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APPLICATION OF DMAIC TECHNIQUE TO IMPROVE SUPPLY CHAIN EFFICIENCY

By

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Declaration

I declare that this study is my original work, and that, to the best of my knowledge, it contains no material that has previously been published or authored by another person, nor does it contain content that has been substantially used to obtain any other academic degree at Durban University of Technology or any other educational institution. Additionally, I declare that the intellectual substance contained in this thesis is the result of my efforts. This study acknowledges any support offered by others, notably in the use of sample analysis equipment.

01/05/2024

Bongakonke Thandwayinkosi Mthembu Date:

Dedication

I dedicate this study to my parents, my father Mr. T.H Mthembu, and my mother Mrs. H.N Mthembu, whose steadfast support has been important in my academic path since the beginning. I also dedicate this work to my cousin, Mr. T.S Xulu, whose support and motivation have tremendously influenced me during my studies.

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Publications

1. B. T. Mthembu, B. T. Mncwango and O. A. Olanrewaju, "Enhancing Supply Chain Performance: Strategies for Material Waste Reduction and Process Efficiency Enhancement," *2024 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, Bangkok, Thailand, 2024, pp. 1019-1023, doi: 10.1109/IEEM62345.2024.10857112.
2. B. T. Mthembu, B. T. Mncwango and O. A. Olanrewaju, "Exploring Supply Chain Efficiency: Unravelling Root Causes of Waste in Sugar Refining Operations," *2024 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, Bangkok, Thailand, 2024, pp. 375-379, doi: 10.1109/IEEM62345.2024.10857141.

Abstract

This study presents a detailed analysis of the use of Lean manufacturing approaches to improve operational efficiency and minimize waste in the production processes of a sugar packaging company situated in South Africa. Faced with obstacles in fulfilling waste reduction targets and improving operational efficiency, the study attempted to carefully identify underlying sources of waste and implement Lean concepts, notably the DMAIC technique.

The study used a range of Lean problem-solving approaches, beginning with an ABC analysis to identify Stock Keeping Units (SKU) with the greatest waste levels, followed by a mix of the 5- Whys probing methodology and Ishikawa diagrams to go deeper into waste reduction initiatives. Matrix prioritization was then used to prioritize actions and implementations that address identified inefficiencies and issues, leading to the creation and execution of an implementation strategy.

During the improvement phase, waste was significantly reduced, notably in the 500g stock-keeping unit. Despite encountering obstacles associated with 1 kg SKUs, due to variances in the Bill of Materials (BOM), significant progress was accomplished. The DMAIC framework offered an organized method that included problem identification, process evaluation, data analysis, improvement implementation, and control installation.

The study indicated significant waste levels, which were above weekly targets, resulting in a 70% production efficiency, (or 30% inefficiency), emphasizing the need for process improvements. Among other recommendations, the study suggests improving supervisor handover methods and introducing non-conformance reports (NCRs) to increase supplier responsibility and raw material quality. Supplier participation in performance reviews emerged as a crucial driver in dramatically decreasing waste and increasing production efficiency, resulting in a remarkable 20% improvement in production efficiency, thus raising the production efficiency levels to 90%.

In essence, this study sheds light on the efficacy of the DMAIC methodology within the sugar company, offering practical insights into enhancing supply chain efficiency and minimizing waste. By targeting significant process inefficiencies, the research contributes to enhancing sugar production operations, benefiting stakeholders, and bolstering industry competitiveness. The results advocate for the adoption of Lean methodologies to optimize production processes and enhance profitability.

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1. CHAPTER ONE: INTRODUCTION

1.1 Background and Context

Organizations are constantly looking for ways to improve their operations, increase efficiency, and provide more value to their consumers in today's dynamic and competitive business environment [1]. The search for operational excellence has resulted in a greater emphasis on process improvement, a systematic method aimed at improving processes, minimizing waste, and refining procedures to generate better results [2]. Process improvement has become a cornerstone of success in a wide range of industries, allowing businesses to stay ahead of the competition and adapt to changing market needs.

In the sugar refining industry, process improvement is particularly critical. Refineries face unique challenges, such as managing complex production processes, dealing with perishable raw materials, and adhering to strict quality standards. Inefficiencies in these processes can lead to significant waste, both in terms of raw materials and operational costs, ultimately affecting profitability and market competitiveness. By focusing on process improvement, sugar refineries can enhance their production efficiency, reduce waste, and ensure high-quality output. This not only helps in meeting regulatory standards but also in fulfilling customer expectations for consistent product quality.

Process improvement is important for reasons other than operational efficiency. It entails improving product quality, customer satisfaction, and overall organizational performance. Organizations can streamline their operations, decrease costs, and speed up the pace at which products and services are brought to market by fine-tuning internal processes. This flexibility not only increases productivity but also enables companies to better satisfy consumer demands and respond to shifting trends.

1.2 Process Improvement Methodologies

Methodologies for process improvement give formal structures for systematically evaluating, analysing, and perfecting many areas of an organization's activities [3]. One of the effective methodologies is Six Sigma Define, Measure, Analyse, Improve, and Control (DMAIC). It is a data-driven and organized technique for finding inefficiencies, fundamental causes of issues, and possibilities for improvement [4]. It has been utilized in a wide range of industries, from manufacturing and healthcare to finance and services, showing its flexibility and success in a variety of scenarios.

The purpose of process improvement is to promote a culture of continuous improvement in which every person is empowered to detect bottlenecks, offer changes, and contribute to the general growth of the firm. According to Rebouillat [5], by embracing process improvement methodologies such as DMAIC, businesses not only improve their internal operations but also develop an environment of innovation and collaboration, laying the foundation for long-term success in an ever-changing business environment.

Lean management, a methodology focusing on creating more efficient production systems by eliminating waste while maintaining quality [6], complements DMAIC. Lean principles, often capitalized to denote the improvement philosophy, aim to reduce waste, boost productivity, and improve value for customers [7]. Originally developed for manufacturing, Lean methods are increasingly applied in service industries to enhance operational effectiveness and customer satisfaction [8]

1.3 Supply Chain and Waste Reduction

A supply chain encompasses the entire network from suppliers and manufacturers to warehouses, distribution hubs, and retailers, through which raw materials are processed and transported [9]. Kehoe [10] describes a supply chain as a system that incorporates planning, sourcing, production, and process development, with material suppliers, manufacturing facilities, distribution hubs, and customers as key elements. Sandoval and Ramos [11] elaborate that these components are linked by the forward movement of materials and the backward flow of knowledge. Similarly, Haddouch et al. [12] assert that the supply chain has a dependent and partially irregular relationship between companies that use sequence communication networks to jointly purchase and convert raw materials into the final products.

In the context of the sugar refining industry, managing the supply chain effectively is crucial due to the complexity of the processes involved and the perishable nature of raw materials. Efficient supply chain management ensures that sugar refineries can reduce waste, optimize production schedules, and maintain high-quality standards throughout the production cycle.

A systematic approach to process improvement, such as Lean management, aims to reduce waste, enhance productivity, and improve customer value. Although Lean principles originated in manufacturing, they are increasingly adopted in service organizations to boost operational efficiency and customer satisfaction [13].

1.4 Procurement Processes and Impact on Waste

Efficient procurement methods are critical in today's supply chain management. Apart from cost savings and supplier performance, one key issue that is sometimes disregarded is their major effect on material waste throughout the manufacturing phase [14]. An optimum procurement process guarantees that the appropriate materials are obtained in the appropriate amount, quality, and period. Excess inventory, increased storage expenses, and eventually material waste as products decay or become outdated can all result from over-purchasing resources. Under-purchasing, on the other hand, might result in manufacturing delays and rework, resulting in material and time waste [15]. Organizations may successfully reduce material waste by matching procurement with production demands.

Applying Lean principles in procurement, such as Just-in-Time (JIT) procurement, helps minimize excess inventory and prevent overproduction, significant sources of material waste [16]. Efficient procurement, influenced by Lean thinking may save resources from lying idling and decaying in storage, resulting in less waste in the manufacturing process.

Measuring procurement performance with key performance indicators (KPIs) such as supplier performance and on-time delivery has a direct influence on material waste. Effective supplier management ensures that supplies satisfy quality requirements, lowering the likelihood of defects or production mistakes, which frequently result in waste [17]. On-time delivery also reduces manufacturing delays, which might result in material deterioration or expiry.

As Prajogo et al. [18] suggest, combining supply chain performance metrics with procurement performance metrics improves total supply chain efficiency. This connection improves forecasting and planning, ensuring that materials are accessible when required. By avoiding supply chain interruptions, the risk of material waste due to unplanned delays or shortages is reduced.

Sustainability-focused procurement techniques may drastically minimize material waste. Sustainable sourcing, which considers environmental considerations as well as product longevity, yields resources that are less prone to deterioration or spoiling.

Organizations may contribute to a more sustainable supply chain and lower their overall material waste impact by selecting environmentally friendly choices.

Adopting a balanced scorecard to evaluate procurement performance provides insights into how procurement decisions affect material waste [19]. Organizations acquire a holistic perspective of their efforts to eliminate waste and enhance supply chain efficiency by assessing procurement's contribution to waste reduction across many dimensions.

Efficient procurement processes are a key component of supply chain management, and their influence goes far beyond cost control [20]. An improved procurement process based on Lean principles helps to reduce material waste in manufacturing. Organizations can not only streamline their procurement but also minimize material wastage by measuring procurement performance, integrating supply chain metrics, considering sustainability, and implementing a balanced approach to waste reduction.

1.5 Company Description

AXY company is a diverse firm with activities in several agricultural and Agri-processing industries. The company has a long history that dates to the nineteenth century and has evolved to become a major participant in the African agri-business sector. The company's principal concentration is on sugarcane farming, which serves as a crucial raw material for sugar manufacture. The company is active in sugarcane cultivation in numerous Southern African countries, including South Africa, Mozambique, Zimbabwe, and Swaziland.

The company engages in a variety of different business categories, including land management and property development, in addition to its sugarcane activities. The corporation strategically uses its land holdings to produce wealth and contribute to the development of sustainable communities. The company produces sugar in several bag sizes; different suppliers supply these various bag sizes (raw materials). It has observed varying conduct from its suppliers in terms of quality and delivery. The company prioritizes sustainable business practices such as environmental protection and community development. They are dedicated to ensuring that their activities have a beneficial influence on the communities in which they operate and the environment with which they engage.

Production controllers oversee ordering products from these stores, and they carefully check inventory levels on the factory floor before making orders. Their ordering method is flexible, as opposed to a rigorous first-in, first-out (FIFO) approach, guaranteeing that production is never hampered due to material shortages.

When the paper reels arrive on the production floor, they are turned into high-quality sugar products. If the materials are discovered to be faulty or unsuitable for production, the corporation immediately commences a Non-Conformance Report (NCR) process, alerting the supplier of the problem. Only the best items make it to the internal warehouse, where they are kept until they are needed.

The supply chain process is completely represented in Figure 1 below, illustrating each stage in their efficient and successful supply chain management.

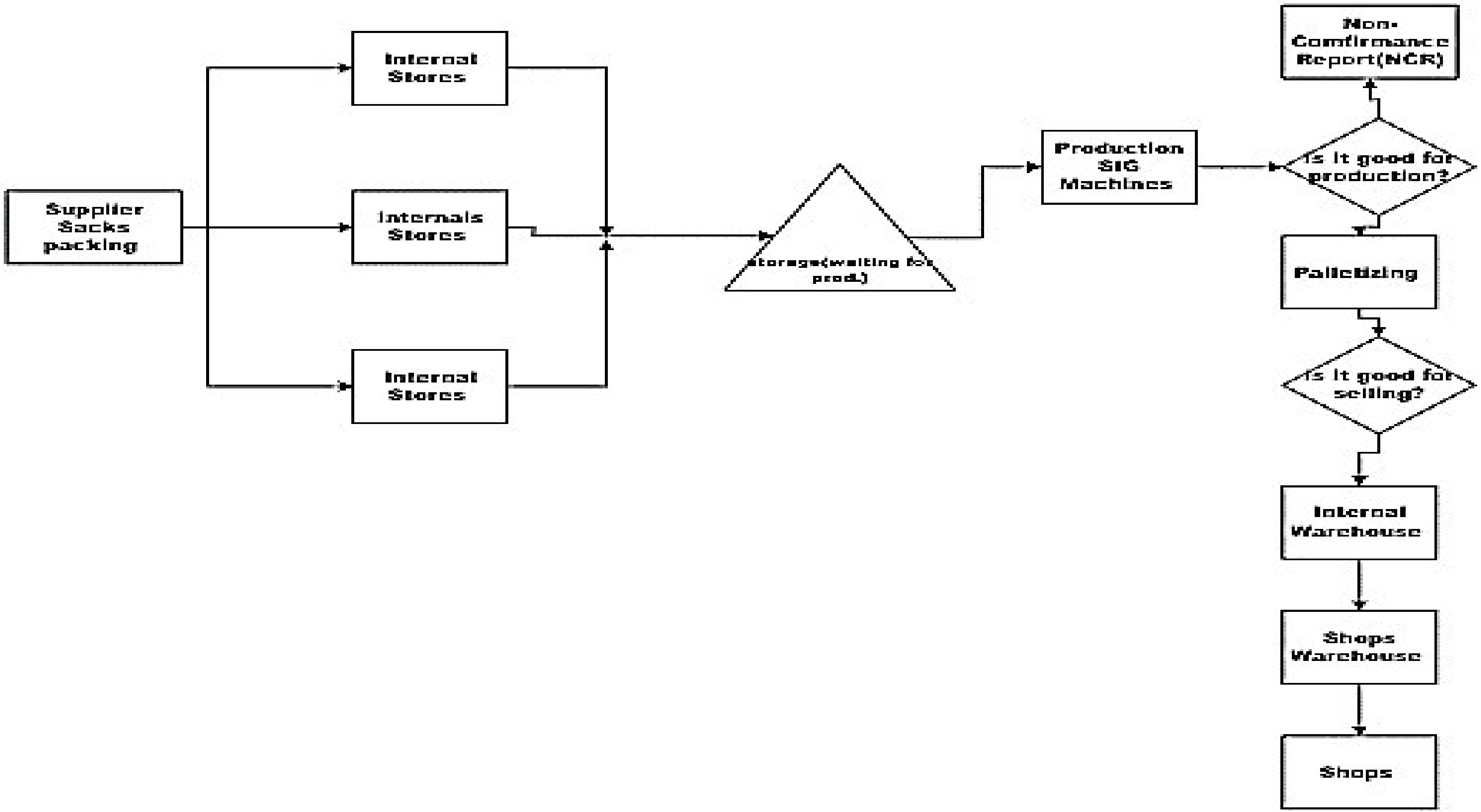


Figure 1: Supply Chain Process Layout

1.6 Problem Statement

Refined sugar is packed in various pack sizes ranging from 1.2 tons to 250g. Its annual production is approximately 420000 tons with an annual cost of R147 million in raw materials (bags, paper, and plastic) in kg. The company has faced difficulty in meeting its weekly waste target of 0.5 tons. The failure to meet this target has been attributed to several problems, including a decreased number of productions, and waste of material wastage on the production floor. As a result, the company has faced reduced operating efficiency, accumulation of extra material on the production floor, and increased waste costs. Companies that fail to review their simplified production line procedures are more likely to generate process waste, such as extra work-in-process inventory and poor space utilization [21]. Figure 2 and Figure 3 display data from June 26 to July 30, 2023, illustrating the cost of waste and waste per ton, respectively.

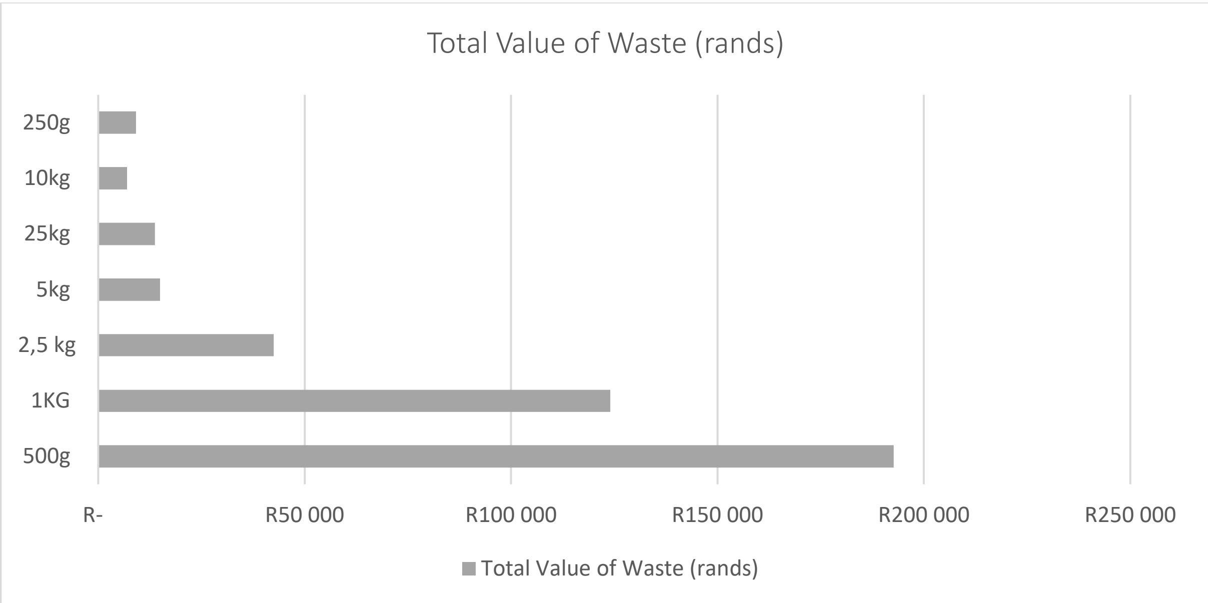


Figure 2: Cost of Waste

Figure 2 illustrates the cost per ton including raw material. The graph illustrates the combined Rand cost per ton of raw materials and sugar, along with the cost of material waste in kilograms, converted into Rand. The Company receives raw materials in the form of bags of sugar from various suppliers. Numerous packs of raw materials were left on the floor, no operators were processing them, and some needed to be returned and stored away from the production line. The production area accumulates a significant amount of unfinished paper reels that are not returned to the supplier for valid reasons. It was discovered that the production area was cluttered with incomplete paper reels, contributing to waste. The company is using the term NCR (Non-Conformance Report) as the term for returning to the supplier. The company is facing inflated material costs, but it is unclear whether the issue lies with the supplier or the production team.

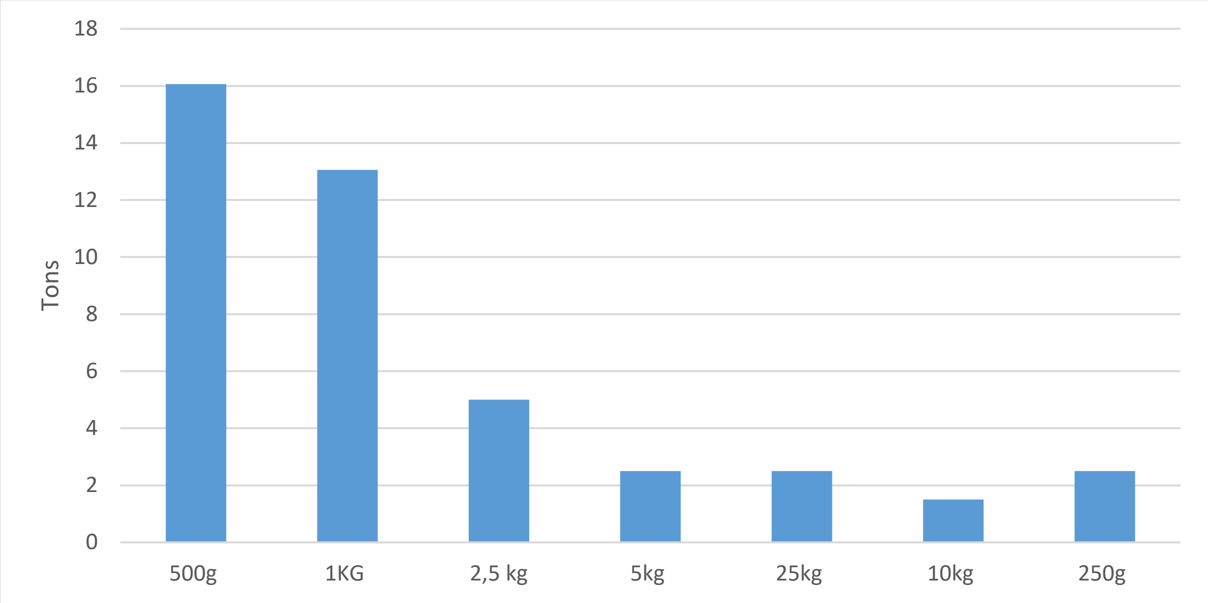


Figure 3: Waste per ton.

Figure 3 highlights high waste levels, indicating a need for consistent implementation of continuous improvement strategies such as Six Sigma.

1.7 Aim

This research aims to investigate the root causes of waste and improve supply chain efficiency through the Systematic implementation of DMAIC, a Six Sigma tool. Additionally, it seeks to investigate the influence of supplier performance, particularly regarding NCR, on waste indicators within the company.

1.8 Research Objectives

The research objectives are:

- Investigate case studies where DMAIC was implemented, to provide direction of implementation grounded on the theory or literature.
- To investigate the existing levels of waste and performance efficiencies.
- To investigate and identify the primary Stock Keeping Unit (SKU) leading to waste.
- To implement the DMAIC methodology to provide solutions for reducing material waste and increasing supply chain efficiency.

1.9 Research Questions

The primary research question is: How can the DMAIC technique be applied to identify and address supply chain inefficiencies while reducing company costs? This leads to four sub-questions:

- Where have case studies utilizing DMAIC been done, and how do different locations affect the outcomes and applicability of the DMAIC methodology?
- What is the current waste and performance levels?
- Which SKU is contributing to the high wastage?
- What are the solutions that can be implemented to improve supply chain efficiencies, emanating from the implantation of DMAIC?

1.10 Hypothesis of the study

The application of DMAIC is expected to result in considerable improvements in supply chain efficiency, resulting in cost savings, higher resource utilization, increased customer satisfaction, and overall operational excellence. By systematically discovering, assessing, and resolving numerous types of waste—including overproduction, excess inventory, underused resources, and inefficient processes—companies utilizing the DMAIC method are expected to experience significant improvements in supply chain efficiency.

1.11 Significance of study

The significance of this study develops from its ability to address significant difficulties in the sugar industry using the DMAIC methodology. The sugar company has a wide range of supply chain management concerns, including sugar waste and material waste. This study attempts to maximize operational efficiency, reduce waste, and improve quality by systematically using DMAIC. Furthermore, the study complements the academic debate by giving actual evidence for the success of DMAIC in a real-world industrial scenario. The findings are likely to educate practitioners, regulators, and researchers seeking long-term solutions for supply chain optimization in the sugar industry.

1.12 Research Methodology

This section describes the study approach used to analyse the selected SKU in the context of supply chain optimization. Research philosophy offers the basic perspective that drives the gathering, interpretation, and application of data about a particular topic [22]. The use of ABC analysis was instrumental in selecting the SKU under consideration in this study.

ABC analysis categorizes SKUs into three groups—A, B, and C—based on their impact on overall inventory value and usage frequency. Category A includes the most critical SKUs that contribute significantly to costs, while Category C consists of lower-impact SKUs. This categorization enables the identification of key SKUs that require more attention for cost reduction and efficiency improvements, guiding strategic decision-making in supply chain management.

It is also significant that this study used the DMAIC approach as an important structure for supply chain process improvement. DMAIC is the Six Sigma tool that provides an organized and data-driven strategy to systematically identifying, analysing, and improving processes. The DMAIC framework allows us to describe the problem, assess existing processes, analyse data to discover inefficiencies, make changes, and develop controls to ensure long-term success. The use of the DMAIC methodology strengthens the robustness and rigor of our research approach, allowing for a thorough evaluation of the SKU's influence on supply chain efficiency. Data on waste will then be collected, and the root causes will be identified using the fishbone diagram approach. Strategies for improving supply chain efficiency and reducing waste will be devised and executed based on a comprehensive examination of these core causes. The research approach employed in this study is described fully in Chapter 3.

