastly in size, resources, and safety practices. This variability complicated efforts to generalise findings but also reinforced the necessity of a flexible, scalable managerial framework capable of addressing diverse operational realities.

Finally, a recurrent issue identified by participants was the complexity of NNR authorisation processes. The documentation was described as excessively technical, turnaround times unpredictable, and costs disproportionate to the scale of operations. Addressing these challenges demanded a balanced interpretation, one that acknowledges the regulator's mandate for safety while recognising the industry's need for practicality and efficiency.

4.3 CONCLUSIONS

The central objective of this study, to develop a managerial framework for handling radioactive material in the scrap metal industry, was achieved through a comprehensive literature review and detailed thematic analysis. The study identified core issues affecting regulatory efficiency, stakeholder communication, and compliance behaviour.

The findings highlight that while South Africa's nuclear regulatory framework aligns with international standards, its implementation within the scrap sector remains fragmented. The existing system is characterised by administrative complexity, limited accessibility of information, and a lack of sector-specific guidance. These shortcomings hinder proactive compliance and contribute to the perception that regulation is punitive rather than developmental.

Participants underscored the critical role of communication and transparency in achieving effective regulation. When operators are clearly informed of expectations and processes, compliance becomes more attainable and sustainable. Conversely, unclear guidance and limited engagement lead to misunderstanding, delays, and reliance on consultants. This dynamic reinforces inequalities, particularly for smaller operators with limited financial and technical capacity.

The study further concluded that stakeholder collaboration and regulations are fundamental to ensuring both safety and inclusivity. By adopting a risk-based and scalable approach, the regulator can ensure that safety standards are met without imposing undue burdens on low-risk facilities. The data also confirmed that effective capacity building, through training, workshops, and accessible materials, has the potential to transform safety culture across the scrap industry.

Ultimately, the study found that a value-driven and participatory approach is essential for bridging the gap between regulatory requirements and operational realities. Such an approach enhances trust, promotes shared responsibility, and strengthens the alignment between safety, compliance, and economic sustainability.

4.4 RECOMMENDATIONS

4.4.1 Simplifying and standardising authorisation processes

Participants strongly recommended the development of simplified, sector-specific authorisation application templates that reflect the unique characteristics of scrap operations. The current forms and processes are modelled on large facilities, creating unnecessary complexity for smaller entities. Clear checklists and guidance should be developed to help applicants navigate requirements more efficiently. This simplification would also reduce overreliance on consultants and encourage direct engagement between operators and regulators.

4.4.2 Enhancing stakeholder communication

A lack of regular engagement was identified as a key weakness in the regulatory environment. Participants proposed reinstating quarterly industry workshops, regulatory bulletins, and digital communication platforms to facilitate ongoing dialogue. Structured stakeholder engagement will ensure that regulatory updates are disseminated promptly and that industry concerns are addressed in a timely, transparent manner. This practice also promotes shared accountability and a sense of partnership between the NNR and scrap facilities operators.

4.4.3 Establishing defined timelines and feedback mechanisms

The absence of predictable turnaround times for application reviews was a significant source of frustration among participants. Clear service-level commitments should be introduced, specifying

expected processing periods for applications. Regular feedback would also enhance efficiency, reduce uncertainty, and promote greater confidence in the regulatory application process.

4.4.4 Creating fair and predictable fee Structures

Participants highlighted inconsistencies and unpredictability in the current hourly-based billing system. The NNR should consider introducing a transparent and tiered fee structure, where charges are proportionate to the size and complexity of each operation. Additionally, annual licensing fees should be suspended once an operator initiates the surrender process, preventing financial strain on inactive facilities. Transparent costing and fair billing practices would improve compliance willingness and reduce resentment toward the regulatory process.

4.4.5 Improving access to regulatory information

Information about the authorisation process was found to be difficult to access and overly technical. Participants recommended developing user-friendly materials, such as simplified guides. Making regulatory information more accessible will empower operators to take ownership of compliance without external intermediaries.

4.4.6 Strengthening industry–regulator collaboration

Participants proposed the formation of an “Industry Regulator Advisory Committee” to encourage regular dialogue, policy feedback, and joint problem-solving. Such collaboration would ensure that policy adjustments reflect the realities of industry operations while maintaining safety integrity. Cooperative frameworks would also prevent duplication between tender conditions and regulatory requirements, streamlining compliance expectations across the sector.

4.4.7 Supporting small operators

Smaller scrapyards face significant barriers to compliance due to high fees, consultant costs, and technical documentation demands. Participants proposed that the NNR adopt a graded compliance model that tailors requirements to the scale of operations.

4.4.8 Leveraging digital transformation

The integration of digital platforms can significantly enhance regulatory efficiency. The participants proposed that the NNR should consider implementing an online Regulatory

Information Management System to facilitate applications, provide instant feedback, and share updates. Automation of document tracking, reminders, and status notifications will reduce administrative load and improve transparency for both regulators and operators.

