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An analysis of factors leading to the production of defective wagons in Transnet Engineering

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PLAGIARISM DECLARATION

SENATE PLAGIARISM POLICY

Declaration by Students

I, Pfananani Thelma Nemakhavhani (Student number: 2516195), am a student registered for MECN 7018A: Research Project in the year 2024.

I hereby declare the following:

• I am aware that plagiarism (using another person's work without their permission and/or without crediting the source) is wrong.
• I certify that the work submitted for assessment of the above degree is my unaided work unless I have expressly stated otherwise.
• I have followed the necessary conventions when referring to the thoughts and ideas of others.
• I accept that if it is believed that this is not my unassisted work or that I have omitted to identify the source of ideas or words in my writing, the University of the Witwatersrand may take disciplinary action against me.

Signature:  Date: 10/03/2024



ABSTRACT

Rail manufacturing industries play a crucial role in many countries by developing cost-effective transportation solutions to move freight more efficiently. To date, the industry has seen the implementation of traditional quality management practices that are critical in driving efficiencies and better-managed operations to improve the quality of their freight wagons. Despite the conventional quality management techniques, the rail industry continues to manufacture defective rolling stock due to design changes, errors and omissions, and inadequate skills.

Over the past few decades, industry and academia have identified various factors contributing to rolling stock manufacturing defects. Nevertheless, which factors were predominantly responsible for the defective wagon production at the Transnet Engineering (TE) Bloemfontein factory remained unclear. Identifying the most prevalent causes of defects is essential in addressing the organisation's quality issues. The primary purpose of this study was to gain insights into the root causes of the defects and recommend strategies to minimise them.

The study used an interpretive methodology to identify the root cause of defective wagons produced at TE. Data was collected using purposive sampling. Ten experienced TE employees actively engaged in freight wagon manufacturing were selected for face-to-face interviews. During the research study, the interviews were conducted with the employees using a semi-structured format that allowed for open-ended questions. Investigative techniques, such as cause-and-effect diagrams and the Five "Whys" root cause analysis tool, were used to investigate defects' root causes on the customer complaints register. Additionally, thematic analysis was applied to thoroughly analyse the interviews conducted with the employees, which allowed for a deeper understanding of the issues at hand.

The findings showed that inadequate skills, human errors and omissions, a lack of quality culture, time constraints, management's failure to enforce accountability, and poor workshop maintenance/machinery all contribute to defective wagon production. The research provided recommendations, including adopting innovative technology and skills transfer programs to enhance the company's quality management practices.

Keywords: Customer complaints register, Defects, Employee perceptions, Freight wagon, Quality management, Root cause analysis, Wagon manufacturing process.

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DEDICATION

I am thrilled to utilise the knowledge and expertise I gained throughout my tenure in the South African railway sector. As a token of appreciation, I dedicate this research report to my mother, who, despite lacking a formal education, has continuously bestowed upon me enduring love, support, and motivation during my academic endeavours.

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I would like to express my sincere gratitude to the Faculty of Engineering and Built Environment Management for granting me the opportunity to pursue my MSc in Industrial Engineering. I am thankful for the valuable input and advice from the experts in this research project. I appreciate the wagon manufacturing and maintenance professionals who actively participated in the research and generously dedicated their time to interviews. Their extensive knowledge and cooperation greatly facilitated the data collection process. Furthermore, I want to convey my deep appreciation and thanks to my supervisor, Dr Mncedisi Trinity Dewa, for being a constant source of inspiration and encouragement and providing valuable suggestions and guidance throughout the study.

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ABBREVIATIONS

AVI	Automated Visual Inspection
CED	Cause-and-Effect Diagram
DLL	Double-Loop Learning
EN	European Standards
ECP	Electronic Pneumatic Control
EQCS	Electronic Quality Control System
ISO	Organisation for Standardisation
KM	Knowledge Management
NCR	Non-Conformance Report
OL	Organisational Learning
QMS	Quality Management System
QIT	Quality Improvement Teams (QIT
RCA	Root Cause Analysis (RCA)
TM	Technology Management
TE	Transnet Engineering
TFR	Transnet Freight Rail
SLL	Single-loop learning
SANAS	South African National Accreditation System
SAP	Systems, Applications, and Products
SOE	Standard Operating Equipment (SOE)
WPS	Welding procedure specifications

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CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 Introduction

This chapter serves as an introduction to the present study and summarises its contents. It discusses the research background, problem, research question, and objectives. The chapter also delves into the significance and benefits of the study, along with its delimitations and assumptions. Furthermore, key terms are defined to ensure clarity. Finally, the chapter concludes by presenting an overview of the study's overall structure.

1.2 Research background/context

In an increasingly complex and advanced business environment, Transnet must establish a strong market presence by offering high-quality freight wagons to ensure future success (Flammini, 2012; Nedeliaková, Panák and Šipuš, 2017). A study by Nedeliaková, Panák, and Šipuš (2017) highlights a competitive connection between innovative trends in process-oriented quality management and the transportation market, particularly in the railway industry. Meeting customer specifications is essential for ensuring satisfaction and compliance with requirements (Golder, Mitra, and Moorman, 2012).

Employees and managers should proactively identify quality issues and resolve errors by addressing their root causes (Chokkalingam *et al.*, 2017). Failure to address these problems could result in significant financial losses for Transnet, potentially amounting to millions or even billions of dollars annually (Flammini, 2012; Magadagela, 2016). Furthermore, understanding the causes and stages of defect occurrence is crucial for comprehending the nature of defects in wagon manufacturing (Daniyan et al., 2022).

Transnet, a significant state-owned enterprise, generates its primary revenue by providing time-of-place utility services to customers through various freight wagons (Transnet, 2020). Transnet has two main divisions: Transnet Engineering (TE) and Transnet Freight Rail (TFR). TE encompasses six major factories, one of which is in Bloemfontein and is responsible for wagon maintenance and manufacturing (the research setting of the current study). The advanced manufacturing division of Transnet focuses on maintaining and producing new freight wagons for TFR, which serves as the internal customer. In 2020, Transnet projected the maintenance of approximately 70,000 freight wagons and manufactured 4,500 new wagons annually (Transnet, 2020).

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Transnet Engineering dedicates itself to expanding its customer base for maintenance and engineering services while adhering to international standards, including those set by the International Organisation for Standardisation (ISO) and European Standards (EN) (Transnet, 2020). Quality is crucial in enhancing wagon availability, achieving volume targets, standardising fleets, boosting productivity, and improving customer service at Transnet (Hecht, 2014). This latter is part of Transnet's operations to provide railway freight services locally and across Africa. The effectiveness of railway operations relies heavily on rolling stock, a fundamental component of the rail system. Rolling stock is built and maintained in advance to meet the anticipated growth in volume and fleet requirements in the coming years.

Transnet Engineering sets itself apart from its competitors by embracing and executing the ISO 9001:2015 Quality Management System (QMS) as a fundamental framework for attaining and sustaining the required operational standards (Transnet, 2020). Implementing the QMS within TE wagons' maintenance and manufacturing factories can enhance operational efficiency, guarantee timely delivery of high-quality products, enhance throughput, and increase customer satisfaction.

Regrettably, TE has produced and delivered defective wagons to TFR, causing significant disruptions to their operations (Transnet Freight Rail, 2022). Despite the manufacturing and delivery of defective wagons and requests for improvement, TE still needs to rectify the situation, leading to significant financial losses for TFR and TE. Quality deviations and failures during wagon manufacturing in TE contribute to significant losses in resources (time) and money (Lokrantz, Gustavsson and Jirstrand, 2018). Before addressing quality issues, it is crucial to identify the root cause of defective wagons to improve TE's manufacturing processes (Ṋemavhola and Ramdass, 2017; Daniyan *et al.*, 2022). The primary aim of this study was to investigate the factors contributing to the underlying causes of TE's production of defective wagons.

1.3. Problem statement

In TE, wagon manufacturing and maintenance projects are started every year, but the outcome of the wagon is of inferior quality, resulting in disputes between stakeholders. Because of these consequences, TFR faces financial losses, customer attrition, and a decline in market share due to issues with newly constructed and maintained freight wagons. Defects are wagons that fail to meet industry standards and expectations (Lucky and Takim, 2015).

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Customer complaints initiated the study due to quality issues in recently built and maintained wagons. According to Transnet's report in 2021, out of the planned production of 168 manganese wagons by TE between April 1, 2020, and March 31, 2021, 82 wagons were identified as defective. This customer complaint represents a significant problem in a single Capex project, resulting in a financial loss of R108 million. Figure 1.1A visually represents the number of defective wagons compared to the total number manufactured.

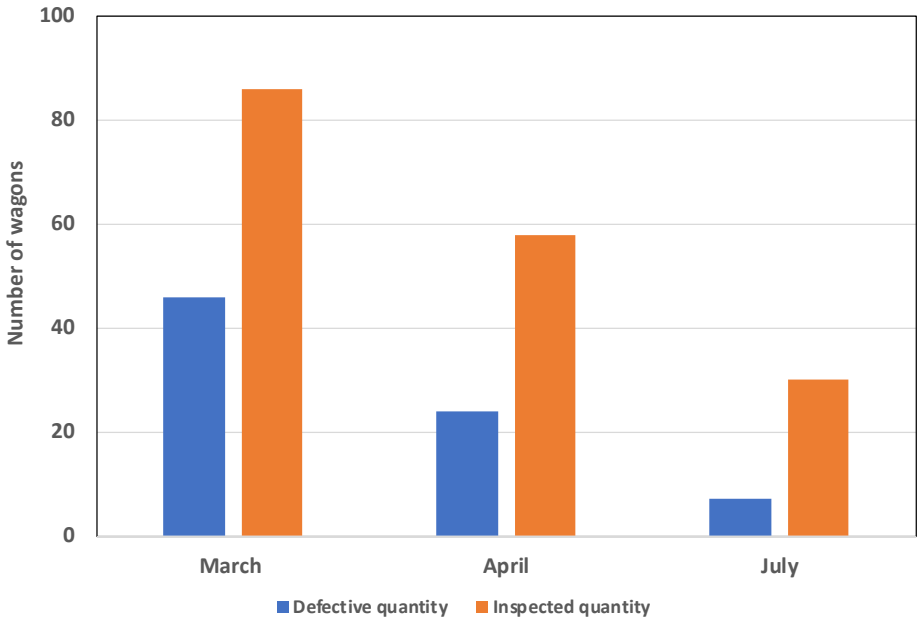


Figure 1.1A: quantity of defective wagons vs total number manufactured in Project A (Transnet Engineering, 2022)

Figure 1.1B illustrates the number of defects per unit, which unveils underlying quality concerns within the Transnet engineering production process. By dividing the total number of defects by the total number of units, Figure 1.1B presents the defects per unit metric, offering insights into the average number of defects found in each wagon and an indicator of the manufactured wagons' quality level.

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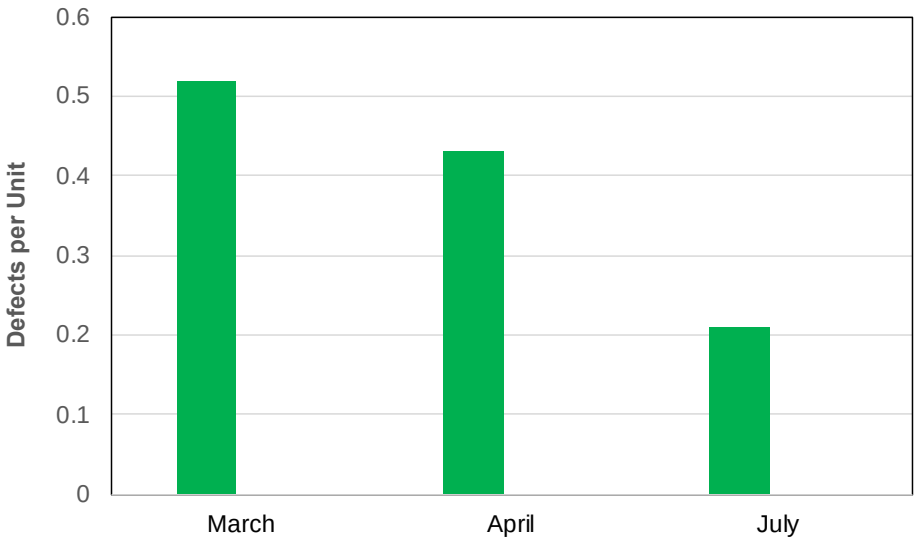


Figure 1.1B: Defects per wagon unit manufactured in Project A (Transnet Engineering, 2022)

Figure 1.2 depicts the defects documented in the historical customer complaints register, highlighting numerous concerns and challenges encountered with the railway wagons received by customers. The identified defects include the use of improper standard operating procedures (SOPs), dimensional discrepancies, and incorrectly assembled components. These defects signify a failure to meet customers' expectations and requirements.

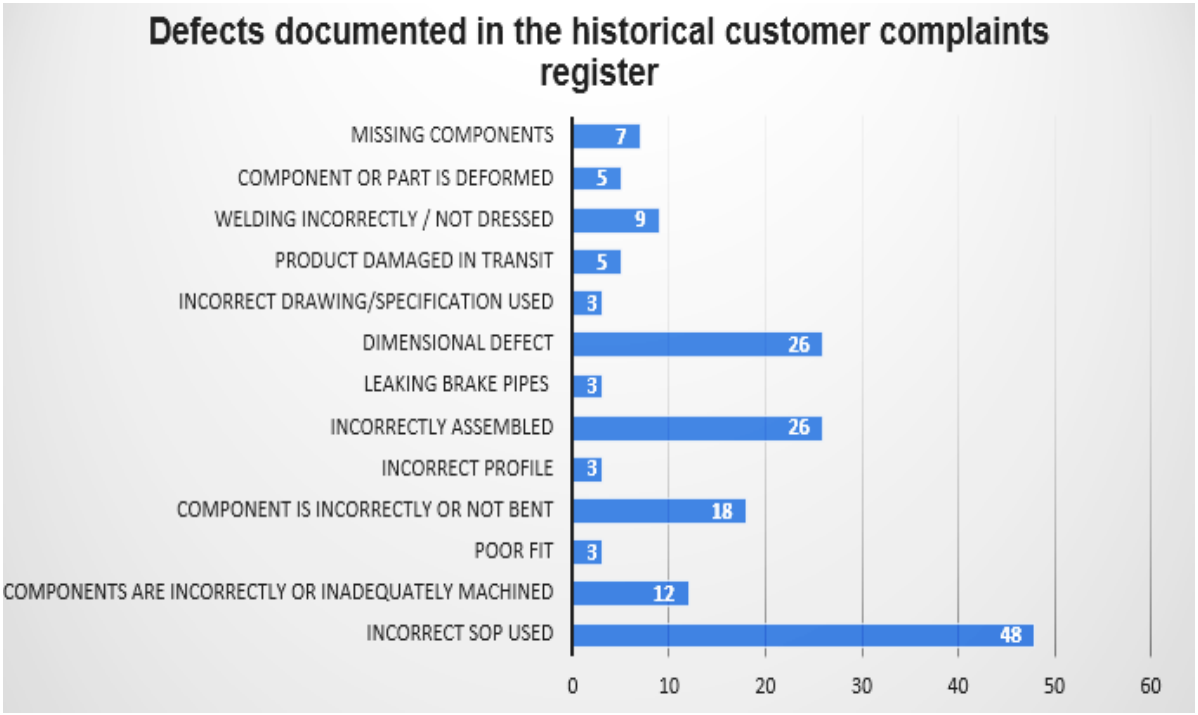


Figure 1.2: Historical customer complaints from 2018-2021 (Transnet Engineering, 2022)

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Various factors contribute to the manufacturing or assembly of defective freight wagons. According to Kolus, Wells and Neumann (2018) , managers are responsible for 85% of quality defects caused by the production process. Additionally, the lack of a QMS in the locomotive factory (Larchenko, Eremenko and Bystrova, 2021) and evolving customer demands (Psarommatis *et al.*, 2022) cause the production of defective wagons. Posch, Holtsinger and Bychkovskii (2015) and Kendall *et al* (2022) have also observed that operator error, process condition alterations, and material composition and distribution changes are responsible for wagon defects during manufacturing and maintenance.

Considering the significant consequences resulting from defective wagons, it is imperative to minimise the occurrence of defects during wagon production to attain a heightened level of reliability and meet customer expectations (Caplice and Phadnis, 2013). A thorough understanding of a problem is directly linked to the ability to uncover its underlying causes, enabling TE to develop effective mitigation strategies once these issues are fully comprehended.

The present qualitative phenomenological study aimed to investigate and identify the root cause of Transnet Engineering's manufacturing of defective wagons. The findings of this study will offer valuable insights into the underlying causes of these defects and provide recommendations for process improvement. By producing non-defective wagons, TE will ensure that TFR maintains its reputation as an outstanding transportation provider while avoiding train cancellations due to wagon shortages (Magadagela, 2016).

1.4. Critical research question

This study formulated the following critical research question (CRQ) that is essential to achieving the study's primary objective.

What are the root causes or factors leading to the production of defective wagons at TE, derived from employee perceptions and historical customer complaints?

1.5. Research objectives

Research objectives refer to "the main thrust of a study" and "the specific issues the researcher intends to investigate" (Kumar, 2018). The study pursued the following research objectives to address its CRQ:

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1. To investigate the factors contributing to producing defective wagons by gathering and analysing relevant literature**.**
2. To identify employee perceptions of the root causes of factors leading to manufacturing defective wagons at TE.
3. To analyse the causes of defective wagons identified in the customer complaints register through root cause analysis.
4. To draw recommendations for reducing the manufacturing of defective wagons in TE.

Upon achieving the research objectives, the study will present recommendations based on the findings. These practical and effective recommendations will help address the problems identified and improve the quality of wagon production. Furthermore, each chapter in the study will cover the objectives or provide essential background information.

1.6 Significance of the study

Factors contributing to defects in freight wagons' manufacturing processes have been the subject of numerous global studies (Mapande, 2019; Silvani, Yanuar and Juliani, 2019; Daniyan *et al.*, 2022). This study has aimed to gain a comprehensive understanding of the underlying causes and to develop strategies for minimising these defects. Scholars (Boronenko , 2013; Rahimov and Ruzmetov, 2018; Mapande, 2019; Silvani, Yanuar and Juliani, 2019; Daniyan *et al.*, 2022) have found that manufacturing errors play a significant role in the production of defective freight wagons. In South Africa, railway quality issues were previously overlooked or ignored (Nedeliakova, Nedeliak and Majercak, 2014; Nedeliaková, Panák and Šipuš, 2017).

Organisations must prioritise minimising defects throughout the manufacturing process to ensure economic success, maintain a competitive edge, comply with regulations, and meet delivery timelines while producing high-quality products. According to research conducted by Nedeliaková, Panák and Šipuš (2017) and Daniyan *et al.* (2022), railway industries across the manufacturing sector have been actively exploring innovative approaches to address quality issues while adhering to rigorous standards. Freight wagons are a common mode of transportation for goods; customers naturally expect reliable, defect-free wagons to prevent any potential malfunctions during transportation.

In addition, Nedeliaková, Panák and Šipuš (2017) suggest that the railway sector can implement various strategies to manage and prevent potential defects effectively. However, while previous studies conducted by Silvani, Yanuar and Juliani (2019) and Daniyan *et al.*

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(2022) at South Africa's TE have examined quality issues, they have not specifically explored the perspectives of employees involved in manufacturing freight wagons or analysed customer complaints. This lack of understanding regarding the recommendations of TE employees for reducing the production of defective wagons in the industry creates a significant knowledge gap. Therefore, it is essential to gather insights from TE workers and address the production of defective wagons to improve quality.

Considering the ongoing discussions surrounding quality issues, the main objective of this study was to address the identified gap. The objective was to improve customer satisfaction using insights from railway wagon manufacturers and customer complaints. The aim was to generate localised findings that would aid in a more profound comprehension of this phenomenon within the local railway industry.

1.7 Beneficiaries of the research

This study explores and analyses the factors contributing to the production of defective freight wagons at TE in Bloemfontein. By identifying these factors, the study will contribute to the existing knowledge and enhance the understanding of the railway sector's operations. The study findings will benefit TE and other freight wagon manufacturers in improving their production quality and reducing the number of defective wagons. It will provide valuable insights for senior railway executives in project, operation, and quality management. The study findings will assist in making informed decisions for improving railway management, operations, and production processes.

1.8 Delimitations and assumptions

1.8.1 Delimitations

This study has several delimitations that need to be acknowledged. Firstly, the study focuses on academic learning environments within the University of the Witwatersrand. The research scope is limited to employee perceptions and historical customer complaints within the TE wagons Bloemfontein factory, which manufactures wagons. Furthermore, the study analysed only customer complaints received between 01 April 2018 and 31 March 2021.

It is important to note that participants from other TE factories or organisations may exhibit different information behaviour than those involved in this study. Generalisations cannot be made based on the results and information obtained from TE, as they may not be universally applicable. To address these limitations, employing a well-designed research instrument and conducting thorough data analysis is crucial.

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This study proposes a concept that can be applied to similar circumstances in the railway sector rather than developing general knowledge from a single case. By acknowledging these limitations and taking appropriate measures, the study aims to provide valuable insights and recommendations applicable to similar contexts in the railway industry (Guba and Lincoln, 1989; Patton, 2002).

1.8.2 Assumptions

As with the delimitations outlined above, the study makes assumptions that must be acknowledged.Hofstee (2006) describes assumptions as the underlying beliefs or premises that researchers often accept without explicitly verifying their accuracy. The study employs a rigorous research methodology to identify the factors contributing to defective wagons. It considers certain assumptions that must be acknowledged to ensure the reliability and validity of the findings.

The study assumes that employees at TE have adequate knowledge of the factors contributing to defective wagons and historical customer complaints. Additionally, it assumes that all participants involved in the study will provide truthful and honest responses during the interviews, ensuring the reliability and validity of the collected data. The study acknowledges the subjective nature of reality and analyses the causes of defective wagons in manufacturing based on participants' perspectives and interpretations. Lastly, the study assumes that the selected research design, data collection methods, and data analysis strategies are suitable and appropriate for effectively exploring the phenomenon of defective wagon manufacturing and gaining comprehensive insights into the underlying causes. The methodological choices outlined in Chapter 3 are assumed to align with the current study's objectives.

1.9 Definitions of key terms

This study defines the following key terms to ensure consistency and clarity throughout the study:

- **Customer complaints register**: A customer complaints register is a tool used to record all customer complaints regarding the freight wagon services provided by a company (Nedeliakova, Nedeliak and Majercak, 2014).

- **Defects:** A wagon with subpar quality characteristics, not meeting specific standards or specifications, and exhibiting deviations from the expected level of quality, performance, or functionality (Mitra, 2016)

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- **Employee perception**: The degree to which employees organise and interpret sensory impressions related to the wagons they encounter or work with to derive meaning and judgments about their quality (Naidu, 2007; Khatri and Ramani, 2019).

- **Freight wagons:** Specialised vehicles designed to transport goods and cargo by rail (Spiryagin *et al.*, 2014). They can transport bulk goods, containers, machinery, raw materials, or finished products.

- **Quality management:** Systematically coordinating activities to ensure wagons meet or exceed customer expectations and conform to defined quality standards (Mapande, 2016).

- **Root cause analysis:** The approach of systematically identifying and addressing the root causes of defects or problems to determine the fundamental factors contributing to their occurrence rather than just addressing their symptoms or immediate causes (Okes, 2019).

- **Wagon manufacturing process:** wagon manufacturing process is complex and involves several interconnected stages to produce freight wagons. These stages include signing agreements, creating components using computer-aided design, fabricating parts, and assemblies, procuring materials, testing, and delivering the final product (Railway Technical Website, 2019).

1.10 Structure of the report

The study report is divided into five chapters, as listed below:

- **Chapter 1: Introduction and study background**
  This chapter presented an overview of the current study, including a theoretical framework, problem statement, objectives, study scope, limitations, and assumptions.