1.13 Limitations

The present research investigates the use of the DMAIC method a Six Sigma tool to improve productivity in the context of supply chain operations in the sugar industry, with a particular focus on reducing waste. Several limitations have been discovered when this research, which should be carefully considered:

The Company's dependence on a Manual System:

The research faces a significant constraint in the shape of the company's dependence on a manual system. This traditional way of operation limits access to historical data and documents, which are critical for performing a complete analysis and understanding the company's developmental history. This constraint may limit the depth of insights gained from this study. Specifically, the manual system of capturing data to SAP means that waste is recorded manually, dependent on what the operator records or the differences noted from the start sensor to the end sensor.

The reliance on a manual approach may limit the depth of the results. Analysing and projecting outcomes requires caution. Future research should address these constraints to gain a better knowledge of Lean management in the sugar industry's supply chain.

1.13 Thesis Outline

This thesis is divided into five chapters, each of which contributes to a detailed grasp of the study issue and its effects. These chapters have been carefully developed to balance one another and make a complete thesis.

Chapter 1: Overview and Research Objectives

The first chapter of this thesis serves as a foundation for the entire thesis. It gives an overview picture of the research initiative in this chapter, introducing the primary study issue, describing the specific research questions that drive this thesis, and explaining the aims that support this study. Chapter 1 establishes a structure for the following research and evaluation by outlining the study's objective and limitations.

Chapter 2: Literature Review

The second chapter is dedicated to a thorough evaluation of the existing studies of information relevant to this thesis. This critical review of linked literature not only synthesizes earlier research findings but also identifies key connections between this body of knowledge and the current investigation.

Chapter 3: Research Methodology

The research approach used in this study is thoroughly explained in Chapter 3. It describes the study design, whether qualitative, quantitative, or mixed-methods approach, as well as the data-gathering tactics and procedures used. Furthermore, this chapter elaborates on the ethical concerns regulating the research process and covers issues of reliability and validity, assuring the study methodology's robustness.

Chapter 4: Findings and Results

The conclusion of data collecting and analysis activities is shown in Chapter 4. The findings of the data analysis are revealed here, along with relevant graphical representations and tables. The data findings are meticulously interpreted, allowing readers to understand their importance in the context of the study topics. This chapter also includes a careful discussion that connects the findings to the current literature, giving light on their implications.

Chapter 5: Conclusion and Recommendations

The final chapter, Chapter 5, acts as the thesis' conclusion. It highlights the core of the study by summarizing the research questions, objectives, and findings. Furthermore, this chapter summarizes the contributions made to the field of study and explores the practical consequences of the research findings. As a final comment, Chapter 5 makes recommendations for future research activities, indicating opportunities for additional inquiry and development.

1.14 Chapter Conclusion

The introduction to this chapter provided background information on the study issue and its historical context. It also described the company's product description, as well as its mission, aims, and research themes. This chapter also emphasized the relevance of the study, its limitations, and its chapter design. The next chapter contains the results of the literature review undertaken for this study. There is a wealth of literature on the application of Lean management to enhance the manufacturing industry. When used to enhance supply chain processes, Lean has produced significant improvements. As a result, it will be used in this study to increase the efficiency of the supply chain in the sugar industry.

2. CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide a comprehensive review of the existing literature related to supply chain efficiencies and waste reduction, focusing on the application of the DMAIC methodology and Lean principles. Several studies [23], [24], [25], and [26] highlight that DMAIC stabilizes and unifies the supply chain process by identifying trouble spots, implementing effective change management techniques, and reducing process variance. This review is structured to align with the study's objectives, presenting relevant theories, case studies, and findings in a logical sequence. Each section is tied to the research objectives, ensuring that the literature reviewed is pertinent and forms a solid foundation for the study.

2.2 Review of Lean in Production or Manufacturing Sector

Lean principles, combined with the Six Sigma-DMAIC methodology, have been extensively applied in the manufacturing sector to enhance process efficiency and product quality. Research by Pei et al. [24] Majstorovic and Sibalija [27], and Desai and Shrivastava [25] exemplify the successful application of DMAIC in various manufacturing contexts. These studies highlight the effectiveness of DMAIC in identifying and eliminating sources of variation, optimizing operational processes, and sustaining performance improvements in manufacturing.

Pei et al. [24] investigated process variation in Taiwan's food sector. Their DMAIC implementation decreased the failure rate of miniature custard buns by 70%. Furthermore, the study has presented principles about what makes a Six Sigma project in the food industry successful. While this study supports DMAIC's usefulness, it lacks an analysis of implementation issues and solutions for overcoming them, creating a vacuum in understanding possible hurdles.

DMAIC was utilized in Serbian metal manufacturing by Majstorovic and Sibalija [27]. The study successfully decreased process variability while increasing the Sigma Level. The study, however, lacks an in-depth investigation of the impact of these changes on product quality and customer satisfaction, limiting insight into the study's larger implications.

Desai and Shrivastava [25] demonstrated the influence of DMAIC on quality and productivity. The study was a success in terms of increasing process yield and output quality. The study investigates the use of the Six Sigma DMAIC approach in a specific sector. With correctly executed control plans, this technique provides a framework for detecting, characterizing, and removing sources of variation in each operational process, optimizing the operation variables, and boosting and sustaining performance, i.e., process yield. Despite these accomplishments, the study does not evaluate the long-term survivability of these advances or how prospective changes in operational factors may affect results, leaving a gap in long-term viability.

Gijo et al. [26] give a case study based on the Grinding Process, demonstrating the Six Sigma DMAIC methodology in action. The major goal of DMAIC in this situation was to reduce process variation and increase process yield. This research demonstrates how using this organized strategy may accelerate a manufacturing process to a world-class level of excellence. The use of the Six Sigma technique resulted in a significant decrease in mistakes throughout the fine grinding process, which dropped from 16.6% to 1.19%. The impact went beyond process improvement, greatly improving the company's financial outlook. Rework was reduced, scrap prices were cut, man-hours were saved, and productivity was increased. Surprisingly, this endeavour resulted in an expected yearly savings of almost USD 2.4 million.

De Mast and Lokkerbol [28] analysed the Six Sigma DMAIC technique via a problem-solving perspective. Their research includes a thorough examination of DMAIC, as well as ideas taken from problem-solving scientific theories. The primary goal of this study is to define the parameters within which the approach functions. The authors contend that identifying these constraints might motivate efforts to improve the technique. Furthermore, the authors argue that DMAIC may have inherent restrictions owing to the impracticality of a universally omnipotent procedure without limitations. Notably, these constraints give a pragmatic advantage by providing a framework to guide users toward appropriateness when applying the DMAIC approach.

Roy et al. [29] conducted a detailed examination of the operational procedures of a specified organization to measure and enhance the current sigma level through increased productivity. The Six Sigma DMAIC cycle was strategically used as part of the methodology used for this attempt. The research successfully used the DMAIC approach to boost production by lowering the failure rate. This research was undertaken within a fan manufacturing company, giving an instructive example of how Six Sigma may create quality and efficiency improvements. It is worth noting that the insights gained from this research apply to a wide range of enterprises, not only fan manufacturing companies. Six Sigma deployment results in a harmonious synchronization of essential aspects such as cost, quality, production time, and control time. The data analysis in the study emphasizes the importance of implementing the 5s approach, demonstrating that its incorporation reduces repeated activities and so saves significant time. This multimodal strategy has resulted in a considerable reduction in the chance of generating faulty goods, which aligns with Six Sigma's goal of defect prevention.

Furthermore, the research looks at the advantages of line balancing, which enhances output by minimizing failures. As a result of this strategic approach, daily production rates increased significantly, rising from 240 to 312 units per day. This increase in output coincides with the basic goal of increasing output levels, underlining the major emphasis of this study. However, the study may benefit from a more in-depth examination of the individual operational factors that were improved and how these modifications affected the results, therefore filling a gap in complete process understanding.

The study by Chan et al. [30] developed a DMAIC methodology within the context of Lean Six Sigma (LSS). The study focuses on the pressing difficulty that SMEs confront while competing with powerful rivals, particularly larger firms that may provide superior products at lower prices. The implementation of DMAIC as a solution was the subject of this inquiry. The authors created and evaluated the DMAIC framework inside a label printing firm that produces computer labels, offset and silkscreen stickers, and barcode labels, among other label kinds. The use of the DMAIC methodology inside this SME label printing organization resulted in a significant increase in label printing productivity. Impressively, the division's productivity increased by 584 impressions per hour, representing a 21.93% increase over the previous manufacturing output. While the study clearly illustrates DMAIC's potential for SMEs, it lacks a detailed evaluation of potential SMEs-specific difficulties and solutions, resulting in a deficit in practical implementation assistance.

2.3 Review of Lean in Supply Chain

The adoption of Lean principles in supply chain management has been shown to address critical challenges such as poor information quality, lack of visibility, and supplier performance issues. Jayaram et al. [31], Agus and Hajinoor [32], and Patri [33] provide insights into the application of Lean techniques in supply chain contexts. These studies illustrate how Lean principles can be leveraged to streamline supply chain processes, reduce waste, and improve overall efficiency.

The study by Jayaram et al. [31] looked at the difficulty companies encounter while managing their supply chains. In this study, some of the most significant challenges were poor information quality, a lack of supply chain visibility, and poor supplier performance. The study suggested using Lean techniques, such as Just-In-Time and Value Stream Mapping, to address these issues. The study concluded that using Lean methods might enhance the effectiveness of supply chain operations generally, however, it did not go into detail regarding gaps in their study or future research.

In another research, Agus and Hajinoor [32] examined how the performance of manufacturing companies in Nigeria was affected by the adoption of Lean production and supply chain management. The findings demonstrated that the manufacturing and supply chain operations were more effective and efficient with the adoption of Lean principles including Total Quality Management, 5S, and Just-In-Time. The authors discovered that firms may cut lead times, get rid of waste, and boost the quality of their goods and services by using Lean principles. Similarly, Patri [33] looked at the difficulties Indian cold chain coordination businesses experience. According to the report, some of the most significant challenges were a lack of infrastructure, ineffective logistics, and subpar supply chain management. The authors suggested using Lean techniques like Kaizen, 5S, and Standard Operating Procedures (SOPs) to address these issues. The study concluded that implementing Lean methods might enhance the efficiency of cold chain logistics procedures overall.

Further highlighting the use of JIT and Kanban, Bappi [34], the study analysed the impact of Lean supply chain management on the performance of Pakistani textile firms. The results showed that the adoption of Lean principles such as pull production, Kanban, and Just-In-Time improved the supply chain efficiency and reduced lead times and inventory carrying costs. The study concluded that Lean principles and tools could help organizations achieve a competitive advantage by improving the performance of their supply chain processes.

Applying Lean concepts to a Brazilian automotive supply chain significantly improved inventory control and delivery performance [35]. The usefulness of Lean concepts in many situations, such as service sectors and emerging economies, is however not well studied. Total Quality Management (TQM) is frequently used in supply chain management, and the research has looked at how it affects productivity. Phan et al. [36] investigated a Vietnamese manufacturing company's supplier performance and customer satisfaction significantly improved after adopting TQM techniques. More study is required, though, to determine the precise TQM techniques that work best in various supply chain environments. There is an expanding text of study on the effectiveness of these technologies, which are used by many firms to increase supply chain efficiency. In a study by Zailani et al. [37], the implementation of RFID technology in a Malaysian logistics firm increased inventory accuracy and decreased labour expenses. However, there is a lack of information on how combining various IT technologies affects the effectiveness of the supply chain.

The use of Six Sigma in supply chain management has also been studied. For instance, research by Näslund [38] discovered that a Danish food processing company's use of the Six Sigma methodology enhanced delivery performance and decreased production variability.

However, the efficiency of Six Sigma in complex and dynamic supply chain systems hasn't been well studied. To increase operational effectiveness and quality, the Lean Six Sigma technique combines Six Sigma (lower variability) with Lean principles (reduce waste). The use of Lean Six Sigma concepts results in shorter lead times, better on-time delivery, and lower operational costs, according to research by Madhani [39].

2.4 Review of Lean In-Service Sectors

The application of Lean principles in the service sector has shown significant potential in reducing waste and improving efficiency. Lean has been implemented in the service sector to reduce waste. Some of those studies that revealed the successful application in this sector include the study of [23], [40] and [41], among others. These studies underscore the relevance of Lean principles in non-manufacturing contexts, demonstrating their potential to address sector-specific challenges and improve service delivery.

The goal of Silva *et al.'s* [23] research was to locate and evaluate how Lean tools were applied to determine which Lean tool to use to solve the problem at a high education level. There is a lack of student equipment supply at the high education level. The study used a qualitative methodology and focused on the use of Lean technologies like continuous improvement and DMAIC. Lean Six Sigma (LSS) received 38.89% of the articles and was the instrument that received the most discussion. Using this instrument, it was feasible to DMAIC the processes of educational institutions. The Voice of the Customer (VOC) tool was used to determine who the institutions' customers were and what values needed to be communicated, placing it in second place overall with 13.89%. The research found several difficulties encountered with implementing Lean thinking in education. Some of these issues included resistance to change, a lack of leadership commitment, insufficient awareness and understanding of Lean principles, and the challenge of adapting manufacturing-focused concepts to the specifics of the educational sector.

The adoption of Lean in higher education in India was the main topic of the study by Sinha and Mishra [40]. Student satisfaction increased because of the study's use of Lean techniques like process mapping and visual management to find and get rid of waste. The value stream helps to eliminate non-value-added time, but the research falls short of eliminating all non-value-added time, particularly because the main issue with the study was getting to and from courses. The study makes it clear that the time is now for higher education in India to begin implementing Lean approaches. The report describes how the application of Lean thinking has enhanced the process's future state relative to its present state. The main objective is to eliminate the many forms of educational waste and create the ideal environment where everyone actively participates in daily growth.

According to Bilakhia [41], Lean initiatives were used to evaluate their impact on various aspects of patient satisfaction. The results show that patient satisfaction at M.P. Shah Hospital has been positively impacted by Lean management. The hospital was able to improve patient satisfaction by streamlining procedures, lowering wait times, improving staff communication, and using Lean concepts. Higher patient satisfaction levels were the outcome of these changes in terms of service quality, staff responsiveness, and the physical atmosphere of the hospital, among other factors. In the report, the hospital's use of certain Lean tools and practices, including value stream mapping, visual management, and continuous improvement projects, is highlighted. It also stresses how crucial it is to involve hospital workers in the Lean transformation process to guarantee its implementation. The article concludes that Lean Management can be a useful strategy for improving patient satisfaction levels at non-profit hospitals. Hospitals can enhance the general healthcare experience for patients, ultimately resulting in improved satisfaction levels, by removing inefficiencies and concentrating on patient-centred treatment. The article helps healthcare organizations looking to improve patient experience through process improvement projects by delivering insightful information about the beneficial effects of Lean management on patient satisfaction in a not-for-profit hospital setting.

2.5 Review of Lean in Procurement

Lean principles have also been effectively applied to procurement processes, enhancing efficiency and supplier performance. Research by Handfield et al. [42], Buzzetto et al. [43], and Meriläinen [44] highlight the positive impact of Lean tools on procurement strategies. These studies emphasize the importance of strategic procurement practices and the application of Lean tools in optimizing procurement processes and enhancing organizational performance.

Handfield et al. [42] state that the study's goal was to look at the connection between company success and procurement strategy. To test their theories, the researchers gathered survey information from 325 executives and experts in procurement. According to the study, procurement strategy significantly affects corporate performance. The influence of other elements, such as organizational culture or industry-specific characteristics, on company success, however, was not considered by the study.

Buzzetto et al. [43] looked at how Chinese construction enterprises performed concerning their procurement practices. According to the report, procurement tactics including supplier management, supplier selection, and quality control greatly enhance the performance of construction companies. Similarly, Meriläinen [44] discovered that adopting an early supplier engagement (ESI) strategy may greatly increase the effectiveness of procurement procedures in the construction sector. Windapo et al. [45] research, which looked at how procurement strategy affected the performance of small and medium-sized businesses (SMEs) in the UK construction sector, is another pertinent one. According to the study, SMEs may considerably boost their performance by using collaborative procurement techniques such as alliances and partnerships, supplier development initiatives, and supplier selection.

Other research on procurement strategy focuses on using technology to increase procurement efficiency. For instance, Madzimure et al. [46] investigated how e-procurement affected the efficiency of procurement. According to the study, e-procurement considerably increases procurement efficiency by lowering lead and cycle times and improving supplier performance through improved communication.

Taghipour et al. [47] looked at the adoption of Lean procurement techniques at a Spanish hospital. The implementation of Lean techniques, such as value stream mapping and just-in-time delivery, improved supplier performance, decreased lead times and raised worker satisfaction, according to the authors. Value stream mapping was utilized in the research as a technique to enhance the performance of the supply chain, however, the value stream's data were not presented. Similarly, Álvarez et al. [48] study looked at the application of value stream mapping (VSM) in a Spanish automaker's procurement procedure. According to the research, VSM deployment decreased lead times and inventory levels and enhanced coordination and communication between the procurement team and other departments. In general, the research was effective in utilizing VSM to increase procurement efficiency.

Şişman [49] investigated how a Turkish manufacturing business used the Lean Six Sigma (LSS) approach in its procurement process. The implementation of LSS, according to the study, led to a 63% decrease in the lead time of the procurement process, a 20% decrease in material costs, and an improvement in supplier performance. The study was successful because it showed all the data's specifics and the findings' percentages, making it simple to follow the suggestions for the next study. Fred’s [50] investigation of the application of Lean tools in a Ugandan construction firm's procurement process was part of another study. The study further states that using Lean tools helped to reduce material waste by 16%, the cycle time for the procurement process by 40%, and the cost of procurement by 20%. Similarly, a study by Odiba et al. [51], the use of Lean techniques in local government procurement in the UK. The study concludes that using Lean tools boosted efficiency in tasks like creating bid papers, choosing suppliers, and going through the negotiating process.

A study conducted by Fish [52] showed that procurement efficiency lowers operating costs improves supplier quality, develops collaboration between suppliers and consumers, and supports innovation. The study also shows that good supplier management, strategic sourcing, and the development of long-term relationships with suppliers are necessary for procurement efficiency. The study did not define any of the techniques for improving supply chain efficiency.

The study by Uyarra et al. [53] looked at the difficulties faced by Chinese procurement experts. The study reveals that some of the biggest obstacles were a lack of skilled personnel, poor communication, and poor supplier performance. The authors suggested using Lean technologies, such as Six Sigma and Total Quality Management, to address these problems. The study concluded that implementing Lean methods might enhance the performance of procurement procedures.

In an additional investigation by Taghipour et al. [54], the effects of introducing Lean approaches, such as Just-In-Time (JIT), Lean Manufacturing, and Kanban systems, in a manufacturing organization's procurement department. The findings demonstrated that the procurement process was enhanced using JIT, Lean Manufacturing, and Kanban technologies. Results show that JIT decreased cycle time, inventory, and material waste, while Lean manufacturing and Kanban systems allowed the company to manage the flow of supplies and eliminate stock-outs.

Maware and Adetunji [55] examined how Lean management affected a Kuwaiti construction company's procurement procedure. The findings revealed implementing Lean tools and techniques including value stream mapping and kaizen enhanced the procurement procedure, decreased procurement costs, and improved supplier performance. The study concluded that by reducing wasteful tasks and streamlining the procurement process, Lean management might improve procurement procedures. Bajjou et al. [56] investigated how the construction sector may apply Lean thinking and techniques to address procurement issues. The study discovered that by using Lean principles including value stream mapping, supplier development, and standardization, the procurement process could be considerably improved. The authors discovered that decreasing stockouts, cutting down on lead times, and enhancing supplier performance all required the use of Lean technologies like the Kanban system, visual management, and error-proofing.

Christopher and Peck [57] observed in another study that procurement efficiency may greatly enhance supply chain performance by ensuring that supplies are supplied on time, at the correct cost, and in the proper condition. According to the study, strengthening the role of procurement in enhancing supply chain efficiency might be achieved by using creative procurement methods and integrating procurement operations with other supply chain tasks.

Similarly, Pereira et al. [58] discovered that the responsiveness, agility, and flexibility of the supply chain closely correlate with procurement effectiveness. The study found that supply chain efficiency is significantly influenced by procurement, notably in terms of inventory control and risk reduction. Lastly, Christopher and Peck [57] found that by facilitating the coordination of operations between suppliers and consumers, procurement efficiency increases supply chain flexibility. They observed that raising supply chain resilience against uncertainties and disruptions requires boosting procurement efficiency.

2.6 Review of ABC Analysis

ABC analysis, or Pareto analysis, is a valuable tool for inventory management, resource allocation, and supplier management. Research by Ravinder and Misra [59], Alsmadi et al. [60], and Bodina et al. [61] demonstrates the effectiveness of ABC analysis in various domains. These studies underscore the utility of ABC analysis in prioritizing high-value items, suppliers, or patients, resulting in cost savings and enhanced operational efficiency.

Ravinder and Misra [59], Alsmadi et al. [60], and Bodina et al. [61] have investigated the use of ABC analysis in various domains, including inventory management, supply chain optimization, and resource allocation. Ravinder and Misra [59] conducted an interesting study on the usage of ABC analysis in inventory management. They discovered that classifying inventory products into A, B, and C classes based on their worth and consumption patterns helped businesses better allocate their resources. This resulted in lower carrying costs, greater cash flow, and fewer stockouts, all of which increased profitability.

Alsmadi et al. [60] used ABC analysis to manage suppliers in a new environment. Their research found that by categorizing suppliers and allocating resources accordingly, firms were able to strengthen connections with high-value suppliers and optimize procurement procedures. This strategy resulted in cost reductions, higher product quality, and more on-time delivery.

Furthermore, Bodina et al. [61] researched healthcare resource allocation. They used ABC analysis to categorize patients based on their medical resource consumption, allowing hospitals to distribute resources more efficiently like medical staff and equipment. This method lowered patient wait times, increased healthcare quality, and increased patient happiness.

The success of these investigations may be linked to the efficient use of ABC analysis, which offered unambiguous insights regarding resource priority. Organizations were able to spend resources more strategically by focusing on high-value commodities, suppliers, or patients, resulting in cost savings, enhanced efficiency, and improved performance. These examples show how ABC analysis can be a beneficial tool in a variety of sectors, allowing for informed decision-making and eventually contributing to the success of businesses and institutions.

2.7 Application of Six Sigma-DMAIC in Supply Chain

The Six Sigma-DMAIC methodology has been applied in supply chain contexts to reduce lead times, improve quality, and enhance operational efficiency. Tennakoon and Palawatta [62], Baysan et al. [63], and Prashar [64] provide examples of successful DMAIC implementation in supply chain management. These studies demonstrate the versatility of DMAIC in addressing various supply chain challenges, leading to significant cost savings and efficiency improvements.

One of the earliest and most influential studies on the application of DMAIC in supply chain efficiency was conducted by Tennakoon and Palawatta [62], who used DMAIC to reduce the lead time and improve the quality of the warehouse process of a Korean automotive parts company. The authors found that DMAIC helped them to streamline the process, eliminate non-value-added activities, reduce lead time, and improve product quality.

In another study, Baysan et al. [63] applied DMAIC in a Chinese electric company to reduce inventory holding costs. They found that the methodology was successful in identifying and eliminating waste, reducing inventory costs, and improving overall supply chain efficiency. The authors highlight the importance of involving stakeholders and using data analysis in decision-making at every stage of DMAIC.

Additionally, Prashar [64] used the DMAIC methodology in a Chinese construction supply chain to reduce waste and improve operational performance. They found that DMAIC helped identify the root causes of waste in the process and eliminate it, resulting in significant cost savings and improved supply chain efficiency. Moreover, Clancy et al. [65] used DMAIC to reduce waste and improve the efficiency of the supply chain in an Indian pharmaceutical company. The study found that DMAIC helped in identifying the root causes of the problem and developing solutions to improve the supply chain's efficiency.

Gaikwad et al. [66] applied DMAIC in their study to identify and address inefficiencies in the supply chain of a manufacturing company. The Define phase involved mapping the current supply chain processes, and the Measure phase included data collection to analyse process performance. The Analyse phase identified the root causes of supply chain issues, while the Improve phase implemented process changes. The Control phase established monitoring mechanisms to sustain improvements. The specific gaps in this study may depend on the context and findings of the research. However, some potential gaps could include a limited focus on broader supply chain integration, a lack of consideration for external factors impacting the supply chain, or a narrow scope that doesn't encompass the entire supply chain network.