4.4.9 Alignment of measurement and monitoring instruments

Participants noted a mismatch between regulatory limits expressed in becquerels per gram (Bq/g), Bq/cm² and the dose-rate readings (μSv/h) measured by scrapyards portal monitors. This creates confusion when interpreting compliance results. It is therefore recommended that the NNR provide clear instructions on interpreting alarms and thresholds. This will ensure consistent measurement and accurate assessments across the scrap industry.

4.5 PROPOSED MANAGERIAL FRAMEWORK FOR HANDLING RADIOACTIVE MATERIAL IN SOUTH AFRICA'S SCRAP METAL INDUSTRY

The proposed Managerial Framework for Handling Radioactive Material in South Africa's Scrap-Metal Industry has been developed from the findings of this study, guided by international best practices and regulatory requirements of the NNR. It provides a structured process that integrates regulatory compliance, operational management, radiation protection, and monitoring mechanisms to ensure safe handling of radioactive materials, particularly those originating from mining and mineral processing activities. The proposed managerial framework is detailed below.

4.5.1 BACKGROUND

South Africa's scrap-metal recycling industry contributes significantly to economic growth, job creation, and environmental sustainability through material recovery and reuse. However, the sector faces serious risks from the inadvertent inclusion of radioactive materials in scrap streams, which can lead to radiological exposure and contamination.

The Proposed Managerial Framework for Handling Radioactive Material in South Africa's Scrap Metal Industry serves as a practical guide for standardising how facilities identify, control, and manage radioactive materials that may appear in scrap streams. Developed from the study's empirical findings and aligned with the National Nuclear Regulator Act 47 of 1999 and IAEA safety guidelines, the framework bridges the gap between regulation and on-site practice. It provides an end-to-end management process covering authorisation, operational control, monitoring, and emergency response, ensuring that scrap-metal facilities operate safely and efficiently. The

framework's holistic structure encourages proactive compliance, enhances safety awareness, and promotes a consistent national approach to radiation protection within the recycling industry.

4.5.2 PURPOSE

The purpose of this framework is to guide scrap-metal facilities in South Africa on how to manage and handle radioactive materials, mainly originating from Mining and mineral facilities, safely and in full compliance with the National Nuclear Regulator Act 47 of 1999. It seeks to streamline the authorisation process and strengthen radiation safety practices. The framework also promotes capacity building, transparency, and operational efficiency, ensuring that facilities protect workers, the public, and the environment while supporting a sustainable and compliant scrap-metal industry.

4.5.3 APPLICATION PROCESS

This section outlines the step-by-step process that a scrap-metal facility in South Africa must follow when applying for an authorisation (Certificate of Registration – *COR* or Certificate of Exemption – *COE*) to handle or process radioactive scrap (GUI-IAM-001) (National Nuclear Regulator, 2020b). This process aligns with the NNR Act (Act 47 of 1999), Safety Standard and Regulatory Practice No. R.388.

4.5.3.1 Application Initiation and Preparation

The facility must obtain the application form from the NNR (website), appoint a qualified Radiation Protection Specialist (RPS) (request a list from the NNR) to guide the preparation of all technical submissions. This ensures compliance with regulatory and safety standards from the onset. The preparatory phase includes the following key actions:

- Appointment of RPS: The RPS must be competent and qualified.
- Completion of NNR Application Form (GUI-IAM-001): The applicant must complete the standard authorisation form available on the NNR website.
- Payment of Application Fee: Proof of payment must accompany the submission to initiate the review process (gazette annually and available on NNR website).

4.5.3.2 Radiation Protection Procedures to be submitted

1. Radiological Safety Assessment: A detailed assessment of all radiological hazards associated with facility operations and materials handled.
2. Worker Radiation Protection Programme (RPP): A site-specific plan detailing monitoring, dose control, and worker protection measures.
3. Medical Surveillance Programme: Ensures that radiation workers undergo pre-employment and periodic medical examinations by an occupational health practitioner.
4. Physical Security Programme: Outlines security measures to prevent unauthorised access, theft, or tampering with radioactive materials.
5. Waste Management Programme: Outlines the process of waste classification and categorization.
6. Occurrence Notification and Emergency Procedures: Defines steps for immediate response to incidents.

4.5.3.3 Supporting Documentation Required

1. Financial Declaration: Confirms financial capacity to sustain safe operations, equipment maintenance, and potential decontamination costs.
2. Board Resolution: A signed resolution confirming the organisation's commitment to regulatory compliance and designating authorised signatories.

4.5.3.4 Submission and Acknowledgement by the NNR

After preparation, the complete application package is submitted to the NNR. The NNR acknowledges receipt, records the submission, and issues a reference number. The application then enters the internal review phase.

4.5.3.5 Internal Review and Evaluation by the NNR

The NNR conducts a multi-tier technical and administrative evaluation, which includes:

- Verification of completeness of the application form and payment confirmation.
- Technical assessment of the Radiological Safety Assessment and Radiation Protection Programmes to ensure adherence to safety standards.