- **Chapter 2: Literature review**
  The most current and pertinent literature on the causes of defects in the manufacturing process and strategies for minimising them has been reviewed and synthesised. Relevant studies delineating rolling stock defects within the context of the railway industry were examined and synthesised.

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- **Chapter 3: Research methodology**

  This chapter delineates and elaborates on the research methodology employed in the study. It comprehensively expounds on the methodology, elucidating the research design, selected research paradigm, data collection and analysis methods, and ethical considerations.

- **Chapter 4: Findings and discussions**

  This chapter examined the research findings and themes derived from the data analysis. The transcribed interviews yielded empirical results centred on the primary themes and sub-themes concerning employee experiences.

- **Chapter 5: Key findings, conclusions, and recommendations**

  The study's relevant literature is summarised in the chapter, presenting the research findings. A detailed conclusion and recommendations are then provided based on guidelines from (Bloomberg and Volpe, 2012).

1.11 Conclusion

This section briefly introduced the present research report, delineating the study's context, research question, and study objectives. The subsequent section will undertake an in-depth analysis and comparison of the applicable literature concerning wagon manufacturing processes, the causes of defects, and strategies for minimising defects within rolling stock manufacturing studies.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A thorough literature review is crucial to any research project as it forms the basis for understanding the research question and objectives. In this study, the literature review focuses on the problem of defective wagon production in the railway industry. It presents a comprehensive evaluation of relevant literature and a critical analysis of existing research studies and theories in related fields to understand the subject matter deeply. The review covers several aspects, such as defining industry-specific terminologies related to defects, examining the manufacturing process of wagons, assessing employee perceptions on factors contributing to defective wagon production, and scrutinising customer complaints related to defects. Additionally, the review introduces the root cause analysis (RCA) concept, explores the various factors contributing to defective wagon production and investigates potential strategies for reducing defects. The literature review section aims to identify the root causes of defects in wagon production and suggest proactive measures and quality improvement initiatives to help minimise defects and improve the wagon manufacturing process.

2.2 Literature review search methodology

The conventional literature review methodology, as outlined by Ridley (2012), was used to examine, and present the relevant literature. This methodology adopted a critical approach, a standard practice in many research projects, as highlighted by Jesson, Lacey and Matheson (2011). According to Bowell and Kemp (2014), conducting a literature review and engaging in academic writing, in general, necessitate the application of critical thinking skills. Therefore, the literature review involved critically evaluating the studies and constructing a well-supported argument based on research evidence. In other words, the approach involved questioning and challenging the viewpoints, ideas, opinions, and perspectives of other researchers and industry practitioners in the railway sector. This process required significant time due to the extensive reading and research involved.

Rowley and Slack (2004) and Xiao and Watson (2019) suggests extracting keywords from the research topic and questions to generate search terms that can narrow the search and focus on literature related to the topic of interest. Xiao and Watson (2019) reported that despite specific search terms, literature reviews often yield many results in the first round of searches.

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Based on the topic, research question, and objectives, relevant published literature was searched in journals, conferences, and databases using the following keywords:

- Customer complaints
- Defects
- Employee perceptions
- Root cause analysis
- Freight wagon
- Wagon manufacturing process
- Quality management

Bibliographic databases like Google Scholar, Scopus, and ISI Web of Science were accessed to obtain relevant resources. These databases played a crucial role in assessing and evaluating publications. Chadegani *et al.* (2013) highlight that Scopus and ISI Web of Science are digital libraries with a vast collection of literature from peer-reviewed journals, including those ranked by the Institute for Scientific Information (ISI).

The initial phase of literature screening involved examining publications based on the research topic, keywords, and abstracts obtained from the search databases. A more detailed review was conducted on the selected publications, considering the inclusion and exclusion criteria. This process aimed to ensure that the retained publications were unique and did not contain duplicate studies reported in other publications. The validity and reliability of the research findings were further verified by reviewing and comparing the selected publications.

By the University of Witwatersrand's ethno-standard practice, the literature sources utilised by the School of Mechanical, Industrial, and Aeronautical Engineering should generally be five years old. However, the nature of the current study necessitated a departure from this practice since most existing studies on current research topics in the railway industry were outdated. Therefore, while incorporating more recent studies that may have not explicitly addressed wagons, the researcher ensured their theoretical and conceptual relevance to the current study.

The literature materials reviewed in this study encompassed a range of sources, including articles, research reports, PhD theses and master's dissertations, books, and organisational reports. The objective was to comprehensively examine the existing knowledge and gaps about the research topic (Ridley, 2012). The details of the literature review for this study are presented in the subsequent section, aligning with the rationale explained above.

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2.3 Definition of defects and different terminologies used in the railway industry

Multiple definitions of defects in the railway industry are available in the prescriptive literature (Dhafr *et al.*, 2006; Piyachat and Chanongkorn, 2015; Hill, 2018; Neuwirth, 2019). Previous studies have suggested that defects can be synonymous with reworks, snags, non-conformance, quality deviations, quality failures, and faults (Dhafr *et al.*, 2006; Piyachat and Chanongkorn, 2015; Hill, 2018; Neuwirth, 2019). Nevertheless, this research report will adopt the concept of defects. Table 2.1 presents the definitions of a defect within the wagon manufacturing environment and the broader railway industry context.

Table 2.1: Various definitions of a defect

Author (s)	Definition
Dhafr (2006); Björkman and Wisén (2020)	Any issues that cause a wagon to deviate from its intended performance or functionality, such as defective brakes and couplers, uneven weight distribution, or load securing problems.
Neuwirth (2019)	Parts or products that vary significantly from a normal distribution and do not meet wagon quality requirements, specifications, or work instructions, such as assembly errors, functional issues, material flaws, and dimensional deviations.
Ekblad (2015)	Waste components, also known as Muda, are targeted for reduction by organisations to improve efficiency and productivity in lean methodology.
Forsberg and Saukkoriipi (2017)	Wagons that do not meet established quality standards or specifications.

The railway industry has been the focus of numerous studies in academic literature, and a common issue revolves around the necessity for a clear definition. Given the imperative for conceptual clarity in the railway industry, it is crucial to establish an operational definition for the present study. While various researchers have made strides in describing and comprehending defects, quality experts generally concur that defective wagons share a standard definition. Researchers widely agree that a defect encompasses any aspect that falls short of acceptable quality standards (Forsberg and Saukkoriipi, 2007). As defined in this study, a defect is any aspect that fails to meet the expectations or requirements of the customer. This definition emphasises the customer's perspective and the importance of

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meeting customer requirements and satisfaction. Issues can arise from design, manufacturing, materials, functionality, or other aspects that fail to meet customer expectations.

2.4 Wagon manufacturing process in TE

This report focuses on freight wagons categorised as either passenger or freight wagons, as discussed by various authors (Spiryagin *et al.*, 2014; Lissandro, 2021). TE annually manufactures many types of wagons that transport freight, and their designs vary depending on the load, the composition of the train, and the rail route (Spiryagin *et al.*, 2014). Freight wagons consist of three parts: the body, bogie, and wheels. The wagon's body usually holds a freight wagon's central mass. All the wagon's bodies are linked by interconnected springs and dampers, forming a primary and secondary suspension system. The primary suspension links the wheelset and bogie frame, while the secondary suspension connects the bogie and wagon body. Kendall *et al.* (2022) state that high-quality freight wagons must meet specific criteria for their raw materials, manufacturing procedures, and final outputs.

Various authors (Mane, 2017; Railway Technical Website, 2019) have identified and outlined various stages of wagon manufacturing. According to the Railway Technical Website (2019), this process encompasses multiple steps, including contract signing, computer-aided design for component creation, sub-assembly, complete assembly, material procurement, testing, and the eventual delivery of the final product (illustrated in Figure 2.1). The production line for TE freight wagon involves using externally sourced input materials or internally produced ones to create high-quality rolling stock. TE conduct the manufacturing, final assembly, and testing of the wagons in-house for critical components. Mane (2017) asserts that this approach ensures compliance with stringent regulations and adherence to the required standards by wagon manufacturers.

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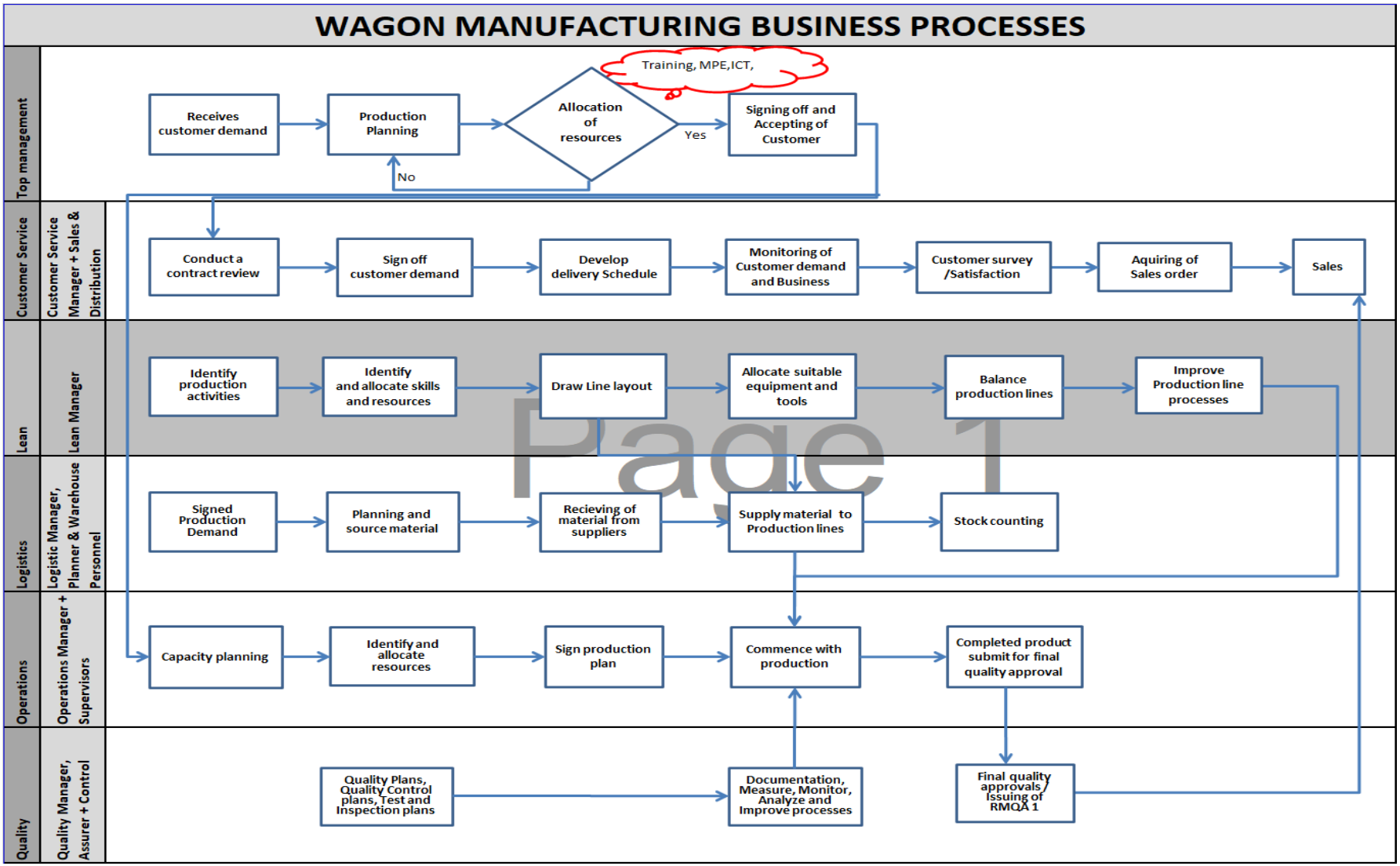


Figure 2.1: Wagon manufacturing process (Daniyan *et al.*, 2022)

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Additionally, Andersen (2011) and Mane (2017) further assert that all components, in-house or procured from outside sources, undergo proper testing using destructive and non-destructive methods. These scholars also emphasise that brake component suppliers must ensure their products are safe and efficient integration during assembly. Thus, the wagon manufacturing process is labour-intensive, necessitating skilled and knowledgeable workers to assemble and integrate numerous subsystems (Andersen, 2011; Spiryagin *et al.*, 2014; Daniyan *et al.*, 2022).

In the production of wagon structures, welding stands as the predominant technological process for components and assemblies (Sasmito, Irawadi and Soebagyo, 2019). Each welded segment of the wagon must fulfil the inherent reliability and safety specifications. Zaripov and Gavrilovs (2021) highlighted that over 95% of wagon assembly involves welding in the factory. Moreover, according to Zaripov and Gavrilovs (2021), approximately 60% of wagon components are estimated to be fitted using welding. Despite the clear technological advantages, welding also has its drawbacks. These include heightened stress concentration resulting from seam defects (such as undercuts, inadequate penetration, pores, and slag inclusions), mechanical inconsistencies in welds, residual stresses, and possible deviations of structural elements from their intended form due to welding deformations (Kendall et al., 2022). The culmination of these limitations can affect the performance of welded structures under static and cyclic loads, ultimately leading to brittle and fatigue fractures (Zaripov and Gavrilovs, 2021).

Research indicates that manufacturers are aware that defects can arise at any point during the wagon's manufacturing process, spanning from the project identification phase to its delivery (Neuwirth, 2019; Daniyan et al., 2022). According to Nedeliaková, Panák and Šipuš (2017), the primary objective of each wagon transformation process is to deliver customer value by examining how railway companies can enhance their operational efficiency. Prior research has contended that the emphasis should be placed on the production process or products rather than solely on the completed wagon to reduce defective wagons (Neuwirth, 2019; Nedeliaková, Panák and Šipuš, 2017). A focus on production processes or development is rooted in the idea that addressing a defect or error early in the process can reduce waste.

Identifying the cause of a defect is often challenging as it is usually the result of multiple causes. The occurrence of product defects is strongly linked to the manufacturing process parameters, meaning that the improper functioning of these parameters can lead to defects in the products. Effective control of these parameters and understanding their connection with

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product defects can assist Quality Improvement Teams (QIT) in minimising and eliminating such defects.

2.5 Employee perceptions of factors contributing to the production of defective wagons

The existing empirical literature in the railway industry indicates that employee perspectives can assist organisations in comprehending the perceived underlying reasons for defects (Arab and Dymling, 2020; Mashabane, 2022). Scholars have demonstrated that qualitative research studies can leverage employee perspectives and perceptions to draw conclusions and address research inquiries (Arab and Dymling, 2020; Mashabane, 2022). Scholars define *perception* as organising and interpreting sensory information to make sense of the world around us (Naidu, 2007; Khatri and Ramani, 2019). Employee perception of factors contributing to producing defective wagons refers to employees' subjective beliefs, opinions, and perspectives regarding the reasons behind defects in wagon production. The perceptions they hold are a result of their experiences, observations, and interactions within the organisation. Perception depends on one's perspective from a particular viewpoint rather than on reality.

According to a recent study by Mashabane (2022), there is a noticeable discrepancy between senior management's and employees' views regarding motivation and product quality. The study also revealed that even among employees, there can be significant differences in how they perceive these phenomena. Humans are inherently unique and can interpret events differently (Khatri and Ramani, 2019). Mashabane (2022) associates these variations in interpretation with factors such as an employee's hierarchical level and the type of employment contract, which can influence their knowledge and comprehension of the research subject. Researchers Khatri and Ramani (2019) found that experiences and situations influence employees' perceptions. Ultimately, Mashabane (2022) concluded that employee motivation is crucial in determining the quality of products produced by manufacturing organisations.

A study conducted by Ekblad (2015) on project-based production in the railway industry showed that understanding employee perspectives is crucial for continuous improvement. Organisations seeking to implement effective improvement programs and problem-solving methods should consider their employees' viewpoints (Ekblad, 2015; Mapande, 2019; Mashabane, 2022). By collecting data from employees' perspectives and perceptions, researchers and organisations can gain valuable insight into how these programs are perceived. Mashabane (2022) found that incorporating employee perspectives into data

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generation leads to more relevant and valuable research. Previous academic research has also demonstrated the importance of employee perspectives in clearly understanding a phenomenon. For example, Arab and Dymling (2020) employed employee perspectives to uncover the underlying reasons for defects mentioned in customer complaints within the manufacturing industry. Their research and existing literature support the idea that incorporating employees' viewpoints is a valid and valuable approach to collecting scholarly information.

Employee perception holds substantial value in organisational outcomes, impacting engagement, work environment, job satisfaction, and psychological well-being. It is often more influential than factual information (Ahmad and Khan, 2018; Santos *et al.*, 2021). Understanding and analysing employee perceptions is crucial for investigating the production of defective wagons. The current research report aims to gain insights into potential wagon manufacturing or maintenance issues by examining employees' perceived root causes of defects at TE. Perception significantly affects employee working relationships and quality outcomes (Schermerhorn *et al.*, 2011). Acknowledging employees' unique perspectives and first-hand knowledge, organisations should actively listen to their perceptions. Incorporating employee feedback and involving them in problem-solving and decision-making processes can foster a culture of continuous improvement and address the underlying causes of defects in wagon production (Charles, Francis and Zirra, 2021).

2.6 Customer complaints on the production of defective wagons

Numerous studies have emphasised the detrimental impact of defects on an organisation's economic well-being, prompting companies to improve their manufacturing processes and increase inspection standards (Ekblad, 2015; Ṋemavhola and Ramdass, 2017; Silvani, Yanuar and Juliani, 2019). Recent research by Rajesh and Palani (2021) and Daniyan *et al.* (2022) discovered that defects in freight wagons could lead to prolonged production time, component rejection and rework, increased production costs, and compromised safety due to the potential for rolling stock failures. Dindar and Kaewunruen (2018) further confirm that train derailments are a clear example of incidents where passenger or freight wagon defects can result in significant financial losses, damage to reputation, or project failure.

Every industry now tailor’s product designs to meet customers' preferences, necessitating the creation of appealing quality (Lin *et al.*, 2017). Consequently, a customer will predefine the performance outcomes of a product that should meet their needs and expect the supplier provider to precisely deliver that. A customer's satisfaction is the feeling of pleasure after comparing their product's performance with their anticipated performance (Syafarudin, 2021).

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Therefore, as illustrated in the current study, customers who receive products that fall short of their expectations may lodge complaints and provide feedback to manufacturers. Customer complaints about defective wagons indicate that customers have identified issues or problems with the railway wagons they have received.

This approach affirms the notable shift in quality experienced over the past decade. The perception of quality has evolved, transitioning from a producer-oriented product development approach to one where the customer plays a more significant role, shifting from a mere buyer to a potential partner (Lin *et al.*, 2017). Research indicates that meeting customers' specifications and requirements is crucial as it directly influences the company's quality and reputation and enhances its competitiveness (Golder, Mitra and Moorman, 2012; Nedeliakova, Nedeliak and Majercak, 2014). By upholding the production of high-quality wagons, TE can cultivate customer loyalty and mitigate the risk and cost associated with manufacturing defective wagons (Curbano *et al.*, 2020).

Rizwan *et al.* (2013) suggests that the closer TE is to its customers, the better it can comprehend their needs and opinions. The categorisation of product requirements into three types (Bergman and Klefsjö, 2010; Lin *et al.*, 2017) - must-be, one-dimensional, and attractive attributes - helps understand why customers prioritise different needs. Figure 2.2 illustrates the Kano model, which provides managers with valuable insights into enhancing customer satisfaction.

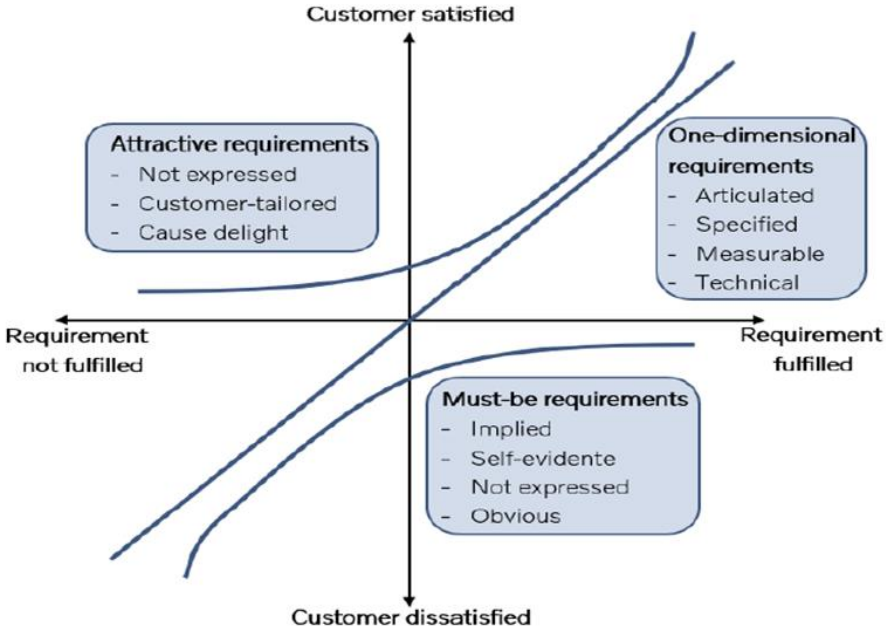


Figure 2.2: The Kano model (Arab and Dymling, 2020)

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The literature indicates that the model proposes satisfaction factors to be dynamic, evolving from sources of delight to essential one-dimensional factors (Matzler *et al.*, 2021). However, there is limited empirical evidence supporting this assumption. Mapande (2019) contends that Transnet Engineering Bloemfontein Locomotive Maintenance overlooked customer satisfaction, hindering quality management processes. The findings of Hohenberg and Taylor (2021) highlight that the significance of attributes in determining overall satisfaction can evolve, a phenomenon attributed to changing expectations. TE must not only enhance but also uphold the consistency of customer satisfaction to sustain competitiveness by minimising recurring defects in wagon production.

Nedeliakova, Nedeliak and Majercak (2014) contend that wagons possessing satisfactory quality and sufficient performance attain customer satisfaction throughout their operational lifespan. Customer complaints about the defective wagons serve as feedback for the TE to identify areas for improvement, rectify the issues raised, and enhance customer satisfaction and loyalty.

2.7 Root cause analysis (RCA)

Research indicates that in the railroad industry, Root Cause Analysis (RCA) is used to identify defects and their underlying causes(Nemavhola and Ramdass, 2017; Silvani, Yanuar and Juliani, 2019; Daniyan *et al.*, 2022) . The goal of RCA is to provide high-quality solutions to customers' issues. According to the American Society for Quality Management (2021), RCA is an essential process for organisations striving to continuously improve through thorough analysis and introspection. Additionally, the business community has acknowledged RCA as the most effective approach for efficiently and consistently solving complex problems with multiple causes (Tague, 2005).

To effectively address the quality issues discussed in Chapter 1, it is crucial first to identify and understand the factors behind producing defective wagons. RCA, as defined by Mahto & Kumar (2008), is a technique that identifies and eliminates the primary causes of defects to prevent future occurrences. Drawing upon a range of sources, including Ishikawa (1985), Andersen and Fagerhaug (2000), Tague (2005), and Okes (2019), RCA is defined as a structured approach that utilises specific techniques to pinpoint and resolve problems. It is essential to identify the root cause of an issue to prevent it from recurring. If the actual root cause cannot be identified, then attempts to address symptoms will only temporarily alleviate the issue, leaving the underlying problem unresolved.

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According to Yuniarto (2012), there is room for improvement in the current RCA tools' ability to comprehend the system-wide implications, address all issues, and use a problem-structuring approach to identify the root cause and propose a solution. Furthermore,Hussin, Ahmed and Muhammad (2016) suggests that human perspectives, perceptions, opinions, and thoughts often contribute to these problems.