Hachimi's [67], research applied DMAIC to optimize inventory management practices in a distribution centre. The Define phase involved defining inventory objectives and identifying key performance metrics. The Measure phase collected data on inventory levels, accuracy, and other relevant factors. The Analyse phase identified process bottlenecks and root causes of inventory issues. The Improve phase implemented changes to optimize inventory levels and processes. The Control phase established monitoring mechanisms to sustain improvements. Some potential gaps in this study could include limited consideration of demand variability, lack of integration with suppliers or customers, or the absence of advanced inventory optimization techniques beyond traditional statistical approaches.

In conclusion, the DMAIC methodology is a powerful tool that can be applied in procurement processes in supply chains to enhance efficiency, quality, and customer satisfaction. Several studies have demonstrated the effectiveness of DMAIC in improving procurement lead time, inventory levels, supplier performance, supply chain performance, and product quality. Organizations operating in the supply chain should consider adopting the DMAIC methodology to reduce costs, improve efficiency, and enhance profitability.

2.8 Application of Six Sigma-DMAIC in procurement

The DMAIC methodology has proven effective in enhancing procurement processes by identifying and eliminating inefficiencies. Studies by Fırat et al. [68], Ottou et al. [69], and Jahani et al. [70] illustrate the application of DMAIC in different procurement contexts. These studies highlight the benefits of DMAIC in improving procurement efficiency, reducing lead times, and enhancing supplier performance.

One of the primary studies on DMAIC in procurement was conducted by Fırat et al. [68], they investigated the DMAIC methodology's use in the Indian automobile industry's procurement procedures and discovered that it was effective in locating and removing flaws, lowering customer complaints, and raising supplier performance. To guarantee effective implementation, the researchers emphasized the significance of clearly describing the issue and including stakeholders in the procedure.

Ottou et al. [69] investigated the use of DMAIC in Bulgarian public procurement procedures in different research. The study discovered that the DMAIC method of process improvement was successful in lowering lead times, raising efficiency, and enhancing supplier performance. The study further recommended combining DMAIC with other quality management methods, such as International Organization for Standardization (ISO) standards, to improve procurement procedures even further. Additionally, Jahani et al. [70] investigated how DMAIC was used in a hospital procurement process in China and discovered that the approach may efficiently shorten the procurement cycle, save money, and boost supplier performance. For the effective application of DMAIC, the researchers emphasized the significance of data gathering and analysis at each level.

The DMAIC technique offers a systematic strategy for locating, examining, and resolving issues in procurement processes [71]. To demonstrate how DMAIC increases the efficiency of procurement procedures, the authors carried out a case study. The adoption of DMAIC in procurement processes led to considerable decreases in lead time, inventory levels, and prices, according to the results. In related research, Rahman et al. [72] examined how DMAIC was used in procurement procedures in the textile sector. The authors employed the DMAIC methodology's five crucial steps to improve procurement procedures. Following the implementation of DMAIC, the findings revealed substantial improvements in the lead time for procurement, inventory levels, and supplier performance.

2.9 Chapter Conclusion

This chapter has reviewed the application of Lean principles and the Six Sigma-DMAIC methodology across various sectors, highlighting their impact on improving efficiency, reducing waste, and enhancing supply chain processes. The literature demonstrates the versatility and effectiveness of these methodologies in addressing sector-specific challenges and driving operational improvements. The insights gained from these studies provide a strong foundation for understanding the relevance and potential of Lean and DMAIC in optimizing supply chain efficiency and performance. Most studies did not focus heavily on business acquisitions for example [73] and [74] their study focused on production, and most of the studies did not include a control phase in their research like [73] no control phase means DMAIC was fulfilled.

3. CHAPTER THREE: METHODOLOGY

3.1 Introduction

This study employs the DMAIC problem-solving methodology, a fundamental element of Six Sigma, to enhance the supply chain efficiency of the company. It explores the application of DMAIC across various sectors within the supply chain, including manufacturing, procurement, and services. The data collection process involves a comprehensive walkthrough to identify key criteria such as waste reduction and cost savings.

During the Define phase, waste metrics were established for each Stock Keeping Unit (SKU), ultimately pinpointing and emphasizing the most problematic SKU. The Measure phase involved data collection and measurement. Waste figures were obtained through a manual approach, wherein the researcher observed, weighed, and recorded each instance of waste. Additionally, data was extracted from Systems Applications and Products (SAP), an Enterprise Resource Planning (ERP) system housing comprehensive information. The purpose of analysing SAP data is to compare it with the researcher's findings and conduct further analysis.

The third phase of data analysis will entail presenting the results using graph analysis. Waste metrics were accurately determined, and the existing process mapping was validated. Results were depicted through descriptive statistics in graphs and other visual aids. Furthermore, comparisons were made with historical data to identify potential factors for process enhancement.

3.2 Research Approach

The research strategy is explanatory, with a case study method used to thoroughly examine DMAIC's implementation in a real-world supply chain scenario. Figure 4, provides a structured framework for developing a research methodology. It guides researchers through layers of decisions, starting from the outermost layer with philosophies, moving inward through approaches, strategies, choices, time horizons, and ultimately, techniques and procedures. This systematic approach ensures comprehensive planning and execution of research, aiding in the clear identification of the research paradigm, appropriate methods, and tools to be used, thereby enhancing the validity and reliability of the study.

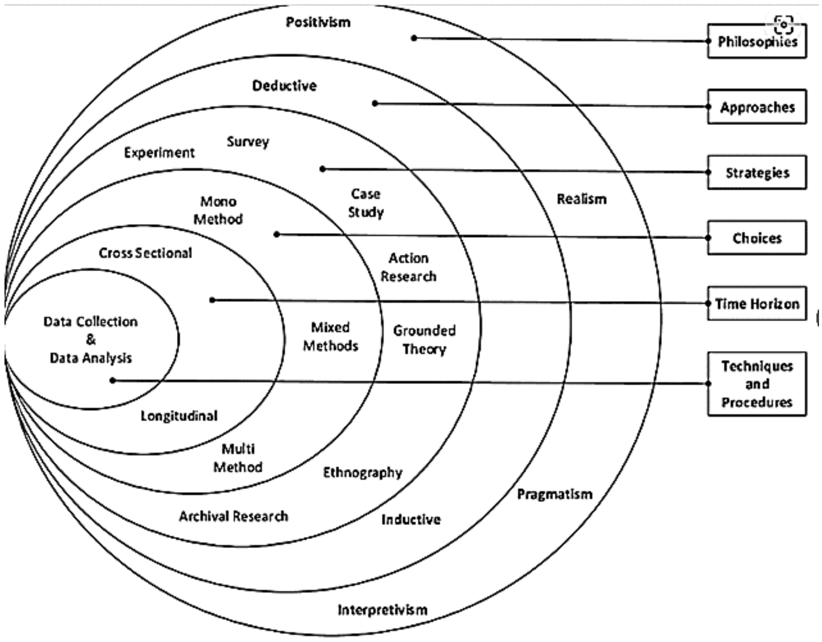


Figure 4: Research Onion

Source: [75]

In this intriguing study, the study takes a positivist approach, drawing on data from supply chain processes. Using the DMAIC technique, the research seeks to evaluate and improve these processes. Epistemologically, an objective and empirical approach is used, concentrating on quantitative data—specifically, waste figures—to expose inefficiencies in the supply chain. The research design adopts an explanatory method, with a case study approach used to investigate DMAIC's real-world application. The intricate position of this company in the food sector supply chain permits a thorough evaluation. The method investigates DMAIC's changing influence on efficiency gains over time. The data collecting technique combines quantitative and qualitative methodologies, using KPI and metrics for quantitative insights while obtaining qualitative data through management walkthroughs, one-on-one meetings, and direct observations. Primary data is gathered on-site, while secondary data is sourced from relevant literature and historical sources, forming a solid foundation for the observational subtopic.

3.2.1 Observation

According to Johnson [76], the observer can take one of four roles: complete participant, complete observer, observer as participant, and participant as observer. Also, Johnson [76] found that the observer can take on four different roles: complete participant, complete observer, observer as a participant, and participant as an observer Figure 5. The study uses two observation roles: observer as participant and participant as observer. This technique enables both active participation and unbiased observation during the study process.

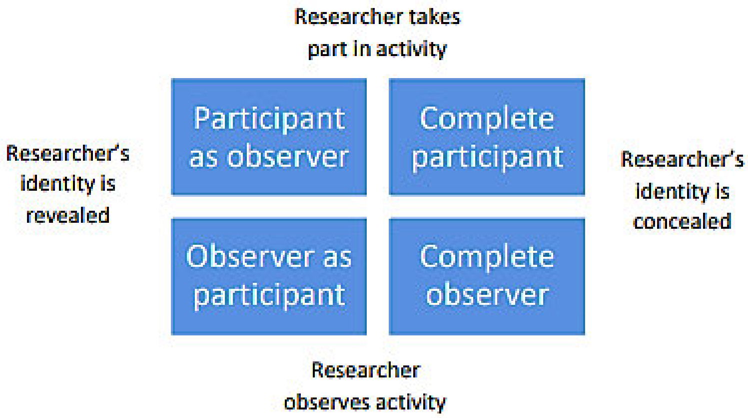


Figure 5: The different kinds of observations

Source: [77]

This study used two observation roles: first, as an observer, promoting interaction and conversation with operators to understand the process and its flow. Data obtained in this capacity aided in the creation of process layouts and a better knowledge of supply chain activities. Once trust was built, the observer-as-participant role was used to reduce researcher interference during measurements. This method revealed the activities of operators as well as possible waste in the operations under study.

3.2.2 Data Analysis

Quantitative data is analysed using statistical software such as Microsoft Excel, with an emphasis on descriptive statistics and inferential analysis. In Chapter 4, the study will utilize Microsoft Excel to make data presentable. Various forms of graphs will be shown, including line graphs, histograms, and bar graphs. To analyse the reasons for waste, a pivot table will be utilized on an Excel spreadsheet to examine the causes of waste. ABC analysis will be used with the aid of Microsoft Excel to choose which SKUs have the most waste, and the research will focus on the two highest.

3.3 The Approach of the Study

This research employs the Lean approach to improvement, with the DMAIC technique being utilized to reach conclusions on the study's stated aim.

The study also adheres to the procedures outlined in performing a Value Stream Mapping (VSM). Smits [78] provides the stages of establishing a product family, mapping a current state map, mapping a future state map, and creating a work plan for making enhancements to attain the future state. The VSM will be displayed during the define phase of the investigation, displaying the current state or process layout of the study.

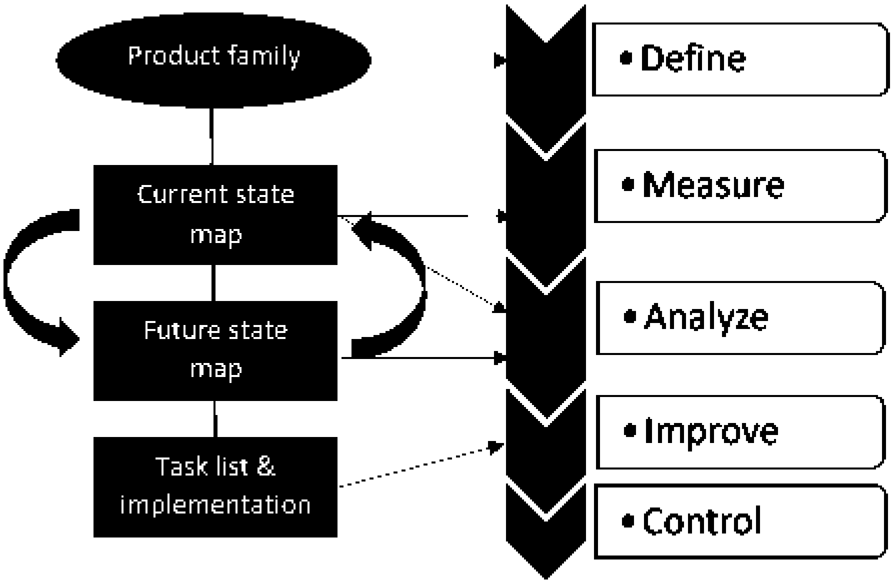


Figure 6: Structure for making VSM and relationship with the DMAIC
Source: [79]

3.4 Define

The define stage guarantees that the problem passes through the DMAIC process and is related to the company's priorities [80]. To identify the problem, the researcher met the manufacturing team. The meeting's goal was to define all the product's processes, from supplier to finished product, analyse all the phases, and assess the obstacles at each stage. The Manufacturing Analyst assists in giving information on SAP to identify the company's historical data. The problem statement was that the company is experiencing too much waste without the underlying cause, and there are supplier delays that influence the supply chain, and the aim is to increase the supply chain efficiency.

3.4.1 Data Collection

3.4.1.1 Company Walkthrough

The primary purpose of conducting a walkthrough of the plant is to gain a comprehensive understanding of its process layout and operational procedures. This walkthrough is essential for gathering the necessary information to draw the supply chain procedures accurately. Key objectives of the walkthrough include:

- To observe and document the various processes the company employs in its operations.
- To create a detailed layout of the supply chain procedures based on direct observations and relevant inquiries.
- To analyse and describe each process step-by-step, highlighting what occurs at each stage.

- To produce visual representations, such as drawings or diagrams, of the process layout and supply chain.

3.4.1.2 SKU Waste Assessment

The technique for assessing SKU waste involved a systematic approach to data collection across product categories such as 250g, 500g, 1 kg, 2.5kg, 5kg, 25kg, and 10kg. Each SKU's waste was quantified in tons and assigned a monetary value per ton in Rands. This economic approach provided a thorough understanding of both weight and cost impact. Each SKU's proportion of material waste was calculated to reflect its contribution to overall waste. A cumulative percentage was also determined, offering insight into the sequential impact of SKUs on total waste. This approach allowed for the detection of high-waste SKUs and patterns in material waste, enabling more informed decision-making.

3.4.1.3 Value stream Mapping

Data collection for Value Stream Mapping (VSM) followed a methodical process. The researcher made detailed observations of the entire sugar refining process, from raw material intake to final product packing. KPIs such as Cycle Time for the Packaging Process, lead times, and inventory levels were meticulously tracked. The cycle times of processes were measured in minutes, along with lead times. Additionally, process mapping tools like flowcharts and timelines were used to visually depict the complete value chain. This comprehensive methodology aimed to identify inefficiencies, bottlenecks, and opportunities for improvement in the sugar manufacturing process, enabling a holistic understanding and targeted advancements.

3.4.1.4 5S Technique

The 5S methodology, originating from Japanese lean manufacturing practices, has been extensively researched for its impact on workplace organization and efficiency. Researchers have applied Sort, Set in Order, Shine, Standardize, and Sustain (5S) to various industries to enhance operational performance. Michalska and Szewieczek [103], demonstrate that implementing 5S leads to significant improvements in productivity, safety, and quality by reducing waste and streamlining workflows. The research highlighted a 30% reduction in time spent searching for tools and materials. The benefits of 5S extend beyond immediate efficiency gains; it fosters a culture of continuous improvement and employee engagement by creating a more organized and safer work environment. Overall, 5S has proven to be a valuable tool in enhancing operational effectiveness and supporting sustainable practices in diverse organizational settings.

The focus of this study is on explaining issues inside the company's operating structure. The study process includes an in-depth evaluation of the company's KPIs via the 5S view. The research intends to find potential flaws and inefficiencies by evaluating the Sort, set in order, Shine, Standardize, and Sustain components. Furthermore, to contextualize the findings, a thorough examination of the company's operating environment will be done. Furthermore, the research will dive into the process layout, critically analysing performance measures within the context of the 5S framework, so contributing to a comprehensive knowledge of operational dynamics.

2.4.2. Summary for the Define Phase

In summary, the define phase includes company walkthrough, problem identification, drawing the process layouts and other activities. Figure 7 below summarises the define phase.

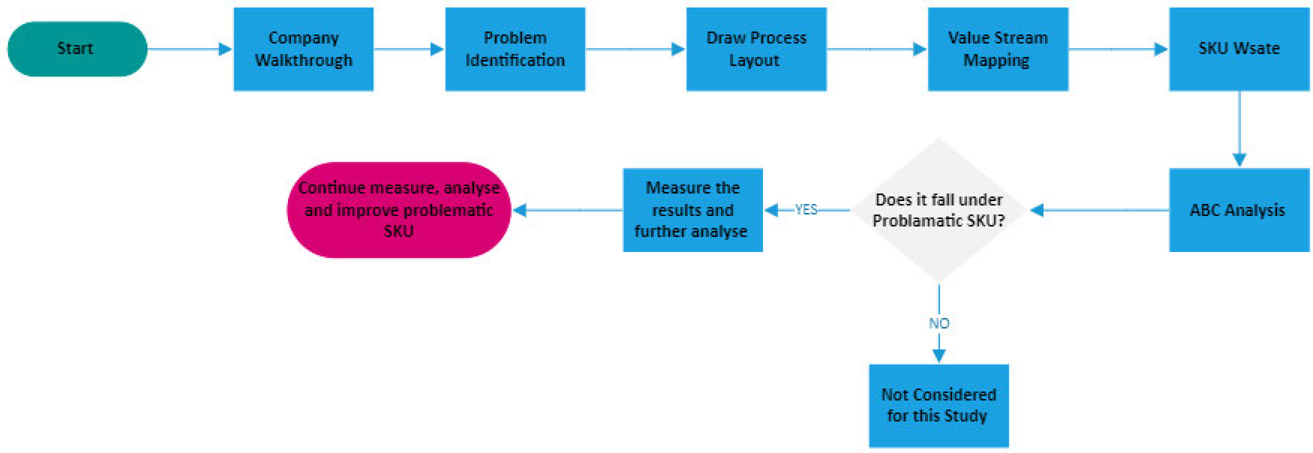


Figure 7: Summary of Define Phase

2.5. Measure

This stage involves measuring the waste collected. Waste data was assessed weekly using historical data from SAP software and real-time data acquired by the researcher. The researcher collected data for 15 weeks to determine the historical data of the company's waste per ton of sugar and related expenses per SKU, to determine which is the greatest. This 15-week period began on June 26, 2023, and included a comparison between SAP and the researcher. The study will focus on waste figures and costs, such as waste by SKU, waste per week, and waste comparisons of the SKU with the highest waste. The study further shows the percentage of NCR versus the waste of material found in the production station.

3.5.1. Waste Numbers

The approach used for waste measurement in this study is simple and effective. The researcher took a methodical strategy that included a thorough examination of numerous waste categories such as overproduction, flaws, waiting times, and excess inventory. Established metrics, particularly the Six Sigma framework, were used to assure precision in analysing the amount of waste in the processes [81].

To calculate waste, a thorough fifteen-week time-series analysis was performed for the problematic SKU that will be selected. The major goal was to compare the actual performance of these SKUs to predetermined objectives and discover any discrepancies. Weekly documentation and waste amount comparisons indicated considerable performance disparities, highlighting the need for improvement in manufacturing or supply chain operations for selected SKUs.

3.5.2 Key Performance Indicators

To establish KPIs for each process, a comprehensive review will be conducted following the initial walkthrough and process documentation outlined in section 3.4.1.1. Data Collection Method: The researcher met process managers and frontline workers will be conducted to gather qualitative insights. Quantitative Data Analysis: Historical performance data from the company's database, obtained from the Manufacturing Analyst, will be analysed. Implementation: KPIs will be developed for each process, ensuring they are measurable, achievable, relevant, and time-bound. This method ensures that KPIs are tailored to drive process efficiency and effectiveness.

3.6. Analyse

This stage involved determining the input elements that contributed to low performance and identifying the cause-and-effect relationships. It begins with the examination of data collected in the preceding stage, utilizing waste quantities, to determine the causes of waste. However, the data collected from SAP and the researcher were converted to Microsoft Excel as a spreadsheet and analysed within. To analyse performance, the findings were presented as descriptive statistics in the form of graphs, tables, charts, and histograms.

Data was acquired from specific SKUs over 15 weeks to compare the supplier's performance and evaluate the reasons for inefficiencies in the supply chain. After selecting which SKU to focus on, a fishbone diagram was created to illustrate the probable causes and determine the underlying issues affecting these SKUs. The fishbone diagram, as the name implies, resembles the side view of a fish's skeleton.

The methods used to obtain this data involved recording the production, waste, and yield percentages for two product versions over 15 weeks. Weekly output statistics and waste levels were documented. The yield percentage was calculated by subtracting waste from production, dividing the result by production, and then multiplying it by 100.

$$Yield\ Rate\ (\%) = (1 - \frac{Production}{Weekly\ Waste}) \times 100$$

This methodical approach allowed for a thorough examination of how each week's production influenced waste and, as a result, the yield percentage. For each week, production amounts reflected the number of units produced, while waste percentages indicated the proportion of material wasted during production. Yield percentages were then computed by subtracting the waste percentage from 100%, revealing the actual useful production. The study began by documenting production quantities and waste percentages over 15 weeks. Each week's performance was examined by calculating the yield percentage, demonstrating the manufacturing process's efficacy in transforming raw resources into useful goods.

Following a thorough evaluation of waste and yield percentages, the research investigated the underlying causes, attributed to the supplier. This study meticulously documented NCR statistics, generated when raw packing materials failed to meet specified parameters. The necessary data was systematically gathered from the SAP system, particularly from the Packaging Manager's report on material return events. This strategic approach aimed to identify and address supplier-related issues revealed during the evaluation of waste and yield percentages.

3.6.1. Reason of the Waste

The study delves deeper into waste data by classifying it according to reasons. The study goes on to explain why sugar is dumped into the drum, mentioning factors including decanting and the corresponding shift for each. Waste was classified according to its causes, such as decanting and shift-related factors. The researcher used a specific form provided to Inventory Controllers to ensure accurate documentation of reworks. This classification helped in understanding how different factors influenced waste levels.

Reject product transferred to rework **Date:________________.**

Material code	Material Description	No. of Balers rejected	Reason for baler rejection	Shift (A/B/C)	Signature
16	5 kg	51	Damage by the palletizer	A	

Figure 8: A sample of the sheet used to collect waste data.

Based on these findings, the researcher continues to improve the spreadsheet for weekly analysis. The goal is to investigate the influence of various factors on waste numbers. The analyses are conducted to address the identified concerns and to mitigate the elements that influence sweeping. This analytical technique helps to determine the fundamental cause behind the waste figures.

3.6.2. Ishikawa diagram or Fishbone Diagram

The Ishikawa diagram, also known as the Fishbone Diagram, is used as a visual aid in this study's technique to systematically evaluate the main causes of waste inside production processes. Ishikawa helps to arrange brainstorming sessions and identify the causes of a certain problem into main branches that resemble fish bones [82]. Each branch represents a significant cause category, such as equipment, processes, people, materials, and the environment.

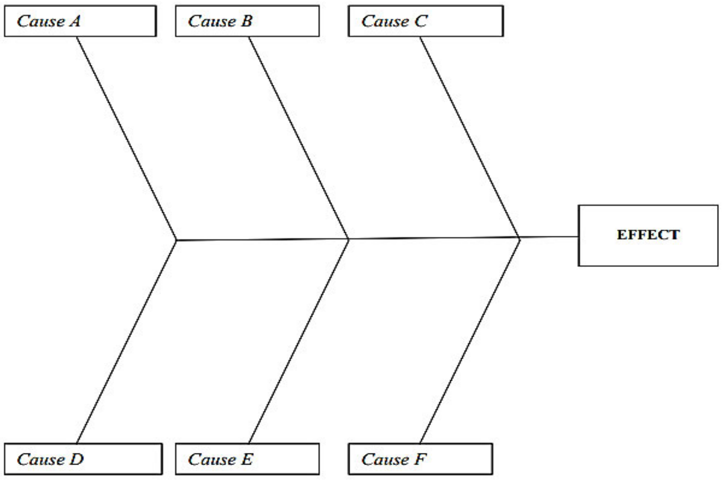


Figure 9: Fishbone Diagram

Source: [83]

The fishbone diagram was created using data from the Figure 8 spreadsheet, which included all instances of "reason baler rejection." Researchers methodically studied these recorded causes and classified them into conventional categories such as Man, Machine, Method, Material, Measurement, and Environment. This extensive classification method entailed analysing each cause for rejection and precisely assigning it to the relevant category.

The fishbone diagram provides a clear visual representation of probable fundamental causes, making it easier to identify underlying difficulties. This rigorous approach allowed the researchers to carefully examine each category of difficulties, resulting in a complete study that is consistent with the DMAIC methodology's aims. The fishbone diagram helped to design focused solutions by visualizing the fundamental causes, resulting in real and long-term improvements in the supply chain process [82].