- Administrative review of corporate governance documents (e.g., financial declaration, board resolution).
- Engagement with the RPS or applicants to clarify deficiencies, if any.

If the NNR identifies gaps, official comments are issued to the applicant. The applicant must address and resubmit corrections within the specified timeframe.

4.5.3.6 Decision and Authorisation

Once the NNR is satisfied that all requirements are met, the application is referred to the Board for approval, then:

- A Certificate of Registration (COR) or Certificate of Exemption (COE) is issued.
- The authorisation specifies conditions under which the facility must operate, such as regulatory limits on radioactive material and monitoring obligations.
- The facility is now legally permitted to conduct activities related to handling radioactive material.

Table 4.1: Summary of the application process

Step	Activity	Responsible Party	Key Output / Document
1	Obtain the application form from the NNR	Applicant	Application form
2	Appoint Radiation Protection Specialist (RPS)	Facility	Appointment Letter
3	Complete NNR Application Form	RPS and Facility	Completed form
4	Pay Application Fee	Facility	Proof of payment
5	Prepare Supporting Documents (RSA, RPP, Security, Medical, Financial)	RPS/facility	Operational Procedures
6	Submit Application to NNR	Facility	Submission receipt
7	NNR Internal Review	NNR Department, NORM Finance and Legal	Review comments (if any)
8	Applicant Addresses Comments	Facility / RPS	Revised documents

9	Application submitted to the board	Board	Approved COR
10	NNR Approval and Certificate Issued	NNR	COR/COE issued

Source: Own

4.5.4 Post-Approval: Compliance and Monitoring

- Appointing the Radiation Protection Monitor (RPM)
- Provide training to the RPM
- The RPM must provide guidance in terms of implementation of the approved radiation Protection Procedures.
- The RPS must continue to provide oversight and review documentation
- Obtain the drive through monitor and/or handheld detectors
- Training of Occupational Exposed Personnel (workers) at a pre-determined frequency
- Medical examination of OEPs at a pre-determined frequency
- Records of radiation monitoring, worker exposure, and incidents must be maintained.
- The facility remains subject to NNR inspections and compliance audits.
- Any changes (e.g., layout, processes, equipment) require formal amendment approval from the NNR.
- Pay annual authorisation fees.

4.5.4.1 Gate Monitoring process

Step 1: The Gate Monitoring Process is a critical radiation screening procedure designed to ensure that radioactively contaminated items do not enter or leave a scrap-metal facility undetected. The process begins when a truck passes through the radiation monitor gate, where sensors check both the vehicle's speed and radiation levels. If a speed alarm is triggered, the truck must re-enter the gate at the correct speed to ensure accurate measurement. If no alarm is triggered, the truck is cleared to proceed.

Step 2: When a radiation alarm activates, the truck is diverted to a designated safe area, and the surrounding zone is cordoned off to restrict access. Qualified radiation personnel then use portable detectors to verify the readings and determine whether radiation levels exceed the NNR-prescribed limits. If levels are below the threshold, the vehicle and its load are cleared; however,

if levels exceed the set limits, an investigation is initiated to locate the specific contaminated item(s) within the load.

Step 3: Once the suspicious parts are identified, they are unloaded, individually scanned, and isolated from the rest of the scrap. Confirmed contaminated items are segregated, secured in appropriate containers, and stored safely pending further regulatory instruction. The facility must immediately notify the NNR, which then provides direction on handling, storage, and disposal. After contamination control measures are completed and the area is verified to be safe, normal operations resume.

This systematic process ensures early detection, isolation, and secure management of radioactive items, thereby protecting workers, the public, and the environment while maintaining compliance with national and international radiation safety standards.

A gate monitoring process is presented on the process flow diagram below:

4.5.4.2 Gate Monitoring process workflow

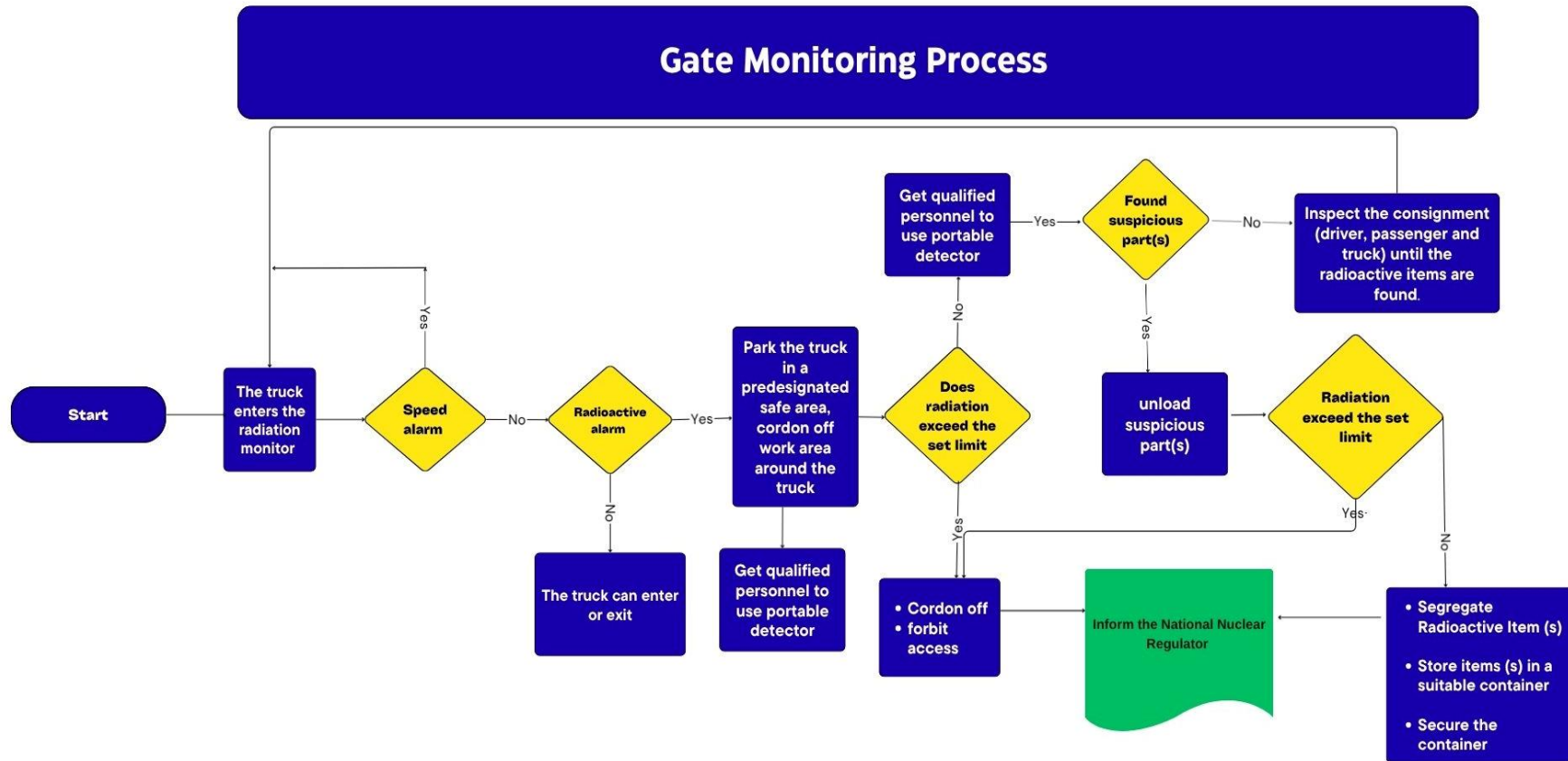


Figure 4.1: Gate Monitoring process

Source: Own

4.5.5 CONCLUSION

The proposed managerial framework provides a comprehensive and practical roadmap for managing radioactive materials throughout the scrap-metal recycling process from authorisation and operational control to detection, monitoring, and response. It aligns national regulatory procedures with internationally recognised safety principles, particularly the IAEA's "Detect → Isolate → Decide" gate monitoring approach. The framework not only clarifies the steps for obtaining and maintaining NNR authorisation but also embeds continuous compliance, training, and capacity-building measures within facility operations. By formalising these practices, the framework promotes a sustainable safety culture, improves regulatory efficiency, and ensures that South Africa's scrap-metal industry operates responsibly and in full compliance with nuclear safety requirements.

4.6 SUGGESTIONS FOR FUTURE RESEARCH

Future studies could explore the following.

- Quantitative impacts of regulatory delays on business performance and environmental safety outcomes in the scrap metal industry.
- The role of digital transformation in automating licensing process, compliance tracking, and information sharing.
- Comparative studies between South Africa and other IAEA member states to evaluate best practices in stakeholder communication and tiered regulation.

4.7 CRITICAL EVALUATION OF THE STUDY

The research objectives set out in Chapter 1 were achieved through thorough design and rigorous implementation. The study's credibility rests on its adherence to ethical protocols, data, and systematic thematic analysis. While qualitative findings provide rich contextual insights, they are not intended to represent the entire industry. Nonetheless, the study's strength lies in its ability to bridge theory and practice, translating regulatory complexity into actionable managerial strategies that can inform both policy and industry reform.

4.8 SUMMARY

Chapter 4 synthesised the empirical findings and translated them into strategic recommendations for improving the management of radioactive materials within South Africa's scrap metal industry. It highlighted the need for regulatory simplification, stronger communication, and a more inclusive,

participatory approach to compliance. By addressing the identified challenges, the proposed managerial framework seeks to establish a culture of safety and cooperation grounded in transparency, accountability, and shared value. These insights pave the way for the next chapter, which presents the proposed managerial framework, detailing its structure, implementation roadmap, and anticipated impact on regulatory effectiveness and industry sustainability.