In a recent study, Daniyan *et al.* (2022)) applied Root Cause Analysis (RCA) to address quality issues in the manufacturing units responsible for railcar bogies (bogie assembly units) within the railcar industry, ultimately enhancing the assembly operation process. Their research demonstrates that this approach effectively identifies potential root causes and their impacts, crucial for design improvement and subsequent control. Similarly, Silvani, Yanuar and Juliani (2019) used the RCA method as part of the DMAIC methodology to pinpoint the causes of defective products leading to production delays and underframe repairs. They incorporated two essential RCA techniques - failure modes and effects analysis and cause-and-effect diagrams - and provided detailed descriptions to advocate for their use in critical railway projects. The authors recommend improvements to material storage characteristics, workstation design, and procedure display, which could significantly benefit railway manufacturing companies.

It is evident from the literature that the RCA process has gained widespread international use in the manufacturing industry for investigating the causes of defects. RCA involves a systematic approach of asking "what" and "why" to identify the root cause of the issue. Moreover, various scholars suggest that this analysis process offers an effective means of establishing action plans that are relevant and efficient in addressing the cause and preventing recurrence (Boyd, 2015; Brook *et al.*, 2015). Figure 2.3 illustrates the critical success factors of RCA.

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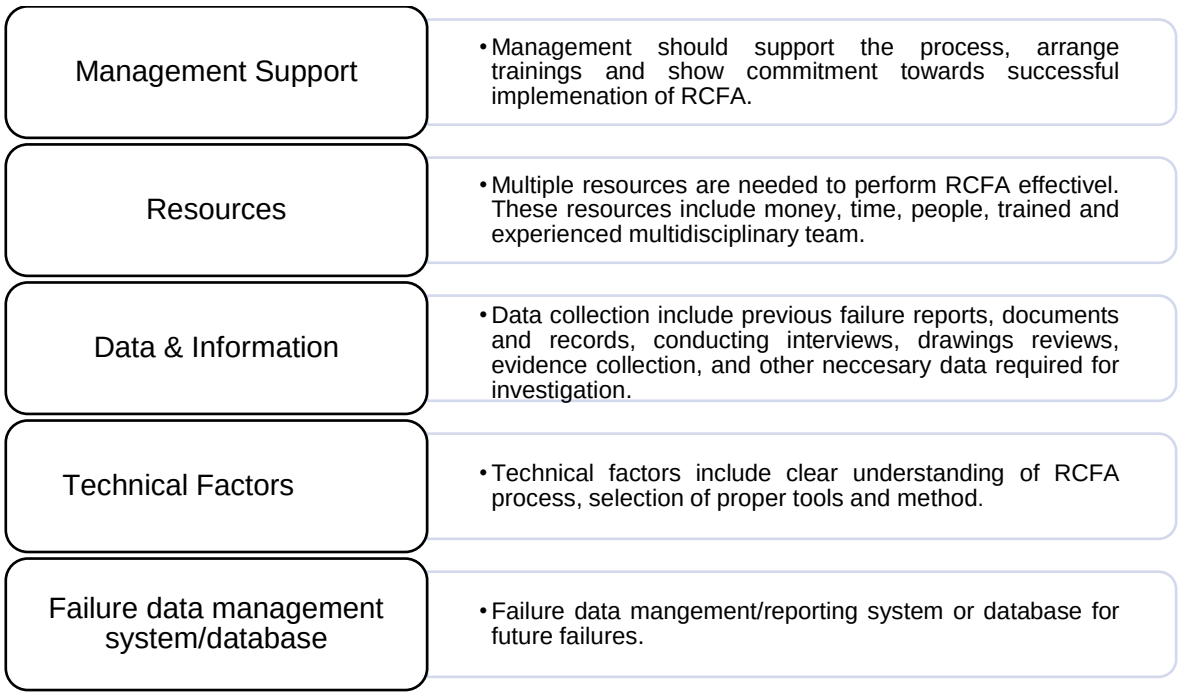


Figure 2.3: Critical success factors of RCA (Hussin, Ahmed and Muhammad, 2016)

2.8 Factors contributing to the production of defective wagons

Numerous studies, including those by Boronenko (2013), Rahimov and Ruzmetov (2018), Mapande (2019), Silvani, Yanuar and Juliani (2019), and Daniyan *et al.* (2022), have highlighted various factors that result in the production of defective wagons. It is paramount to pinpoint the underlying reasons for defects and assess the factors that trigger their emergence at any point in the production process to effectively address quality issues (Ershova *et al.*, 2020). Identifying defects' root causes can increase customer satisfaction and performance. Freight wagons are a critical investment for the railway industry and their profitability hinges on their extended use over 25-30 years. The subsequent section delves into several factors contributing to producing defective freight wagons.

2.8.1 Human factor

The production of wagons entails two primary elements: executing tasks and merging various subsystems (Andersen, 2011; Spiryagin *et al.*, 2014; Daniyan *et al.*, 2022). Poor task execution may lead to human-related issues, resulting in substandard freight wagons. These issues may arise from misinterpretation of work instructions and specifications, incorrect identification of materials, insufficient training or expertise, failure to adhere to standards and tolerances, and the implementation of flawed practices by workers (Nemavhola and Ramdass, 2017; Silvani, Yanuar and Juliani, 2019; Daniyan *et al.*, 2022). Research conducted by Ngadiman *et al.* (2017) has shown that specific actions taken by operators during the bogie assembly process can contribute to defects. While human error is inevitable, defects often

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arise from errors and omissions in design or manufacturing procedures. As Neumann, Kolus and Wells (2016) suggest, managing the human factor can help to minimise such errors and omissions in wagon production. As Shaposhnyk (2018) stated, individuals can employ a unique combination of psychophysiological traits to prevent incorrect actions, thus defining the human factor.

Strategic decisions made by management are the primary cause of inadequate quality in capital expenditure projects related to wagon manufacturing. These decisions can lead to the implementation of inappropriate structures, processes, practices, and technologies that ultimately result in poor quality. Management is primarily responsible for subpar quality since they are often the primary source of variation leading to such issues. Kolus, Wells and Neumann (2018) found that 85% of quality issues arise from the production process, for which management is accountable, while only 15% for which employees are responsible. The approach and attitude of management towards quality also play a critical role in identifying the areas that organisations should focus on to address their quality issues.

Numerous empirical studies have demonstrated a robust connection between human factors, errors, and quality issues (Elnaga and Imran, 2013; Shaposhnyk, 2018; Arab and Dymling, 2020). Elnaga and Imran (2013) emphasise the significance of taking proactive measures to enhance the quality performance of manufacturing staff. Arab and Dymling (2020) suggest that directing attention toward methods and systems rather than individuals can lead to better business outcomes when addressing errors. Furthermore, Shaposhnyk (2018) highlights that considering human elements during product design can result in a superior user experience, better performance, greater satisfaction, and overall product quality.

2.8.2 Quality of raw materials

Several studies, including those conducted by Konyukhov and Efimov (2006), Boronenko, (2013), and Rahimov and Ruzmetov (2018), have emphasised the crucial role of material quality in the production of wagons. This aspect significantly impacts wagons' reliability, durability, and other technical and economic factors. Silvani, Yanuar, and Juliani (2019) research also established a strong link between material quality and the incidence of defects. The study reveals that low-quality materials result in more defective products than high-quality materials. Specifically, Silvani, Yanuar, and Juliani (2019) observed welding defects in underframe components during the production of Linke Hofmann Busch coaches caused by material properties during welding. Furthermore, Nemavhola and Ramdass (2017) revealed that factors such as the material's chemical composition, tensile strength, and variations in spring size are primarily responsible for the inadequate deflection of railcar bogie springs.

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Their findings suggest that most defects arise from improper storage practices and welders' failure to clean the material before welding.

2.8.3 Low level of automation/technology

Research indicates that manual assembly is the prevailing manufacturing process in the South African railway industry (Mapande, 2019; Daniyan *et al.*, 2022). Torres, Nadeau, and Landau (2021) explain that manual assembly involves using human skills and judgment to assemble pre-manufactured parts into a final product. The authors (Torres, Nadeau and Landau, 2021) also emphasise the significance of information quality in work instructions and specifications, along with its presentation and workers' interaction with it, as pivotal factors in manual assembly processes.

The manufacturing industry has replaced human workers with automated visual inspection (AVI) for quality control and monitoring purposes. Daniyan *et al.* (2022) suggest that implementing automation in the freight wagons industry can result in substantial cost savings. Other studies, such as those conducted by Jeong *et al.* (2017) and Brougham and Haar, (2018), highlight the advantages of automation both internally and externally. However, Arab and Dymling (2020) argues that certain manufacturing companies still favour manual assembly despite the benefits of automation. Gibson *et al.* (2014) suggest that implementing automation can decrease human errors and thereby decrease product rejection rates during quality assessments.

Although manual assembly is the primary method employed in many TE factories due to the high cost associated with automatic assembly machines, a case study conducted by Daniyan *et al.* (2022) revealed that defects can also arise from insufficient technology and process automation levels. The authors Daniyan *et al.*(2022) elaborate on how factors such as the limited availability of robots, inadequate configuration, and insufficient levels of automation contribute to producing defective wagons.

Recent research by Ben Sghaier (2021) and Psarommatis *et al.* (2022) has revealed that evolving customer demands often cause product defects. To meet these demands, customers now seek freight wagons that not only fulfil their logistics requirements but also provide top-notch transportation and are efficient for loading and unloading processes. With technology advancing rapidly, railway organisations are increasingly recognising the strategic value of technology in delivering business value. To address quality issues, managers must cultivate capabilities that align with their competitive priorities and manufacturing and business strategies, depending on the competitive environment in which they aim to thrive (Malik, 2019).

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Organisations must allow their strategic vision and goals to guide the adoption of new technologies to support long-term growth and performance (Albukhitan, 2020).

As technology advances, the railway manufacturing industry has turned to robots for manufacturing and material processing, improving production performance and worker well-being (Aashish and Krupa, 2021). However, even with these innovative technologies readily available, the rail industry still requires skilled personnel to implement them effectively. Research conducted by Maheso, Mpofu and Ramatsetse (2019) has shown that inadequate training of operators and engineers on the operation and maintenance of robotics has resulted in financial losses for the industry.

Du Plessis (2020) suggest that the failures in automation within the industry are not attributable to trade, economic, or policy issues. Instead, they stem from the industry's inability to implement effective technology management programs and integrate technology into their strategic objectives. Adopting a proactive approach that emphasises shorter cycle times, enhances technical community productivity and performance, effectively analyses resources and infrastructure, and understands the interdisciplinary requirements of technology project management to introduce new technologies, products, and processes successfully. Automating assembly operations and enhancing human capabilities can improve process efficiency, leading to a decrease in quality defects.

2.9 Reducing the production of defective wagons

To reduce defects, manufacturers should strive for a vision of zero defects while working towards defect reduction as their primary goal (Björkman and Wisén, 2020). According to Daniyan *et al.* (2022), implementing ongoing analysis, control, and improvement programs or methodologies is critical to minimising defects. Hill (2018) suggests that implementing tools for quick defect identification can lead to faster corrections. Dhafr *et al.* (2006) emphasise identifying process flaws and selecting the most suitable tools and methods for improvement projects. Manufacturers utilise various tools to identify the possible causes of defective products, including 5S methodology, fishbone diagrams, fault tree analysis, and Jidoka. These tools reinforce philosophical approaches like problem-solving, rethinking, preventive action, and evaluating the current situation (Psarommatis *et al.*, 2020). The literature explores various learning theories and models that can be applied to minimise the manufacturing of defective wagons, as examined in the following section.

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2.9.1 Double-loop learning

Arab and Dymling (2020) propose two methods for organisations to tackle quality problems: single-loop learning (SLL) and double-loop learning (DLL), illustrated in Figure 2.4. SLL involves identifying and correcting issues within specific governing variables, while DLL requires changing those variables to solve organisational problems (Savolainen and Haikonen, 2007). DLL actively involves all team members in contributing valuable information by asking questions about problem awareness, origin, causes, and consequences, creating a knowledge flow to address the issues. According to Tagg (2010), SLL relies solely on detecting errors and making corrections based on established internal rules and regulations without incorporating external knowledge or allowing modifications. In contrast, as a structured problem-solving methodology, DLL is essential for identifying, analysing, and preventing defects. Jaaron and Backhouse (2017) argue that this approach empowers stakeholders within the organisation to change policies and procedures, potentially leading to new strategies to minimise the production of defective wagons.

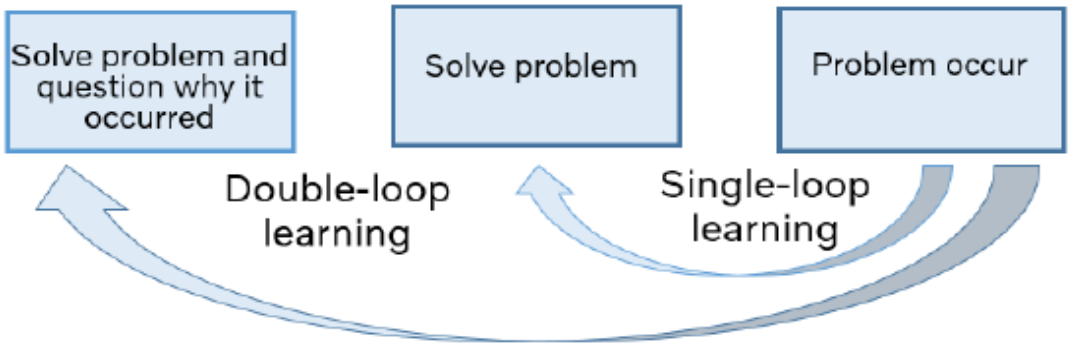


Figure 2.4: Model showing how single and double-loop learning works (Arab and Dymling, 2020)

2.9.2 Knowledge management

In academic literature, Criado-García, Calvo-Mora and Martelo-Landroguez (2020) assert that knowledge plays a crucial role as an input in production processes. Additionally, they underscore that knowledge management (KM) involves integrating people, technologies, techniques, and strategies within an organisation to create, share, and utilise knowledge. Previous research has demonstrated that the railway industry relies on its knowledge bases for survival and expansion (Morant, Westerberg and Larsson-Kråik, 2014). Furthermore, manufacturers of freight railway wagons must effectively manage their knowledge to operate at an optimal level. Georgiev (2013) and Babaei, Radfar and Toloie, (2019) agree with the author above that to minimise the production of defective wagons in this rapidly evolving

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environment; the organisation must adapt KM systems tailored to its distinct characteristics, resources, and duties.

Epetimehin and Ekundayo (2011) highlighted the benefits of implementing knowledge management (KM) systems in their study. The results showed that such systems offer various advantages, including reducing redundant work, avoiding duplicative efforts, decreasing employee training time, preserving intellectual capital in the face of employee turnover, and facilitating organisational adaptation to changing environments and markets. These findings are consistent with the perspectives of North and Kumta (2018), who argue that KM implementation improves operational efficiency and effectiveness, ultimately transforming the competitive landscape by cultivating a learning organisation.

Research suggests that organisations turn to knowledge management to meet a variety of needs, such as sharing best practices with key employees, retaining critical employees' tacit knowledge, improving processes, responding to customer needs, and fostering knowledge sharing among staff (Morant, Westerberg and Larsson-Kråik, 2014; Babaei, Radfar and Toloie, 2019; Abbas *et al.*, 2020). These findings highlight the growing understanding of the strategic significance of managing employee-owned tacit knowledge across personal, organisational, and project boundaries within the railway industry. They also underscore the railway sector's increasing reliance on knowledge management, given the challenges of identifying and accessing relevant knowledge in large organisations. However, despite knowledge management initiatives, the railway industry faces criticism for limited learning capabilities, often resulting in duplicated efforts, repeated errors, and inefficient use of resources (Morant, Westerberg and Larsson-Kråik, 2014; Abbas *et al.*, 2020).

In conclusion, to avoid repeating mistakes or reinventing knowledge, it is crucial to record and manage knowledge for future use (Omotayo, 2015). Effective knowledge management at TE can reduce wagon defects, improve human performance, and enhance customer satisfaction.

2.9.3 Organisational learning

Organisational learning (OL) pertains to the modifications in organisational practices, such as routines, procedures, structures, technologies, and systems, facilitated by individual learning and problem-solving processes (Morant, Westerberg and Larsson-Kråik, 2014). Learning involves recognising and rectifying errors, and its absence can impede such advancements. According to Nedeliaková, Panák and Šipuš (2017), reducing defects in the railway industry necessitates proactive learning about customers, processes, and behaviours, followed by appropriate actions. Companies can pinpoint improvement opportunities through experiential

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learning, which closely intertwines OL with knowledge management (Ekblad, 2015). The literature underscores three learning methods: passive, active, and interactive. Research by Ekblad, 2015; Souza, Sousa and Nunes (2020) indicates that team learning, systems thinking, and mental models are essential learning disciplines for OL. Furthermore, scholars Ekblad (2015) and Souza, Sousa and Nunes (2020) emphasise that OL should encompass five competencies: systematic problem-solving, experimentation with new approaches, learning from experience, learning from other companies and customers, and practical knowledge transfer throughout the organisation.

The study conducted by Ekblad (2015) found that preventing defects requires collecting defect data, analysing root causes, identifying appropriate corrective actions, and disseminating lessons learned to reduce or eliminate future defects.Arab and Dymling (2020) study supported the findings, emphasising the significance of lessons learned as a common approach to counteract knowledge loss at the end of a project.

2.10 Conclusion

This chapter reviews various literature that discusses different perspectives on the theoretical background to support the current study. Any aspect of a product that fails to meet acceptable quality standards is considered defective based on extensive research and analysis of relevant literature (Forsberg & Saukkoriipi, 2017). A review of the widely used wagon manufacturing process has provided valuable insights into the wagon manufacturing process in TE and a broader understanding of potential challenges that can arise during wagon manufacturing.

The review underscores the importance of integrating employee perspectives into effective improvement programs and problem-solving approaches. Drawing on the works of Mapande (2012), Ekblad (2015), and Mashabane (2022), the review illustrates how employee insights aid in uncovering the root causes of defects. Arab and Dymling (2020) exemplify this by utilising employee perspectives to identify the reasons for customer complaints in the manufacturing industry. Emphasising that individual viewpoints, experiences, and interactions shape employee perspectives, the review underscores their value in understanding the reasons behind defects. Recognising the significance of prioritising employee perspectives and involving them in decision-making processes to reduce defective wagon production in the manufacturing sector is widely acknowledged (Ding, 2016; Charles, Francis and Zirra, 2021; Shashanka, 2023). This approach aligns with employee empowerment and participative management principles, recognising employees' invaluable insights in the production process (Ding, 2016; Shashanka, 2023). Research has demonstrated that this approach enhances job satisfaction, commitment, and overall performance while fostering a culture of

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collaboration and continuous improvement within the organisation (Charles, Francis, and Zirra, 2021; Ding, 2016; Shashanka, 2023).

The review emphasised the importance of maintaining customer satisfaction and suggested that companies use customer complaints to minimise recurring defects in wagon production. It is important to note that not all customer complaints indicate poor product quality. The review underscored the vital role of Root Cause Analysis (RCA) in the manufacturing industry, as it helps to discover the core reasons behind defects. RCA enables the development of sound action plans to tackle the underlying causes of problems and prevent their recurrence. However, the review also acknowledged that RCA might not identify all the underlying issues, resulting in incomplete solutions. As a result, human biases and perceptions may limit RCA's effectiveness. In such instances, it may be helpful to supplement RCA with other tools and approaches. Ultimately, the approach's success hinges on the specific circumstances and nature of the problem.

The analysis uncovered multiple factors that contribute significantly to defective wagon production in the railway industry, including human factors, raw material quality, and a lack of automation and technology. Recent research by Mapande (2019) and Daniyan et al. (2022) has shown that outdated technology and manual processes are significant culprits. Scholars Daniyan et al. (2022) agree on the effectiveness of automation in reducing defects but caution that improper programming can lead to adverse outcomes. The review emphasises the importance of carefully considering automation parameters to achieve operational excellence and prevent defects. Thus, balancing manual and automated processes is essential for optimal results.

The review section delved into various learning theories that have the potential to minimise the production of defective wagons. The review carefully analysed each theory to understand its underlying principles and determine its suitability for mitigating the likelihood of wagon defects. The literature review suggests that the railway sector can utilise three learning theories to address the challenge of defective wagon manufacturing. These theories include double-loop learning, knowledge management, and organisational learning. Double-loop learning involves questioning the assumptions and values that guide organisational practices, while knowledge management entails effectively capturing, sharing, and utilising knowledge related to wagon manufacturing processes. Organisational learning fosters a culture of continuous learning, experimentation, and knowledge sharing. By integrating these three learning theories, organisations can work towards minimising defects and promoting continuous improvement in wagon manufacturing processes.

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Researchers around the globe conducted studies on the production of defective wagons. South African scholars have made notable contributions to this topic. However, existing literature should focus more on the experiences and opinions of employees rather than just industrial tools and techniques. It is crucial to incorporate the perspectives of manufacturing workers to fully comprehend the reasons behind producing defective wagons. However, the current literature on this matter must be expanded in scope and depth, highlighting the need for further exploration. Several studies have explored the factors that lead to the production of defective wagons, and the consensus among scholars is that defective wagons can significantly impact the financial stability of a railway company.

The subsequent chapter provides an in-depth overview of the research methodology to address the research question and objectives.

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CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This study utilised empirical qualitative research methods to investigate, analyse, and pinpoint the root cause of defective wagon production. Human perceptions, decisions, and outcomes are influenced by past experiences, shaping and moulding future perceptions. Consequently, the study delved into the experiences and perceptions of TE employees to comprehend the factors influencing defective wagon production. The unique perspectives held by employees of the organisation under study can offer valuable insights for addressing the quality issues outlined in Chapter 1.

This section comprehensively outlines the methodology employed to accomplish the study's objectives. It encompasses the collection, analysis, and interpretation of empirical qualitative data, ultimately serving the overarching purpose of the study. The researcher carefully executed the selection of research design, methods, instruments, and analysis techniques to ensure that the study effectively and validly addressed the research objectives. The methodology was informed by drawing from pertinent literature on research methodology and previous studies with similar objectives, thus gaining valuable guidance. This section presents the research process and elucidates the assumptions that influenced the methodological decisions. It begins by delineating the philosophical assumptions that guided the chosen research design and methods, concluding with exploring the ethical considerations pertinent to the present research study.

3.2 Overview of research methodology

Developing a research question is the fundamental basis of the current research project (De Vos *et al.*, 2011), guiding every aspect of the study and leading to conclusions drawn from the findings (Nieuwenhuis, 2007). According to Gray (2019), research methodology encompasses the set of procedures and approaches that the study intends to utilise, outlining the planned conduct of the research. Similarly, (Walliman, 2021) underscores that the research methodology significantly influences the validity of the research findings. Therefore, it is crucial for the study to carefully select the most appropriate methods to ensure the validity, reliability, and rigour of the findings.

The research methodology depicted in Figure 3.1 was employed to accomplish the study's objectives, comprising three distinct phases: (1) theoretical work, (2) fieldwork, and (3)

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conclusion and recommendation. During the theoretical work phase, the study conducted a comprehensive literature review and interviews to gain a deep understanding of the underlying problem at TE. The literature review focused on critically analysing the existing knowledge related to defects in freight wagons. As Marshall *et al.* (2013) suggested, a literature review serves various purposes, including gaining insights from previous studies, addressing research gaps, and building upon prior research findings.

Ten TE employees were interviewed in person using a semi-structured approach to ascertain the underlying reasons behind quality concerns. Customer complaints were analysed using a cause-and-effect diagram and the Five Whys RCA tool, while employee interviews underwent a thematic analysis. In addition, the study drew upon TE archival data about customer complaints, total production, defects, and defect types.