3.6.3. Material Specification

The methods used to obtain data on the material properties of the highest wastage that will be selected included a thorough review of their specifications. This thorough method assures conformity with established standards, as indicated by the tolerances for bag width, bag length, gusset width, and bottom width. These strict quality control techniques highlight the company's dedication to assuring the fitness and integrity of packing materials. The purpose of the research to look at material specifications is to investigate the material to see if there is any modification that might increase waste. The material specifications as the primary SKUs with the most waste will be shown. This information was collected from the raw packaging material manager who I in charge of carrying the NCR files and material specification documents.

3.6.4. Bill of Materials variance and Material variance

This study focuses on examining Material Variance, especially Bill of Materials (BOM) variance in the operational environment Material variance, particularly BOM variance, was analysed to compare actual material costs and quantities against standard costs and quantities provided by SAP. The study focused on discrepancies between recorded production data and actual observations, investigating potential inefficiencies or inaccuracies in the manufacturing process.

The data for this study were gathered by reviewing production records for the highest problematic SKU during 15 weeks. Discrepancies between the production data recorded in the SAP system and the researcher's observations were detected methodically. To investigate these variances, an in-depth study of Bill of Material (BOM) irregularities within the company was carried out. The SAP-generated data indicated a higher resource consumption than the specified needs, raising worries about potential inefficiencies in the manufacturing process. The study used the SAP system as an important tool to discover and rectify abnormalities in BOM-related data, providing light on potential flaws in standard settings, changes in real production circumstances, or differences in recording and reporting methods.

3.6.5. 5-Why Analysis

The 5 Whys approach is used as a thorough problem-solving tool to identify the underlying causes of material waste and supply chain inefficiencies. The first step is to identify a specific problem linked to waste and supply chain efficiency. Following that, a series of "Why" questions are developed and iterated up to five times, resulting in a thorough examination of the underlying reasons for the identified problem. Data is collected and evaluated methodically at each level, allowing for the discovery of underlying problems. This procedure is repeated until a thorough grasp of the underlying cause, or systemic difficulties is obtained.

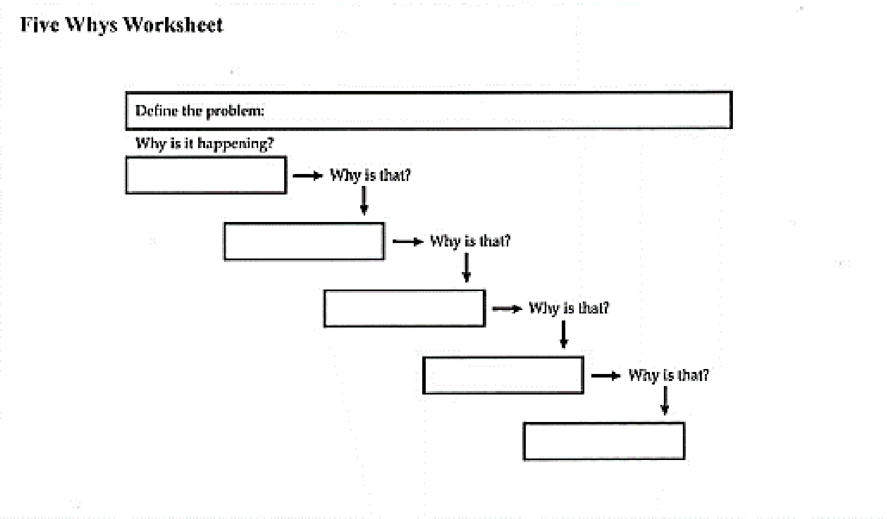


Figure 10: 5 Why Process

Source: [84]

The 5-Why Analysis was created utilizing the fishbone diagram, with concerns or causes drawn from Figure 8 data. These reasons were depicted on a fishbone diagram, with categories such as Man, Machine, Method, Material, Measurement, and Environment. Each category's reasons were then subjected to a thorough 5-Why Analysis to determine the root causes. This methodical approach guaranteed that each single reason was properly investigated within its category. The 5-Why Analysis for each factor presented potential remedies to the fundamental issues uncovered. This strategy not only explained the underlying difficulties but also gave concrete actions for change, which were consistent with the DMAIC methodology's purposes.

The findings of the 5 Whys research are carefully documented, establishing the foundation for presenting tailored remedies to each identified underlying cause. Furthermore, to assess the effectiveness of the provided solution. This methodological approach enables a methodical and detailed examination of waste concerns in the context of supply chain management, ultimately helping to the creation of successful Lean management strategies.

3.7. Improve

The main objective of the Improve phase is to find potential ideas utilizing brainstorming approaches, as well as to develop and choose solutions [85]. The improvement phase is the point in the research process where potential remedies to the discovered problem's core causes are methodically defined. This step of the DMAIC process is distinguished by its predisposition for developing creative thinking since it promotes the production of solutions rather than depending solely on statistical analysis. It also preserves an experimental dimension, as seen by the deliberate study of each possible suggestion on a lesser scale before considering full-scale execution.

The next chapter, Chapter 5, is dedicated to the presentation of the study's recommendations and will prominently display the consequences of the improvement efforts that are poised to increase supply chain efficiency. This is the stage of optimizing the process and implementing countermeasures, as well as looking into new methods to improve the company's supply chain line and save money. In the previous stage, the resource or equipment that consumes the most was identified, and the causes of variation were found; now there is a new approach to solve this problem by minimizing waste in the line.

3.7.1. Matrix of Prioritization

The Matrix of Prioritization is a strategic tool used after the 5 Whys analysis in the DMAIC process. This technique combines data from the 5 Whys to show the fundamental causes of material waste in the supply chain. Issues are then evaluated for impact and feasibility, resulting in a matrix with these criteria as axes [104] . The matrix divides problems into three categories: high, medium, and low impact and feasibility. Prioritization is done by focusing on topics that fall into the "High Impact, High Feasibility" quadrant, which represents significant difficulties with viable answers. This strategic decision-making tool facilitates the development of action plans and solutions by using insights from the 5 Whys study. Following implementation, these solutions are continuously monitored to guarantee efficacy, flexibility, and sustainability in managing material waste concerns within the supply chain.

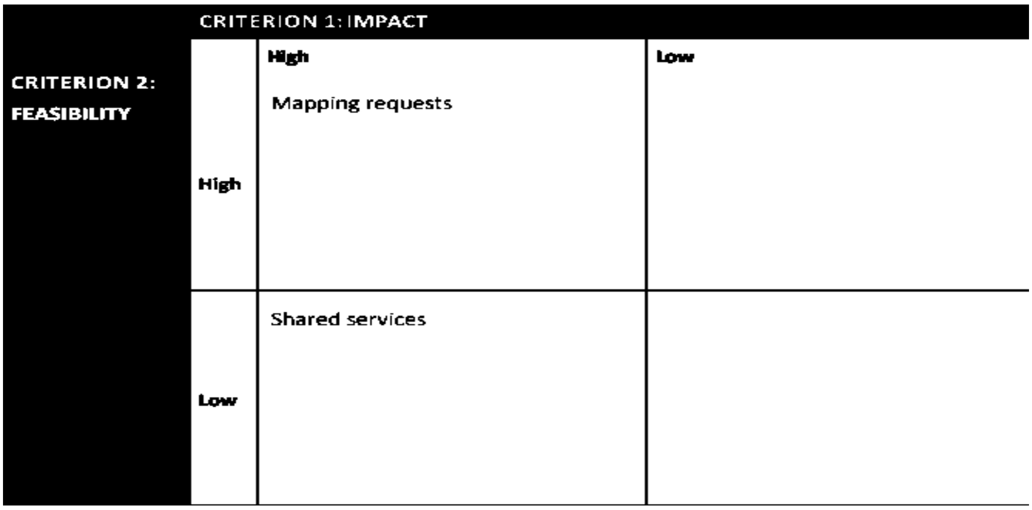


Figure 11: Matrix of Prioritisation

Source: [86]

After presenting the 5-Why Analysis with possible solutions, the study proceeded with a prioritization matrix. All possible solutions identified in the 5-Why Analysis were assigned symbolic words or numbers. These symbols were used in Figure 11 to classify each solution based on criteria such as low effort and high impact. The matrix diagram represented the many alternatives inside their respective categories, providing a clear picture of which solutions would be the most successful and viable to execute. This prioritizing approach guaranteed that the research focused on high-impact, controllable solutions, which aligned with the DMAIC methodology's aims of driving substantial and efficient changes.

3.7.2. Implementation Plan

The implementation plan details the steps required to execute the chosen solutions, specifically those with a high impact on waste reduction but requiring low effort in implementation. This comprehensive plan includes specific actions, timelines, responsibilities, and resources needed for the improvements. It outlines the sequence of tasks and milestones to ensure the smooth integration of solutions into existing processes. The plan also incorporates contingency measures to address potential issues that may arise during implementation. By focusing on high-impact, low-effort solutions, the plan ensures efficient resource use and maximizes the effectiveness of the improvements, leading to sustainable waste reduction and enhanced supply chain efficiency.

3.7.3. RASCI Analysis

The Responsible, Accountable, Supportive, Consulted, and Informed (RASCI) analysis is used to define roles and responsibilities for the implementation of solutions [109] . It clarifies who is responsible for executing tasks, who is accountable for ensuring completion, who will provide support, who needs to be consulted, and who should be kept informed. This analysis helps to streamline communication and ensure that all stakeholders are appropriately involved in the implementation process. By clearly delineating these roles, the RASCI analysis promotes accountability, minimizes misunderstandings, and enhances collaboration, ensuring a smooth and effective implementation of the chosen solutions.

3.7.4. Summary for Improve Phase

In summary, the Improve phase involves developing potential solutions and prioritizing them using a matrix. Solutions are evaluated based on their impact and effort. High-impact, low-effort solutions are selected, and their implementation follows a RASCI analysis to ensure effective execution. Figure 12 below summarises the improve phase

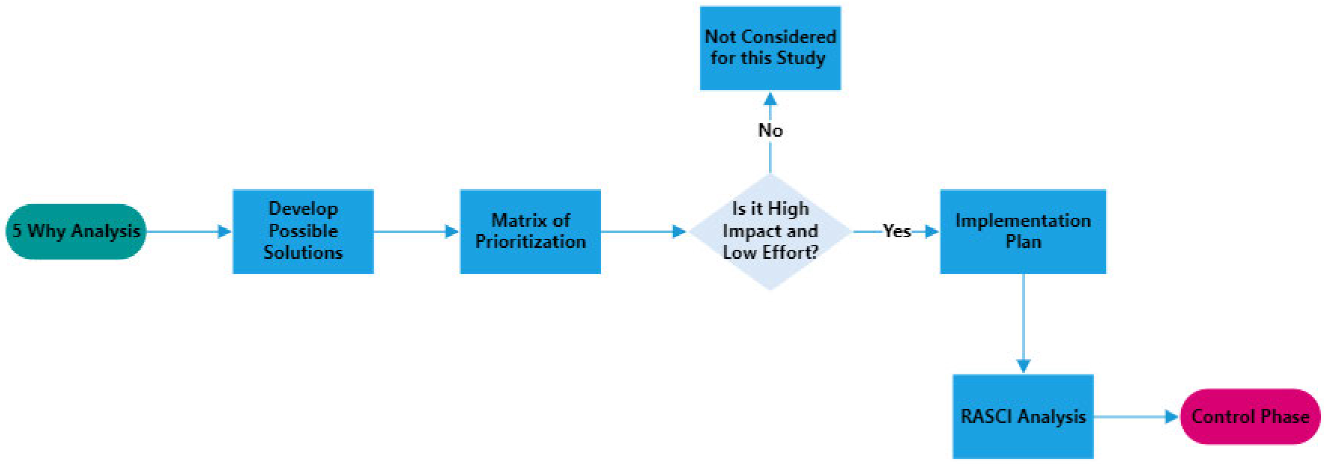


Figure 12: Summary for Improve Phase

3.8. Control Phase

The Control phase is the critical stage in the research process, transitioning from the idea of improvements to the concrete implementation of the recommended changes, which include both behavioural and physical modification. This phase also includes the crucial duty of updating work instructions and procedures, providing the necessary training to the workforce on these new protocols, implementing mechanisms for continuous monitoring of the redefined processes, and developing a strategic action plan. It is critical to emphasize that the Control phase includes the development of systems to analyse and maintain supply chain performance metrics and material waste levels. The primary goal of this phase is to ensure the endurance of the changes made during the enhancement phase.

The last adjustment is made, and the closing performance and any associated changes are noted. Rigorous follow-up and remedial action, together with thorough documentation, can enhance the likelihood that the advantages are maintained. This phase involves control over the improvement. It is the process of managing and sustaining the achievements made during the improvement phase. As previously stated, DMAIC is a continuous improvement technique used to handle new improvements. Management must continue to carry out the same procedures of this project, connect with the company's suppliers, and grow the number of suppliers who will aid the supplier in performing. Suppliers often perform when they face competition. Table 1 shows an overview of the five DMAIC phases and their objectives.

Table 1: DMAIC Layout for the Research

DMAIC Phase	Description
Define	- Identify the problem: Identify areas of material wastage that could affect supply chain efficiency.
	- Tools that will be used: 5S,
Measure	- Collect data: Gather data on current material usage and wastage.
	- Establish baseline metrics: Determine the current level of material wastage.
	- Identify KPIs: Select KPIs to measure material efficiency.
Analyse	- Analyse root causes: Identify the reasons for material wastage, such as supplier issues or production inefficiencies.
	- Use data analysis tools: Value stream mapping, Fishbone diagram
Improve	- Develop improvement strategies: Propose solutions to address root causes.
	- Test solutions: Do the Implementation plan for High-priority possible solutions and test improvement strategies on a small scale.
Control	- Standardize processes: Establish standardized processes to maintain gains.
	- Implement controls: Put controls in place to prevent material wastage from recurring.
	- Continuously monitor: Regularly monitor 5S and improvements recommended.

3.9. Research Purpose

The goal of this study work was to investigate and demonstrate how the DMAIC approach can be used to improve supply chain efficiencies, in a systematic manner. A secondary goal of the study is to minimize waste in the supply chain by using the DMAIC technique to demonstrate and execute changes in a manufacturing process. The study's goal was not considered exploratory because the methodologies utilized had been carefully evaluated and executed in previous investigations. The study's goal might be described as both descriptive and explanatory. The goal is descriptive since it intends to explain how DMAIC may be used to enhance supply chain efficiency. The goal is also explanatory since it seeks to explain why issues occur to provide solutions.

Table 2: Summary of Methodology of Objective

Objective	Research Method	DMAIC Phase	Technique/Tool Being Used
To investigate the existing levels of waste and performance efficiencies	Observation and Quantitative	Measure	• Meet with the manufacturing team to map out the company process layout. • Utilize statistical analysis for quantitative data. • Use 5S principles and waste metrics for each SKU.
To investigate and identify the primary SKU leading to waste	Quantitative	Analyse	• Collect SKU-specific waste data from production records, NCRs, and Yield %. • Apply data analysis tools such as Excel for pattern identification. • Conduct ABC Analysis and Ishikawa (Fishbone) Diagram to identify root causes.
Investigate case studies where DMAIC was implemented, aiming to provide implementation guidance grounded in theory or literature	Qualitative	Define	• Select relevant case studies from similar industries. • Analyse historical data and reports from identified case studies. • Conduct a literature review on Lean management in various sectors to gather theoretical insights.
Implement DMAIC methodology to provide solutions for reducing material waste and increasing supply chain efficiency	(Mixed) Qualitative and Quantitative	Improve and Control	• Synthesize findings from literature review, case studies, and data analysis. • Test proposed solutions and graphically demonstrate improvements. • Use 5 Whys Analysis, Matrix of Prioritization, and RASCI Analysis for solution development and implementation.

3.10. Chapter Conclusion

In this chapter, a detailed account of how data were collected and the steps the researcher intends to take to analyse the data and interpret the results are presented. The study technique employs the DMAIC framework and the ABC procedure to give a systematic and complete approach to addressing material waste in the supply chain. It combines quantitative and qualitative methods to give useful information for optimizing supply chain operations and decreasing material waste.

Table 2 presents a complete summary of how each aspect of the technique efficiently achieves the objectives set out in Chapter 1. It highlights the methodology used in each objective and highlights tools or techniques that were used to achieve those objectives

3. CHAPTER FOUR: FINDINGS AND RESULTS

4.1. Introduction

The findings include a complete review of the company's sugar refining operations, with an emphasis on waste management and operational efficiency. The research examines key components of the company's supply chain, manufacturing procedures, and quality control systems. The primary purpose is to identify operational bottlenecks, optimize resource use, and increase overall efficiency. The study explores critical areas such as SKU selection, material handling, quality control, and machine performance, giving significant information for strategic decision-making.

4.2. Define Phase

4.2.1. Supply chain procedure.

The supply chain process is a complex and critical part of every manufacturing operation, ensuring that raw materials are managed efficiently and effectively from the time they arrive at gate security until their final application in production. This complex process has several stages, each of which contributes to the overall success and efficiency of the supply chain. The results scrutinises each step of the supply chain process, including material arrival at gate security, inventory management, material requisition, warehouse operations, production, quality inspection, packaging, material disposal, waste management, documentation, and continuous improvement. This is depicted in Figure 13 below.

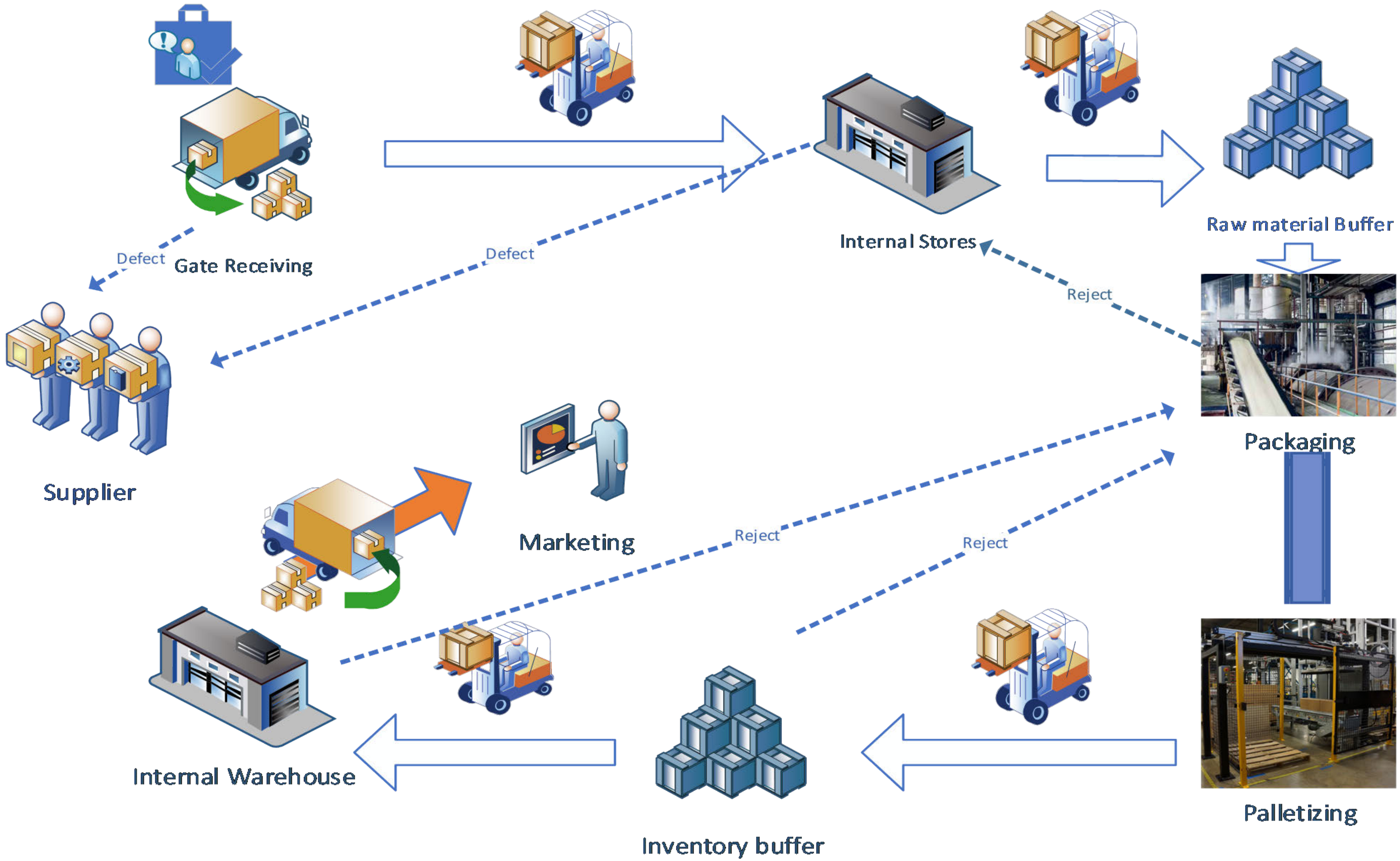


Figure 13: Supply Chain Layout

a. Material Receiving:

Raw packaging materials arrive at the gate security checkpoint, where the two security guards are stationed. This is a critical step to ensure that the materials meet safety and quality requirements. The security guards extensively check the items, observing for evident damage, contamination, or quantity anomalies. This first examination establishes the basis for the materials' quality and integrity throughout the supply chain.

Furthermore, security officers contact the Packing Material Controller to confirm the delivery and ensure that all essential documentation is in order. This verification method is critical for preserving supply chain openness and correctness. Any defects or difficulties discovered during this stage may be corrected immediately, avoiding any interruptions later.

b. Quality Control:

After passing the gate security checkpoint, the materials are moved to the quality checker. This stage entails keeping track of the quantity, item type, and locations of raw packaging materials across the factory. To accomplish this quickly, the Quality Controller uses a checklist to check all the material's specifications.

The unloading of material takes place in an open-air environment with no protective cover for bad weather conditions and moisture to reels of paper. These materials are placed on the exterior driveway, where they would be transported by forklift operators to an enclosed internal store facility.

c. Internal Stores operations:

Unloading and Inspection:

Forklifts are used to unload materials from the delivery truck. During this step, the Quality Controller with the assistance of the Packaging Material Controller, carefully examines the material for any damage, contamination, or amount irregularities. Any faults that are discovered are reported and corrected as soon as possible. Those reels or plastic with defects discovered during unloading are easily raised as NCR, which implies they are returned to the supplier.

*Storage***:**

Materials are moved to specific storage locations within the facility once they have passed inspection. The company has three separate raw materials stores where their items can be stored. Before storing the material, a weighing of the item is performed to record the weight of reels of raw packing material. Labelling and storage layout is critical for preventing damage and infection. When items are stored in an ordered manner, they may be quickly discovered and retrieved when needed.

d. Material Buffer:

The Packaging Material Controller takes materials from stores in response to requisitions made by the Production Controller during the relevant shift, which are often owing to a shortage in the production area. All these materials are temporarily stored in an open, not marked waiting area, pending recovery by the production personnel. The Packaging Material Controller begins the material removal procedure on the Systems, Applications, and Products (SAP) system upon placement within the buffer area.

e. Production:

Material Ordering:

The Production Controller oversees initiating requisitions for the required number of raw packaging materials. It is typical for the Production Controller to grant the appropriate permission before the start of this requisition procedure, acting as a safety mechanism to exercise control over material requests and reducing the risk of excessive or unapproved requisitions. Following the fulfilment of the request, the Packaging Material Controller is responsible for updating the SAP system to indicate the release of materials for manufacturing purposes.

Quality Inspection:

The inspection is carried out by the Production Controller and the Machine operator who works with the material. They examine for any damaged or poor-quality materials. If any problems are discovered, they submit them to the Packaging Material Controller, who can raise the NCR and notify the supplier. The quality inspection guarantees that only materials that satisfy the specified requirements are utilized in production, preserving product quality.

Packaging Process:

Packaging materials, such as bags or boxes, are incorporated into the production process as needed during the packaging process. Only one operator is required to start the machine and verify the fallen bags. The bags are then bundled in balers and transported via conveyors to the palletizer. Packing one pallet has a cycle time (CT) of 10 minutes, and requires one dedicated worker.

The packaging machine has an important feature that prevents defective paper reels from being used in the process. It detects moisture on the paper or defects in the paper from requirements. This is critical for reducing waste in the production line because it reduces the chances of both machine damage and the production of rejected sugar products. This approach not only promotes production efficiency but also adherence to quality standards, emphasizing its importance in improving the process of production.

Palletizing process:

The palletizing process is critical for efficiently organizing the number of balers in preparation for transportation. This phase has cycle time, lasting only 6 minutes to complete a pallet, and requires the presence of a single worker. The palletizing process is an automated method that requires little assistance, principally the supervision of a single operator.