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ANNEXURE A: PERMISSION LETTER



Dear Managing Director

REQUEST FOR PERMISSION TO CONDUCT A STUDY

I am writing to formally to request permission to conduct a research study titled “Developing a managerial framework for managing radioactive material by the scrap metal industry in South Africa.” This study is part of my Master of Business Administration (MBA) Programme at North-West University, under the supervision of Mr. Johannes Coetzee.

The main objective of this study is to develop a managerial framework for handling radioactive material within the South African scrap metal industry. This research seeks to identify regulatory gaps, assess current administrative processes, and propose strategies to enhance safety and compliance within the industry.

To achieve this objective, I intend to collect data through structured interviews involving employees with at least one to two years of experience in radiation protection, directly involved in handling radioactive material and ensuring compliance within your organisation.

Information collected during this study will be kept strictly confidential and used solely for academic purposes. I am committed to ensuring minimal disruption to your organisation’s daily operations.

I believe that the findings of this study could provide valuable insights into improving the regulatory framework for managing and handling radioactive material within the scrap metal industry. I will also share a summary of the research findings which may assist in improving your organisation’s safety and compliance strategies.

I have attached an informed consent form and a set of semi-structured interview questions for your review. I would greatly appreciate your support in facilitating this research by granting me access to the relevant employees. Please populate and sign below if you are in agreement.

Should you require any further information or wish to discuss this request in more detail, I am available at your convenient time.

The ethics No is NWU-00669-25-A4 for this study.

I look forward to your positive response.

Sincerely,

Kefilwe Mookodi

I (Title, Name and Surname)

(designation e.g., CEO or MD)

hereby grant Ms. Kefilwe Mookodi permission to conduct research as outlined above. Special conditions if any

signed Date

Email..... Contact number.....

ANNEXURE B: INFORMED CONSENT



DEAR PARTICIPANT

INFORMED CONSENT LETTER TO INTERVIEW PARTICIPANTS

You are invited to take part in a research study that forms part of a Master of Business Administration (MBA) degree. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and how you might be involved. Also, your participation is entirely voluntary, and you are free to say no to participating. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the NWU Economic and Management Sciences Research Ethics Committee (EMS-REC) and will be conducted according to the ethical guidelines and principles of the North-West University and other international ethical guidelines applicable to this study.

Title of the project: Developing managerial framework for handling radioactive material in the scrap metal industry in South Africa.

Institution: NWU Business School

Ethics Reference Number: NWU-00669-25-A4

Names and contact details of project staff

	Supervisor	Researcher
Title, name & surname	Mr Johan Coetzee	Ms. Kefilwe Mookodi
Full Names		Kefilwe Veronica Mookodi
Function in Project	Principle Investigator	Researcher
Telephone	082 821 7177	064 686 0081

What is this research study all about?

The research project is on Developing a Managerial Framework for Handling Radioactive Material by the Scrap Metal Industry in South Africa. The aim of this study is to gather insights regarding the administrative and legal processes involved in handling radioactive materials within the scrap metal industry. The findings will help develop documented guidance for the industry on safe handling practices and regulatory compliance.

Why have you been invited to participate?

You have been invited to participate in this research study because you fall into at least one of the following categories:

- Managers and,
- radiation protection officers within the nuclear material scrap processing environment will be selected to ensure that the sample includes individuals who can provide comprehensive and insightful information on the research topic.

What will be expected of you?

You will be expected to:

- Participate in a 45 – 60min semi-structured interview with the researcher at a suitable time and private area without interruptions that is convenient for both parties via an online platform. This will be scheduled by the researcher once approved by the NWU ethics committee.
- Respond to the questions in an open and honest manner.
- Inform the supervisor should you feel or experience any form of discomfort or distress during the research process and inform the supervisor if you at times feel the need to terminate your involvement in the research process.

Will you gain anything from taking part in this research?

This research study intends to give you a voice to reveal, explain and reflect on management of radioactive scrap facilities in South Africa. No monetary reward shall be made available for participation in the study. You will however be furnished with a two-page communique on the outcomes of the study, upon approval of the dissertation, that you can utilise to improve your compliance with the NNR regulations.

Are there risks involved in your taking part in this research and what will be done to prevent them?

Participation in this study does not create any physical risk to you as the study does not involve any physical activities or experiments. We, however, have identified certain ethical principles that shall be always maintained to prevent any damage to you. The focus of these principles will be to protect your dignity and keep all records provided private and confidential.

How will we protect your confidentiality and who will see your findings?

You will be assigned a unique participant ID. Our interview will be recorded and saved with reference to the ID, but data collected shall be regarded as confidential and will not be shared with any 3rd party that is not directly involved in the research process. Personal details of participants and their direct input to the research study shall not be made public. All records of the research shall be kept for a retention period and destroyed by an appropriate means. The findings of the study will be made public however will not contain any raw data that might incriminate certain individuals. All records will be managed in accordance with POPI Act 4 of 2013 guidelines.