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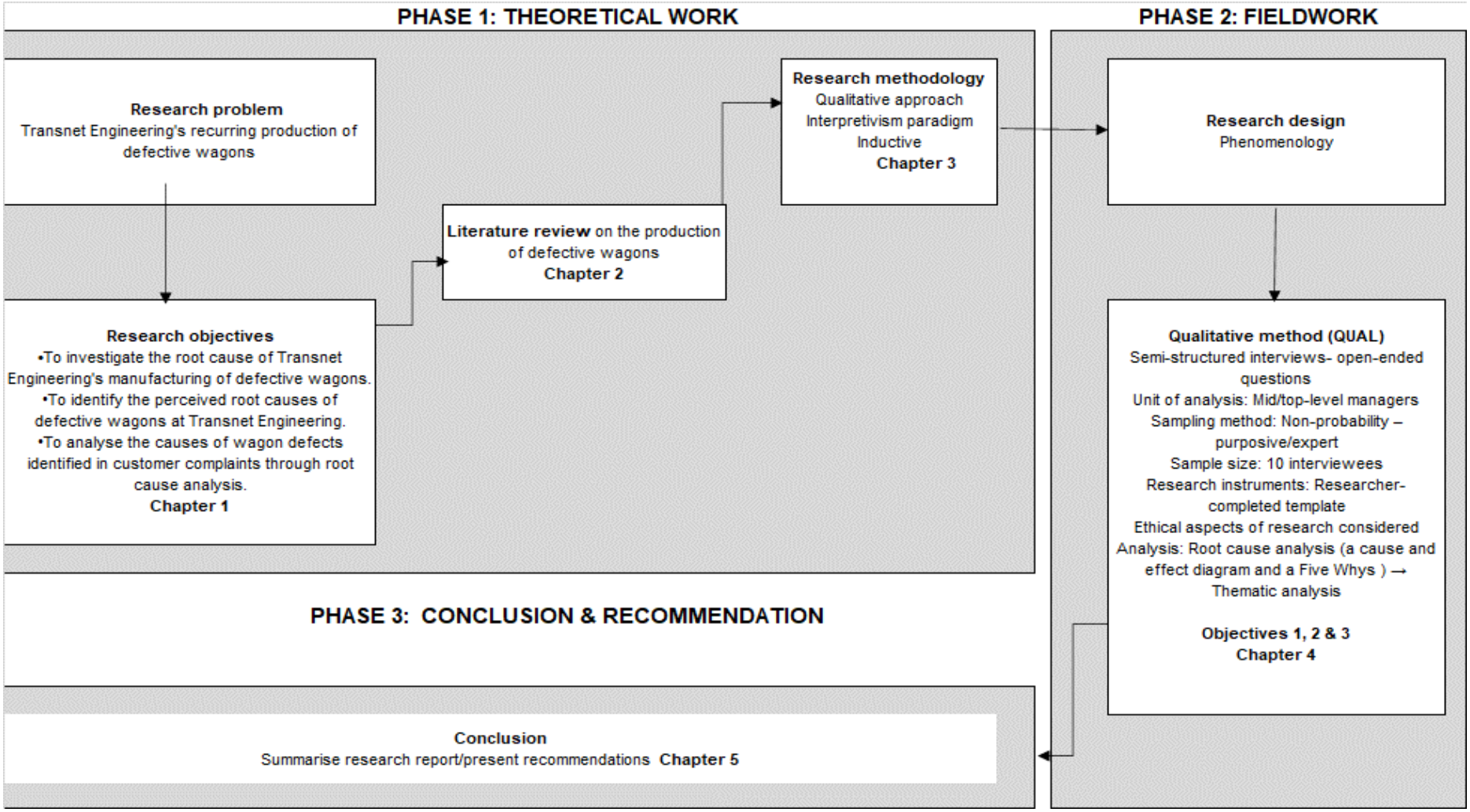


Figure 3.1: Overview of the methodological process for the research project.

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3.3 Research paradigm/philosophy

A research paradigm refers to a researcher's fundamental beliefs that shape their worldview, place in the world, and potential relationships with it and its components (Guba and Lincoln, 1994; Tamminen and Poucher, 2020). These beliefs provide researchers with a conceptual framework to systematically study the world (Kamal, 2019) , guiding them in choosing research instruments, participants, and methods for their reports (Muzari, Shava and Shonhiwa, 2022). The three primary dimensions of a research paradigm are ontology, defining truth and reality; epistemology, explaining how the researcher acquires knowledge about truth and reality; and methodology and methods, describing how research is conducted (Antwi and Hamza, 2015).

When conducting research, a researcher has a variety of paradigms at their disposal to guide their approach. In the literature study, positivism and interpretivism are two widely recognised research philosophies that significantly impact every study (Cresswell, 2013; Cooper and Schindler, 2014; Creswell, 2015; Creswell and Poth, 2016). The positivist research philosophy employs methods from natural science to investigate social reality. This paradigm constructs reality from tangible entities that can be measured and verified (O'Gorman and MacIntosh, 2015). However, Rubin and Rubin (2011) argue that this approach overlooks that individuals perceive events differently and that both perspectives hold truth.

Furthermore, as Kivunja and Kuyini (2017) asserts, positivists may need help to tackle social issues adequately due to their limited understanding of the root causes of certain phenomena. Positivism as a research framework typically entails utilising a deductive methodology alongside precise quantitative measurements to enable researchers to establish and authenticate causal laws (Neuman Lawrence, 2014; Neumann, Kolus and Wells, 2016).

In contrast, interpretivism posits that social research demands a unique approach, as concepts derived from natural sciences are inadequate in explaining the complexities of social reality. This paradigm acknowledges the existence of multiple apprehensible and equally valid facts, meaning that no two individuals can experience the same truth (MacIntosh and O'Gorman, 2015). Additionally, this perspective aligns with the researcher's belief that human interactions reinforce reality and the social world. Maree and Van der Westhuizen (2009) also support this view, arguing that the researcher plays a crucial role in interpreting how individuals perceive the world around them. Moreover, this paradigm asserts that uncovering meaning requires deep reflection because it conceals. Therefore, given that the current study aims to explore the varying perceptions of employees within TE, this paradigm is suitable since the knowledge obtained from this research is expected to be highly subjective and differ among individuals.

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This study employed an interpretive paradigm rooted in social science research to uncover the underlying reasons behind TE's production of defective wagons. This approach provided a deeper understanding of the interaction process and revealed hidden meanings. Rather than proposing solutions, the study identified factors contributing to quality issues. An interpretive paradigm was selected for the study as it aligned with the specific purpose of comprehending a phenomenon within a particular context. The study determined that this paradigm was suitable for achieving its objectives, given its compatibility with the subject matter and environment under investigation. Additionally, it facilitated the comprehensive and detailed collection of information from participants (Yin, 2015).

3.4 Research design

Research can be classified using quantitative and qualitative approaches influenced by philosophical, paradigmatic, and methodological traditions. As noted by Sekaran and Bougie, (2016), a research design outlines a researcher's plan for investigating a phenomenon. Silverman (2013) and Martin et al. (2014) agree that a research design determines the methods of data collection, measurement, and analysis. To address research questions effectively, Yin (2015) emphasises the significance of selecting a design that aligns well with the topic under investigation.

During the literature review conducted for this study, it became evident that there has been extensive global research on the factors leading to the production of defective freight wagons in the railway industry. However, despite the growing body of research on substandard freight wagons, there has yet to be a comprehensive analysis of the factors contributing to producing defective wagons in a specific wagon factory in TE. The primary motivation of the study was to conduct an empirical analysis that delves into employees' perspectives on the factors contributing to the production of defective wagons and the root causes of the defects cited in customer complaints within selected manufacturing organisations. Consequently, the study focused on thoroughly understanding the phenomenon's significance through the participants' viewpoints. Thus, a qualitative approach was adopted (Yin, 2015). Zikmund *et al.* (2012) further emphasise that qualitative research methodologies address research objectives by employing strategies that enable the researcher to propose interpretive explanations of events without relying on numerical measurements.

Qualitative research methods not only align with one of the fundamental assumptions of interpretivism (Van den Hoonaard and Van den Scott, 2012; Yanow and Schwartz-Shea, 2015), but they also possess a significant characteristic of finding, explaining, and describing the data collected for the study, a feature precisely employed in this study. Furthermore,

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scholars state that qualitative research methods are known for generating a wide range of detailed descriptions that provide comprehensive information about a small number of individuals (Merriam and Tisdell, 2015; Merriam and Grenier, 2019). This approach contributes to a deeper understanding of the data collected in the study. Consequently, employing this approach in the current study was highly advantageous as it facilitated the provision of comprehensive descriptions and a profound comprehension necessary to offer a broader perspective to answer the objectives posed by the research question (Van den Hoonaard and Van den Scott, 2012; Merriam and Tisdell, 2015).

The qualitative research method has a significant advantage in fully immersing the researcher in the participant's world. The participant makes informed decisions and experiences specific encounters, which deepen understanding of the context. Van den Hoonaard and Van den Scott (2012) further notes that "talking" is crucial in qualitative research, setting humans apart from other living beings. This strength gave the researcher a broader comprehension of the underlying causes behind TE's production of defective wagons. Due to its context-specific, detail-oriented, generative, and focused nature, the qualitative research method was the most appropriate choice for this design. It provided a pragmatic and substantial solution to the quality issues by focusing on individual experiences and understanding.

The effectiveness of qualitative research hinges heavily on the researcher's proficiency, particularly in conducting interviews and building rapport with participants. In the early stages of this study, the researcher faced challenges in earning the trust and cooperation of the participants. However, by employing clear communication and providing a comprehensive overview of the study's objectives, the researcher was able to cultivate robust connections with all the employees involved.

One challenge of conducting qualitative research is the possibility of specific details losing relevance due to the descriptive nature of the data. Furthermore, the researcher may become overly subjective when presenting descriptive elements (Bryman, 2016). To mitigate these risks, a quality manager carefully monitored the research process and emphasised the importance of providing specific descriptions rather than generalisations.

3.4.1 Applicability of phenomenological design

Qualitative research encompasses various research designs, including ethnography, grounded theory, narrative analysis, phenomenology, and case study (Silverman, 2013; Creswell and Poth, 2016). Each approach has unique characteristics easily identifiable when

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the researcher's methods are well-defined. These approaches can be utilised individually or in combination with one another.

The current study utilised a descriptive phenomenological design to uncover authentic meanings (Lopez and Willis, 2004). Descriptive phenomenology portrays things as observed and offers insight into the phenomenon's evolution and purpose over time (Harrison *et al.*, 2009; Shosha, 2012) . The descriptive phenomenological approach is a flexible, interpretive, open, and adaptable method that allows the researcher to engage deeply and reflect on the phenomenon under investigation (Vagle, 2018). In this study, the researcher employed the descriptive phenomenology design to comprehensively understand the research question and gather the necessary evidence to capture individual lived experiences and the essence of those experiences. The researcher applied Husserl's phenomenology to set aside biases and preconceptions, enabling an exploration of how employees perceive the factors contributing to defective wagon production.

According to Husserl's phenomenological philosophy, it is imperative to maintain impartiality by intentionally setting aside any preconceived notions, biases, or judgments (Shosha, 2012). This bracketing process is crucial in descriptive phenomenological research as it helps eliminate preconceptions regarding the research phenomena (Wojnar and Swanson, 2007). The goal is to differentiate between the known description of the phenomenon and the descriptions provided by the participants. Researchers often prefer Husserl's phenomenology as it requires minimal first-hand knowledge of the investigated data, allowing for a realistic and descriptive account of individual experiences. The focus is typically on describing personal perspectives and interpretations rather than explaining them.

3.5 Data collection

The researcher utilised a qualitative phenomenological design in this research report and paired it with data collection methods specifically chosen for the study. Phenomenological research incorporates diverse data sources, including traditional techniques such as interviews and observation, as well as more creative methods like drawing, collage, and creative writing (Vagle, 2018) . To ensure the most effective data gathering, researchers must maintain an open mindset throughout the research process and actively engage participants in reflection and conceptualisation. It is also crucial to tailor data collection methods to the phenomenon investigated.

The process of data collection is a vital aspect of research methodology. It enables researchers to gather evidence that supports their research question and investigative

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experience. Systematically analysing information from various sources to expand knowledge about existing phenomena is involved in this process. Flick (2018) suggests that researchers construct and generate knowledge through their interactions with participants and documents in qualitative research. According to Yin (2017), researchers should use the data collected during the process to explain the phenomenon under study and answer their research questions. This study collected qualitative data by conducting interviews with ten employees of TE and analysing relevant documents that align with our research objectives, questions, and theoretical perspective.

3.5.1 Document analysis

The scholar delved deeply into many documents and academic articles, meticulously analysing and categorising the information to ensure clarity. The data gathered aimed to identify the underlying causes of manufacturing defects in wagons. To address the issue, the researcher delved into historical data, including production levels, defect types, and occurrence frequency, and consulted internal reports that evaluated past analyses. The researcher's comprehensive analysis of these materials laid a solid theoretical foundation for the study. The historical data was particularly invaluable in providing critical insights into the problem (Cresswell, 2013), making it an indispensable source of information.

To analyse the quantitative data from the historical customer complaints register, the researcher utilised Microsoft Excel and created histogram graphs (section 1.3). These methods were employed to gain a comprehensive understanding of the factors contributing to the production of defective wagons. Document analysis, primarily a qualitative research technique, was used to interpret and build upon the information presented in the documents. It allowed for a rigorous investigation into the underlying causes of manufacturing defects, adding depth and nuance to the research findings.

During the investigation, document analysis was a dependable and efficient way of gathering information for analysis without the need for transcription. The researcher leveraged the insights gained from document analysis to create targeted interview questions, improve the validity and reliability of the data, and elevate the quality of the interview responses (Merriam and Tisdell, 2015; Flick, 2018).

While confidentiality has benefits, it can challenge researchers seeking access to pertinent company data (Cresswell, 2013). Bowen (2009) states that individuals often create documents with a purpose independent of the research agenda. As a result, these documents may contain biases and provide incomplete details when addressing a research question. The documents

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may be invalid or flawed and do not accurately represent the research phenomena. To address this, the researcher secured permission from the organisation (Appendix A) via an approval letter and sought out credible sources to ensure the accuracy of the study findings. Additionally, the researcher meticulously adhered to stringent document analysis procedures, sorting relevant data, verifying its accuracy and appropriateness, and establishing a comprehensive repository of qualitative texts (Cresswell, 2013). Through this rigorous approach, the researcher ensured that the research outcomes accurately reflected the observed phenomena.

3.5.2 interviews

Interviews are commonly regarded as the most effective method when using Husserlian phenomenology in research (Giorgi, 2009). In qualitative research, interviews build knowledge by facilitating interaction between the researcher and the participants (Flick, 2018). Interviews help gather first-hand opinions and attitudes, test hypotheses, establish correlations between variables, and explore various issues (Taylor, Bogdan and DeVault, 2015). As Merriam and Tisdell (2015) highlight, interviews are a crucial component of qualitative research as they enable us to gather information on topics we cannot directly observe.

Conducting qualitative interviews helps to create a comprehensive understanding of a phenomenon, allowing participants to express their experiences, skills, and inner perceptions effectively to the interviewer (Schultze and Avital, 2011). Additionally, this approach offers several benefits, such as improving response rates, ease of adaptability, maintaining high engagement levels throughout the interviews, and facilitating efficient evaluation of data correctness and suitability for exploration (Bell and Waters, 2018).

While qualitative interviews offer valuable insights, they can be time-consuming and complex (Bell, Bryman and Harley, 2022). However, it is essential to acknowledge that interviews have limitations and challenges. For instance, subjective and unreliable results can occur (Alshenqeeti, 2014; Denscombe, 2017). Additionally, several variables can impact the study's credibility during an interview (Denscombe, 2017). These include the researcher's proximity and demeanour, which may inadvertently influence the results, and recording equipment, which can be startling for study participants. Therefore, it is crucial to avoid inappropriate interviewing tactics that can cause anxiety for people.

To optimise these interviews and establish a healthy rapport with interviewees, the researcher followed the interview guidelines suggested by (Cresswell, 2013). These included purposive sampling to identify interviewees, conducting semi-structured interviews, and audiotaping

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questions and responses during the interview. The researcher also took notes to supplement the recordings, interviewed in a quiet and comfortable location chosen by the participant, obtained consent from the interviewee to participate in the study, created a flexible question-posing schedule to guide the conversation, and used probes to elicit additional information.

3.6 Research Instrument

3.6.1 Semi-structured interview

To gather qualitative research data, researchers use various tools like interviews, document analysis, observations, and focus groups (Cresswell, 2013; Muzari, Shava and Shonhiwa, 2022). The selection of an appropriate research instrument is crucial because it allows participants to share their opinions and responses freely without being influenced by the researchers' preconceived ideas about the topic (Wilkinson, Joffe, and Yardley, 2011). According to (Giorgi, 2009), interviews are a standard method used in descriptive phenomenological design. (Bell, Bryman, and Harley, 2022) suggest that researchers generally classify qualitative research interviews as semi-structured or unstructured based on the level of organisation and structure of the interview questions.

After thoroughly reviewing literature sources (Maree, 2007; Leavy, 2014; Bell, Bryman and Harley, 2022), the researcher evaluated the benefits and drawbacks of structured, semi-structured, and unstructured interviews. Based on these findings, the researcher determined that semi-structured interviews would best fit the current research design and would help achieve the research objectives with a limited number of TE employee participants. This approach allowed the researcher to focus on crucial issues important to TE employees and provided an opportunity for them to express their opinions. Due to the limited information available on the causes or contributing factors of defective wagons (Cridland *et al.*, 2015), it was particularly crucial.

The study focused on employees' different perceptions to understand the root cause of TE's manufacturing of defective wagons. The researcher required several detailed, open-ended, and structured close-ended questions to gain this understanding and investigate the critical research question. Also, the researcher needed some flexibility to ask improvised follow-up questions for TE employees to verbally express their perspectives and experiences (Maree, 2007). The researchers kept a schedule of questions to answer, and if they misunderstood any questions, they adjusted and rephrased them to improve understanding (Roulston and Choi, 2018).

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Multiple factors, such as the interview structure, the types of questions posed, the interviewer's skills, and the quality of the responses provided by the interviewee, influence the quality of the data collected through semi-structured interviews (Ajagbe et al., 2015). As a result of a semi-structured interview, participants may provide less detailed answers or omit certain information. Participants were given the interview guide before the interview to ensure they provided meaningful and relevant responses during the interview (Larkin, Flowers and Smith, 2021). Novice researchers often encounter challenges in determining when and how to ask prompt questions or probe responses, leading to difficulties retrieving crucial information. A root cause analysis was conducted to address this limitation, followed by individual interviews to address this weakness. This approach allowed the researcher to establish connections between the interview discussions and the root cause analysis results. The researcher utilised probing questions to elicit additional information and adjust the questioning approach based on their perception of the need for further exploration (Cresswell, 2013; Merriam and Tisdell, 2015). Furthermore, the researcher developed skills by transcribing interviews and preparing participants for the time commitment.

Semi-structured interviews offer many benefits, although they may have some potential drawbacks. When focusing the conversation on the study's objectives, interviewers can gather relevant data more efficiently. The interactive nature of these interviews allows for a dynamic exchange between the interviewer and participants, enabling the exploration of follow-up questions and verbal expressions. While semi-structured interviews offer more flexibility than structured interviews, they still provide a degree of structure that unstructured interviews lack. Considering the proficiency and time constraints, the researcher has thoroughly evaluated the practicality of using semi-structured interviews. This qualitative study found that semi-structured interviews were appropriate and effective for researchers of all experience levels (Rowley, 2012).

3.6.2 Interview Schedule

Before conducting the participant interviews, the researcher prepared a semi-structured interview guide that steered the conversation towards the research topic without being overly prescriptive (Cridland *et al.*, 2015). The researcher developed the guide in alignment with the study's objectives and the research question derived from them, acknowledging that the interview serves the researcher's purpose of acquiring knowledge (Brinkmann, 2012). Intentionally designed to be adaptable and flexible, the semi-structured interview guide allowed for dialogue, the ability to rearrange the question sequence, and seamless transitions between different questions.

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The researcher derived three fundamental interview questions from the main research question, the problem statement, and their personal experience in wagon manufacturing. The researcher divided the interview guide in Appendix B into two sections. Section A focused on gathering essential information and creating a relaxed atmosphere to break the ice (Rabionet, 2011; Cridland *et al.*, 2015) by asking general questions. In contrast, section B encouraged employees to share their personal and authentic insights based on their experiences manufacturing defective wagons within their specific contexts and environments.

(Kallio *et al.*, 2016) assert that conducting prior research on the topic area is crucial in preparing for a semi-structured interview. The interview questions were developed based on existing knowledge, explicitly focusing on design changes, omissions and errors, and inadequate skills contributing to defective wagon production. These questions were intentionally open-ended to encourage detailed discussion and facilitate participants sharing their unique perspectives, beliefs, and views (Clarke and Braun, 2013). The researcher aimed to elicit spontaneous, in-depth, and vivid responses from the participants by attentively listening and positively reflecting on any comments regarding their individual life experiences.

(Peel, 2020) states that the purpose of using this research instrument is not to dictate what interviewees should say but to provide avenues for conceptualising issues and establishing connections based on emerging responses. The flexibility of the semi-structured interview protocol facilitated achieving this objective (Adeoye-Olatunde and Olenik, 2021).

3.6.3 Pilot interview

(Collis and Hussey, 2009) suggest that researchers commonly conduct a pilot research phase to develop a well-designed interview guide for collecting interpretive data. (Strydom, 2011) recommends executing the pilot study according to the researcher's plan for the primary investigation. In this study, the researcher evaluated the effectiveness of their interview tools and questions by conducting a pilot interview with a TE quality inspector and production manager who were randomly selected. The study aimed to assess the potential findings that these interviews could generate (van Zyl, 2014). Based on feedback, the researcher slightly modified the questions to enhance participants' understanding and used the revised interview schedule as the leading guide for the current study. (Doody and Doody, 2015) suggest that a pilot study offers valuable insights to support researchers during their research studies. Consequently, the primary study integrated the pilot study conducted in this research.

Participants were invited via email to partake in a systematic data collection approach for this study. From January to February 2023, the researcher conducted semi-structured face-to-face interviews with ten TE employees, including the pilot interview. These interviews ranged from

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45 to 60 minutes, considering the time required to collect the relevant information and achieve satisfactory comprehension to fulfil the study's objectives.

3.7 Population and Sampling

3.7.1 Study population

The core of research revolves around examining a group of individuals willing to participate, commonly referred to as the population. (Cooper and Schindler, 2014; Shaheen and Pradhan, 2019; Bell, Bryman, and Harley, 2022) assert that the term "population" denotes the complete set of elements from which the researcher aims to conclude, encompassing the comprehensive list of its members. Furthermore, (Krieger, 2012), define the population as a group comprising all pertinent individuals relevant to a study. In the present research, the population under consideration consisted of employees between the ages of 30 and 50 years involved in wagon manufacturing at the TE wagon manufacturing factory in Bloemfontein.

The workforce directly engaged in the process of wagon manufacturing was categorised as "direct employees." On the other hand, "indirect employees" consisted of quality inspectors, production supervisors, engineers, and managers. The indirect employees were divided into three categories based on specific eligibility criteria, as detailed in Table 3.1. Mashabane (2022) deemed this population suitable for the study because they could offer valuable information about the root causes of wagon defects due to their distinctive position. Their extensive experience and insights into the underlying reasons for wagon defects within the investigated organisation made them ideal participants for the research.

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Table 3.1: Categories of sampling units.

Category	Description of category	Description of units
A	Assemble wagons according to specifications or work instructions. On the other hand, quality inspectors check the quality of wagons manufactured by operators and have the authority to release or hold products based on quality analysis.	Wagon manufacturer personnel and quality inspectors.
B	As supervisors, they oversaw production processes and supervised operators to ensure products met customer standards. By enforcing the company's policies and procedures, they influenced product quality.	Production supervisors.
C	Designed production processes and influenced product quality through subordinate management, positively impacting their teams to achieve organisational goals. The task involved ensuring that the products delivered met the requirements of the customers while increasing the company's profits.	Engineers and managers.

3.7.2 Unit of analysis

Sampling involves selecting a smaller subset of elements from a larger population (Miner, 2015). In this study, the researcher included ten TE staff individuals who possessed knowledge and experience in defective wagon manufacturing. As (Bartholomew *et al.*, 2021) highlights, the importance of sampling lies in identifying unique traits within a specific community rather than simply focusing on group size. Qualitative research suggests that gathering insights from a small subset of elements provides an accurate representation of the larger population. Therefore, it is crucial to align the sampling process with the primary research question, methodology, and study objectives (Maree, 2007).