Stretch Wrapping:

After the full pallet of sugar palletized, stretch wrapping takes place on the pallet. Stretch wrapping takes only 2 minutes, involves only one worker, and covers 2 meters. Stretch wrapping is the final task that ensures the pallets of sugar goods are firmly packed, preventing damage during shipment. This process is a manual process. Following the stretch wrapping, the product is routed to the inventory controller's buffer, where it awaits retrieval by the internal warehousing department.

Inventory controller's buffer:

The good product is then forklifted to LS01, which is temporary storage, where the inventory Controller will verify the pallet of sugar to ensure that it is ready to be sent to the internal warehouse. Following the inspection, paperwork for moving the good products to the FN06, the internal warehouse, is created. The marketing department takes its sugar from FN06 to the customer. Figure 14 below summarizes the supply chain process explained in this section.

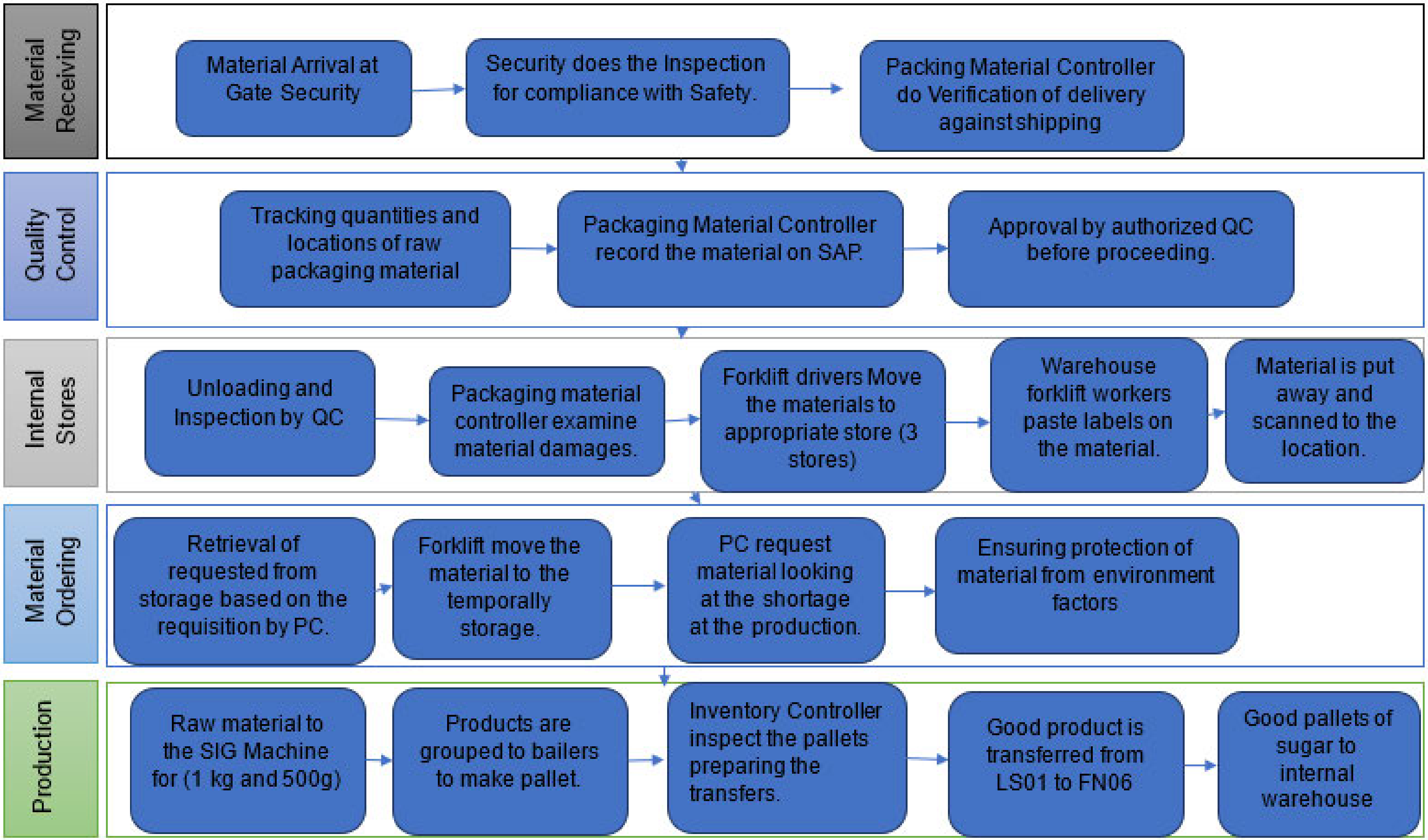


Figure 14: Processes Layout

4.2.2. Inbound Processes

4.2.2.1. Material Receiving:

A company's infrastructure and logistical components are critical to its overall operational efficiency and product quality control. The status of the company's reception facilities looks to be severely unsatisfactory. This shortcoming is defined by the lack of suitable protection for the receiving area, possibly exposing arriving products to inclement weather.

The absence of shelter is a major problem since it exposes the received materials to the weather [87]. Exposure to rain, severe temperatures, or other weather-related variables can cause material deterioration, leaving them unsuitable for use in manufacturing operations. This not only jeopardizes the final product's quality but also offers a financial risk owing to probable material waste and higher procurement expenses.

Furthermore, the manual nature of the receiving procedure exacerbates these difficulties. Currently unloads supplies from supplier trucks using human labour and forklifts. These items are subsequently dumped directly into the reception area's open, unprotected floor. The consequences of this conduct are numerous.

Figure 15: Delivering area for material.

First, keeping products on an exposed and dirty surface might lead to infection, compromising their quality and safety. This might lead to concerns with product quality and compliance with applicable requirements. Furthermore, dirt and debris on the floor may become mixed with the materials, raising further quality control difficulties.

Second, manual material unloading not only causes operational inefficiencies but also represents a safety concern to the personnel. Heavy lifting and material movement with forklifts in inclement weather can result in accidents, injuries, and increased worker fatigue.

Subsequently, the poor state of the reception area, which is characterized by a lack of shelter and a manual unloading procedure, poses a substantial operational and quality control problem. Addressing these concerns is critical to the company's long-term growth, product quality, and employee well-being. To successfully overcome these issues, a thorough assessment of receiving procedures and investment in appropriate infrastructure is required.

a. Gate Security Checkpoint Efficiency:

- ***KPI: Security Check Time***
  - The average time it takes for security officers to conduct a thorough check of incoming raw packaging materials.
  - Measurement: Minutes per delivery
- ***KPI: Accuracy of Security Checks***
  - The percentage of correctly identified issues (damage, contamination, or quantity anomalies) during security checks.
  - Formula:

$$\frac{\text{Number of correctly identified issues}}{\text{Total number of security checks}} \times 100$$

- ***KPI: Documentation Verification Time***
  - The time is taken to verify essential documentation, including contacting the Packaging Material Controller.
  - Measurement: Minutes per delivery

b. Communication and Verification:

- ***KPI: Communication Response Time***
  - The average time it takes for security officers to communicate with the Packaging Material Controller and confirm delivery details.
  - Measurement: Minutes per communication

- ***KPI: Corrective Action Timeliness***
  - The average time taken to address and correct any defects or difficulties discovered during the security check.
  - Measurement: Minutes per corrective action
- ***KPI: Accuracy of Documentation Verification***
  - Definition: The percentage of correct documentation verified during the process.
  - Formula:

$$\frac{\text{Number of correct verifications}}{\text{Total number of verifications}} \times 100$$

4.2.2.2. Quality Control:

After passing through the gate security checkpoint, the materials are sent to the quality checker. This stage involves keeping track of the quantities, types, and locations of raw packaging materials throughout the production. To complete this swiftly, the Quality Controller employs a checklist to review all the material's requirements.

Concerns have been raised about the correctness and consistency of product specifications due to the lack of current testing and dependence on obsolete paperwork in the company's quality control methods. The last reported testing was in 2016, and the absence of future testing may be ascribed largely to budget constraints. As a result, the company has implemented an eye inspection approach in which a product's cleanliness is employed as a proxy for other standards. This technique has drawbacks and may result in considerable differences in product quality and compliance.

The purpose of this study is to determine if materials classified under the same Bill of Materials (BOM) display the uniformity suggested by their classification. This study's premise is that relying exclusively on visual examination for product conformity evaluation may not effectively capture the complex specifications of diverse materials. The study aims to give actual proof of the consistency, or lack thereof, among materials categorized under the same BOM by addressing this key gap in the quality control process. Such insights might help to enhance the company's quality assurance policies and testing techniques to assure product consistency, compliance, and customer happiness.

- ***KPI: Material Yield Rate***
    - The percentage of usable raw packaging materials obtained after passing through the quality control stage.
    - Formula:

$$\frac{\text{Usable material quantity}}{\text{Total material quantity received}} \times 100$$

4.2.2.3. Internal Stores operations:

The company has installed an automated lift system to provide efficient material transfer to its interior storage. The cleanliness and thorough cleaning standards of this interior storage room are impressive. The interior storage is rectangular, measuring around 15 meters in length and 8 meters in breadth. While the organization is committed to keeping a clean and orderly workplace, research done on-site found a substantial concern relating to material handling and storage methods.

The untidy piling of items is a major source of worry in the interior depots. In other cases, the organization uses a racking system to precisely organize the items, guaranteeing effective space use. This recommended practice, however, is not always followed, since some things are left strewn on the floor with no adequate organizing or storage solutions. This inconsistency in material storage offers several issues.

Figure 16: Packing Material stores.

The exposure of materials to sugar dust is one of the most serious concerns. Inadequate sugar dust protection can hurt the quality and integrity of the stored items. This is a major concern, especially if the materials are to be used in sectors with high-quality standards. Sugar dust can degrade the quality of materials, resulting in significant damage and contamination risks.

The company must address these storage and housekeeping challenges to ensure the safety and quality of its supplies. The research emphasizes the need for regular and structured material handling processes, as well as the installation of preventive measures to protect materials from contaminants such as sugar dust, eventually protecting the company's product quality and integrity.

- **KPI: NCR (Non-Confirmation Report) Rate**
    - The percentage of materials identified with defects or issues during unloading that are raised as NCRs.
    - Formula:

$$\frac{\text{Number of NCRs}}{\text{Total Materials Unloaded}} \times 100$$

4.2.2.4. Material Buffer:

The Packaging Material Controller takes materials from stores in response to requisitions made by the Production Controller during the relevant shift, which are often owing to a shortage in the production area. All these materials are temporarily stored in an open, not marked waiting area, pending recovery by the production personnel. The Packaging Material Controller begins the material removal procedure on the SAP system upon placement within the buffer area.

The lack of a defined location for the placing of materials awaiting production, along with the absence of floor demarcations, results in the firm failing to comply with the 5S protocol. Furthermore, there is a significant gap in preserving items against sugar contamination due to the lack of any type of shelter or covering for the stored materials.

Figure 17: Material in the Production Area

4.2.2.5. Production

Shopware software is used to complete machine performance monitoring and tracking of Overall Equipment Effectiveness (OEE). The diagram below offers an overview of the software's many categories and features. Shopware, in essence, acts as the core operational software, storing critical information about procedures and operational rules. However, it is worth mentioning that the most recent adjustments or additions to these operating manuals were made in 2016, perhaps indicating a need for more current documentation and rules within the company's operational structure.

Figure 18: Shopware Software

The following graph depicts the OEE performance of each production equipment. The firm is now operating at a substandard OEE level of 48%, which is much lower than the company's declared performance objective of 55%. This gap between actual and goal OEE highlights the company's current issues in reaching its intended operational efficiency. The data analysis of machine performance shows that the OEE percentages for various SKUs consistently fall below the target of 55%. This indicates that the machines are not operating at the expected efficiency levels.

The OEE for the SKU '500g' is 40%, which is 15% below the target. Similarly, the SKU '1kg' has an OEE of 36%, falling 19% short. The '2.5kg' and '5kg' SKUs show OEEs of 36% and 61%, respectively, with the former falling 19% short and the latter exceeding the target by 6%. The SKU '25kg' has an OEE of 49%, missing the target by 6%, while the '10kg' SKU has an OEE of 53%, falling just 2% short. The '250g' SKU performs better, achieving an OEE of 60%, surpassing the objective by 5%.

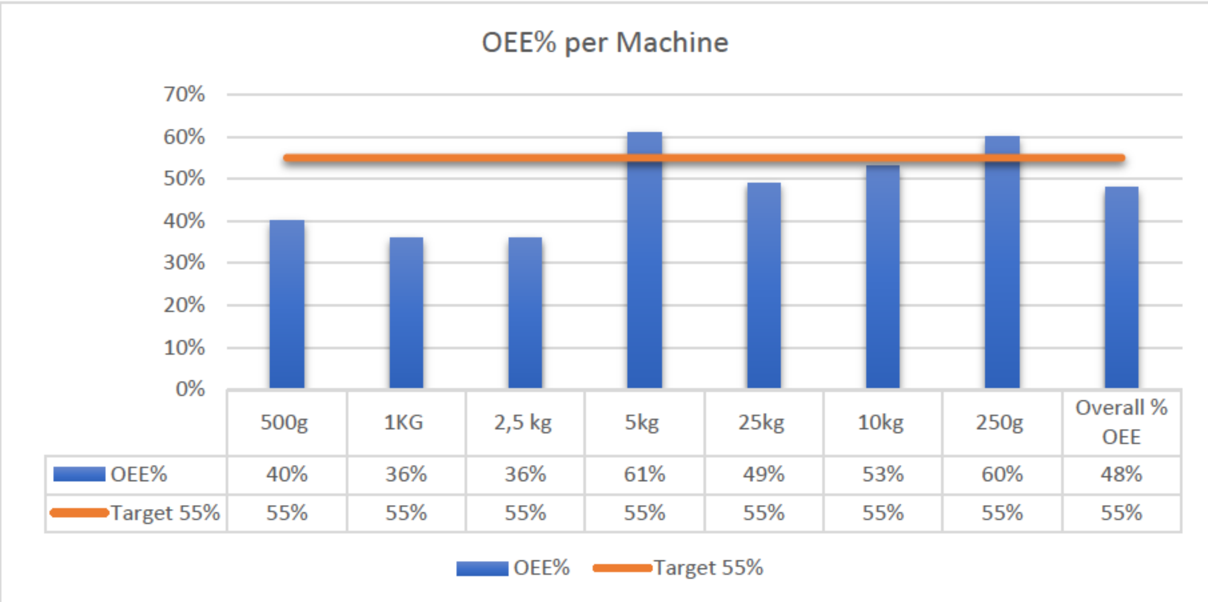


Figure 19: OEE % Performance per each machine by SKU.

The overall OEE for the complete machine performance is calculated at 48%, a significant 7% divergence from the aim of 55%. These data suggest that extensive performance improvement measures are required to increase the machine's efficiency and production. Identifying and correcting the fundamental causes of OEE underperformance, such as downtime, availability, and quality losses, will be critical to meeting the target and guaranteeing optimal production output.

- **KPI: Cycle Time for Packaging Process**
    - The time taken to convert raw materials into sellable items during the packaging process.
    - Measurement: Minutes per unit or batch
- **KPI: Production Efficiency**
    - The ratio of the actual output to the maximum potential output during the packaging process.
    - Formula:

$$\frac{\text{Actual output}}{\text{Maximum potential output}} \times 100$$

- **KPI: Palletizing Cycle Time**
    - The time taken to complete a pallet during the palletizing process.
    - Measurement: Minutes per pallet
- **KPI: Defect Recognition Rate**
    - The percentage of defects recognized and reported during the palletizing process.
    - Formula:

$$\frac{\text{Number of recognized defects}}{\text{Total pallets processed}} \times 100$$

- ***KPI: Stretch Wrapping Time***
    - The time is taken to complete the stretch wrapping process for each pallet.
    - Measurement: Minutes per pallet
- ***KPI: Stretch Wrapping Defect Rate***
    - The percentage of pallets with defects identified during the stretch wrapping process.
    - Formula:

$$\frac{\text{Number of } pallets \text{ with defects}}{\text{Total pallets}} \times 100$$

4.2.2.6. *The inventory controller's buffer*

The good product is then forklifted to LS01, which is temporary storage, where the inventory Controller will certify that the pallet of sugar is ready to be shipped to the internal warehouse. Following the inspection, documentation is generated to move the good items to the FN06, internal warehouse. The marketing department delivers FN06 sugar to the consumer.

Figure 20: Waste of sugar.

Identifying reject occurrences is critical in supply chain management and quality control, especially in the context of logistical and operational issues within a warehouse or storage facility. Many rejections are discovered at this step due to pallets' high vulnerability to damage during the handling operations performed by palletizers and forklifts, which is aggravated throughout transit. As a result, broken bags or pallets are redirected to the red 1-ton drums for ultimate transport to the repair area, incurring a significant R10, 000 per ton rework expense. This cost is especially noteworthy when considering the massive amount of 500g bags, which totals an astounding 16.06 tons. The lack of a formal directive for the movement of sound inventory to LS01 complicates matters even further, leading to congestion and operational inefficiencies.

Figure 21: Poor stacking and waste of sugar.

Furthermore, the presence of sugar dust in the region not only raises hygiene problems but also raises the possibility of cross-contamination. Furthermore, the lack of floor demarcations exacerbates operating difficulties, potentially leading to safety dangers and organizational inefficiency. The confluence of these factors highlights the critical need for comprehensive process improvements, such as improved handling and storage practices, organizational protocols, and sanitation measures, to mitigate the negative consequences of reject occurrences and optimize operational efficacy within the warehouse facility.

- ***KPI: Verification Accuracy Rate***
    - The accuracy of verifying pallets in the inventory controller's buffer before moving to the internal warehouse.
    - Formula:

$$\frac{\text{Number of accurately verified pallets}}{\text{Total pallets inspected}} \times 100$$

4.2.3. SKU Selection

The ABC analysis of data on material wastage of various SKUs gave substantial insights into resource allocation and waste reduction measures. The data was collected over 15 weeks. Two SKUs, 500g and 1kg, were chosen because they contributed to 80% of total material waste. Amin and Kushwaha [88] emphasized the effectiveness of using ABC analysis to optimize inventory management operations inside a manufacturing plant, resulting in improved resource allocation, lower stock holding costs, and increased overall operational efficiency. This classification was accomplished by a methodical approach that considered the value of waste per ton, the overall worth of waste in Rands, and the percentage of material waste.

Table 3: Waste by the SKU

SKU	Waste (tons)	value of Waste per ton (rand per ton)	Total Value of Waste (Rands)	% of material wastage	Cumulative %of Material Wastage
500g	16,06	12000	R 192 720	48%	48%
1kg	13,06	9500	R 124 070	31%	78%
2,5 kg	5	8500	R 42 500	11%	89%
5kg	2,5	6000	R 15 000	4%	93%
25kg	2,5	5500	R 13 750	3%	96%
10kg	1,5	4675	R 7 013	2%	98%
250g	2,5	3650	R 9 125	2%	100%

The SKU 500g has emerged as a focus point requiring immediate attention in the context of material waste, accounting for a startling 48% of overall material waste. This SKU has a waste value of 16.06 rand per ton, resulting in a significant total waste value of R192, 720. These numbers not only highlight 500g as the epicentre of material waste but also highlight its critical role in the entire waste reduction effort. The magnitude of waste associated with this SKU needs immediate and extensive interventions to enhance its manufacturing and handling procedures. It is not only a key aspect, but the cornerstone for reducing waste and increasing efficiency. To adequately solve this issue, the company must investigate options for process development, tight quality control procedures, and inventory management refinements targeted particularly to 500g. This strategic approach offers not just significant cost savings but also coincides with the commitment to more sustainable and ethical corporate practices, making it the focal point of any overall waste reduction plan.

Within the 'B' category, 1kg contributes significantly to material waste, accounting for 31% of total material waste. With a material waste percentage of this scale, a waste value of 13.06 rand per ton, and a total waste value of R124, 070, 1kg is a critical component in the larger context of waste reduction initiatives. Although it does not attract the same amount of attention as the leading 500g in the 'A' category, the importance of 1kg should not be overlooked. It provides a compelling chance to achieve serious change, with large cost savings and operational efficiency benefits on the table. The company may make significant headway in minimizing the environmental and financial costs associated with 1kg waste by applying focused initiatives such as process optimization, quality control upgrades, and inventory management refinements. As such, it needs concentrated attention and a proactive strategy to realize its promise for sustainable materials management and fiscal restraint.

The 'C Category' includes SKUs such as 2.5 kg, 5kg, 25kg, 10kg paper, and '250g' These SKUs collectively account for 21% of total material waste. Although the individual waste rates for these SKUs are lower than those in the 'A' and 'B' categories, their aggregate contribution to wastage remains significant. As a result, it is critical to focus coordinated efforts on waste reduction for this group of SKUs. The company may improve efficiency and cost-effectiveness across a range of goods by applying initiatives to reduce waste in this area, supporting more sustainable and economically sensible operations.

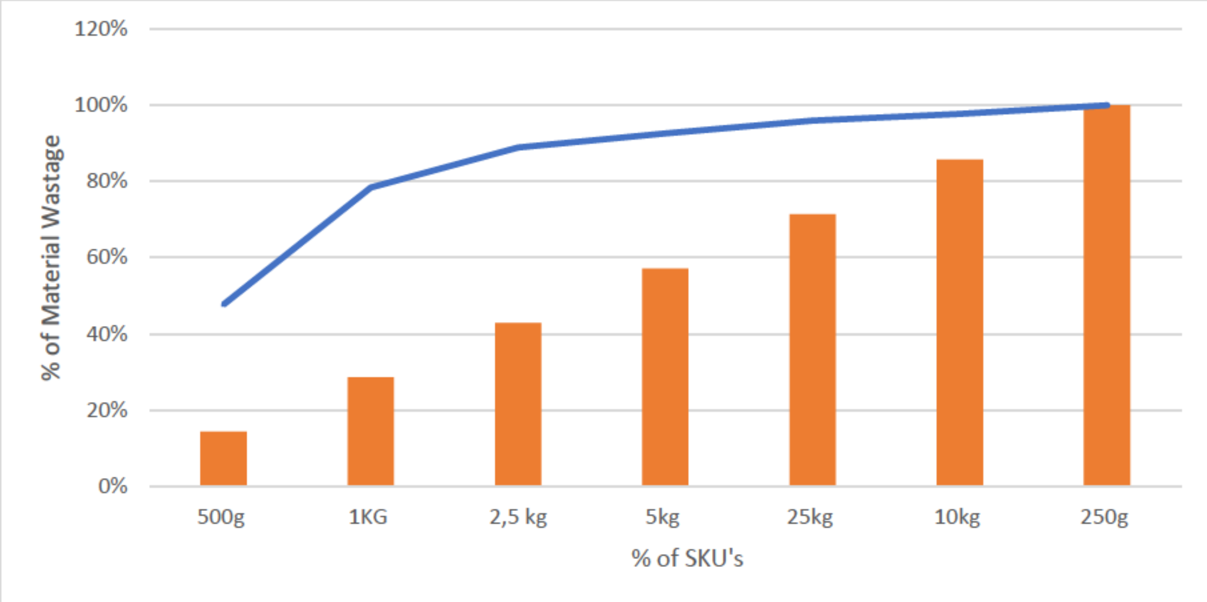


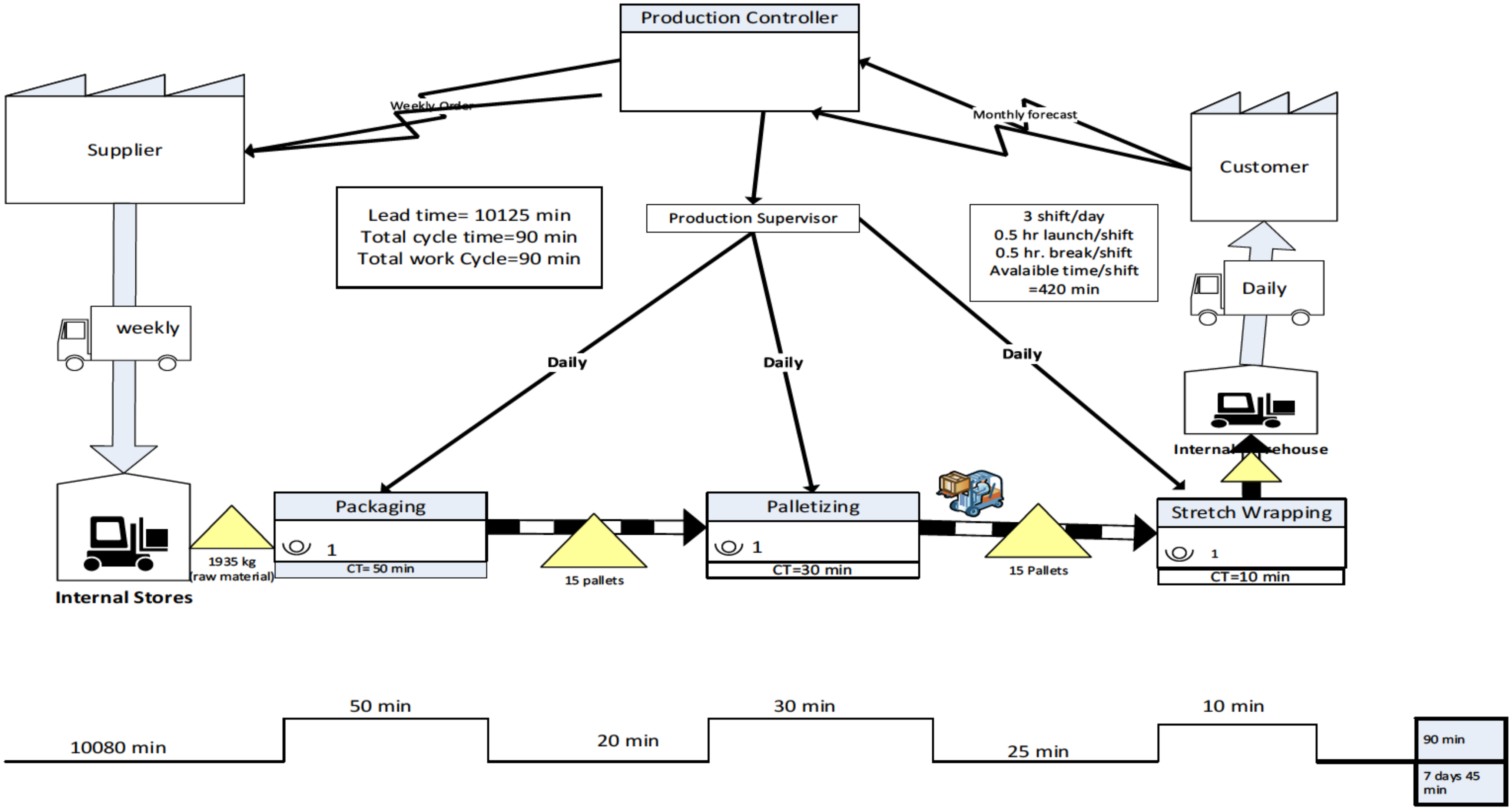
Figure 22: Percentage cumulative of waste.