What will happen with the findings or samples?

The findings concluded in the study will be for academic purposes and will only be utilised to add to the current body of available knowledge.

How will you know about the results of this research?

Participants in the study, should they require, will be made aware of the results of the research, through a two-page communique, by means of electronic mail. The electronic final version of the dissertation will also be made available if requested.

Will you be paid to take part in this study and are there any costs for you?

Participation in this study will not yield monetary value to you. There is no cost envisaged to you except the time that you spend participating in this study. This study will be funded by the researcher himself.

Is there anything else that you should know or do?

You may contact the supervisor, Mr Johan Coetzee on 082 821 7177 if you have any further questions or problems. You will receive a copy of this information and consent form for your own purposes.

ANNEXURE C: DATA COLLECTION TOOL



Interview Guide for Scrap Metal Facility Operators Regarding the development of managerial framework for handling radioactive material in the scrap metal industry.

Thank you for taking the time to participate in this interview. The purpose of this discussion is to gather insights on the administrative and legal processes involved in handling radioactive materials in the scrap metal industry. We aim to provide documented guidance that outlines the arrangements necessary for safely managing these materials. Your feedback is valuable in identifying challenges and opportunities for improvement in this critical area. Please be assured that all information shared will remain confidential and will only be used for research purposes.

Section 1: Introduction question

Can you describe your role within the scrap metal facility and how long you've been involved in the industry?

Probing Question: How have your responsibilities evolved since you started?

Section 2: Awareness of Regulatory Requirements

Can you describe the sources of information or guidance that informed you about the need for National Nuclear Regulator authorisation when handling radioactive material? How clear and accessible was this information?

Probing Question: Was the information easy to access and understand?

Section 3: Licensing Process Experience

Can you describe the process your facility followed to obtain a nuclear authorisation from the NNR for handling radioactive materials? What were the key steps in this process?

Probing Question: How long did the licensing process take from start to finish?

What difficulties, if any, did you encounter when working with the National Nuclear Regulator to obtain the necessary authorisation?

Probing Question: Were there any specific challenges that stood out to you?

Section 4: Guidance and Support from National Nuclear Regulator

What kind of guidance or support did you receive from the National Nuclear Regulator during the licensing process? Was the guidance provided clear and helpful?

Probing Question: How accessible were National Nuclear Regulator representatives when you needed support?

What improvements could be made in the guidance provided by the National Nuclear Regulator to assist facilities in navigating the licensing process more effectively?

Section 5: Communication and Awareness

How can awareness of National Nuclear Regulator regulations be improved within the scrap metal industry, especially for unauthorised facilities?

Probing Question: Would industry seminars or online resources help increase awareness?

Do you have any suggestions for how the National Nuclear Regulator could better communicate their requirements and updates to stakeholders in the scrap metal industry?

Probing Question: Would a digital platform or app for updates be useful?

Section 6: Administrative Processes for Handling Radioactive Materials

What processes or arrangements does your facility have in place for the safe handling of radioactive materials?

Probing Question: Can you outline the key steps involved in these processes?

How do you ensure that employees are trained and aware of the procedures for handling radioactive materials?

Probing Question: What specific training programs or resources do you utilise?

Section 7: General Feedback and Final Thoughts

Is there anything else you would like to add about the administrative processes for handling radioactive materials in your facility?

Probing Question: Is there anything you feel was particularly positive or negative about your experiences?

Do you have any final thoughts on improving regulatory compliance and awareness within the industry?

Probing Question: How can unauthorised facilities be encouraged to comply with regulations?

Closing

Thank you once again for your time and insights. Your feedback is crucial in helping us enhance industry practices and regulatory support for handling radioactive materials. We may follow up if any further clarification is needed.

ANNEXURE D: TRANSCRIPT

SECTION 1 : INTRODUCTION QUESTION

Interviewer: Can you describe your role within the scrap metal facility and how long you've been involved in the industry?

Participant 3: Thank you very much for inviting me to participate in your study. I am a Safety, Health and Quality Manager at our scrap metal processing facility, where I have been employed for almost five years now. My role includes ensuring occupational health and safety compliance, environmental management, and implementation of quality systems. I also coordinate regulatory compliance, including engagement with the National Nuclear Regulator (NNR), and oversee the safe handling of potentially contaminated or radioactive materials.

Interviewer: How have your responsibilities evolved over the five years that you have worked here?

Participant 3: When I started, my role focused mainly on general health and safety and ISO compliance. Over time, as awareness of radiation risks in scrap metal grew, particularly after applying for tenders with high-risk scrap producers such as mines, I became responsible for implementing a radiation protection programme and managing our licensing processes with the NNR.