3.7.3 Sampling method

Scholarly research distinguishes sampling methods into probability and non-probability (Edmonds and Kennedy, 2016; Shaheen and Pradhan, 2019). Each method has advantages and disadvantages, as well as the potential for sampling bias. The choice between these approaches depends on factors such as the researcher's available resources, the study's nature, and the desired level of generalizability and applicability (Miner, 2015). In the case of this study, non-probability sampling was employed due to its flexibility (Bell, Bryman and Harley, 2022).

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The primary aim of this study was to enhance comprehension of the factors contributing to producing defective wagons at Transnet Engineering. This study aimed to acquire in-depth knowledge and insights concerning a specific group of individuals, namely employees directly and indirectly involved in manufacturing. To align with the chosen research design, non-probability sampling, a method known as purposive sampling, was implemented (Maree, 2007; Nieuwenhuis, 2007). Scholars (Bell, Bryman and Harley, 2022)define *purposive sampling* as the deliberate selection of individuals who have experienced a particular phenomenon, thereby enabling the inclusion of research participants closely associated with the phenomenon investigated.

Researchers conducting phenomenological studies must ensure they familiarise the sample participants with the case, event, and phenomenon under investigation (Creswell, 2015; Creswell and Poth, 2016; Algozzine and Hancock, 2017) . According to (Creswell and Poth, 2016), researchers must carefully align their sample with the explored theories. In this study, purposive sampling was deemed appropriate despite its limitations, such as limited generalisability (Bell, Bryman and Harley, 2022). This method targeted individuals who were directly or indirectly involved in the manufacturing of products and were therefore well-qualified to provide valuable insights into the underlying reasons behind the occurrence of defective wagons (Edmonds and Kennedy, 2016; Bell, Bryman and Harley, 2022). The study based its selection criteria on profession, power, expertise, or comprehension. Non-probability purposive sampling was deemed relevant for this research as it included individuals with diverse perceptions, experiences, and opinions regarding the factors contributing to freight wagon defects.

Cohen, Manion and Morrison (2007) and Flick (2018) highlight the significance of purposeful sampling in enabling a thorough and comprehensive understanding. Consequently, participants for this study were carefully selected to ensure the inclusion of individuals who could offer insightful perspectives. Purposive sampling was employed as a technique and a crucial element of the overall strategy, allowing for the deliberate selection of the most suitable interviewees for the study. As a sub-technique within purposive sampling, expert sampling was utilised to identify and choose interviewees possessing the required expertise, thereby providing credible insights for the research. Researchers contend that the participants' various work tasks and positions contribute to a more comprehensive understanding of the research issue (Persson and Jonsson, 2020). The different areas of expertise for the current study included quality inspectors, production operators, product development, and procurement personnel. Since each participant had different job responsibilities, their experience and

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response uncovered new and valuable information that no other participant could have provided.

3.7.4 Criteria used to select participants

The sampling method employed in this study is purposive, wherein participants are selected based on predetermined criteria that align with the research objective (Maxwell, 2008). The study establishes these criteria using academic and professional literature as a foundation (Edmonds and Kennedy, 2016; Bell, Bryman and Harley, 2022). The study's purpose aligned with seeking participants directly or indirectly engaged in manufacturing wagons as TE employees. To enhance the study's precision and evidential value, inclusion and exclusion criteria were established, as (Yadav, 2022) recommended. The study used the following inclusion criteria to select participants:

i. The participants needed to work at Bloemfontein's wagon maintenance and manufacturing factory.
ii. The participants needed to possess a maximum of three years of experience handling wagon defects, actively participate in Capex projects right from their initiation, and possess comprehensive knowledge of the identified issues within each project.
iii. Participants were required to have proficiency in English and be capable of effective communication in the language.
iv. Participants must be willing to participate voluntarily.

The study established specific criteria for participant selection, including employment at the wagon maintenance and manufacturing factory in Bloemfontein. Additionally, participants were required to have a maximum of three years of experience in handling wagon defects, actively engage in Capex projects from their inception, and have a comprehensive understanding of the issues identified in each project. Fluency in English and effective communication skills were also necessary. Finally, participation was voluntary and dependent on the willingness of each potential participant.

The initial selection criteria (i) focused on identifying suitable participants and a study location that would encourage the involvement of a broad range of TE employees, including operators, quality inspectors, production personnel, and maintenance supervisors. By including these diverse perspectives, the study was able to address the research question at hand effectively.

The second criterion (ii) involved selecting participants based on their knowledge and involvement in the research subject, specifically their direct or indirect interaction with the

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manufactured wagons (Bell, Bryman and Harley, 2022). The primary aim of this study was to gain a more profound understanding of a contemporary event by examining it from the perspectives of individuals who had direct involvement in the researched event (Reed, 2017; Yin, 2018). The researcher prioritised individuals believed to have the most significant understanding of the subject matter (Cohen, Manion and Morrison, 2007; Flick, 2018), enhancing the study's validity.

The third (iii) and final criterion (iv) aimed to ensure that participants possessed a high level of linguistic fluency, clarity in their communication, and the ability to express themselves effectively (Horsfall & Hayter, 2014). Moreover, their willingness to actively participate in the study was considered. The individuals identified through purposive sampling needed unique qualifications to describe their experiences articulately and reflectively (Reed, 2017). Participants who did not meet these selective criteria were excluded from the study, as their limited descriptions would hinder their ability to respond to open-ended or probing questions. The study's researcher meticulously adhered to Brinkmann's (2018) guidelines for rigorous purposive sampling. Only the appropriate employees were invited for individual semi-structured interviews to ensure the validity and reliability of the study's findings. The focus was on obtaining high-quality and in-depth insights rather than simply increasing the number of participants. This approach ensured that the qualitative study was of the highest possible standard.

3.7.5 Sample size

Shaheen and Pradhan (2019) and Bell, Bryman, and Harley (2022) highlights the significance of identifying the ideal sample sizes in qualitative research, particularly when faced with data and theoretical saturation challenges. The data quality collected plays a crucial role in determining the amount of valid and usable information available. Like other qualitative traditions, phenomenological research typically involves a small sample size to guarantee thorough exploration. Nonetheless, researchers must still establish specific guidelines for determining the sample size in phenomenological research. While (Giorgi, 2009) suggests a minimum of three participants, (Morse, 1994; Creswell, 1998) recommend at least six and five to twenty-five participants, respectively.(Marshall *et al.*, 2013) further supports that studying large samples in qualitative research yields limited benefits. Instead, the optimum sample size depends on the inclusion criteria set for the participants in the study. (Lakens, 2022) agrees that the completeness and quality of information provided by participants should guide the determination of the sample size.

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Therefore, this study prioritised the quality of participants and the valuable information they could provide rather than focusing solely on the number of participants. According to (Marshall *et al.*, 2013), fewer participants can be sufficient in qualitative research if they provide significant relevant information. The task of determining an appropriate sample size to maintain scientific validity while avoiding excessive participant interviews was assigned to the researcher. By doing so, the study aimed to prevent wasting participants' valuable time and ensure that the data collected could be effectively analysed (Francis *et al.*, 2010).

This study interviewed ten knowledgeable individuals involved in railway wagon manufacturing or maintenance, including operators, quality inspectors, production supervisors, engineers, and managers. This diverse selection of participants allowed for an in-depth exploration of the factors contributing to defective wagons. (Bell, Bryman, and Harley, 2022) suggest that a randomly selected sample size, regardless of the population size or sampling location, can yield a representative sample with minimal error probability. The researcher employed a random selection process based on participant categories, ensuring a range of perspectives and settings were represented in the study, thereby maximising the richness of the findings.

The researcher created a comprehensive list of employees directly involved in the product and first-line management personnel responsible for production, quality, and maintenance/manufacturing processes. Next, the researcher contacted these individuals to inquire about their interest in participating in the study. The researcher contacted those who expressed interest via phone or email, explained the purpose of the study, scheduled interview dates and times, and discussed ethical considerations. Subsequently, the researcher emailed the participants to confirm the interview details (time and location) and thoroughly explained the study's purpose and ethical guidelines. A follow-up reminder email was sent one week before data collection. Figure 3.2 depicts the process of obtaining the sample and the measures taken to establish professional and ethical communication with the participants.

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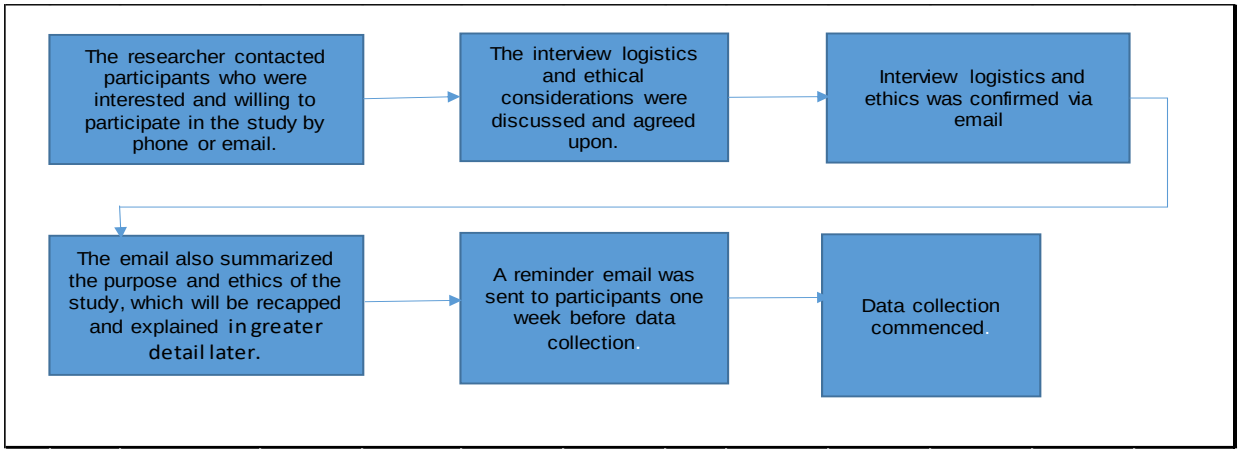


Figure 3.2: An overview of how the sample was obtained.

3.8. Data analysis

The data analysis process began as soon as the researcher gathered the data. It involved understanding, interpreting, and consolidating information gathered from responses to answer research questions (Creswell, 2015; Merriam and Tisdell, 2015). As (Maree, 2019) notes, qualitative data analysis enables researchers to synthesise their observations and identify relevant patterns, themes, phrases, or words.

The literature indicates that various methods, such as matrix analysis, thematic analysis, template analysis, and industrial engineering tools, can be utilised for analysing qualitative data (King, Horrocks and Brooks, 2019). The researcher conducted the data analysis twice, employing thematic analysis and Root Cause Analysis (RCA), as the study content holds significance from the participant's perspective. This approach aligns with a Husserlian interpretation of phenomenology. According to (Sloan and Bowe, 2014) , the choice of phenomenology type and the collected information guide the selection of an appropriate data analysis methodology to depict the experience accurately. Furthermore, (Algozzine and Hancock, 2017) emphasise the necessity of analysing and evaluating data related to the research question. They propose this approach to assist researchers in maintaining the integrity of descriptions provided by research participants and identifying pertinent themes and patterns within the data.

Kiger and Varpio (2020) noted that the data analysis process is both laborious and time-consuming, a realisation made by the researcher. Extracting meaning from data requires extensive involvement, which makes this observation expected. The researcher approached the data analysis inductively to uncover emerging themes from the data. However, the participants' responses were based on interview questions derived from the researcher's

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familiarity with the reviewed literature, indicating a priori reasoning (Vaismoradi *et al.*, 2016). (Vaismoradi and Snelgrove, 2019) acknowledge the inevitability of this blend of inductive and deductive theme extraction processes, as the researcher's knowledge of existing literature will inevitably influence the process.

3.8.1 Thematic analysis

(Bryman, 2016) posits that thematic analysis centres on identifying, analysing, and categorising themes as essential components within datasets. This process allows for extracting pertinent data related to the research question and establishing connections among these themes. This approach enables researchers to effectively present comprehensive and in-depth data, enhancing the understanding of producing defective wagons (Terry *et al.*, 2017).

The researcher chose this approach in the study due to its compatibility with an interpretivist philosophical perspective (Vaismoradi *et al.*, 2016). Additionally, the method's adaptability to diverse research questions and data types, facilitating the derivation of data-driven codes and themes, was considered significant (Clarke and Braun, 2013). Moreover, (Vaismoradi and Snelgrove, 2019) emphasise that thematic analysis allows for a comprehensive exploration of meaning within the context, leading to a genuinely qualitative examination of the texts. (Terry *et al.*, 2017) argue that thematic analysis is highly flexible, accommodating various forms of analysis without being constrained by specific theories or epistemologies. The researcher considered manifest and latent interpretations during the thematic analysis process when developing the final themes(Vaismoradi and Snelgrove, 2019).

Furthermore, (Nowell *et al.*, 2017) assert that thematic analysis can be used in various qualitative research forms and is not dependent on epistemological presumptions. However, limited, and insufficient literature may impede its use, posing challenges for novice researchers implementing this technique. Additionally, it is essential to note that thematic analysis has limitations, such as the inability to draw definitive conclusions from language usage and limited interpretive power (Clarke and Braun, 2013).

The researcher used (Cresswell, 2013) thematic analysis framework for this qualitative study to ensure an efficient and reliable analysis process. The goal was to address possible shortcomings and achieve an efficient analytical outcome.

3.8.1.1 Data analysis process

The data analysis process adhered to Creswell's (2013) thematic analysis framework, a six-step approach suitable for this qualitative study:

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Step 1: In the initial phase, exhaustive interviews were conducted with 10 TE employees involved in wagon production, generating substantial data that required efficient management. The interviews were transcribed verbatim into Microsoft Word documents following Yin's (2018) guidelines for phenomenological studies. The researcher, continuously reflecting on the research question, organised the data into meaningful segments, clearly focusing on defective wagon production issues and ensuring the study's purposefulness.

Step 2: The researcher, maintaining an unwaveringly unbiased perspective, reviewed the transcripts multiple times to understand the content comprehensively. This immersion facilitated the identification of preliminary ideas and recurring themes related to defective wagon production, ensuring the study's objectivity. The researcher carefully noted significant emerging patterns, enhancing the study's reliability.

Step 3: The researcher coded manually and exported the resulting data to Microsoft Excel for further analysis. This software enhanced the analysis by providing filtering options, allowing data visualisation in various patterns, thereby supporting the exploration of emerging themes (Vaismoradi *et al.*, 2016). The researcher systematically assigned labels to key data segments, refining and expanding the codes to develop a comprehensive coding framework. An inductive coding strategy focused on participants' remarks (Fereday and Cochrane, 2006), with continuous updates and detailed descriptions enhancing the accuracy of the codes.

Step 4: After coding, the researcher analysed the codes to identify broader themes that encapsulated the underlying factors of defective wagons. The researcher clustered related codes into coherent themes that reflected significant patterns in the data. Each theme was defined in detail, emphasising its relevance to the research question. This process enhanced the overall understanding of the study and solidified the findings (Baxter and Jack, 2008).

Step 5: The researcher constructed a narrative highlighting the identified themes and their implications, incorporating direct quotes from participants to support the findings. The researcher used tables to clarify the presentation and communicate the factors contributing to defective wagon production.

Step 6: The research findings were critically analysed and contextualised to address the research question. This analysis involved comparing the results with existing knowledge in the field Cresswell (2013) and reflecting on their practical implications for improving the production process. The researcher synthesised the data using relevant extracts and organisational

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tables, demonstrating the connections between the data, research question, and overall analysis.

3.8.2 Root cause analysis (RCA)

RCA was used to identify underlying causes of defective wagon manufacturing issues. As noted by (Slameto, 2016), these root causes are frequently not immediate or obvious and may involve multiple layers of causation. RCA techniques can be applied independently or in combination with others in practical settings. Research by Maxwell (2012) and Yin (2017) suggests that selecting the most appropriate technique depends on the specific problem and context, ultimately leading to meaningful research findings.

This research report only delves into some aspects of RCA. However, the CED, specifically in the context of quality problem analysis and resolution, has demonstrated its utility in the railway industry (Denniss, 2017). Given multiple causes and a singular effect in this study, the CED technique, combined with the Five Whys analysis, was modified, and implemented to examine defects identified in the customer complaint register systematically. The primary objective was to systematically identify critical issues and their underlying causes using a structured approach. The data analysis process followed a prescribed 4-step sequence, which involved:

Step 1: Entailed articulating the problem statement and RCA process objectives to avoid potential misconceptions or preconceived notions. The researcher diligently collected and objectively analysed data from the SAP customer complaint register to avoid confirmation biases.

Step 2: The researcher identified common patterns or themes among complaints and organised them based on their origins using the Cause-and-Effect Diagram (CED).

Step 3: The identified themes were thoroughly analysed to identify common and significant issues, ultimately identifying the root causes of multiple complaints.

Step 4: The researcher systematically used the Five Whys technique to determine the root cause of the identified issue.

Establishing a welcoming and inclusive environment was critical for facilitating an effective RCA process, especially in the context of producing defective wagons. The study created an environment where all participants felt safe expressing their opinions without fear of criticism

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or repercussions. Clear and transparent guidelines guided the RCA process and clarified individual roles and responsibilities. Furthermore, while acknowledging that specific issues may lack a clear or solvable root cause, the study emphasised the importance of managing symptoms and mitigating their impact rather than focusing solely on identifying a single cause (Denniss, 2017).

To address biases that could impact the RCA process in the context of defective wagon production, the researcher assembled a diverse group of specialists to offer varied viewpoints and counteract individual biases. Furthermore, the researcher encouraged the RCA team to question assumptions and conclusions, promoting a thorough analysis and mitigating the impact of cognitive biases (Guo et al., 2013). Throughout the process, systematic and thorough methodologies were essential. The involvement of various stakeholders and experts ensured diverse perspectives, enriching, and strengthening the analysis (Salihoglu & Beşikçi, 2022).

3.9 Ethical considerations

Research studies aim to acquire knowledge and reduce mistakes while adhering to ethical norms. Ethical standards are vital in promoting teamwork, collaboration, and trust among all parties involved in the research process.(Resnik, 2015) states that ethical considerations are crucial in research studies. The following section briefly outlined the critical ethical considerations influencing a current study.

3.9.1 Ethical clearance

An essential aspect of conducting ethical research is recognizing potential ethical dilemmas and using them to create guidelines, protocols, methodologies, and laws that govern qualitative research practices. These measures protect the rights of human subjects and prevent any harm from occurring (Pietilä *et al.*, 2020; Olson, 2023). Before beginning data collection, the researcher obtained research ethics approval from the University of Witwatersrand's school ethics committee in February 2023. Appendix C contains the notification of ethics approval, and the ethical clearance number is MIAEC 001/23. The researcher upheld the following ethical standards in the present study, including internal information and TE employees.

3.9.2 Informed consent

This study meticulously upheld the importance of informed consent, a fundamental principle of ethical research. As stated by Vanclay, Baines and Taylor (2013), participants must be adequately informed, comprehend the research, and be aware of the possible consequences

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of their participation for their consent to be voluntary. Therefore, the researcher must furnish pertinent information, identify potential participation risks, and address concerns regarding participant data collection (Vanclay, Baines and Taylor, 2013). The ethical dilemma of obtaining informed consent is particularly poignant when research subjects are minors. Leedy and Ormrod (2023) argue that human research always requires informed consent, even if the participants are of legal age.

The researcher took great care to obtain informed consent from employees at TE before enlisting them as participants for data collection. Before data collection, the researcher provided each participating employee with a consent form (Appendix D) and a participant information sheet (Appendix E). The consent form clearly outlined the study's purpose, assured privacy and confidentiality, allowed participants to withdraw from participation, and emphasized the absence of exploitation or pressure from unbiased individuals involved in data gathering. The participant information sheet comprehensively described the research procedure, including interview techniques and study specifics. The researcher also offered personal explanations as needed to address any inquiries. The researcher required participants to sign an informed consent form per the Data Protection Act (2003). The researcher then securely stored these forms in a locked repository, which only they could access. The researcher ensured that prospective participants were fully informed about the procedures and associated risks, making consent to participate in the study crucial. The researchers assured the participants that participating in the study carried no risks and that they could decline or withdraw from the study at any time without facing any negative consequences.

3.9.3. Voluntary participation

Leedy and Ormrod (2023) emphasise that those in positions of authority must not pressure individuals to participate in a study and should always be voluntary. In the current study, the participation of TE employees was entirely voluntary, allowing them to decide whether they wished to participate. Additionally, Fox and Bayat (2008) state that participants can withdraw from the study anytime. The researcher frequently confirmed with the participants whether they were willing to continue and informed them of their right to withdraw before they signed the informed consent form. By establishing a mutual understanding, the researcher ensured that participants could provide accurate information and would not be held accountable for any inaccuracies that may have arisen while reporting the study's findings.

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3.9.4 Privacy, anonymity, and confidentiality

Upholding the participants' privacy rights is crucial in all research studies involving human subjects, with anonymity and confidentiality taking top priority (Pietilä *et al.*, 2020). The study implemented the anonymous presentation of research data to protect the participants' confidentiality (Leedy and Ormrod, 2023). The researcher handled the interview data carefully, maintaining respect, dignity, and confidentiality. Prior to participating in the study, individuals were notified of their right to privacy and offered the option to decline voluntary participation. They were also free to refuse interviews or questions that made them uncomfortable, and the choice to provide documents for analysis was entirely voluntary (Welman, Kruger and Mitchell, 2005).

The researcher collected the data with utmost confidentiality by obtaining consent from the participants before gathering information. The informed consent statement of the present study addressed confidentiality and explicitly outlined the measures taken to handle any detailed information provided by TE employees regarding their perceived root causes of defective wagon production.

Considering multiple grievances received by TE regarding defective wagons, the researcher ensured that each participant's comments were kept confidential and handled with utmost discretion and sincerity. The researcher-maintained anonymity and confidentiality throughout the data collection and analysis by using pseudonyms to protect the participants' identities. It is crucial to note that qualitative research presents a higher risk of identification as it involves reporting actual statements from genuine individuals in research reports. We assured the participants that we would safeguard electronic data with passwords and delete it after two years by the policy on good research practices. Additionally, we informed the participants that we would not disclose any information that could identify them to anyone not directly involved in the study.

3.10. Validity and reliability

Validity and reliability are essential aspects of qualitative research that ensure accurate and trustworthy findings. The current research report implemented methodologies to maintain rigour throughout the research process, with the interplay between reliability and validity influencing the analysis and development of the study. The study considered various strategies to address reliability and validity in the design, analysis of results, and overall assessment of the qualitative research project.

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3.10.1 Validity

Leedy and Ormrod (2023) define *validity* as the degree to which a research tool or instrument precisely measures the intended construct or variable. The literature distinguishes between two types of validity: internal and external (Cooper and Schindler, 2014; Leedy and Ormrod, 2023). Internal validity relates to the ability of a research study to draw accurate conclusions about cause-and-effect relationships within its data. On the other hand, external validity is concerned with the generalizability of research findings across different individuals, settings, periods, and other relevant factors. In the context of the current study on the production of defective wagons at Transnet Engineering, the researcher ensured internal validity by accurately capturing the factors leading to the defects through effective data collection and analysis methods. The researcher assessed external validity by evaluating how well they could apply the findings to other similar manufacturing environments.

This study, grounded in an interpretivist philosophical perspective, does not seek to ensure external validity, limiting its findings' generalisability. Instead, it prioritises achieving a higher level of internal validity. To establish this validity, the researcher implemented strategies outlined by Morse et al. (2002), as detailed in Table 3.2. A consistency was observed between the participants' statements and the recorded data, resulting from the researcher's extensive engagement with the respondents. The researcher actively participated in lengthy meetings to allow ample time for data collection, facilitating the generation of a comprehensive understanding of the topic. The study incorporates data gathered from interviews and participant comments. Additionally, member checking, or participant verification, was utilised; participants received transcript analyses to review for accuracy. The researcher employed a semi-structured interview template to pose questions to understand the participants and their perspectives holistically.