Furthermore, the remaining SKUs, known as the "C Category," account for the remaining 21% of material waste. These SKUs, which include 2.5 kg, "5kg, 25kg, 10kg, and 250g, should not be neglected despite producing lesser percentages of material waste. Their overall impact is significant, necessitating a coordinated effort to address waste reduction for this category of SKUs.

The use of an ABC analysis in this study is motivated by the requirement for strategic inventory management to improve resource allocation and reduce material waste. The ABC analysis classifies SKUs according to their contribution to overall waste, allowing for a more focused approach to waste reduction activities. For many reasons, the two highest-wastage SKUs, "500g" and "1kg," are preferred.

Firstly, the SKU "500g" accounts for 48% of all material waste, making it the most influential SKU in terms of waste development. The significant waste value of R192, 720 emphasizes the need to eliminate wastage in this area. Second, SKU "1kg" comes in second with a 31% contribution to material waste, indicating its significant influence on total inefficiencies. The study's focus on these two SKUs seeks to generate significant gains in waste reduction and operational efficiency. This prioritizing adheres to the ABC analysis principles, ensuring that efforts are concentrated where they have the greatest impact, hence improving the overall efficacy of inventory management systems.

4.2.4. Value Stream Mapping



4.3 Measure Phase

4.3.1 Waste Numbers

The collection of this thorough data over fifteen weeks was crucial for various reasons, including its close alignment with existing literature and best practices in product management and operational efficiency. According to Marques [89] assessing the performance of product SKUs versus specified objectives enables firms to discover operational strengths and weaknesses, which is critical for strategic planning and continuous improvement initiatives. This data is used as a diagnostic tool, providing information on the condition of the waste on these two SKUs.

Table 4: Waste Results for 500g and 1kg

Weeks	500g	1 kg	target	gap for 500g	gap for 1kg
W 1	1,03	1,04	0,5	0,53	0,54
W 2	1,02	0,91	0,5	0,52	0,41
W 3	1,06	0,86	0,5	0,56	0,36
W 4	1,06	0,75	0,5	0,56	0,25
W 5	0,94	0,87	0,5	0,44	0,37
W 6	1,03	0,73	0,5	0,53	0,23
W 7	1,09	0,91	0,5	0,59	0,41
W 8	0,98	0,67	0,5	0,48	0,17
W 9	0,89	0,76	0,5	0,39	0,26
W 10	0,75	0,98	0,5	0,25	0,48
W 11	1,06	0,75	0,5	0,56	0,25
W 12	1,04	0,95	0,5	0,54	0,45
W 13	2,02	0,98	0,5	1,52	0,48
W 14	0,89	0,87	0,5	0,39	0,37
W 15	1,2	1,03	0,5	0,7	0,53
Total	16,06	13,06		8,56	5,56

Using the gathered data (refer to Table 4), the research methodically followed the weekly output of both the "500g" and "1kg" SKUs, comparing these results to a single performance objective. Week 1 observations revealed a considerable performance overshoot for both SKUs, with "500g" and "1kg" showing surpluses of 0.53 tons and 0.52 tons, respectively, which exceeded the goal limit. These first disparities highlighted possible inefficiencies in the operational or supply chain systems, prompting rapid changes [90].

Week 8 is particularly appealing since it reveals a loss in performance for "1 kg," with the lowest difference among them, while "500g" shows a substantial improvement with a positive gap. This might imply that difficulties for the "500g" SKU were resolved but not for the "500g" SKU, underlining the need for consistent and balanced performance across both items.

Weeks 12 and 13 are notable for having significant gaps for both SKUs, showing probable operational issues and external factors influencing manufacturing or delivery. These gaps, particularly for "500g," are significant and require quick repair. For the last 15 weeks, the cumulative gap for both SKUs was 8.56 tons for 500g and 5.56 tons for 1 kilogram. This result indicates that these two SKUs require improvement since they are failing to meet the company's aim.

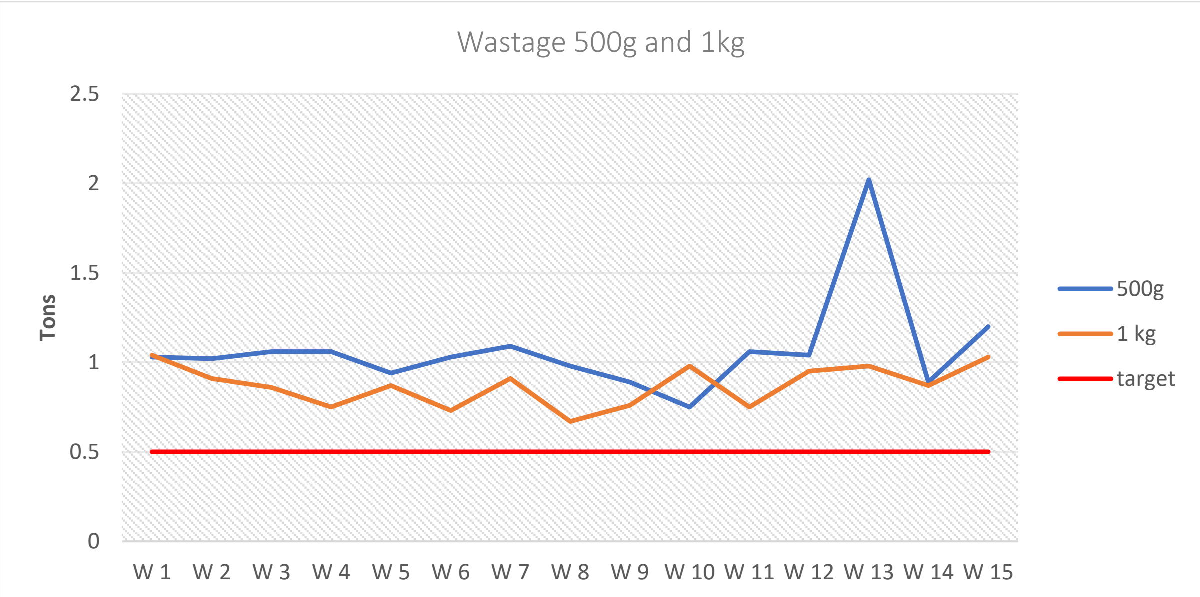


Figure 23: Relationship between wastes with the target for 500g and 1 kg.

The study used sensor technologies to track reject rates across production conveyors, discovering disparities between "500g" and "1kg" SKU performance versus predetermined standards. This data gathering was critical in identifying inefficiencies and leading targeted changes [91]. Analysing reject rates using start and end sensor differences gave a more nuanced knowledge of production waste, emphasizing the need for adaptive management techniques to improve operational efficiency and customer satisfaction [92]. This strategy emphasizes the convergence of technology and operational optimization in manufacturing.

4.3.2 Key Performance Indicators

- KPI: **Production Efficiency**

Production efficiency is measured by dividing the actual output by the maximum possible production throughout the packing process and multiplying by 100. This KPI is critical since it directly indicates the efficacy and optimization of the packaging process [93]. A high production efficiency shows a well-optimized process, which is critical for increasing supply chain efficiencies within the DMAIC framework by identifying areas for improvement in the Define and Measure stages [94].

- The ratio of the actual output to the maximum potential output during the packaging process.
- Formula:

$$\frac{\text{Actual output}}{\text{Maximum potential output}} \times 100$$

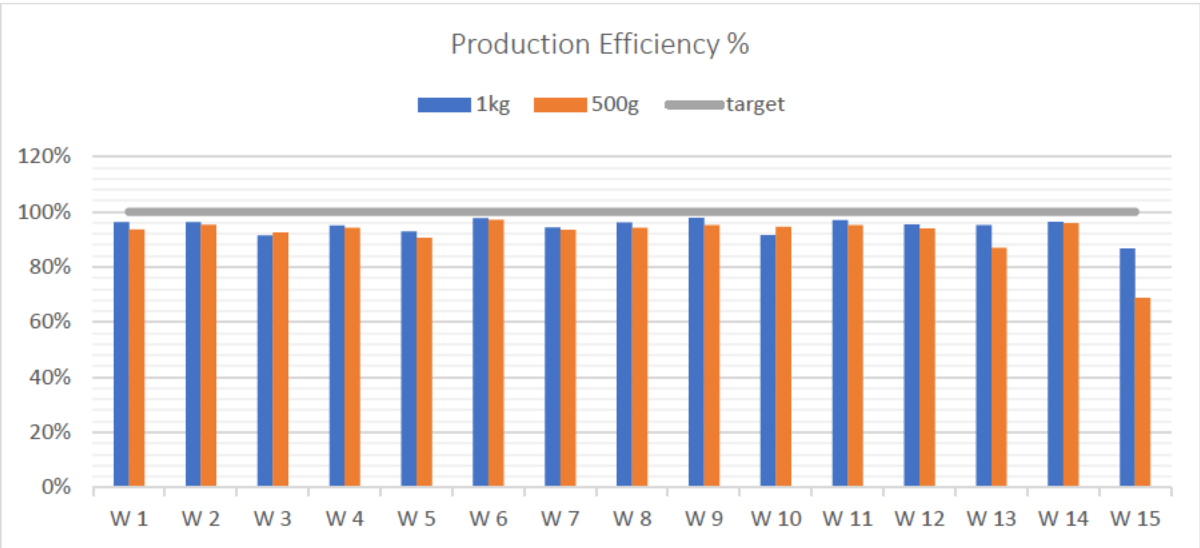


Figure 24: Production Efficiency%

- KPI: **Yield Rate**

Yield rate assesses the effectiveness of raw packing material use by estimating the proportion of useable materials after quality control. This statistic is derived from thorough tracking of raw material intake to acceptable output. It is critical for the analysis phase of DMAIC because it helps detect loss locations in the supply chain, driving focused changes toward resource optimization and waste reduction [95].

- The percentage of usable raw packaging materials obtained after passing through the quality control stage.
- Formula:

$$\frac{\text{Usable material quantity}}{\text{Total material quantity received}} \times 100$$

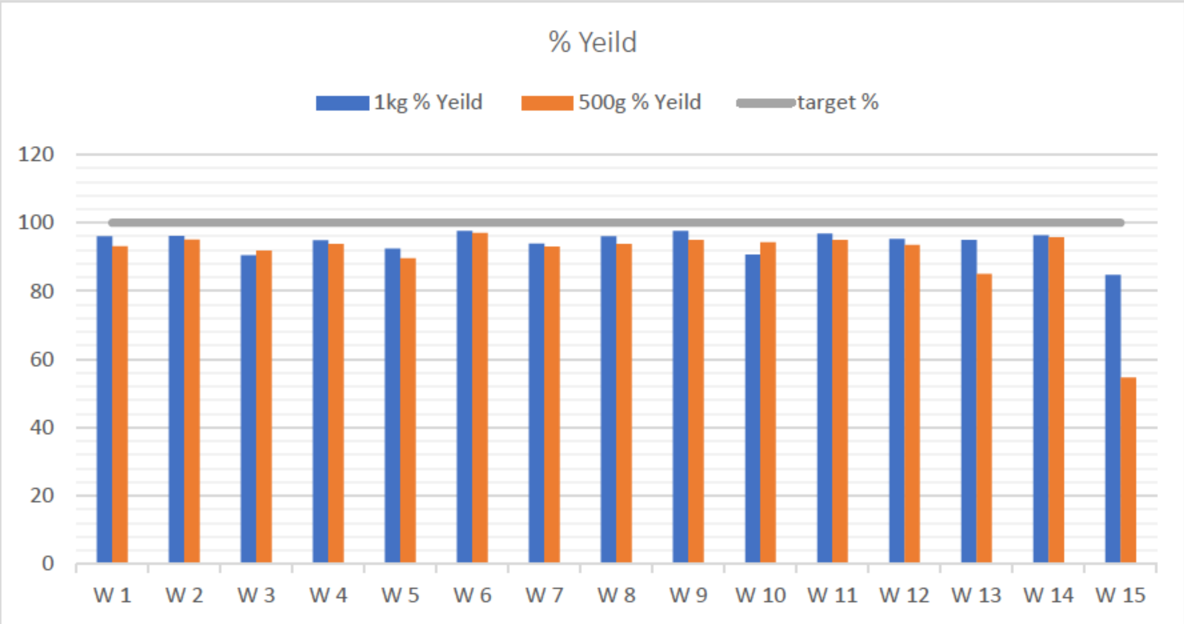


Figure 25: Yield% for 500g and 1kg.

- KPI: **NCR (Non-Confirmation Report) Rate**

The NCR rate is calculated as the proportion of materials marked for faults during unloading divided by the total number of materials unloaded. Data collection for this KPI requires comprehensive examination and documentation of material quality upon delivery. It is an important metric inside the DMAIC's Improve phase, offering a clear objective for decreasing supply chain inefficiencies by addressing quality issues at their source [96].

- The percentage of materials identified with defects or issues during unloading that are raised as NCRs.
- Formula:

$$\frac{\text{Number of NCRs}}{\text{Total Materials Unloaded}} \times 100$$

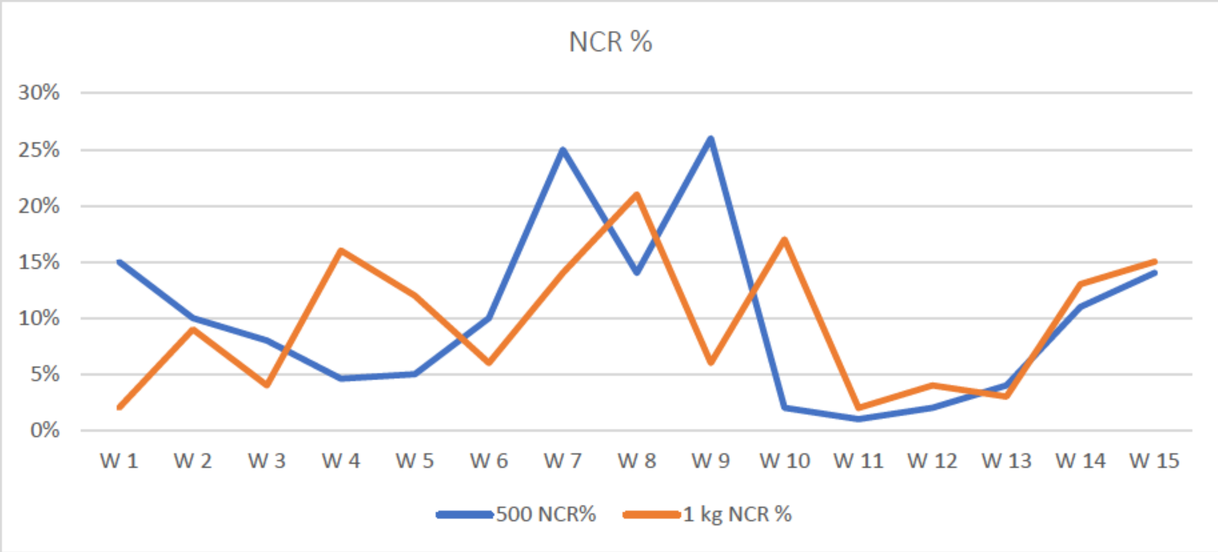


Figure 26: NCR % for 500g and 1kg.

- KPI: **Cycle Time for Packaging Process**

The packing cycle time includes the time it takes to convert raw materials to completed items, which is measured in minutes per pallet. This information is gathered by time studies at each packing stage. Companies may discover bottlenecks in the packing process by assessing cycle time, which is critical for the Control phase of DMAIC, assuring long-term efficiency gains [97].

- The time taken to convert raw materials into sellable items during the packaging process.
- Measurement: Minutes per pallet

Table 5: Production Processes

Processes	**Time Taken**
Packaging	50 minutes
Palletizing	30 minutes
Stretch wrapping	10 minutes

4.4 Analyse Phase

4.4.1 Reasons of Waste

Table 6 shows an evaluation of waste across several SKUs, categorized by various causes of waste. In this session, the study focuses on two SKUs: 1kg and 500g, both of which generate a lot of waste. Table 4, which displayed the waste amounts, allowed for a more in-depth investigation of the core causes of waste. The study looked at operator-recorded data on the spreadsheet, as shown in Figure 8 to identify specific instances where bags did not reach the last sensor. Singh et al. [98] conducted a detailed case study examining the root causes of waste in manufacturing processes and discovered that inefficient material handling practices, a lack of standardized procedures, and insufficient quality control measures were key contributors, resulting in the implementation of targeted strategies to minimize waste and optimize production efficiency, resulting in improved operational performance. Understanding the core causes is critical for optimizing supply chain operations, increasing operating efficiency, and reducing [98].

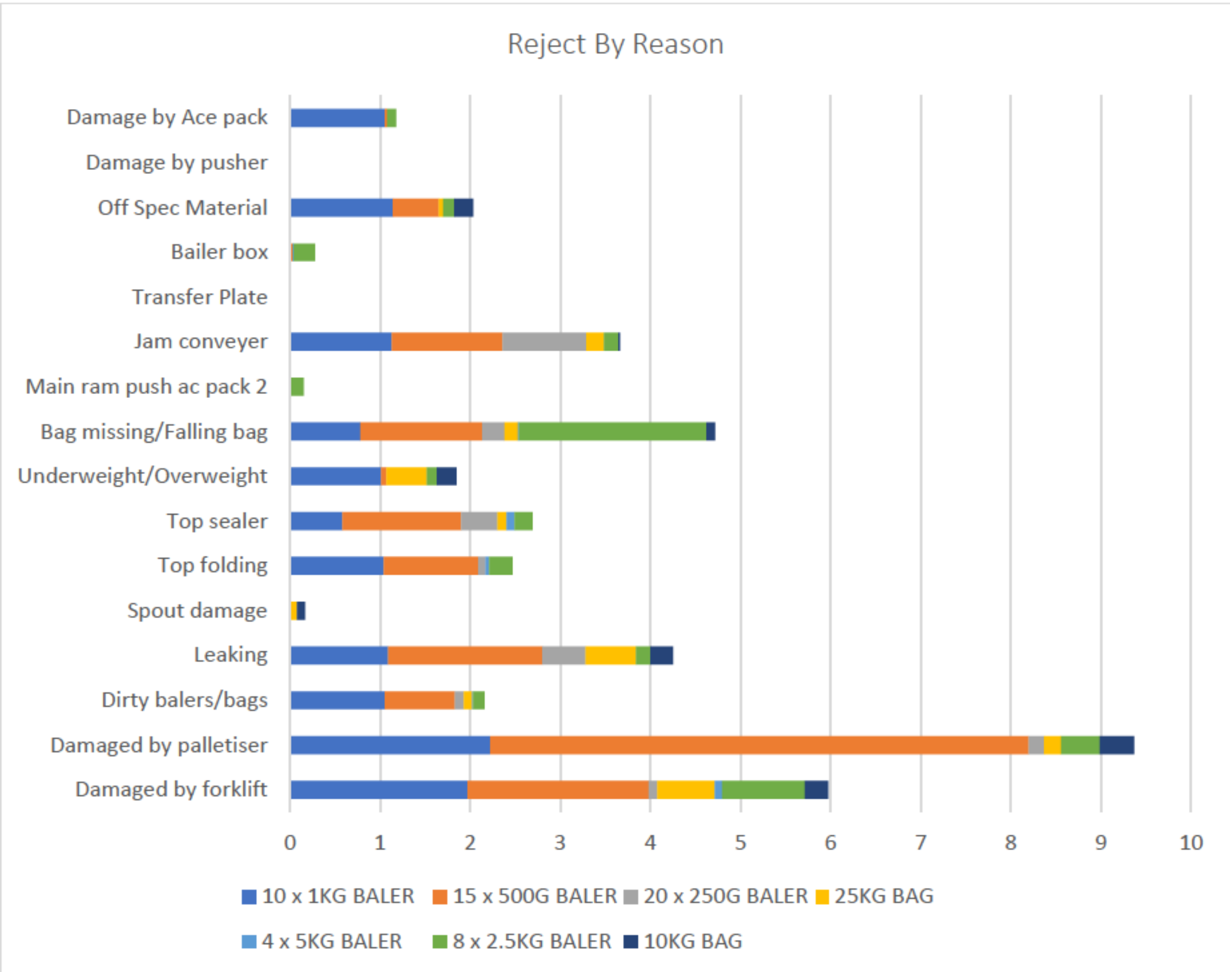


Figure 27: Reject by Reasons for All the SKU

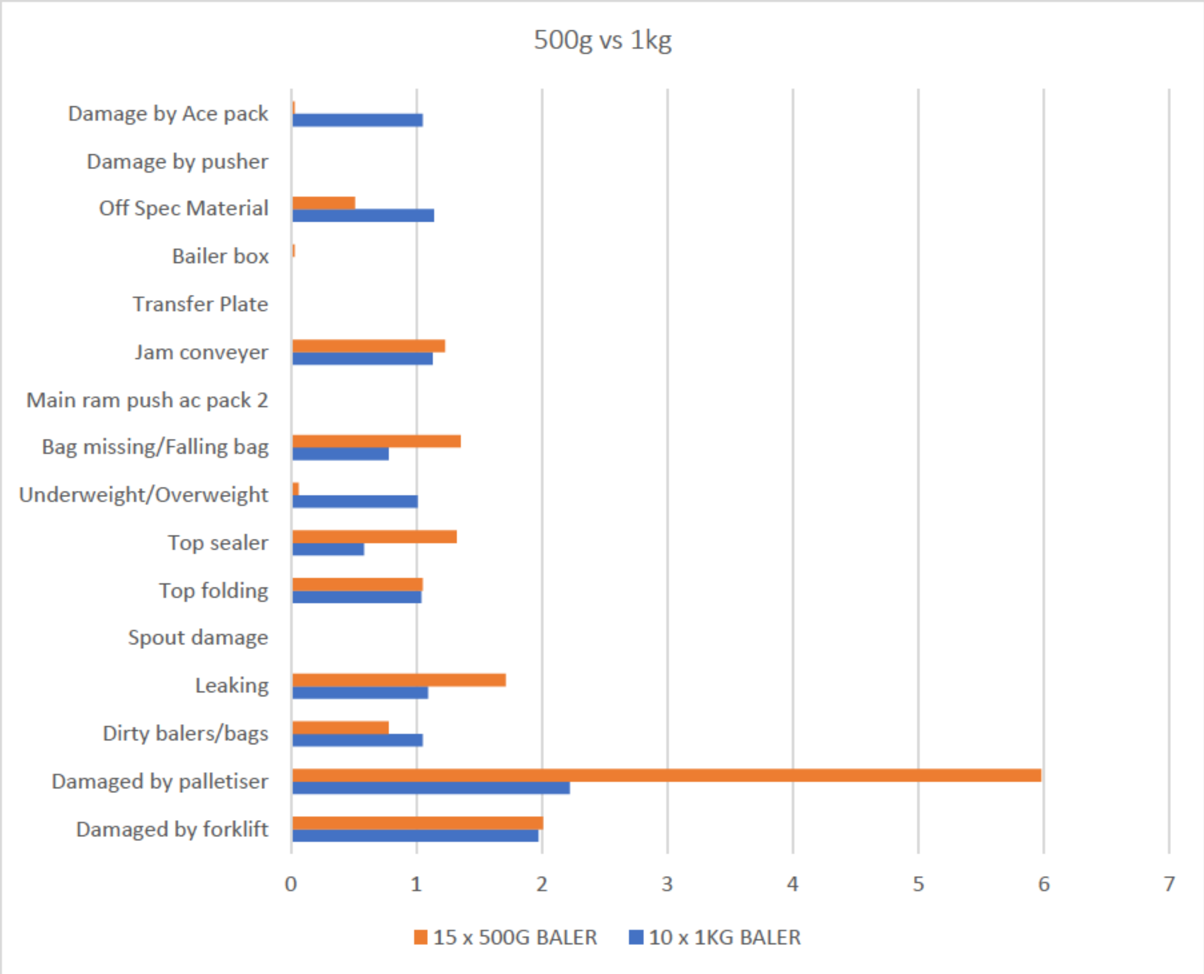


Figure 28: Reject by Reason for 500g and 1kg.