SECTION 2: AWARENESS OF REGULATORY REQUIREMENTS

Interviewer: Can you describe the sources of information or guidance that informed you about the need for NNR authorisation when handling radioactive material, and how clear and accessible was that information?

Participant 3: We were first made aware of the NNR authorisation requirement when applying for a tender at a mine to collect their scrap metal. The mine required all scrap handlers to be authorised by the NNR to remove material from site due to the potential presence of naturally occurring radioactive material. This prompted us to approach the NNR directly for guidance.

Interviewer: Was the information easy to access and understand?

Participant 3: It was accessible upon request but challenging to interpret. The NNR did provide regulatory documents, but they were quite technical and not specific to the scrap metal industry. We had to seek clarification from NNR representatives and eventually relied on a Radiation Protection Specialist to guide us through the regulatory requirements.

SECTION 3: LICENSING PROCESS EXPERIENCE

Interviewer: Can you describe the process your facility followed to obtain nuclear authorisation from the NNR, and what were the key steps in this process?

Participant 3: The process began with an internal readiness assessment. We then prepared and submitted an application to the NNR that included a radiation protection program, site plans, and safety procedures. The NNR conducted a site inspection and made follow-up requests for additional information. Based on their recommendation, we hired a Radiation Protection Specialist to help us prepare the technical documents.

Interviewer: How long did the licensing process take from start to finish?

Participant 3: The entire process, from our first contact with the NNR to receiving the licence, took about 9 to 11 months.

Interviewer: What difficulties, if any, did you encounter when working with the NNR to obtain the necessary authorisation?

Participant 3: The major challenge was the cost of application and compliance. The Radiation Protection Specialist recommended by the NNR charged high consultation fees. On top of that, we had to pay a non-refundable fee to the NNR. For facilities like ours, this combined cost is a significant burden. Additionally, interpreting the technical requirements without an NNR background was very difficult, we therefore needed the RPS services.

Interviewer: Were there any specific challenges that stood out to you?

Participant 3: Yes, the financial aspect stood out. We were fully committed to compliance, but unexpected consulting fees and application charges strained our budget. Another challenge was the lack of industry-specific examples or templates to guide us through the documentation process.

SECTION 4: GUIDANCE AND SUPPORT FROM THE NATIONAL NUCLEAR REGULATOR

Interviewer: What kind of guidance or support did you receive from the NNR during this licensing process, and was this guidance clear and helpful?

Participant 3: We received regulatory documents. The guidance lacked practicality. The documents were generic and not specific to scrap operations. Without hiring a Radiation Protection Specialist, we would not have been able to meet the technical standards.

Interviewer: How accessible were the NNR representatives when you needed them for support?

Participant 3: It took multiple follow-ups to get clarity, which affected turnaround times. The NNR communicate with formal letters, which is time consuming as they take long. So, I will say they are not easily accessible. This is part of why many facilities rely on external consultants, adding more cost to our budget.

Interviewer: What improvements could be made in the guidance provided by the NNR to assist facilities in navigating the licensing process more effectively?

Participant 3: The NNR should provide a scrap-metal-specific licensing guide, compliance checklist, and sample documentation. Hosting online training sessions and offering pre-application advisory support would also help. Most importantly, they should consider subsidising Radiation Protection Specialist support to reduce costs for smaller operators.

SECTION 5: COMMUNICATION AND AWARENESS

Interviewer: How can awareness of NNR regulations be improved within the scrap metal industry, especially for unauthorised facilities?

Participant 3: Awareness can be improved through regional outreach campaigns, collaboration with municipal authorities, and industry bodies such as South African Police Services through their Secon hand Goods Act.

Interviewer: Would industry seminars or online resources help increase awareness?

Participant 3: Yes, absolutely. Online resources, workshops, and downloadable guides would make a big difference. Even short videos in local languages explaining what NNR authorisation is and why it matters could help smaller or informal facilities.

Interviewer: Do you have any suggestions for how the NNR could better communicate their requirements and updates to stakeholders in the scrap metal industry?

Participant 3: They could create a dedicated scrap industry portal on their website, use mailing lists, and hold annual stakeholder briefings. Communication should be simplified and include visuals to break down complex processes.

Participant 3: Would a digital platform or app for updates be useful?

Participant 3: Yes, a mobile app would be very useful, especially if it included application tracking, regulation summaries, safety alerts, and direct messaging with inspectors. It would modernise the process and improve access to information for all stakeholders.

SECTION 6: ADMINISTRATIVE PROCESSES FOR HANDLING RADIOACTIVE MATERIALS

Interviewer: What processes or arrangements does your facility have in place for the safe handling of radioactive material?

Participant 3: We have installed fixed radiation detectors at our weighbridge and entry points. If a load sets off an alarm, we isolate it immediately in a quarantine area. Our Radiation Protection Officer investigates, takes readings, and logs the incident. If radiation is confirmed, the NNR is notified, and we arrange safe disposal.

Can you outline the key steps involved in these processes?