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Table 3.2: Strategies for establishing validity (Morse *et al.*, 2002)

Strategy	Description	Application in the current study
Methodological coherence	Congruence between the research question and the components of the method	Appropriate application, justification, and description of the methodology
Appropriate sample	Participants who best represent or have knowledge of the research topic	Sampling from a population with the required characteristics (purposive sampling)
Thinking theoretically	Ideas emerging from data are reconfirmed in new data.	Semi-structured interviews were conducted until no further new themes/ideas emerged from additional interviews.

3.10.2 Reliability

Ensuring the reliability of qualitative research findings is essential for study replication and consistent results (Brink, 1993; Kumar, 2018). Reliability refers to the consistency of a research instrument in measuring specific constructs or variables. This study employed various measures to enhance the reliability of the research instrument, ensuring it consistently yields stable data over time (Zikmund *et al.*, 2012; Cooper and Schindler, 2014; Bell and Waters, 2018; Kumar, 2018).

To achieve reliability, the researcher meticulously documented and systematically categorised raw data and analyses at each stage, enhancing transparency and allowing for process replication by other researchers. The coding process was iterative, involving continuous refinement to integrate new insights. This adaptability to emerging data is vital to the research. A standardised method for data recording, including audio recordings, was used to maintain consistency and minimise subjective interpretation. Additionally, an in-depth analysis of codes to identify broader themes and the incorporation of direct participant quotes in the final narrative strengthened the reliability of the findings.

The validation of themes and descriptors was thorough. An expert quality manager and a doctoral-prepared lecturer reviewed and validated the themes to ensure consistency. Any new themes that emerged were acknowledged, and the researcher compared their thematic analysis with the reviewers' findings to reach a consensus on the identified themes and meanings within the transcribed material.

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CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSION

4.1 Introduction

This study aimed to identify and describe factors contributing to defective wagon production based on historical customer complaints and employee perceptions. Chapter 3 provided a thorough examination of the research methodology. The chapter's initial section provides insight into the participants interviewed for the study. The second part delves into the findings from semi-structured interviews and root cause analyses (RCAs), exploring the themes that emerged from the data analysis. Additionally, the discussion and explanation of empirical research findings will be compared to reviewed literature about freight wagon manufacturing defects to determine the essence of the research study.

4.2 Profile of participants

The study used several eligibility criteria to select interviewees from the same organisation. The criteria included their knowledge and understanding of the research subject, years of experience and areas of expertise, hierarchical position in the manufacturing organisation, and their direct or indirect interaction with freight wagons manufactured. The selected interviewees had gained years of experience in wagon manufacturing businesses that employed over 250 people.

Table 4.1: Profile of the interviewees.

Interviewee ID	Years of experience	Area of expertise
A	10	Quality inspector
B	7	Prototype manager
C	11	Wagon fitter
D	17	Welder
E	14	Jig/fixture engineer
F	8	Logistic manager
G	10	Warehouse manager
H	10	Production manager
I	20	Technical production supervisor
J	8	Continuous improvement specialist

The study adopted a top-down approach and selected interviewees from the TE wagon manufacturing business. A total of ten individuals were interviewed and grouped into direct

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and indirect employees based on their job positions. Three were direct employees (operators), while the other seven were indirect employees (quality inspectors, supervisors, engineers, and managers). The interviewees had varying levels of work experience ranging from five to twenty years, and their ages were between 30-58. Their main areas of expertise were quality management, product development, operations, supply chain management, and continuous improvement, as shown in Table 4.2. The responses provided by the interviewees were quite varied, contributing to a broader understanding of the research issue. Four interviewees had expertise in operations, two in supply chain management, two in product development, one in quality management, and one in continuous improvement.

Table 4.2: Areas of expertise of interviewees.

Areas of expertise	No of interviews	% of interviewees
Quality management	1	10%
Product development	2	20%
Operations	4	40%
Supply chain management	2	20%
Continuous improvement	1	10%

The interviewees have a wide range of expertise that extends beyond any specific capex project or type of freight wagon. However, they share a common experience of manufacturing and maintaining freight wagons at TE Bloemfontein, which is the subject of the current investigation. The respondents have provided unique and insightful perspectives due to their varied job responsibilities.

4.3. Thematic Analysis

The thematic analysis process presented by Creswell (2009) led to the following results:

The researcher predetermined these three main themes of defective wagons:

- **Participants' perceptions of ensuring high-quality wagons:** The first theme explored the perspectives on processes, practices, and standards required to uphold high-quality wagon manufacturing, including participants' beliefs about contributing factors to quality, the significance of quality control measures, and opinions on current quality assurance processes.

- **Participant's perception of what causes defective wagons to be manufactured**: The theme delved into the participants' comprehensive understanding of the factors and root causes of producing defective wagons.

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- **Participant’s perception of recommendations to minimise defective wagon production:** The theme centred on collecting the participants' perspectives and suggested measures for minimising defects in the manufacturing of wagons.

The researcher investigated the relationship between existing literature and participants' perspectives on ensuring high-quality wagon production while discussing and elucidating the findings. The following sections delve deeper into this relationship, addressing the factors that contribute to the production of defective wagons. Furthermore, the current study presents participant-recommended strategies for minimising defective waggon production.

4.3.1 Participants' perceptions of ensuring high-quality wagons

The primary theme revolves around the characteristics of high-quality wagons, supported by six sub-themes. These sub-themes are elaborated upon below, offering valuable insights into what participants consider as defining features of high-quality wagons. Direct extracts from the participants, showcasing their perceptions of high-quality wagons, can be found in Table 4.3 in Appendix F.

4.3.1.1 Satisfying customer specifications and meeting their requirements

The participants emphasised the pivotal role of customers in determining the specific features they desire in their wagons. As a result, the organisation must consistently review and implement these requirements to ensure the production of high-quality wagons. Customers assess the quality of products based on their experiences with products that align with their specified needs (Nedeliaková, Panák and Šipuš, 2017). To achieve the production of wagons without defects, a holistic approach that involves cooperation between railway management and employees is essential (Dávid, 2013).

The participants indicated that the wagons they manufacture must stay consistent with the drawing or specification. Customers, according to some participants, have the final say on quality. (Nedeliakova, Nedeliak and Majercak, 2014) concur, stating that in the railway industry, quality efforts aim not only to meet specifications and reduce defects and variations but also to ensure the wagons reach customers in a reliable state they can be used extensively throughout their lifetime. When the railway factory produces wagons that do not meet the customer's specified requirements, those wagons are considered defective.

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Participants consider a wagon excellent quality when it fully meets their customer needs. Customers' satisfaction with the wagon depends on its performance after use, compared to its original design specifications (Golder, Mitra and Moorman, 2012). Similarly, (Mapande, 2019) notes that locomotives of exceptional quality meet and exceed customers' requirements.

According to the feedback from participants, wagons that do not meet customer needs and requirements often lead to complaints and dissatisfaction. Such grievances typically arise due to manufacturing defects, non-compliance with specified criteria, and usability issues. As a result, manufacturers incur significant expenses when receiving defective wagons. Moreover, the most significant cost of such wagons is the damage they cause to a company's reputation in the market when sent to customers (Flammini, 2012; Magadagela,2016)

4.3.1.2 Regular inspection and testing of wagons

Evans and Lindsay, (2012) state that quality inspection includes measuring, examining, testing, and gauging different product characteristics. The outcomes of these assessments are then compared to the specified requirements to assess the conformity of each element. The scholars (Evans and Lindsay, 2012) further affirm that inspection is highly effective and efficient for detecting defects at the desired level and ensuring that the manufactured wagons meet the necessary quality standards.

The participants' responses indicated the necessity of adhering to legal and technical standards while certifying, validating, monitoring, controlling, and testing products. All products undergo inspection and testing at predefined stages to ensure defect-free upon production, as required by regulations, specifications, and contracts. (Carruthers, 1999) supports these responses by asserting that experienced employees can efficiently handle measurement and examination. Skilled staff plays a significant role in helping the organisation produce defects-free wagons.

Based on most participants' feedback, the production preparation process *(3P)* exercise identified a comprehensive list of check sheets and hold points. The participants were highly engaged in the exercise and provided invaluable input, which aided in identifying these critical check sheets and hold points. The inspection plan is updated to clearly state areas where specific inspections are required, the equipment and skills involved, and the applicable procedures. General industry and specific contract/specification requirements form the plan's basis. Product Development Engineering must have approved any deviations from inspections and tests to continue to the next manufacturing stage. Quality inspections identify

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opportunities for wagons through testing and assessments to contribute to quality improvement processes. (Groover, 2020) states frequent inspections are essential in wagon manufacturing to ensure quality.

4.3.1.3 Periodic validation and calibration

The maintenance plant and equipment are responsible for inspecting and testing tools, and it issues calibration certificates for those that meet the required safety and proper working condition standards. As reported by the participants, specific tools and measuring equipment undergo regular validation and calibration, and the service provider responsible for this process is SANAS-approved. The participants also highlighted the efficiency of optimising maintenance processes using SAP's Planned Maintenance system. To support the participants' responses,(Carruthers, 1999; Evans and Lindsay, 2012) emphasise the importance of the quality department creating a comprehensive inventory of all relevant measuring and testing instruments while establishing a recall and recalibration procedure and schedule for each item. Furthermore, the author (Groover, 2020) stresses that periodic validation and calibration of tools and equipment are essential to ensure accuracy and repeatability throughout the wagon manufacturing process.

4.3.1.4 Training

Participants' responses revealed that the training program used skill matrices to connect individual skills to work activities. This approach simplifies the process of identifying and correcting any skill deficiencies. TE's primary focus is not on training, which is already widely practised when creating personnel training systems, but on supporting and verifying inspectors' wagon manufacturing and maintenance skills to ensure compliance with specified instructions. The engineering faculty oversees training requirements and has facilities in all centres and some maintenance factories to meet demand. Data shows that the in-house training plan accommodates various skill needs, including engineering and administrative courses. When experienced tutors for specific skills are unavailable, TE enlists external service providers to lead training. Moreover, the quality department conducts awareness campaigns and team talks in Letsema. (Nikitin *et al.*, 2020) noted that training enhances problem-solving skills and demonstrates the organisation's dedication to developing human resources.

4.3.1.5 Management of non-conformances

Based on the feedback, the organisation has a robust system for reporting and managing non-conformances. This system relies on SAP Quality Management software and effectively handles customer complaints, vendor complaints, and internal non-conformances. The

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participants noted that non-conforming products are quickly identified, isolated, and reported. The participants noted using problem-solving techniques like the Five Whys and Ishikawa diagrams to investigate and determine the root cause of the issues and then implement appropriate corrective actions.(Evans and Lindsay, 2012) support this approach, stating that TEs must provide timely root cause analysis and corrective action for each Non-Conformance Report (NCR).

4.3.1.6 Audits

Audits are conducted regularly at the TE manufacturing plant to ensure the production of non-defective wagons. TE facilities engaged in manufacturing and maintaining rolling stock or rolling stock components hold ISO 9001:2015 certification. The participants highlighted the significance of audits in ensuring the delivery of high-quality wagons. These audits assess the processes, facilities, and technical expertise involved in the repair or manufacturing of products. TFR management can have confidence that TE processes and technical expertise in wagon manufacturing meet high standards and guarantee adherence to customer requirements.

4.3.1.7 Summary of participants' perceptions of ensuring high-quality wagons

The view among participants regarding high-quality wagons revolves around an organisation's capacity to produce wagons that match customers' specifications and needs. They must be fit for their intended purposes. They must also keep current customers and attract new ones. Evans and Lindsay (2016) state that quality depends on fulfilling the participant's requirements. Any deviation from these requirements suggests poor quality in this context. Organisations must communicate these rigorous requirements to prevent misinterpretations and facilitate effective communication. Timely reporting and addressing deviations are vital to improving and ensuring wagon quality.

During the discussion, the participants highlighted the significance of validating and calibrating tools and measuring equipment. In addition, they emphasised the need for regular wagon inspections and audits to ensure that the products comply with the latest standards. As (Evans and Lindsay, 2012) noted, process operators conduct inspections and checks to guarantee that wagons proceeding to the next production phase adhere to the specified standards.

Based on the participant's input, the wagon manufacturing company has implemented a quality management system according to ISO 9001:2015 standards. This system includes internal and external control measures, root cause analysis tools, and quality assurance experts, with all employees actively participating in the quality assurance process. The

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manufacturers of these wagons prioritise training and skill acquisition to produce top-quality products. (Spiryagin *et al.*, 2014) noted that the assembly and integration of various subsystems to create high-quality wagons requires a specialised skillset and knowledgeable workforce.

4.3.2 Participant's perception of what causes defective wagons to be manufactured

The primary theme of the discussion revolves around the factors leading to defective wagons, supported by nine sub-themes outlined below. Table 4.4 in Appendix G contains verbatim participant quotations that provide further insight into their perceptions

4.3.2.1 Poor preservation of rolling stock components.

The consensus among participants was that inadequate preservation of rolling stock components resulted in the production of defective wagons. These defects encompassed a range of concerns, including bulging sides, manifold leaks, failed meggering and continuity tests, water-filled junction boxes, stuck brakes, and flooded DB 60 valves. These problems lead to operational issues and potentially costly delays.

In support of the participants' views, (Carruthers, 1999) asserts that it is necessary to conduct inspections of rolling stock components every fortnight while they are waiting to be used to maintain their conditions. Inspections play a pivotal role in maintaining the optimal condition of these components while in storage, ensuring that they adhere to quality specifications even in the presence of abnormal circumstances or challenges.

As (Carruthers, 1999) suggested, reporting on the condition of rolling stock components every month is crucial while only highlighting significant issues or deviations from expected conditions. Furthermore, suppliers who provide these components should furnish detailed information on their preservation methods during storage to ensure adherence to quality standards. These suppliers take pride in maintaining the integrity and quality of their rolling stock components by proactively ensuring reliability and high quality. However, the end of the TE fiscal year can add pressure to the wagon manufacturing process, which may cause it to be overlooked and lead to costly delays.

4.3.2.2 Inadequate training of personnel

All the interviewees agreed that the industry needs more personnel training. Even though the organisation has a training plan, the participants pointed out that training is a significant obstacle. Training employees in new skills can be challenging without experienced internal tutors because of the extra costs and the impact on production. The nature of a wagon capex

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manufacturing project frequently necessitates reorientation, particularly after significant milestones. At these points, the project's disciplines, direction, technology, or pace may need to be adjusted to accomplish the next set of objectives.

The Letsema program, held daily by the organisation, aims to raise awareness, and encourage team discussions among employees. Although some participants have reported receiving training, the data suggests a notable demand for further training in the wagon manufacturing industry. During the discussions, the participants highlighted the significance of accurately identifying and evaluating rolling stock components. They also emphasised the need to minimise the occurrence of defective wagon manufacturing by providing proper training to the personnel.

In support of the participants' views, Carruthers (1999) and (Nicholas and Steyn, 2020) emphasise that personnel must be skilled and preferably certified in the measurement techniques necessary to gauge the calibre of a characteristic. Older and more experienced tradespeople and technicians involved in wagon manufacturing for many years are employed. (Carruthers, 1999; Mashabane, 2022), however, maintain that such employees will require a refresher or formal training in the technique and process of inspection so that they can exercise sound judgment and correctly interpret specifications. The need for training personnel grows as technology advances. (Carruthers, 1999; Mitra, 2016) further assert that training wagon manufacturers' employees in quality inspection is essential as this is a crucial part of the product value chain. The data shows that preventing one rework or repair through training recovers the cost. Management must consider the cost of ignorance or lack of skill when they think training is expensive.

4.3.2.3 Lack of effective inter-departmental communication

Inadequate communication among all stakeholders has emerged as a significant factor responsible for quality issues in the manufacturing process, producing defective wagons. Respondents highlighted that insufficient communication regarding operational or product-specific document changes was a root cause of these defects. A study by (Mapande, 2019) has identified that the inadequacy of communication and substandard artistry are the main causes leading to the recurrence of defects in the production process. It has become apparent that the organisation's failure to engage all stakeholders in the initial manufacturing phases has contributed significantly to the production of defective wagons.

Early collaboration among departments such as marketing, product design, manufacturing, quality assurance, and new product development is crucial to pursuing defect-free wagons.

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This collaboration enables all stakeholders to understand their roles and responsibilities in the manufacturing process clearly. (Deming, 1986) emphasised that it is essential for members of an organisation to work as a team, emphasising the importance of collaboration in the pursuit of quality.

4.3.2.4 Lack of lessons learnt

One of the most common causes of defective wagon production is a failure to learn from past mistakes. Lack of lessons learnt refers to repeating mistakes due to a failure to learn from previous experiences or mistakes or attempting to reinvent the wheel (Arab and Dymling, 2020). Participants described how, over time, productivity, and quality improvement, and how, when a similar type of wagon begins production, the process performance decreases with similar defects from the previous project.

Previous attempts have been made for several years to solve the problem of defective wagon manufacturing. However, retaining the knowledge and experiences from the completed project is challenging for future reference. Relevant data is often not recorded or saved alongside corresponding actions, which puts valuable insights and lessons learned at risk of being forgotten. (Ekblad, 2015; Arab and Dymling, 2020) suggest that documenting failures and successful remedies in a lesson-learned repository can preserve knowledge and reduce the likelihood of repeating past mistakes.

4.3.2.5 Lack of knowledge sharing

Participants discussed how a lack of knowledge about completing a task leads to developing a solution that is less likely to work. Personnel are usually faced with this problem when working with new concepts, unfamiliar designs, or manufacturing processes. In this case, the production of defective wagons resulted from an incomplete understanding of the sequence of work. Technical knowledge is essential throughout the wagon manufacturing process because understanding the purpose of each procedure will assist employees in eliminating defects.

The collected data indicates that a substantial portion of the company's knowledge primarily exists as tacit knowledge. This statement concurs with (Abdelatif *et al.*, 2015).(Wilson and Campbell, 2016), citing that comprehensive documentation may be lacking when there is a significant reliance on tacit knowledge. In exploring these responses from participants, the authors additionally contend that while tacit knowledge can exist in isolation, explicit knowledge relies on being tacitly comprehended and put into practice. (North and Kumta,

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2018) affirm that companies typically possess more tacit knowledge than what they explicitly express.

Moreover, the researcher emphasises the necessity for companies to enhance their knowledge management by ensuring that knowledge is effectively stored and shared among members within the organisation.

4.3.2.6 Time constraints and pressure

Participant feedback suggests that time constraints significantly contribute to producing defective wagons. Many participants observed that employees tend to make more errors when working under tight deadlines, particularly towards the end of the fiscal year. The pressure from management to meet daily targets can lead to rushed manufacturing, potentially compromising the wagons' integrity. There is a push to expedite work in the rolling stock manufacturing sector before the prototype gains approval due to time constraints. However, it is crucial to integrate quality into every step of the process, as relying solely on inspections cannot accomplish this objective (Nedeliaková, Panák and Šipuš, 2017).

In the wagon manufacturing business, a lack of planning stresses the project, leading to continuous rework and placing unreasonable demands on people's time. Consequently, this results in poor quality of the manufactured wagons. Participants' responses highlighted that focusing solely on quantity over quality jeopardised the wagons' quality. Maintaining quality throughout the manufacturing process of the wagon is only possible if the employees who perform the work understand and accept that good quality starts with them. Effective task management is crucial for achieving exceptional results in any organisation. Employees need sufficient control over tasks to ensure high-quality performance and successful outcomes. To avoid errors, Edmondson (2012) argues that a quality-focused system is necessary instead of just catching mistakes before they reach the customer.

Rushing through tasks to meet production targets can lead to the need for rework, which ultimately compromises quality. As quality is a long-term goal, employees should consistently aim for improvement rather than settling for acceptable performance levels.

4.3.2.7 Poor documents and records control

Mapande emphasises the importance of maintaining quality documents such as standard operating procedures, work instructions, and control statements to ensure the proper execution of activities and processes. Participants in the study observed that deficiencies in systems and processes for managing quality documents and records resulted in defective

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wagon production. Keeping track of the latest specifications, procedures, and work instructions takes time and effort. The inadequate documentation, disorganised filing systems, and outdated record-keeping practices used by various TE factory departments caused quality standard violations and compromised the structural integrity of wagons. These findings align with Nkosi (2016) research, which supports the view that poor document and record control can lead to defective wagons. It emphasises the importance of identifying quality issues and implementing corrective measures in manufacturing, which relies on accurate and accessible records.

4.3.2.8 Poor quality control

The participants indicated that insufficient management and monitoring of quality inspections, insufficient material inspection, and reliance on sample inspections all contributed to defective wagon production. During production or when released for operation, non-conformities were found in the wagons. Furthermore, quality inspections are carried out in almost every manufacturing system to prevent nonconforming products from reaching final customers or end-users. A defective wagon reaching the customer may jeopardise the firm's ability to compete (Genta, Galetto and Franceschini, 2020). Maintaining quality standards in wagon manufacturing requires proper monitoring and management of the inspection process.

Data indicates that the TE Bloemfontein factory heavily relies on manual labour for its inspection process, resulting in inconsistencies and subjective outcomes. (Groover, 2020) highlights that this approach can detrimentally affect quality and efficiency. Inspections typically occur after a significant delay, making it challenging or impossible for participants to address product defects promptly. Any components failing to meet the required quality standards must undergo scrapping or rework, leading to additional costs.

4.3.2.9 Poor identification and traceability

Defective wagons plague the manufacturing industry due to insufficient oversight and handling of NCR (Non-Conformance Report) components. Workers frequently need to be able to place components correctly during the manufacturing process due to inadequate product identification and traceability practices. Participants in the industry have identified several rolling stock components requiring more appropriate labelling and better traceability measures. Additionally, rejected items need clear markings, resulting in their inadvertent usage during production. The absence of a secure or access-controlled NCR area only exacerbates the problem, ultimately the producing defective wagons.

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Participant feedback also unveiled that some measuring equipment remains uncalibrated due to the absence of markings indicating the next calibration date or asset number on the equipment or its associated certificate. Ensuring proper item identification and traceability throughout the manufacturing process is imperative. (Groover, 2020) states that all calibrations should be traceable to international standards, and the masters used for machine control must undergo accurate calibration and configuration.

4.3.2.10 Summary of the participants' perceptions of what causes defective wagons to be manufactured

The participants' feedback revealed that the lack of proper quality control mechanisms and monitoring systems was the primary reason for defective wagon production. Late detection of these issues often resulted in delayed identification of defects, leading to significant losses. In addition, inadequate training programs and supervision of inexperienced workers further complicated the matter.

The participants' feedback revealed that inadequate control over documents and records related to manufacturing activities can lead to errors, omissions, and oversights that contribute to the production of defective wagons. Also, improper storage conditions lead to defects such as corrosion or rust at TE.

Participants also raised concerns about prioritising quantity over quality, which compromised the final products to meet production targets. Unrealistic goals and expectations set by management worsened the situation, posing safety risks and damaging the company's reputation. Additionally, ineffective communication channels and the lack of integrated information systems resulted in missed opportunities for continuous improvement. The participants identified inadequate exchange of information between departments and failure to learn from past projects as contributing factors to defective wagon manufacturing.

4.3.3 Participant's perception of recommendations to minimise defective wagon production

The study has identified six sub-themes, detailed below, that offer valuable recommendations for improving the prevention of defective wagon production. These sub-themes suggest preventive measures that effectively address the factors contributing to producing defective wagons. Direct quotes from participants, emphasising their suggestions for minimising defective wagon production, are presented in Table 4.5 in Appendix H.