Table 6: Waste by Reasons for every SKU

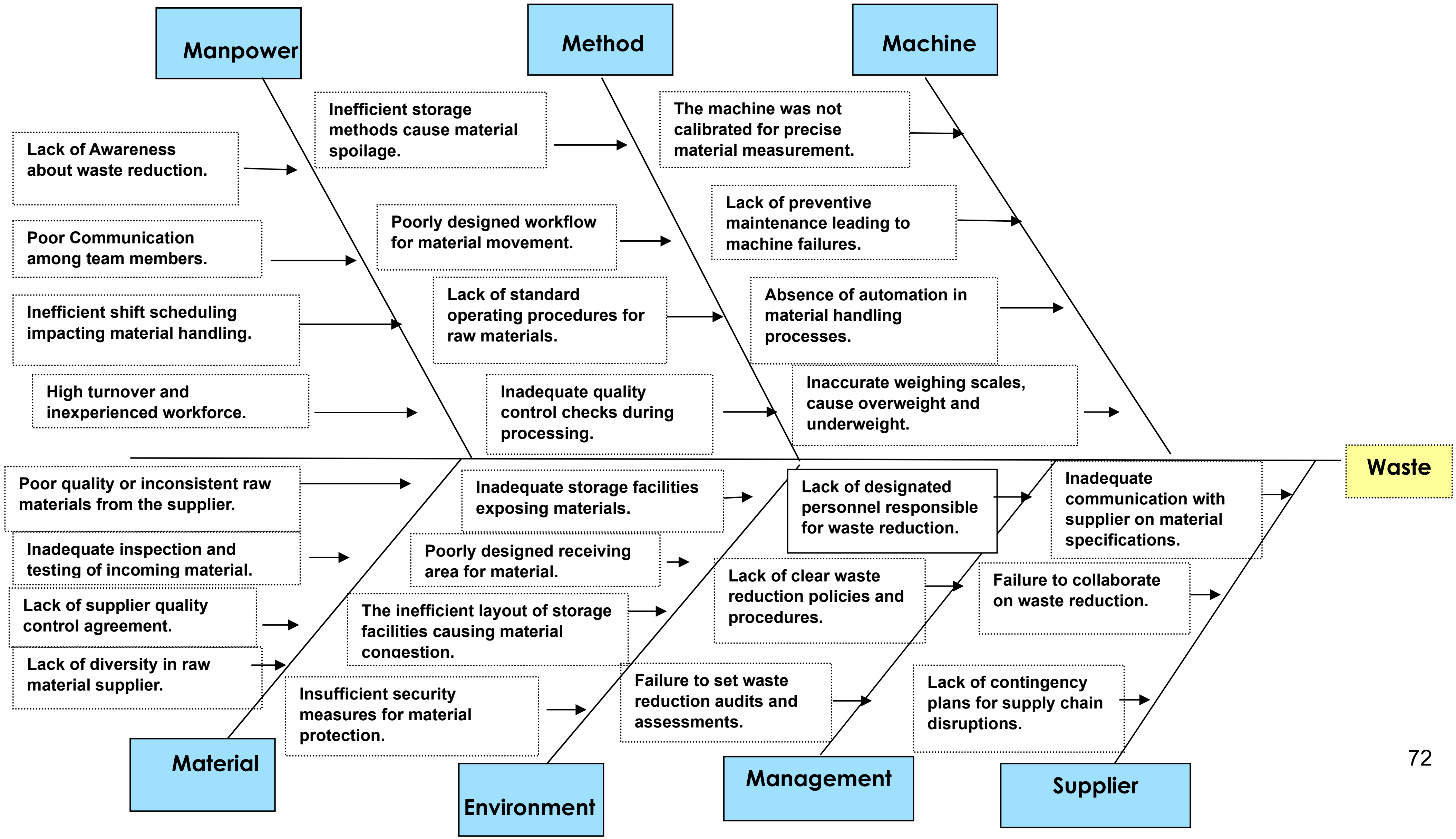
	Sum of Tons																
	Damaged by forklift	Damaged by palletiser	Dirty balers/bags	Leaking	Spout damage	Top folding	Top sealer	Underweight/Overweight	Bag missing/Falling bag	The main ram push ac pack 2	Jam conveyer	Transfer Plate	Baler box	Off Spec Material	Damage by pusher	Damage by Ace pack	Grand Total
1kg	1,97	2,22	1,05	1,09		1,04	0,58	1,01	0,78		1,13			1,14		1,05	13.06
500g	2,01	5,98	0,78	1,71		1,05	1,32	0,06	1,35		1,23		0,03	0,51		0,03	16.06
250G	0,095	0,17	0,1	0,48		0,08	0,4		0,25		0,925						2.5
25KG	0,64	0,19	0,09	0,56	0,075		0,103	0,45	0,15		0,2			0,05			2.5
5KG	0,08		0,01			0,04	0,09		0,01				0,01		0,01		2.5
2.5KG	0,92	0,43	0,13	0,16		0,26	0,2	0,108	2,08	0,15	0,16		0,24	0,12		0,1	5
10KG	0,26	0,38		0,25	0,09			0,22	0,1		0,02	0		0,21			1.5

With a total waste of 13.06 tons, the SKU "1 kg" stands out. This significant waste is ascribed to a variety of circumstances, including 1.97 tons lost owing to forklift drivers, 2.2 tons damaged by palletiser, 1.05 tons for filthy bags, and 7.87 tons due to other causes such as top sealer and jam conveyer difficulties. While some of the waste may be ascribed to machinery and handling, there are significant possibilities for improvement in lowering these losses. Broken pallets, in particular, demand attention to improve pallet integrity and handling operations.

Similarly, "500g" has a high overall wastage of 16.06 tons, with considerable losses attributed to a variety of factors, including 5.59 tons damaged by the palletiser, 2.01 tons damaged by forklift, and 1.71 tons lost owing to leaks. This SKU also has top sealer and top folding difficulties, resulting in 1.32 and 1.05 tons of waste, respectively. The palletiser's high amount of damage is a major issue, and a detailed investigation of the equipment and operational methods is required to offset these significant losses.

In all circumstances, it is critical to acknowledge that the causes of waste are numerous and may necessitate multifaceted remedies. Equipment maintenance, handling procedures, quality control, and packing processes may all be improved to assist in decreasing the waste of these high-value SKUs. Taking a holistic approach to these challenges will not only result in cost savings but will also increase product quality and customer happiness. Furthermore, it is critical to develop monitoring and feedback mechanisms to detect early warning indications of problems and resolve them promptly, therefore contributing to the long-term efficiency and sustainability of the manufacturing process.

4.4.2 Cause and Effect Diagram



Date	Material code	Material Description	No. of Balers rejected	Unit Weight	Cal Ton	Reason for baler rejection	Shift (A/B/C)	Prices	Cost	Weeks
26/06/2023	1	25KG BAG	1	25	n	Broken Pallet	A	386,5	-	W 1
26/06/2023	1	25KG BAG	1	25	n	No slip sheet	A	386,5	-	W 1
26/06/2023	1	25KG BAG	2	25	y	Damaged by palletiser	B	386,5	773,00	W 1
26/06/2023	15	8 x 2.5KG BALER	2	20	y	Damaged by forklift	B	358	716,00	W 1
26/06/2023	16	4 x 5KG BALER	6	20	y	Top folding	B	357,2	2 143,20	W 1
26/06/2023	13	20 x 250G BALER	3	5	y	Top folding	B	111,8	335,40	W 1
26/06/2023	1	25KG BAG	1	25	n	No slip sheet	B	386,5	-	W 1
26/06/2023	20	15 x 500G BALER	1	30	n	Broken Pallet	C	149,55	-	W 1
26/06/2023	20	15 x 500G BALER	1	30	y	Bag missing/Falling bag	C	149,55	149,55	W 1
26/06/2023	15	8 x 2.5KG BALER	1	20	y	Damaged by palletiser	C	358	358,00	W 1
26/06/2023	15	8 x 2.5KG BALER	1	20	y	Damaged by palletiser	C	358	358,00	W 1
26/06/2023	20	15 x 500G BALER	4	30	y	Leaking	C	149,55	598,20	W 1
26/06/2023	1	25KG BAG	3	25	n	Improper Packing	C	386,5	-	W 1
27/06/2023	21	10 x 1KG BALER	105	10	y	Dirty balers/bags	A	189,9	19 939,50	W 1
27/06/2023	13	20 x 250G BALER	7	5	y	Bag missing/Falling bag	A	111,8	782,60	W 1
27/06/2023	20	15 x 500G BALER	26	30	y	Dirty balers/bags	A	149,55	3 888,30	W 1

Figure 29: Spreadsheet used by Researcher.

Figure 29 was used to draw the cause and effect diagram presented in section 4.4.2. This diagram was based on the reasons for baler rejection, as detailed in the preceding analysis. Researchers meticulously examined the data, identifying and categorizing the causes of waste. These causes were organized into standard categories such as Man, Machine, Method, Material, Measurement, and Environment. Each identified cause was thoroughly analysed to ensure an accurate representation of the factors contributing to baler rejection. This systematic approach allowed for a comprehensive visualization of the causes of waste, facilitating targeted improvements in the supply chain process.

4.4.3 Yield Percentage vs Waste.

The 15-week research on the production, waste, and yield percentages for 1 kg and 500g SKUs sheds light on the sugar refinery's operational efficiency and waste management techniques. Somsen et al. [99] revealed the impact of yield percentage versus wastage on production effectiveness within a production environment, showing that improving yield percentages may result in substantial reductions in waste, thereby improving the use of resources and productivity in general, which leads to improvement in operational efficiency and a reduction in expenses associated with material waste. The data shows significant changes in yield percentages across different weeks, highlighting possible difficulties in the manufacturing and supply chain operations.

The yield percentages for the 1 kg SKU vary from 84.74% to 97.68%, whereas the 500g SKU has a greater range of 54.67% to 96.97%. Week 15 stands out as a very hard phase for both SKUs, with considerably lower yield percentages, indicating operational concerns affecting production efficiency.

The numbers show that certain weeks have lower output percentages, showing inefficiencies across the supply chain. These inefficiencies might result in greater waste, reducing the company's resource usage and cost-effectiveness. It is critical to understand the core reasons for these changes since continuously low yield percentages can lead to financial losses and disturb the smooth operation of the supply chain.

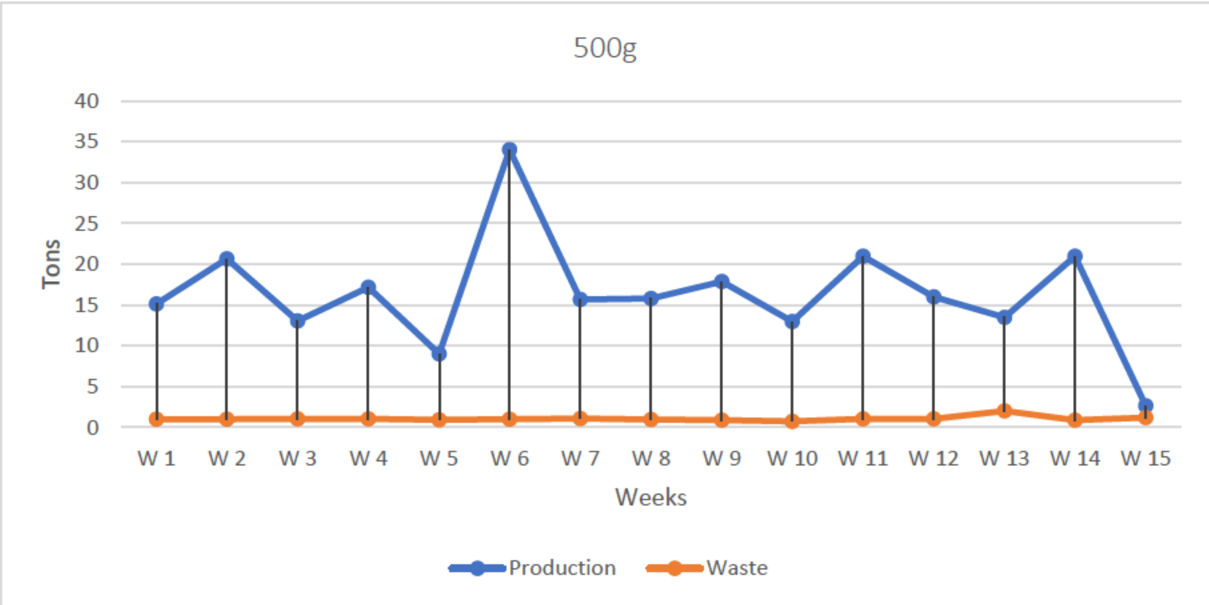


Figure 30: Production vs Waste.

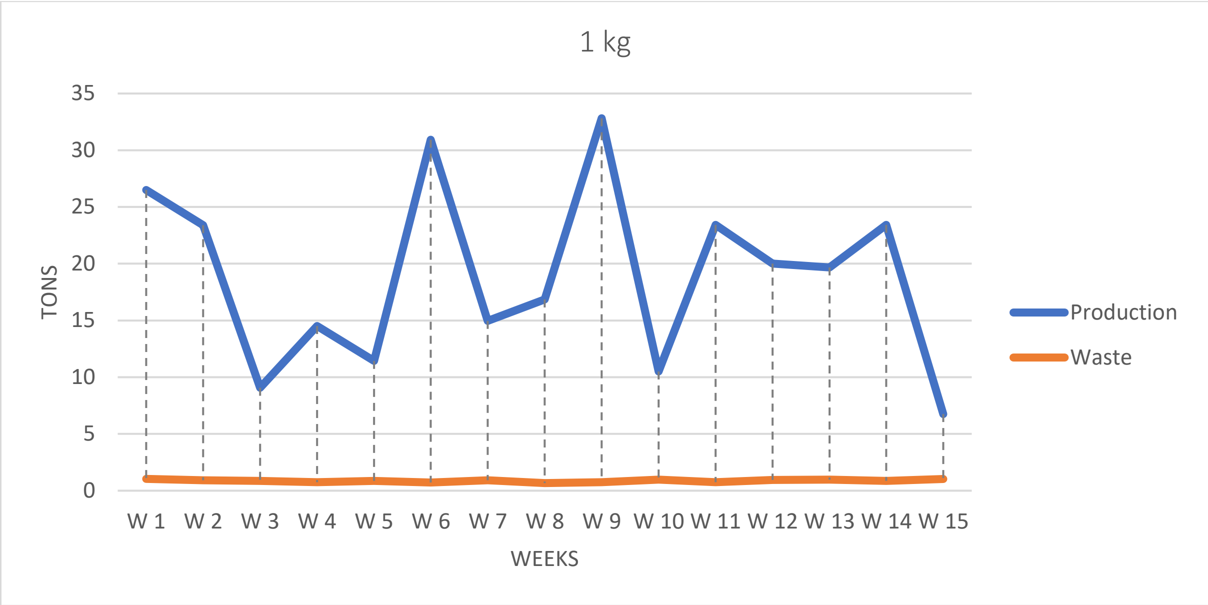


Figure 31: Production vs Waste.

Furthermore, the study emphasizes the value of a resilient and adaptive supply chain. Steps must be taken to maintain regular yield percentages, assuring a stable and reliable supply of products to fulfil market demand. This includes improving manufacturing processes, maximizing resource use, and applying quality control measures to eliminate waste.

The data for the 1 Kg product over 15 weeks shows a clear association between increased waste and a negative influence on production and yield percentages. Waste percentage fluctuations have a direct impact on yield percentages, creating problems for the whole manufacturing process. The yield declines dramatically to 84.74 in Week 15 when the waste rate is 1.03. This significant fall in yield suggests a potential operational bottleneck, showing that more waste negatively impacts the manufacturing process, resulting in a lower yield.

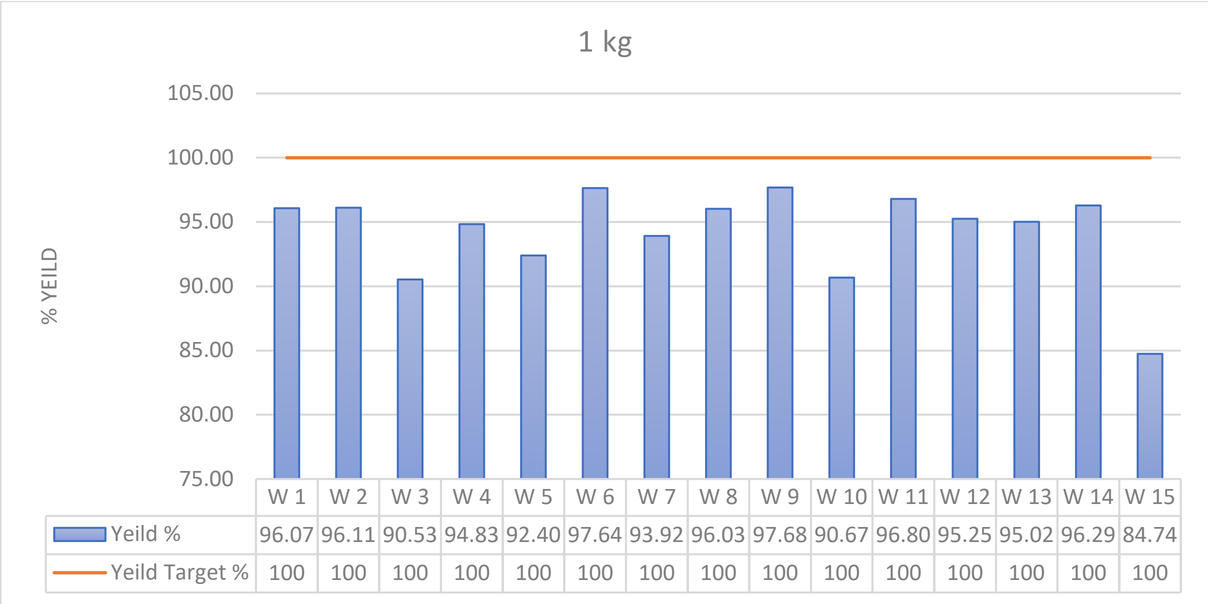
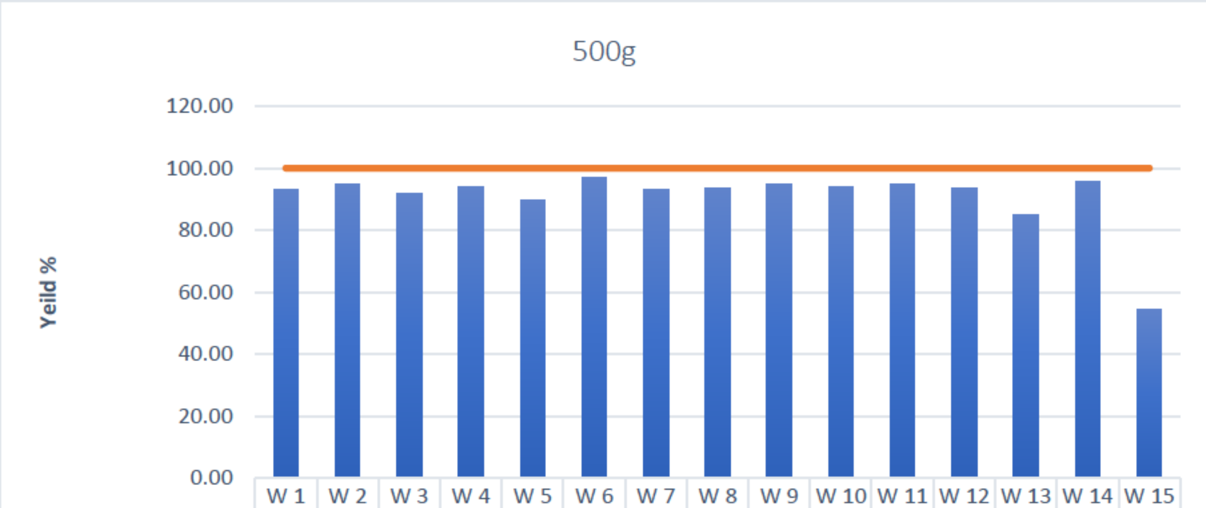


Figure 32: 1 kg Yield%

Further research over multiple weeks indicates a consistent pattern: as waste increases, yield decreases. For example, in Week 13, while waste peaks at 0.98, the output falls to 95.02. This shows that excessive waste reduces manufacturing efficiency, resulting in a poorer yield than the intended norm. The link is both mathematical and practical, underlining the significance of waste reduction measures to improve production efficiency and obtain greater yield percentages.

These findings highlight the importance of waste management in the industrial process. Waste reduction is critical for ensuring a sustainable and effective business. By concentrating on process optimization and waste reduction, a balance may be struck, assuring targeted production efficiency and successful manufacturing operations. Addressing waste-related difficulties is critical for maintaining a high yield and reaching production objectives.

The data for the 500g product over 15 weeks shows a clear association between waste rise and its influence on production and yield. Waste percentages change, which has a direct impact on yield percentages and, as a result, total production efficiency. In Week 15, for example, with a waste rate of 1.2, the yield % falls dramatically to 54.67. This significant fall in yield shows a potential operational difficulty, showing that more waste negatively affects the manufacturing process, resulting in a lower yield.



	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	W 15
Yeild %	93.18	95.07	91.87	93.83	89.58	96.97	93.05	93.80	95.02	94.22	94.95	93.49	85.00	95.76	54.67
Yeild Target %	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Figure 33: 500g Yield %

Analysing multiple weeks indicates a similar pattern: as waste increases, yield decreases. For example, in Week 13, if waste reaches 2.02, the yield declines to 85.00. This shows that excessive waste reduces manufacturing efficiency, resulting in a poorer yield than the intended norm. The link is not just mathematical, but also operational, indicating that efforts should be directed toward waste reduction measures to improve production efficiency and attain greater yield percentages.

4.4.4 Material Specification

The material parameters of two specific SKUs, 500g and 1kg, have been examined. The 500g SKU has dimensions of 264X75 mm and is of the 'Pre-Print' kind. It is made of a 75gsm Axelle Swan material that comes in a variety of colours, including Blue (HWB065), Red (HWR166), Yellow (HWT158), and Green (HWG234). This SKU's packaging is put on SP 2 returnable pallets. The criteria for selecting packing materials stress the material's appropriateness for the individual product it holds. A Certificate of Analysis (COA) is required for each batch of this SKU to ensure quality control.