Participant 3: Yes, the process includes: initial screening of all incoming scrap using radiation monitors; isolation of flagged materials; assessment by the RPO with handheld devices; notification to the NNR if radiation is confirmed; engagement of a licensed waste disposal company; and record-keeping of the entire incident process.

Interviewer: How do you ensure that employees are trained and aware of the procedures for handling radioactive material?

Participant 3: We run annual radiation awareness training for all staff. New employees receive induction training, and we conduct refresher toolbox talks every quarter. The RPO and key supervisors receive more in-depth external training. We also ensure employees undergo annual medical checks.

Interviewer: What specific training programs or resources do you utilise?

Participant 3: We use RPS providers recommended by the NNR. Internally, we supplement this with SOP manuals. We also debrief staff after any real incident to reinforce learning.

SECTION 7: GENERAL FEEDBACK AND FINAL THOUGHTS

Interviewer: Is there anything else you would like to add about the administrative processes for handling radioactive material in your facility?

Participant 3: Managing radioactive material safely requires a structured and well-documented approach. We have invested in systems to ensure compliance, including equipment calibration, incident logging, and radiation protection procedures. However, maintaining this system is resource-intensive.

Interviewer: Is there anything you feel was particularly positive or negative about your experiences?

Participant 3: Positively, the professionalism of our NNR officials and the clarity of their expectations during the application process were reassuring. Negatively, the high cost of compliance including consulting fees and NNR application costs and the lack of tailored support for our industry were significant challenges.

Interviewer: Do you have any final thoughts on how we can improve regulatory compliance and awareness within the industry?

Participant 3: The NNR should focus more on enabling compliance, not just enforcing it. Awareness and support should be more accessible, especially for emerging businesses.

Interviewer: How can unauthorised facilities be encouraged to comply with regulations?

Participant 3: Introduce a phased compliance program. Offer discounted licences for first-time applicants and publicise the benefits of compliance, such as access to more tenders and risk mitigation. Recognition of compliant facilities could also motivate others to comply.

ANNEXURE E: ETHICS APPROVAL LETTER OF STUDY



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11 June 2025

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Economic and Management Sciences Research Ethics Committee (EMS-REC) on 11 June 2025, the Economic and Management Sciences Research Ethics Committee hereby **approves** your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-REC) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title:	Developing a managerial framework for handling radioactive material by the scrap metal industry in South Africa														
Study leader/Supervisor (Principal investigator/Researcher):	Mr J. Coetzee						University no.:	10306498							
Student:	K.V. Mookodi						University no.:	16908449							
Ethics number:	N	W	U	-	0	0	6	6	9	-	2	5	-	A	4
Institution Study number Year Status Status: S = Submission; R = Re-submission; P = Provisional authorisation; A = Authorisation															
Application type:	Single study - Postgraduate research						Risk level:	Low/minimal risk							
Commencement date:	6/11/25														
Expiry date:	6/11/26														
<i>Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.</i>															

Special in process conditions of the research for approval (if applicable):

None.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The study leader/supervisor (principal investigator)/researcher must report in the prescribed format to the EMS-REC:*
 - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*
 - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the EMS-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-SCRE and EMS-REC reserves the right to:*
 - *request access to any information or data at any time during the course or after completion of the study;*
 - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
 - *withdraw or postpone approval if:*
 - *any unethical principles or practices of the study are revealed or suspected;*
 - *it becomes apparent that any relevant information was withheld from the EMS-REC or that information has been false or misrepresented;*
 - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or*
 - *new institutional rules, national legislation or international conventions deem it necessary.*
- *EMS-REC can be contacted for further information or any report templates through the secretariat. Botlenyana Maluleka (Botlenyana.Maluleka@nwu.ac.za / +27 18 2852436) or the chair Prof Diana Viljoen-Bezuidenhout (Diana.Viljoen@nwu.ac.za / +27 16 9103403).*

The EMS-REC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the EMS-REC or the NWU-SCRE for any further enquiries or requests for assistance.

Yours sincerely,

Prof Diana
Viljoen-
Bezuidenhout

Digitally signed by Prof
Diana Viljoen-
Bezuidenhout
Date: 2025.06.18
12:04:56 +02'00'

Prof Diana Viljoen-Bezuidenhout

Chairperson: NWU Economic and Management Sciences Research Ethics Committee

ANNEXURE F: LANGUAGE EDITOR CERTIFICATE



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31 October 2025

To whom it may concern

This is to certify that I have read and edited the mini-dissertation of Ms KV Mookodi (16908449) entitled:

Developing a managerial framework for handling radioactive material in South Africa's scrap metal industry

The student corrected the errors identified to my satisfaction. The language of the dissertation is of an acceptable academic standard.

Yours sincerely

Prof HP Drummond

Language editor

Original details: (20559607) C:\Users\20559607\Desktop\Helen Drummond\Documents\MyFiles\FNAS Deputy Dean\Letters\

ANNEXURE G: TURNITIN SCREENSHOT

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