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4.3.3.1. Knowledge management and communication

The participants recommended that the organisation thoroughly assess its document revision process. They also suggested enhancing communication and distribution among relevant departments to ensure that the wagons consistently meet current standards. To promote continuous improvement and enhance quality control, the organisation needs to collect data, analyse it for meaningful insights, and share it to create knowledge about potential solutions. Transferring knowledge ownership from individuals to the company is essential to safeguard critical knowledge from being lost. The participants indicated that the shared platforms in the wagon manufacturing industry contain only some valuable information. As a result, relevant employees need access to it. This approach will help the organisation manage its knowledge effectively and promote employee understanding. Losing substantial expertise over time risks knowledge loss, and the organisation cannot afford to let that happen (North and Kumta, 2018). To ensure effective knowledge management and communication, a clear strategy and structure accessible to all employees within the organisation is essential. Documents stored in SAP should be organised and accessed only by authorised users.

Participants suggest that it is crucial to maintain clear and consistent communication with employees regarding necessary activities, requirements, and information. It will assist the organisation in monitoring and adapting to changes in manufacturing processes effectively. Participants recommend communicating the introduction of new equipment or tools to provide context and understanding. Lombard, van Waveren and Chan (2014) emphasise the importance of ongoing, precise information from employees, suppliers, and customers to maintain quality within an organisation. By analysing this information, management can make informed decisions, highlighting the need for transparent communication channels and a culture of information exchange. A well-structured knowledge management and distribution system allows organisations to engage with diverse stakeholders, ultimately enhancing the company's overall quality (North and Kumta, 2018). Consistently engaging with stakeholders offers valuable learning opportunities for the organisation, making it essential to welcome their ideas, contributions, and innovative perspectives proactively from the outset of manufacturing. Using written communication instead of verbal agreements is recommended to ensure proper documentation.

4.3.3.2. Continual employee training

The participant's responses to the study support Sun's (2020) conclusion that specialised quality training is necessary for successful quality management within organisations. This formal training equips employees with the necessary skills and expertise to reduce defective

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wagon production. The training should allow employees to develop solutions to quality issues and implement them effectively in real-world scenarios.

Training can vary from broad awareness, which everybody must have, to precise quality training per discipline, trade, and operation. The orientation process will highlight further training needs when a skilled team are available. It is also necessary to orientate all workers when they join a project team to explain the critical aspects of their task/requirements/information and stipulate all procedures, specifications, regulations, requirements, and other documents. To ensure that a specification or work instruction is accurate, (Groover, 2020) recommends including the activities and equipment needed and describing the necessary skills. Training is also an essential form of management communication. Training needs flow from complementing existing skills to performing a task effectively. The availability and effective utilisation of suitably trained and skilled staff are vital to delivering defective-free wagons. The quality of training and orientation received can only be as good as the trainer selected. Delivery of defect-free wagons depends on the part played by every individual.

4.3.3.3. Technology management

The importance of technology in improving quality has been a recurring theme among participants. By adopting new manufacturing methods, technology enables organisations to stay current and competitive in their respective industries. TE should integrate technology management (TM) activities and tools to make technology investment decisions promptly and ensure effective capacity development. As shown in Figure 4.1, the proposed six-step TM aligns with the technology life cycle. It is necessary to maintain company performance and market position (Gregory, 1995). Successful TM hinges on integrating skilled personnel and effective routines (tools)(Iansiti, 1995).

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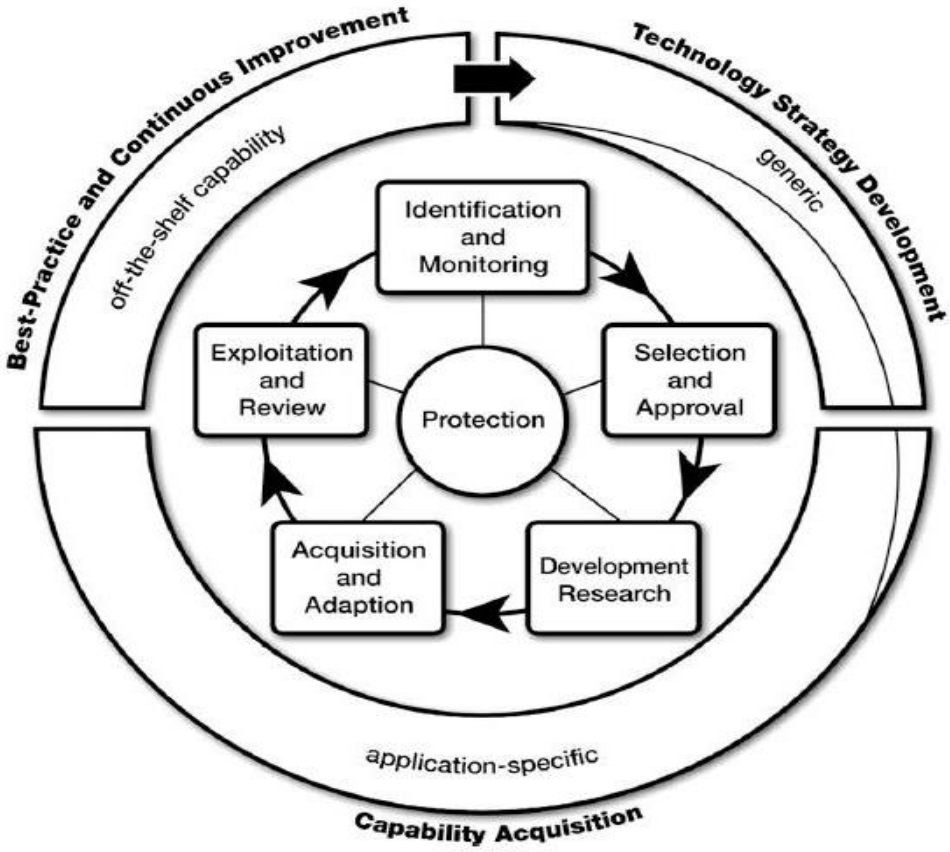


Figure 4.1: A proposed integrated technology management solution (Teece, Pisano and Shuen, 1997)

By implementing a thorough TM solution, TE can better align its operations with its customer's demands and preferences while facilitating greater involvement from its team members and partners. Given that technological capabilities are a subset of dynamic capabilities. It is essential to effectively integrate and reconfigure resources, both internal and external capabilities, to adapt to ever-changing market conditions.

4.3.3.4. Organisational culture and climate

According to the participants, the organisation's culture and climate must adhere to company procedures, specifications, regulations, and requirements. A study by Lombard et al. (2014) found that organisations with a quality-focused culture are agile innovators who anticipate and respond to their customers' needs. Such organisations are likely to avoid customer dissatisfaction and can achieve market leadership. To foster a culture of quality, leadership needs to prioritise this value by demonstrating unwavering support and attention to detail. It is a powerful insight to recognise that culture starts from the top and that building a climate of quality promotion within an organisation requires a unified understanding of what quality entails. To achieve this, departments must have clarity on the definition of quality, and employees must collaborate across different functions to develop innovative ideas for

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improving quality through cross-silo teamwork. (Lombard, van Waveren and Chan, 2014) have shown that collaboration is essential to creating an effective environment for implementing quality management systems.

It is not uncommon for companies to conduct audits in response to customer complaints, but this practice can sometimes impede progress and make it challenging to gauge success. The pressure to deliver quick results can cause employees to overlook the importance of maintaining a quality-focused culture, creating a difficult balance between speed and quality. In their study, (Lombard, van Waveren and Chan, 2014) emphasise the significance of cultivating a quality culture to support effective quality management practices. Clearly defined roles, responsibilities, and expectations within the quality division can help streamline processes and prevent misunderstandings. Delegation can empower individuals to take ownership of quality-related tasks while ensuring accountability and oversight. Establishing an effective quality production system that embraces failures and incorporates lessons learned into current initiatives is crucial. This approach encourages continuous learning.

4.3.3.5. Organisational structures and governance

There was a consensus among all the interviewees that the timing of implementing solutions within an organisation can make or break the success of project management. As outlined in participants' responses, addressing some of the root causes of defects was postponed until the project was near completion, leading to substantial financial losses. Participants emphasised that an efficient organisational framework is essential to ensure timely decision-making and implementation, which is crucial for project execution. Hence, there is a significant need to enhance the organisational structure.

Enhancing the organisational structure encompasses establishing trust, empowering leaders, granting ownership, and expanding organisational boundaries. The establishment of trust is of paramount importance in the context of organisational structure improvement. When trust is the foundation of employee relationships, it fosters open communication, consistency, and accountability. Cultivating trust among TE's employees can facilitate open communication, leading to the timely implementation of tools. Moreover, empowering leaders has a significant impact on enhancing the organisational structure. Even though holding low positions within the organisation, these leaders should exhibit leadership qualities and offer guidance as needed.

(Mitra, 2016) asserts that top management needs to prioritise the quality of their products to drive improvement. (Lombard, van Waveren and Chan, 2014) further emphasised that quality

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should be an integral part of all operations and not just an optional add-on, as a lack of quality can jeopardise the very existence of a company. Management needs to get all team members committed and supportive for success. Employing the Lessons Learned method fosters collective ownership in addressing issues. Additionally, promoting a culture of contribution beyond job roles is crucial.

4.3.3.6. Equipment Reliability

The participant's responses highlighted the importance of implementing preventive maintenance as it ensures that tools and equipment are readily available. Literature shows the crucial role of reliable equipment in achieving product quality and fulfilling various manufacturing objectives, which supports this perspective (Sharma & Shudhanshu, 2012; Singh & Ahuja, 2015). Additionally, Mehdi et al. (2010) support the viewpoint expressed by the participants as they stress the significance of preventive maintenance and reliable equipment in reducing the production of defective wagons and achieving high-quality wagons. Singh and Ahuja (2015) also contend that scheduled maintenance is critical for manufacturing organisations to meet product quality targets and maintain machine availability.

4.3.3.7 Summary of the participants' perceptions of preventive measures to reduce the production of defective wagons

The participants also emphasised the significance of employee training and continuous training on manufacturing procedures, troubleshooting techniques, and defect analysis. Transparent and open communication channels within the organisation are critical to promptly identifying and resolving potential defects. Establishing a robust reporting mechanism is necessary to identify and address defects immediately. Additionally, the participants emphasise the importance of knowledge management practices in facilitating the sharing of best practices and lessons learned, thereby preventing the recurrence of defects.

The participants propose implementing effective governance and organisational structures to address the production of defective wagons. Creating a positive organisational culture and climate is essential in promoting a quality-focused mindset and preventing defects in wagon production. The participants underscored the importance of fostering a culture of continuous improvement, accountability, and attention to detail. They recommend leveraging scientific methods and information technologies to improve product quality and identify areas for improvement. Effective technology management is essential in reducing the production of defective wagons.

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The participants recommend incorporating regular inspections, calibrations, and preventive maintenance of manufacturing machinery to ensure the production of high-quality and defect-free wagons. They also suggest monitoring and controlling the storage of critical components to prevent failures and defects during production. Clear and well-defined procedures for quality control, defect identification, and traceability throughout the production process are crucial to minimising the risk of defects.

4.4 Root cause analysis (RCA)

Analysing the root causes of problems and their effects is crucial to reducing the production of defective freight wagons (Daniyan *et al.*, 2022). The researcher, personnel, and managers collaboratively and meticulously reviewed historical customer complaints through discussions and brainstorming sessions. They aimed to gain a comprehensive understanding of quality issues. In these sessions, the team drew on their collective knowledge and experience in wagon manufacturing to identify six critical categories: machine, method, materials, environment, measurement, and personnel. They then used the identified causes to create a Cause-and-Effect Diagram (CED), as shown in Figure 4.2. This diagram visually connects each cause to its corresponding category, providing a structured visualisation highlighting potential factors contributing to the problem.

The team meticulously prepared for the brainstorming sessions by conducting a comprehensive review of historical customer complaints and relevant quality data to set the stage for informed discussions. Staff and managers, hailing from diverse professional backgrounds and areas of expertise, actively engaged in the sessions. The design of these sessions aimed to maintain a sharp focus and guarantee equitable opportunities for contribution from all participants. The study introduced negative brainstorming to stimulate the exploration of unconventional ideas and employed relaxation techniques to foster a stress-free brainstorming environment. The team carefully recorded all the ideas and potential causes that emerged for subsequent analysis. This methodical strategy, enriched by negative brainstorming and relaxation practices, laid the groundwork for idea generation and investigating possible causes. The careful documentation of all ideas and the development of a Cause-and-Effect Diagram further refined the visualisation of potential factors that could impact the production of defective freight wagons.

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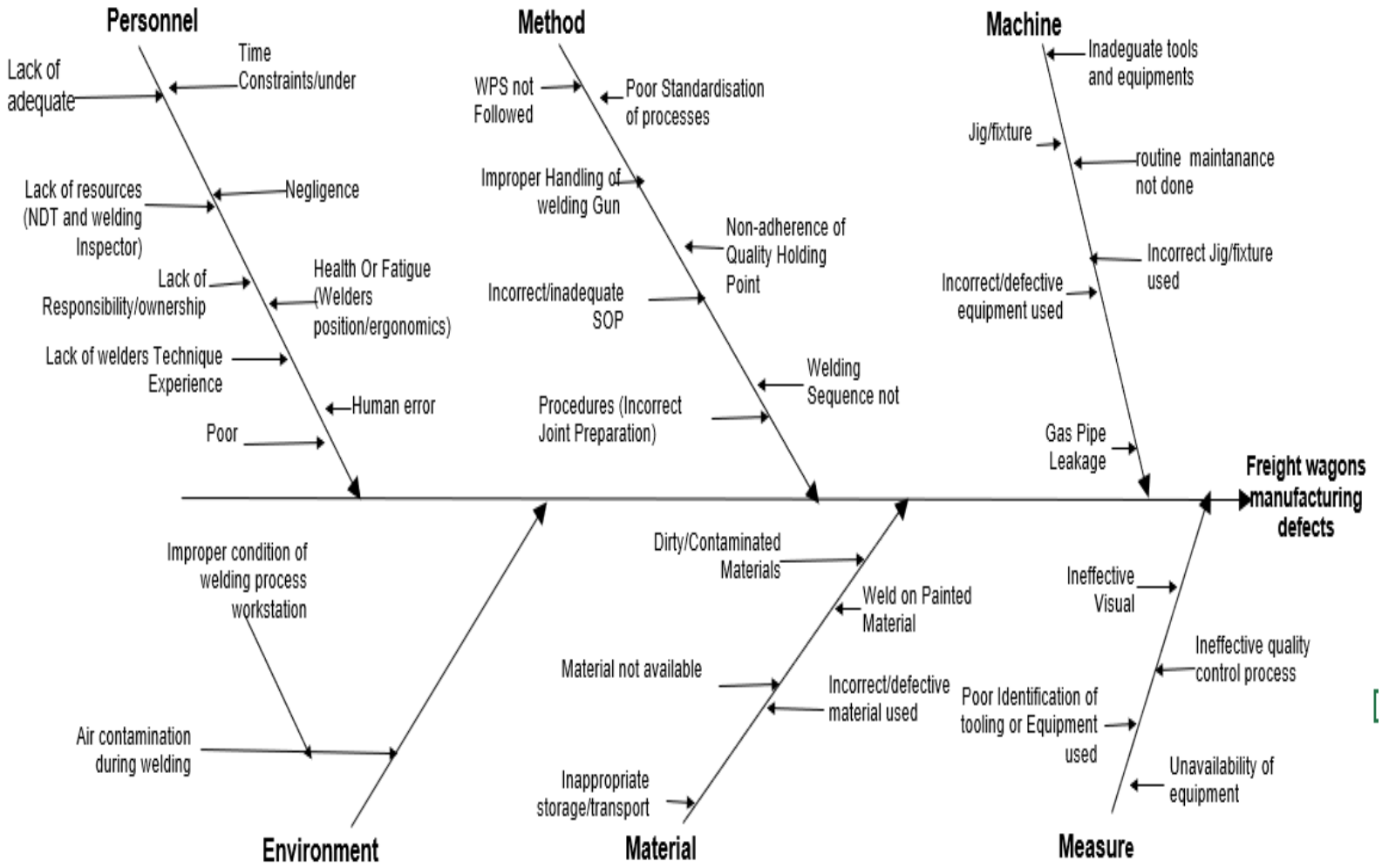


Figure 4.2: Cause and effect diagram leading to defects.

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The study utilised the Five Whys methodology to explore the root causes and consequences of challenges encountered in the CED approach. This approach fostered open discussion and collaboration among team members. The study successfully identified the underlying causes of organisational challenges that led to the manufacturing of wagon defects, employing the five whys. The analysis focused on the final "Why" to determine the fundamental or root cause of defective wagon production. This strategic approach prevented the team from merely treating symptoms and ensured that underlying issues were addressed. Figure 4.3 outlines the factors at TE that contribute to producing defective wagons, categorised as operations, material science/welding, quality/continuous improvement, and PEMM.

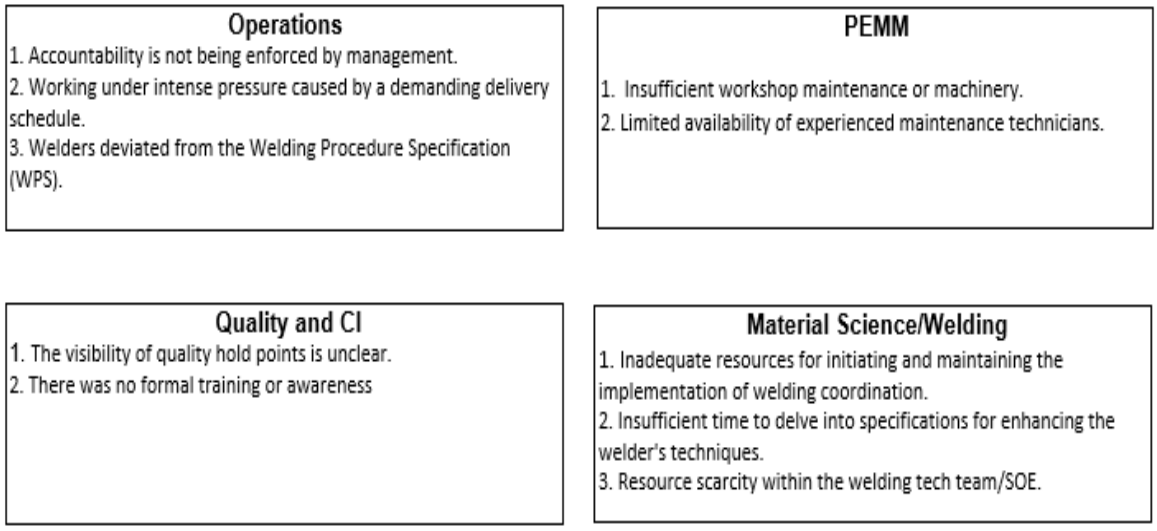


Figure 4.3: Factors contributing to the production of defective wagons at TE.

The absence of product compliance inspections resulted in the production of defective wagons. The lack of clarity on quality hold points has made it difficult to determine the necessary checks, equipment, skills, and procedures to ensure quality. Consequently, workers have needed clarification on when and where to pause production for specific checks, leading to the production of defective wagons. Moreover, poorly marked hold points have made it arduous to pinpoint the root cause of any quality issues that may arise. According to a study by Evans and Lindsay (2016), inaccurate inspections lead to inadequate repair of defects in the manufacturing process.

The analysis reveals that the operator's insufficient training and awareness caused the defects in the wagons. According to (Mukwena, Wessels and Pretorius, 2019), when employees do not receive proper training, they may need to fully understand the importance of maintaining

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manufacturing standards and following procedures to ensure wagon quality. These findings concur with (Nikitin *et al.*, 2020; Sun, 2020) study that a lack of welding certification, limited experience with welding techniques, faulty equipment, and deviations from established welding procedures can all impact wagon quality. To address these issues, scholars (Nikitin *et al.*, 2020; Sun, 2020) recommend that organisations enforce mandatory training requirements and workshops to enhance their workforce's technical skills in manufacturing railway wagons.

In the wagon manufacturing business, the absence of management enforcing accountability among employees can be a significant obstacle to progress. Overcoming this challenge requires management to provide appropriate training and team morale-building activities while fostering a culture of problem-solving and innovation. Accountability is crucial to ensure that employees are responsible for producing high-quality wagons at TE. Without it, employees may be more likely to cut corners or overlook potential quality issues, leading to defective wagons. Additionally, a lack of accountability can result in a culture of complacency and disregard for quality, which can have serious consequences. By promoting a culture of accountability, TE's management can ensure that its employees take pride in their work and produce the best possible wagons for their customers.

The five whys revealed that the challenges arose because the operators deviated from the welding procedure specifications (WPS). These specifications outline the appropriate materials, techniques, and quality control measures for welding (ISO. 15607:2019). Failure to follow the guidelines resulted in improper welding techniques, the use of unsuitable materials, or the omission of quality control measures.(Posch, Holtsinger and Bychkovskii, 2015; Kendall *et al.*, 2022) found that deviating from WPS produced defective products. Therefore, strict adherence to the WPS is essential for ensuring consistent product quality and maintaining consistency throughout the welding process.

Inadequate time for reviewing welding specifications has negatively impacted TE wagon's welding process and quality. Complying completely with welding specifications and process parameters is crucial for successful welding operations. Not reviewing welding specifications can lead to inconsistent welding quality, increased defect rates, and higher costs due to rework and scrap. Tight deadlines have compelled employees to bypass quality checks or expedite production, resulting in subpar quality standards and inducing worker stress. Balancing project requirements with the team's well-being is essential to ensure optimal results.

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The shortage of experienced maintenance technicians and poorly maintained workshop equipment caused the defective production of wagons. The delay in identifying and addressing equipment issues led to equipment breakdowns, downtime, and reduced production efficiency. A lack of workshop maintenance and machinery resulted in increased defects due to equipment malfunctions or inconsistencies in production. TE must increase personnel and support welding tech teams to improve wagon quality. Additionally, the failure of the Standard Operating Equipment (SOE) team to maintain and calibrate welding equipment contributes to a lower standard of output. By providing adequate resources, the welding technical and SOE teams can effectively manage the welding process, ensuring the highest quality. Organisations must invest in the necessary resources to produce high-quality wagons.

4.5 Summary

The responses of the participants were analysed and discussed. The findings support previous work by (Konyukhov and Efimov, 2006; Boronenko Yu, 2013; Nemavhola and Ramdass, 2017; Silvani, Yanuar and Juliani, 2019). Five broad and direct label categories were identified based on the patterns discovered in the in-depth interviews. Frequency or repeatability in RCA (CED and five whys) indicates the presence of cornerstone causes. The findings support previous work by (Deming, 1986), who found that 94% of an organisation's problems reside in the system (processes, structure, and organisation).

The study finding indicates that involving employees in identifying and implementing quality control measures and production line design is crucial for ensuring the production of high-quality wagons. Failure to involve employees in the process results in a lack of engagement and ownership of the quality management process, leading to defective wagons. As such, companies need to cultivate a culture of accountability and responsibility among all employees involved in the production process to ensure high-quality wagons. Employees can achieve effective quality control by involvement in decision-making and receiving relevant training and necessary resources.

The organisation's overreliance on quality control inspectors leads to a reactive approach to quality management, which must be improved to ensure consistently high-quality wagons. A proactive approach that involves designing and implementing quality processes and procedures throughout production is necessary to build quality into wagons. This approach, known as quality assurance, focuses on preventing defects and errors from occurring in the

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first place rather than just catching them after they happen. The organisation adopted ISO 9001:2015 as its Quality Management System to build quality into its products.

In conclusion, providing employees with additional training and support is essential to enhance their abilities and expertise in developing efficient solutions for quality concerns and avoiding recurrence. Failure to involve quality personnel during the development phases to identify and address potential quality issues early in the product development process contributes to defective wagons and subsequent customer complaints.

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CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The study's conclusion aligns with its main goal, which is to gain a more profound insight into employees' perspectives on the production of defective wagons and to analyse customer complaints to investigate root causes. In this section, the attainment of research objectives is explored. The chapter thoroughly reviews the research methods employed and examines the research outputs, establishing their connections to the originally outlined research objectives. It highlights the findings derived from both theoretical work and fieldwork. Additionally, the chapter puts forth recommendations, discusses research limitations, and suggests directions for future work and studies.

5.2 Conclusion of the research question and objectives

5.2.1 Critical research question

The research inquiry posed within the framework of this study was:

- What are the root causes leading to the production of defective wagons at Transnet Engineering, as derived from employee perceptions and historical customer complaints?

The study addressed this CRQ by conducting a qualitative research study that involved interviewing experienced wagon manufacturers and analysing historical customer complaints at the TE at Bloemfontein factory. The study examined the collected data in the fourth chapter and identified and analysed the main themes and sub-themes. Through this process, three overarching themes and their respective sub-themes emerged, providing a comprehensive answer to the research question.

The study used the cause-and-effect diagram and the five whys technique to analyse the causes of defects reported in the customer complaint register. This approach enabled the identification of potential root causes and a deeper understanding of the factors impacting wagon quality and customer satisfaction.

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5.2.2 Research objectives

The primary thrust of a study is its research objectives, which define the specific issues being investigated (Kumar, 2018). The study pursued the research objectives to address the CRQ of the research, as outlined in the following section.

5.2.2.1 To investigate the factors contributing to producing defective wagons by gathering and analysing relevant literature.

The first objective was to investigate thoroughly the factors that lead to defective wagons. The study reviewed relevant literature, including research studies, academic papers, industry reports, and other credible sources. By closely examining the literature, the study obtained valuable insights and information to uncover the underlying causes of wagon defects. With a comprehensive understanding of the issue, we actively developed effective strategies to prevent and eliminate wagon defects in the future.

5.2.2.2 To identify the employee perceptions of the root causes of factors leading to the manufacturing of defective wagons at Transnet Engineering

The study achieved research objective two by conducting a semi-structured interview with industry experts based at TE at the Bloemfontein factory. One-on-one interviews were conducted with wagon manufacturers to gain insight into their experiences with the causes of defective wagon manufacturing. The study transcribed and analysed the interview data using thematic analysis, generating the main themes and subthemes. The study transcribed and analysed the interview data using thematic analysis, generating the main themes and subthemes. Three main themes with their sub-themes emerged from the data analysed to achieve Objective 3.

The causes of defective wagon production at TE include poor communication and information sharing between departments and with customers, insufficient quality control, time constraints and pressure, inadequate documents and records control, poor knowledge sharing, and issues with material identification and traceability. The fourth chapter of the study discusses these central themes and subthemes in detail, providing insight into the factors contributing to producing defective wagons as perceived by employees in the industry.

5.2.2.3 To analyse the causes of wagon defects identified in historical customer complaints through root cause

The study thoroughly analysed historical customer complaints using the cause-and-effect and five whys' diagrams. The study found that many defects were related to manufacturing process

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errors. The five whys diagram explored the identified challenges' underlying root causes and cause-effect relationships. From the analysis, the study discovered that several factors have contributed to the production of defective wagons, including a lack of product compliance inspections, unclear quality hold points, insufficient training and awareness among operators, deviations from welding procedure specifications, insufficient time for reviewing welding specifications, a shortage of experienced maintenance technicians, and poorly maintained workshop equipment. All these factors were fundamental causes of defective wagon production.

5.2.2.4 To summarise the findings, draw conclusions and recommendations in reducing the manufacturing of defective wagons in the railway industry.

The study accomplished the fourth research objective by consolidating and documenting all study aspects, including conclusions and recommendations, into a comprehensive final report. The report aimed to reduce the production of defective wagons in the railway industry by incorporating recommendations based on empirical findings from thematic and root-cause analyses. The study identified key themes and factors contributing to defective wagon manufacturing through these methodologies. The final report detailed the research methodology, data collection procedures, and analysis techniques to arrive at these conclusions. Ultimately, the report aimed to provide actionable recommendations for the industry to minimise the production of defective wagons.

To minimise the production of defective wagons, Scholars (Nikitin *et al.*, 2020; Sun, 2020) recommend that organisations prioritise mandatory training and workshops to enhance their workforce's technical skills, provide resources to improve wagon quality and foster a culture of problem-solving and innovation. The study's findings indicate that effective communication and proper distribution are paramount to reducing defective wagon production. Written communication is highly encouraged for record-keeping, and a well-defined strategy and structure are crucial. Ongoing employee training and investment in new technology are essential to stay current. It is important to note that leaders should set a positive example to establish a positive organisational culture and climate. Lastly, inspecting and maintaining production tools and equipment before use is crucial for safety and efficiency.

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5.3 Recommendations

Based on the research findings, the study proposes the following recommendations for TE Bloemfontein factory:

Cultivate a culture of continuous learning and practical training, utilising advanced technologies to enhance employee development. As demonstrated in the studies by Nikitin et al. (2020) and Sun (2020), virtual reality technologies show promise in reducing training costs and improving safety for wagon maintenance and manufacturing.

Engage in skill transfer programs that provide hands-on training to enhance skills and broaden expertise. Encourage experienced employees to mentor and guide their less experienced colleagues, facilitating the exchange of knowledge and expertise. To adapt to the rapidly evolving railway industry, prioritise ongoing learning and knowledge-sharing. Additionally, to streamline operations and foster innovation, tacit knowledge can be converted into explicit knowledge for efficient access and information exchange.

Minimise defective wagon production by documenting both successes and failures from past projects. Regular feedback sessions involving stakeholders and team members can identify areas for improvement, best practices, and potential risks. The factory can enhance efficiency, reduce costs, and improve outcomes by creating a database of lessons learned. Encourage a proactive approach to learning and process refinement to ensure success.

Foster a quality culture within the factory by effectively communicating quality policies and objectives. Empower operators to make informed decisions, diligently evaluate customer feedback, thoroughly investigate quality concerns, and consistently implement corrective and preventive measures. Regularly review and enhance quality checkpoints and production line layouts to establish a culture of continuous improvement. Allocate resources adequately and leverage new technologies to enhance overall quality.

Implement an Electronic Quality Control System (EQCS) to streamline the quality control process, ensuring consistency and compliance. Involve quality personnel in product development to identify potential issues early and ensure adherence to established standards, ultimately leading to higher quality and customer satisfaction.

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5.4 Suggestions for future research

The research report draws upon the insights of industry experts in wagon manufacturing and conducts a thorough root-cause analysis to understand the factors that lead to defects in wagons. Although the research report identifies the causes of defective wagon manufacturing, it lacks a practical plan for railway manufacturing industries to reduce the production of defective wagons in the digital economy. Therefore, it is crucial to conduct further analysis to gain a deeper understanding of these factors and develop effective strategies to mitigate them in the future. Additionally, given the scope of the subject matter, a comprehensive and extensive study that covers all TE manufacturing facilities should be pursued to provide a more holistic perspective.

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Appendix A: Permission letter received from TE

Transnet SOC Limited
Registration Number
1990/000900/30

160 Lynette Str.
Kilner Park
Pretoria
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Lynne East
Pretoria, 0039
T +27 12 391 1304
F +27 12 391 1371

MEMORANDUM

www.transnet.net

TO : Ralph Mills, Chief Executive; Transnet Engineering

FROM : Magan Govender, General Manager; Manufacturing; Transnet Engineering

DATE : 26 September 2022

SUBJECT : **REQUEST FOR PERMISSION TO CONDUCT RESEARCH BY PFANANANI THELMA NEMAKHAVHANI (SAP NO 1458)**

PURPOSE:

1. The purpose of this memorandum is to request approval from the Chief Executive, Transnet Engineering, Ralph Mills, for Pfananani Thelma Nemakhavhani (Thelma) to conduct research in the Transnet Engineering Wagon Business in Bloemfontein, as part of her research towards a Master's of Science Degree in Industrial Engineering at the University of the Witwatersrand.

BACKGROUND:

2. Thelma (Sap number 1458) is currently employed in Transnet Freight Rail as Project Manager (Bloemfontein), with 10 years of service at Transnet and the research topic is "An analysis of factors leading to the production of defective wagons in Transnet Engineering".

3. Thelma is the beneficiary of the Transnet Freight Rail bursary pursuing her studies part-time at the University of the Witwatersrand and is busy with a master's degree proposal for a research module as a prerequisite to complete the degree.

DISCUSSION:

4. The Wits University ethics committee's requirement is that an approval letter from an organization indicating that the organization allows Pfananani Thelma Nemakhavhani to conduct such studies be submitted.
5. This study will be of voluntary participation, and confidential information will not be divulged. A non-disclosure and confidentiality agreement have been signed with Thelma.
6. The information that will be provided by the employees of Transnet Engineering will be purely for academic purposes and cannot be used for any other purpose. The research findings will be

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shared with the Wagon business team and the Executive Manager, Wagons Manufacturing situation in Bloemfontein, upon the organization's request.

7. The research sample for this study requires 5 (five) to 10 (ten) participants who are part of the Transnet Engineering workforce and their identity will be kept confidential.

8. The study might benefit Transnet with the research findings and may adopt them for implementation.

BUDGET & FINANCIAL IMPLICATIONS

9. None

RECOMMENDATIONS:

10. It is therefore recommended that the Chief Executive grant permission to Pfananani Thelma Nemakhavhani to conduct that research in the Transnet Engineering Wagon Business, as part of his Master of Science degree in Engineering: Industrial.

COMPILED BY:

Thelma Nemakhavhani
Wagon Project Manager (TFR)
Date: 17/10/2022

RECOMMENDED/NOT RECOMMENDED:

Kobus du Plessis
Executive Manager Wagons Manufacturing
Date: 17/10/2022

RECOMMENDED/~~NOT RECOMMENDED~~

Modike Makgothokga
Centre Executive, Bloemfontein
Date: 17/10/2022

RECOMMENDED/~~NOT RECOMMENDED~~

Magan Govender
General Manager; Manufacturing (TE)
Date: 23/01/2023

An NDA understanding should be signed as a pre-requisite.

APPROVED/~~NOT APPROVED~~

Ralph Mills
Chief Executive; Transnet Engineering
Date: 2023/01/31

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Appendix B: Interview guide

Research Project Title: ***An analysis of factors leading to the production of defective wagons in Transnet Engineering***

Dear Participant,

Thank you for accepting to participate in this study. Please complete this consent form as you see appropriate. By signing this consent form, you are indicating that you have read and understood the description of this study and that you agree to the terms as described below:

	Mark with X	
	YES	NO
I confirm that I have read and understood the information about this study as provided in the participant's information sheet.		
I understand that my participation is voluntary and that I am free to withdraw at any time without any penalties or negative consequences against me.		
I grant permission for the interview to be audio recorded		
I agree that the information I provide may be treated as strictly confidential and anonymous and only the research team will have access to the interview data.		
I understand that the information acquired from the interview will not be recorded in excess of what is required for this study.		
I agree that the results of this study may be recorded in academic journals and at conferences.		
I have had the opportunity to ask any questions related to this study and I have had all my questions answered to my satisfaction		
I may request a report summary, which will come as a result of this study.		

With full knowledge of all above-mentioned terms, I agree to participate in this study

Participant		Consent taken by (Researcher)	
Name		Name	
Signature		Signature	
Date		Date	

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Appendix C: The ethics approval notification

Bruno Emwanu <Bruno.Emwanu@wits.ac.za> Mon, 20 Feb 2023, 15:52

to Thelma, me, Mncedisi

Dear Thelma,

I am pleased to inform you that the School Ethics Committee completed assessing your ethics application for your MSc research report titled: "An analysis of factors leading to the production of defective wagons in Transnet Engineering" and it has been ratified by the University Main Ethics Committee (non-medical). Your ethics clearance number is MIAEC 001/23.

Please use your ethics clearance number as a reference for all future correspondence on this matter.

By copy of this email, your supervisor is also informed.

Regards,

Dr. Emwanu

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Appendix D: The participant agreement form



Research Project Title: ***An analysis of factors leading to the production of defective wagons in Transnet Engineering***

Dear Participant,

Thank you for accepting to participate in this study. Please complete this consent form as you see appropriate. By signing this consent form, you are indicating that you have read and understood the description of this study and that you agree to the terms as described below:

	Mark with X	
	YES	NO
I confirm that I have read and understood the information about this study as provided in the participant's information sheet.		
I understand that my participation is voluntary and that I am free to withdraw at any time without any penalties or negative consequences against me.		
I grant permission for the interview to be audio recorded		
I agree that the information I provide may be treated as strictly confidential and anonymous and only the research team will have access to the interview data.		
I understand that the information acquired from the interview will not be recorded in excess of what is required for this study.		
I agree that the results of this study may be recorded in academic journals and at conferences.		
I have had the opportunity to ask any questions related to this study and I have had all my questions answered to my satisfaction		
I may request a report summary, which will come as a result of this study.		

With full knowledge of all above-mentioned terms, I agree to participate in this study

Participant		Consent taken by (Researcher)	
Name		Name	
Signature		Signature	
Date		Date	

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Appendix E: The participant information sheet

Information Sheet for Interview Participants
Research Project Title: An analysis of factors leading to the production of defective wagons in Transnet Engineering

An invitation: My name is Thelma Nemakhavhani and I am a qualified Electrical Engineer who is currently employed at the Operations Command Centre, RSM wagon project department, in Transnet freight rail (TFR) Bloemfontein. I am a part-time MSc student at the University of the Witwatersrand's School of Mechanical, Industrial, and Aeronautical Engineering, where I am supervised by Dr Mncedisi Trinity Dewa.

The data collected and its analysis will provide an insight into factors contributing to the production of defective wagons at Transnet Engineering, improve quality achievement levels in newly built and maintained wagons, and thus increase customer satisfaction. I hereby invite you to take part in my research because you are the most knowledgeable and experienced about the subject, as well as through your direct or indirect interaction with manufactured wagons. The research will be carried out between January and February 2023. Participation in the study entails face-to-face interviews with you at a location and time of your choosing.

Please be aware that your participation in this study is entirely voluntary, and you may opt out at any time. Your permission will be sought at the time of the interview. If you do not want the interviews to be recorded, we will respect your wishes. The data analysis results will be included in my MSc dissertation report and may be published in academic journals and at conferences. This study's potential discomfort and risk are limited to privacy and confidentiality. All responses will be kept strictly confidential, and the information you provide will only be used for this research. On request, a summary of the research findings will be made available to you.

Project context: Currently, TFR is dissatisfied as newly built and maintained rolling stock is being staged due to defects, resulting in a loss of revenue, customers, and market share. Defects, in this study, are defined and seen as wagons that do not meet expectations or accepted standards of quality. The continuous production of defective wagons at TE leads to high scrap production, reworks, and unresolved non-conformance reports. During the manufacturing of wagons, defects can result from operator error, changes in process conditions, changes in composition proportion, distribution of materials, etc. To uncover the perceived root causes of the company's defects, interviews with the employees who experience the issue or problem under study will be conducted. The investigation findings will lead to preventative action that can be implemented to minimize the release of defective wagons, improving TE's performance and customer satisfaction.

Purpose of Interview: To identify the perceived root causes of defective wagons at Transnet Engineering.

Duration and data storage: The interview will last for at least an hour. Please note that interviews will be audio-recorded, then transcribed onto a password-protected computer and destroyed after two years. You may review, edit, or erase the transcripts and audio recordings of your interview if you wish to do so. Your responses will be treated as confidential, and computer transcripts will not contain references to any persons (including yourself) or organizations. Such references will be replaced by codes known only to me, and all data will be stored securely.

I look forward to hearing from you.

Yours faithfully
Pfananani Thelma Nemakhavhani
University of the Witwatersrand
Johannesburg, South Africa
Private Bag 3, WITS 2050, South Africa
Tel:083 263 1231
Supervisor: Dr Mncedisi Trinity Dewa
Contact details: +27(0) 11 717 7378

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Appendix F: Participant's perception of ensuring high-quality wagons

Table 4.3: Participants' perception of ensuring high-quality wagons.

Main theme: Participants' perception of ensuring high-quality wagons	
Sub-theme	**Quotations from responses**
Satisfying customer specifications and meeting their requirements	"A standard operating procedure was developed and implemented to serve as a guide during the manufacturing process." "Stanchions repair station has been identified as a hold point" "After the repair is completed, a procedure and quality control sheet are created to capture information." "Welding plan specification was approved by technology management." "Standard template created to ensure consistent cutting of stanchions." "Pipe welding processes are verified following the drawing to ensure compliance with specification requirements"
Regular inspection and testing of wagons	"Non-destructive testing was implemented as part of the inspection. Quality coverage was conducted and implemented to ensure that all sections were equally covered in terms of quality." "In-line inspection is used to monitor the surface preparation process." "Holding points are in place, and supervisors and artisans are adhering to them, to ensure wagons arrive at their destination without incident." "Before any movement, all stations are inspected, and at holding points, quality personnel perform final inspection and document verification." "After welding a, welders self-inspect all products worked on. The quality assurance manager performs a weekly welding walkthrough with the help of a weekly welding audit questionnaire."
Periodic validation and calibration	"Supervisors ensure that all measuring tools used in their section are calibrated and in good working order." "Maintenance Plant and Equipment verified welding machine parameters and documented all information for the next verification date." "The instrument is registered on the Local Inventory list, allowing it to be tracked for the calibration due date."

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Main theme: Participants' perception of ensuring high-quality wagons	
Sub-theme	**Quotations from responses**
	"Adoption and implementation of procedure manual calibration rolling stock/infrastructure measuring instruments and legal metrology requirements." "The trammel Jig is checked every week. The standard operating procedure was also reviewed."
Training	"All wagon fitters who perform tack welding are certified." "All stakeholders were educated on the proper handling and storage of brake system pipes." "The quality department conducted training on how to use welding plan specification and developed the standard operating procedure." " Welders were trained on how to read and use welding plan specification." "The current planner in charge of the schedule is well-trained and experienced." "A team meeting was held in Letsema to discuss the importance of surface preparation." "Training is provided before employees are assigned to a job to ensure that they are aware of and understand the task at hand. The quality assurance manager will monitor the process for adherence monthly." "The operator was trained and evaluated on the job to perform the pre-start inspection."
Management of non-conformances	"When non-conformances, whether related to a physical product or activity, are detected they are dealt with in a timely and decisive way". "It is critical to capture non-compliance report data in a consistent, structured manner to perform proper and valid analyses".
Audits	"Pay closer attention to the internal auditor's evaluation." "Internal auditors can help increase organizational effectiveness and efficiency by providing insights and recommendations based on data and business process analysis and assessment." "At the very least, the company is more active in planning, establishing, and maintaining audit activities in frequency, methods, responsibilities, reporting, required corrective actions, and organized documentation."

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Appendix G: Participant's perception of what causes defective wagons to be manufactured

Table 4.4: Participants' perception of what causes defective wagons to be manufactured.

Main theme: Participant's perception of what causes defective wagons to be manufactured	
Sub-theme	**Quotations from responses**
Poor preservation of rolling stock components	"The lack of wooden blocks to support the floor plates when they are stacked." "There are inadequate storage facilities inside the workshop." "Poor brake pipe handling while transporting pipes from the store to the production line". "Complete wagon fitted with brake components while waiting for ECP kits, a severe storm arose, tearing this top outer plastic slightly and allowing some rain in".
Inadequate training of personnel	"Since outsourcing training had been discontinued due to cost savings, the company did not send an employee for retraining." "The other reason for the production of defective wagons is a lack of refresher training." "The planner had no formal training; he was seconded from another company and given exposure." "Because the quality control personnel were not properly trained to verify and record welding parameters." "The operator was not properly trained to know and understand the pre-start inspection as specified in the Standard operating procedure." "Personnel movement is uncontrolled, and there is no induction of item/production process requirements." "Capturing forms and processes were misunderstood by quality control during machine verification and interpreted incorrectly by the welding inspector." "There was no clear understanding on how the AAR manual must be controlled"
Lack of effective inter-departmental communication	"Supplier not responding to non-conformance report or responding too slowly."

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Main theme: Participant's perception of what causes defective wagons to be manufactured	
Sub-theme	**Quotations from responses**
	"There is no proper communication between the customer and the customer service manager." "Due to the customer's late contract signing, the company was instructed to continue building wagons based on the approved prototype as a work instruction." "Inadequate information was shared with maintenance plant and equipment." "Changes to the specification document were not communicated." "The design manager was aware of the design and development plans but was unaware that the design and development inputs and outputs needed to be documented on both SAP and the design office record." "The information that Vitemax had been discontinued on welding of brake pipe was never received due to a lack of welding plan specification and miscommunication." "Because the specification was not provided to the operations and quality departments, the application was not completed." "Operators failed to notify the quality controller that a thorough inspection was required before welding the cracks."
Lack of lessons learned	"We keep finding the same defects"
Lack of knowledge sharing	"Lack of knowledge on drawgear specification requirements" "The operator was not aware of the calibration requirements for measuring equipment"
Time constraints and pressure	"I don't care how many years of experience you have if someone is rushing you, you will make a mistake". "The client's demand plan arrived too late, leaving the business with insufficient time to order long-lead materials before we are expected to start producing wagons. "Pressure on the next financial deliver schedule is increased by concessions for work in process wagons without materials".

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Main theme: Participant's perception of what causes defective wagons to be manufactured	
Sub-theme	**Quotations from responses**
Poor documents and records control	"No implemented controls for nesting documents being implemented by product development." "Because the procedure was not yet finalised by authorised personnel from corporate quality." "No method or procedure for selection of products as critical to quality products" "No check sheet available" "Not all welding plan specifications were available at the time in the manufacturing cycle" "Document work schedule report (profile section) was not available because the printer was not working" "Pre-heating was not included in standard operating procedures regarding the actual temperature to be used when preheating pipes for bending." "There was no evidence of specification ' "The employee in charge of filling out the documents did not file them daily, as required by the warehouse."
Poor quality control	"Top centre casting was not properly inspected to raise non-conformance report against the supplier." "The bends of the CR ends were not thoroughly inspected." "Quality control struggles to inspect products due to difficulties in controlling inspection process variables." "Welding inspection is inadequate or non-existent." "Quality control failed to identify the nonconformance, and proper incoming quality inspection was not performed." "As sample inspection was used, neither the supplier nor the incoming inspection was identified. Only the top section was delivered as expected." "The employee did not measure the coupler height, but instead used the dimensions that were most frequently measured."
Poor Identification and traceability	"Unmarked/unidentified material was received from the store." "Metrology Laboratory could not calibrate due to a lack of traceability because no asset number was on the scale."

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Main theme: Participant's perception of what causes defective wagons to be manufactured	
Sub-theme	**Quotations from responses**
	"There are no material markers to identify or mark the material." "The store has no control over the quality of dye sprays." "No lockable or access-controlled NCR area, material (safety chain) was rejected but was later taken to the production line." "Missing actual amps and volts data on 2.4 daily welding machine verification"

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Appendix H: Participant perception of recommendations to minimise defective wagon production

Table 4.5: Recommendations to minimise defective wagon production.

Main theme: Participant perception of recommendations to minimise defective wagon production	
Sub-theme	**Quotations from responses**
Knowledge management and communication	"My recommendation is that proper communication and effective distribution to all relevant disciplines be prioritized to ensure that the product always meets the most recent requirements" "I believe that effective communication is critical to ensuring that all project stakeholders have a common understanding of the project requirements." "Written communication is preferred for record keeping and possible future reference." "Develop a clear strategy and structure that is accessible to all employees" "Promote communication and tracking of various stakeholders' activities"
Continual employees training	"Create more training for operators manufacturing wagons so that they understand the concept of quality" "My suggestion is that industry allocate more funding and budget to training" "Employees should receive training and be held responsible for failing to comply "
Technology management	"To keep up with current trends, the organization's technology should be improved."
Organizational culture and climate	"Starts from the top"
Organizational structures and governance	"The current organizational structure must be restructured." "Individuals with leadership qualities should be trained." "I believe management should consider developing trust and expanding organizational boundaries."

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	“To improve responsibility or lack of ownership, a decision should be made with buy-in from everyone in the organization.”
Equipment reliability	“Ensure that all production tools and equipment are serviced or maintained.” “Before using a welding machine, the operator and supervisor must inspect them to ensure that they are still in good working order.”

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