Table 7: 500g Material specification

Description	500g
Size (mm)	264X75
Type	Pre-Print
Construction	75gsm Axelle Swan
Colour	1. Blue HWB065 2. Red HWR166 3. Yellow HWT158 Green HWG234
Pallets	4. SP 2 – returnable
Criteria of the packaging material	Fit for purpose for product specific. A certificate of analysis (COA) is required for each batch.
Details of the test conducted	Random incoming tests conducted on raw materials i.e. grammage, tensile, slip angle, etc.
Tolerances for Test	As per supplier specification, must be within aim.
Tolerances	Bag Width $\pm 1\ mm$ Bag Length $\pm 4\ mm$ Gusset Width $\pm 2\ mm$ Bottom Width $\pm 2\ mm$

Furthermore, the 1kg, with dimensions of 264X75 mm, falls within the 'Pre-Print' category. It is made of the same 75gsm Axelle Swan material that comes in Blue (HWB065), Red (HWR166), Yellow (HWT158), and Green (HWG234). This SKU is palletized on SP 2 returnable pallets as well. The requirements for '1kg Sig Machine' packing material coincide with its appropriateness for the product it contains, and each batch, like the preceding SKU, requires a Certificate of Analysis (COA) to ensure consistent quality.

Table 8: 1 kg Material Specification

Description	1kg
Size (mm)	264X75
Type	Pre-Print
Construction	75gsm Axelle Swan
Colour	1. Blue HWB065 2. Red HWR166 3. Yellow HWT158 4. Green HWG234
Pallets	SP 2 – returnable
Criteria of the packaging material	Fit for purpose for product specific. A certificate of analysis (COA) is required for each batch.
Details of the test conducted	Random incoming tests conducted on raw materials i.e. grammage, tensile, slip angle, etc.
Tolerances for Test	As per supplier specification, must be within aim.
Tolerances	Bag Width $\pm 1\ mm$ Bag Length $\pm 4\ mm$ Gusset Width $\pm 2\ mm$ Bottom Width $\pm 2\ mm$

Random incoming tests on raw materials are performed in both circumstances, encompassing factors such as grammage, tensile strength, and slip angle, among others. Tolerances for these tests comply with supplier guidelines, emphasizing that measurements must fall within the given objective. Tolerances for measurements include 1 mm for bag width, 4 mm for bag length, 2 mm for gusset width, and 2 mm for bottom width. These careful material standards and quality control procedures demonstrate the company's dedication to assuring the integrity and fitness of the packing materials for both the 500g and 1kg SKUs.

The analysis indicated that the supplier's performance in terms of meeting material criteria varies, resulting in an increasing percentage of NCRs. This discrepancy in performance has been related to the supplier's inability to satisfy the material standards mentioned in the research. Table 7 and Table 8 provide the material specifications of both SKUs and what does the company expect. These data show that the supplier's inability to consistently satisfy material needs is a key driver to the growing NCR %, emphasizing the importance of targeted changes in the supply chain process.

4.4.5 Material- Bill of Material (BOM)

For two distinct product weights (500g and 1 kg), the results show a constant difference between the production (Prod.) amounts recorded by, the SAP system and those seen by the researcher over 15 weeks. This disparity is critical for understanding the production dynamics of the company. The SAP data constantly indicates higher waste statistics than the researcher's findings and usual wastage. Mathrani [100] conducted a successful case study to investigate the discrepancy between the BOM recorded in the company software and the actual materials present on the production floor, revealing the importance of aligning digital records with physical inventory to improve supply chain efficiency.

The production results, shown in Table 6, are based on data obtained from the production conveyor. SAP data reflect trash that is automatically recorded by the company's software system, considering the difference between the conveyor's start and end sensors and the BOM. The researcher waste estimates were determined manually by weighing each off-spec bag and documenting the results. This multifaceted approach allows a thorough assessment of waste across the manufacturing process, accounting for both automated and manual data-collecting techniques.

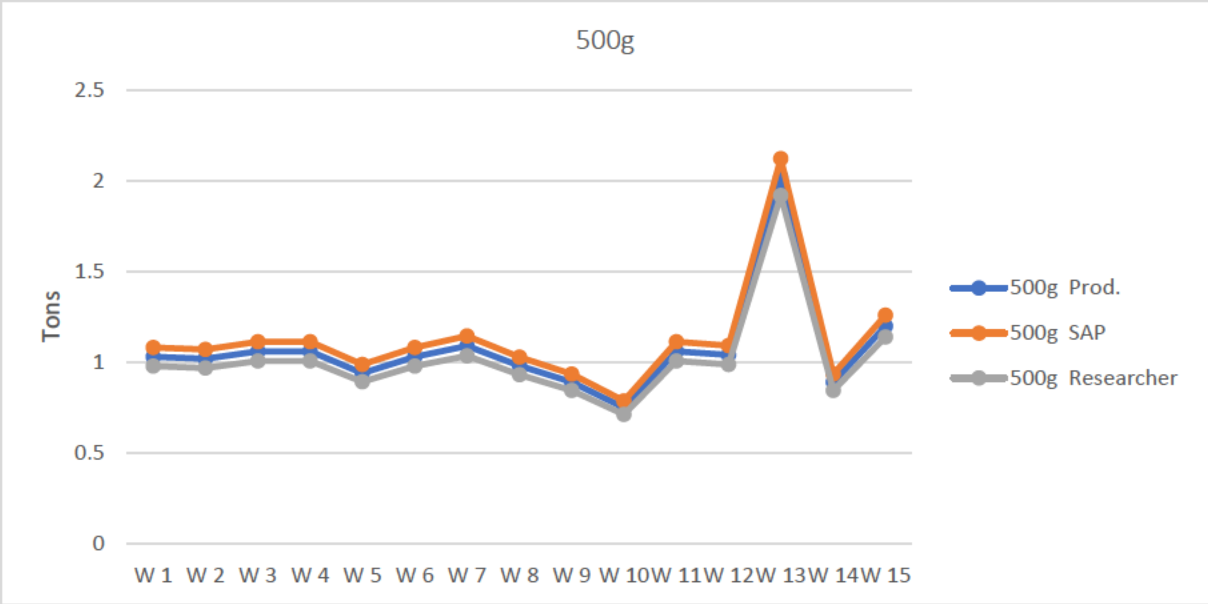


Figure 34: Production waste vs SAP waste vs Researcher waste.

The SAP numbers for 1 kg products ranged from 1.1466 to 2.121 times higher. This significant variation raises concerns regarding potential SAP system flaws or disparities in the measuring and recording processes.

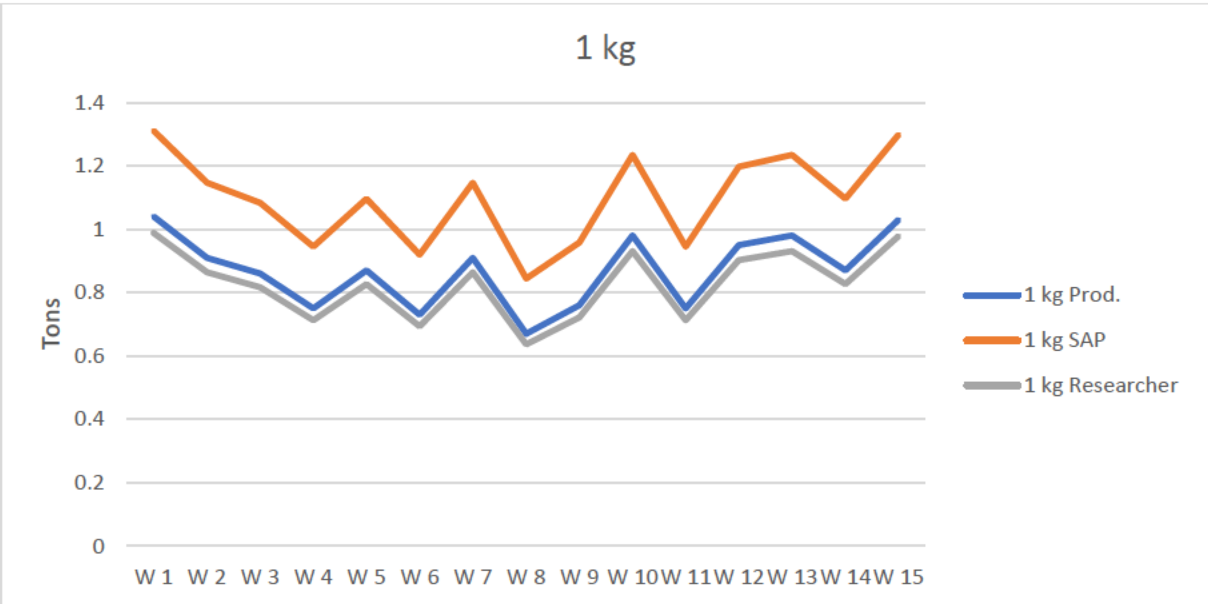


Figure 35: Production waste vs SAP waste vs Researcher waste.

The investigation into BOM discrepancies, as documented in the SAP system, found a significant disparity between the real and standard amounts. The Appendix page reveals the company's standard BOM, as well as the Appendix for seven items (25kg, 10kg, 5kg, 2.5kg, 1kg, 500g, and 250g). Notably, when compared to established criteria, the SAP-generated data suggests a larger use of resources, both in terms of quantity and cost.

This mismatch reveals itself in the form of improved outcomes and higher waste during the production operation.

The SAP system, which is intended to methodically record and manage numerous aspects of corporate operations, has emerged as a vital tool for discovering and addressing BOM-related abnormalities. The observed variation, in which the system suggests consumption levels that exceed the established norms, raises serious concerns regarding the quality of the recorded data and the efficiency of resource usage.

The higher results and increased waste, as shown by the SAP data, point to possible inefficiencies in the manufacturing process. It necessitates a detailed investigation of the causes contributing to this increased consumption. Inaccuracies in the original standard setting, variances in real production circumstances, or differences in the recording and reporting systems inside the SAP system are all possible factors.

4.4.6 Non-Conformance Report (NCR)

An NCR is raised whenever the supplier fails to fulfil the material specifications outlined in Table 7 and Table 8. This failure to meet requirements causes production issues and accumulates waste. According to company procedure, if any material does not meet the specifications, the Production Controller is responsible for raising an NCR to notify the supplier of the material fault. This process ensures that the supplier is aware of the issue and can take corrective action to prevent future occurrences, thereby improving overall production efficiency and reducing waste.

The findings of the study on NCR and its influence on waste in the manufacture of 500g packaging material show a clear link between lower NCR rates and higher waste. Perfeqta [101] discovered that careful reporting of NCRs resulted in significant enhancements in productivity, reducing downtime by 25% and improving product quality by 15%, while the lack of NCR reporting associated with rising waste and constant errors, underscoring the pivotal role of NCR reporting for improving efficiency in operations as well as eliminating inefficiency. The NCR rates for both poly and paper materials were recorded weekly over 15 weeks.

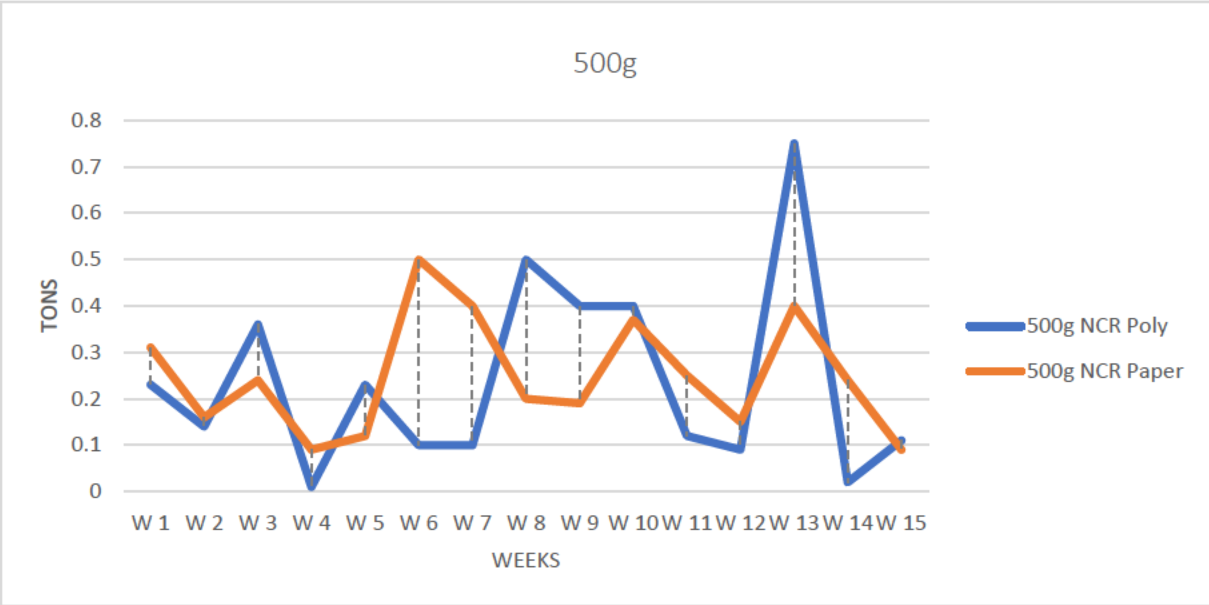


Figure 36: NCR Result for 500g.

Throughout the trial, changes in NCR rates were seen. Weeks with lower NCR rates, such as Week 4 (Poly: 0.01, Paper: 0.09), Week 5 (Poly: 0.23, Paper: 0.12), and Week 14 (Poly: 0.02, Paper: 0.24), were associated with increased trash. This pattern implies that a weaker focus on discovering and fixing non-conformities may lead to higher amounts of waste in the production process.

In contrast, for weeks with greater NCR rates, such as Week 13 (Poly: 0.75, Paper: 0.4), the trash recorded was considerably smaller. This inverse link implies that a more thorough approach to resolving non-conformances might help to waste reduction.

The study of NCR rates and their influence on waste in the manufacture of 1 kg packaging material indicates a strong link, emphasizing the importance of quality control in waste reduction. NCR rates for both poly and paper materials were regularly measured for 15 weeks.

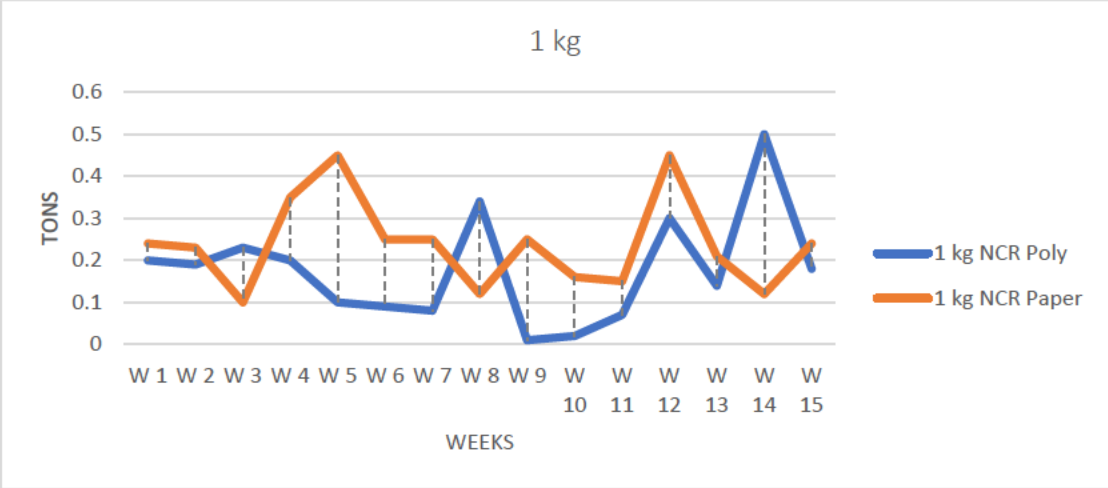


Figure 37: NCR Result for 1kg.

The investigation revealed significant trends, demonstrating a clear link between low NCR rates and increasing waste in several cases. Weeks with lower NCR rates, such as Weeks 5 (Poly: 0.1, Paper: 0.45), 6 (Poly: 0.09, Paper: 0.25), and 9 (Poly: 0.01, Paper: 0.25), were associated with greater waste levels. This shows that a reduced emphasis on discovering and addressing non-conformances might lead to increased waste during the manufacturing process. Conversely, weeks with greater NCR rates, such as Week 14 (Poly: 0.5, Paper: 0.12), had lower waste levels, demonstrating an inverse link. This demonstrates the influence of a good NCR management system on waste reduction.

4.4.7 5 Why Analysis

In the Improve phase, the research used the 5 Whys analysis to investigate the underlying causes of our observed problems, these observed problems are taken from the fishbone diagram in 4.4.2. Nagi & Altarazi [102] successfully utilized the 5 Whys analysis in the DMAIC guidance to identify the root causes of waste in manufacturing workflows, demonstrating its effectiveness in generating actionable insights for quality improvement and working simplifying, resulting in a notable 30% decrease in waste production and reduced process variability.

Each issue was symbolically portrayed, with a visual signal for simple identification. These symbols not only helped with the analysis but also acted as category identifiers in our Prioritization Matrix. This strategic approach enabled us to methodically prioritize the identified challenges, leading to effective and focused remedies. The usage of symbols expedited the communication process, allowing the team to comprehend the core of each issue and its related solution quickly.

Table 9: Five Why Analysis for Manpower

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solution
M1	**Lack of awareness about waste reduction practices**	No training programs in place	Budget constraints prevent training initiatives	Lack of emphasis on waste reduction in company priorities	Lack of understanding of the impact of waste on operations	Insufficient communication about the importance of waste reduction	Provide frequent training on waste reduction strategies.
M2	**High turnover and inexperienced workforce**	Insufficient onboarding processes	Lack of investment in employee development	Poor working conditions contribute to high turnover	Lack of engagement and mentorship for new employees	Lack of career growth opportunities for employees	Improve onboarding procedures for new staff.
M3	**Poor communication among team members**	Lack of effective communication channels	No team-building initiatives	Cultural or language barriers affecting communication	Lack of leadership in fostering a communicative environment	Lack of regular team meetings and updates	Create efficient communication channels and team-building efforts.
M4	**Inefficient shift scheduling impacting material handling**	Lack of proper planning for shift schedules	Absence of feedback mechanisms for schedule optimization	Poor coordination among shift teams leads to inefficiencies	Lack of flexibility in adapting to changing production demands	Inadequate utilization of technology for scheduling purposes	Establish a strong planning mechanism for shift schedules to enable effective organization and coverage.

Table 10: Five Why Analysis for Methods

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solution
MT1	**Inefficient storage methods cause material spoilage**	Lack of proper storage space	Inadequate organization of storage areas	Poor visibility of materials leading to oversight	Lack of monitoring systems for temperature and humidity control	Absence of regular checks on the condition of stored materials	Reorganize storage spaces for efficiency and improve visibility with adequate labelling.
MT2	**Lack of standard operating procedures for raw materials**	No established procedures for receiving and handling raw materials	Lack of training on proper handling procedures	Absence of documentation for reference on handling procedures	Lack of communication on changes in handling procedures	No feedback loop for continuous improvement in handling procedures	Create standard operating procedures for handling raw materials and provide training on correct handling techniques.
MT3	**Poorly designed workflow for material movement**	Lack of workflow analysis to identify bottlenecks	The absence of collaboration among departments impacts workflow	Inefficient use of space and resources in the workflow design	Poor communication of workflow changes to relevant teams	Lack of adaptability in the workflow design	Conduct workflow analysis to identify bottlenecks and improve communication for workflow changes.
MT4	**Inadequate quality control checks during processing**	Lack of trained personnel for quality control checks	Insufficient investment in quality control equipment	Lack of integration of quality control checks into the process	Absence of regular audits on the effectiveness of quality checks	No clear guidelines on the frequency and methods of quality checks	Train people to conduct quality control inspections and invest in quality control equipment.

Table 11: Five Why Analysis for Machine

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solutions
MC1	**Insufficient budget for regular maintenance**	Insufficient budget for regular maintenance	Lack of a scheduled maintenance plan	Limited awareness of the importance of preventive maintenance	High costs associated with machine downtime	Lack of a system for monitoring and scheduling maintenance	Implement a maintenance monitoring and scheduling system.
MC2	**Lack of calibration procedures for machines**	Lack of calibration procedures for machines	Inadequate training on calibration procedures for operators	Absence of regular checks on the accuracy of machine calibration	Lack of documentation for reference on calibration procedures	No feedback loop for continuous improvement in calibration procedures	Train operators on calibrating techniques and regularly verify machine calibration for correctness.
MC3	**Lack of regular calibration for weighing scales or meters**	Lack of regular calibration for weighing scales or meters	Limited awareness of the impact of inaccurate measurements	Absence of routine checks on the accuracy of weighing scales	Inadequate maintenance of weighing equipment	No clear guidelines on the frequency and methods of calibration	Regularly calibrate weighing scales or meters.
MC4	**Limited investment in automation technologies**	Limited investment in automation technologies	Lack of expertise in integrating automation into processes	Concerns about job displacement due to automation	Inadequate communication on the benefits of automation	Resistance to change in adopting automation technologies	Effectively communicate the benefits of automation and overcome opposition to change while using automation technology.

Table 12: Five Why Analysis for Material

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solutions
MM1	**Poor quality or inconsistent raw materials from suppliers**	Lack of clear quality standards for raw materials	Insufficient communication with suppliers	Absence of regular quality checks on incoming materials	Limited understanding of the impact of poor-quality materials	No collaboration with suppliers for continuous improvement	Set defined quality criteria for raw materials and improve communication with suppliers.
MM2	**Inadequate inspection and testing of incoming materials**	Lack of standardized procedures for material inspection	Insufficient training on inspection procedures for personnel	Absence of equipment for thorough testing of incoming materials	No documentation of inspection results	Limited accountability for material inspection	Create consistent methods for material inspection and ensure accountability for material inspections.
MM3	**Lack of supplier quality control agreements**	Absence of clear quality control agreements with suppliers	Limited negotiation and collaboration on quality control	Lack of awareness about the benefits of quality control agreements	Concerns about additional costs for implementing agreements	Resistance to change in adopting quality control agreements	Ensure unambiguous quality control agreements with vendors.
MM4	**Lack of diversity in raw material suppliers**	Heavy reliance on a small number of suppliers	Limited exploration of alternative suppliers	Concerns about the stability and reliability of new suppliers	Lack of incentives for diversifying supplier base	Insufficient monitoring of market trends and supplier performance	Diversify supplier base to lessen and offer incentives to diversify supplier base.

Table 13: Five Why Analysis for the Environment

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solutions
E1	**Inadequate storage facilities exposing materials to the elements**	Lack of covered storage space for materials	Insufficient investment in improving storage infrastructure	Failure to anticipate and address weather-related risks	Limited consideration of long-term storage needs	Inadequate risk assessment for material exposure to the elements	Invest in covered storage for supplies and plan storage to account for weather concerns.
E2	**Poorly designed storage areas leading to inefficiencies**	Lack of systematic planning in designing storage areas	Absence of input from material handlers in storage area design	Inadequate consideration of workflow and accessibility in design	Limited utilization of technology for efficient storage	Insufficient monitoring of storage area efficiency	Use methodical planning to design storage places and prioritize workflow and accessibility in design.
E3	**The inefficient layout of storage facilities causes material congestion**	Lack of optimization in storage facility layout	Insufficient consideration of material flow in layout planning	Poor organization of storage spaces contributes to congestion	Limited use of storage optimization tools and techniques	Inadequate flexibility in adapting to changing storage needs	Optimize storage facility layouts by considering material movement.
E4	**Insufficient security measures for material protection**	Lack of comprehensive security protocols for material protection	Limited investment in security infrastructure for materials	Inadequate training on security procedures for personnel	Minimal use of surveillance technology for material protection	Lack of regular audits and assessments of security measures	Develop comprehensive security mechanisms for material protection.

Table 14: Five Why Analysis for Management

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solutions
MG1	**Lack of designated personnel responsible for waste reduction**	Absence of clear roles and responsibilities for waste reduction	Limited awareness of the importance of a dedicated role	Failure to prioritize waste reduction responsibilities	Insufficient allocation of resources for waste reduction activities	Lack of commitment from top management to appoint designated personnel	Establish defined roles and responsibilities for waste reduction.
MG2	**Lack of clear waste reduction policies and procedures**	Absence of a structured framework for waste reduction policies	Limited communication and training on waste reduction policies	Failure to establish enforceable procedures for waste reduction	Inadequate monitoring and feedback mechanisms for policy compliance	Lack of integration of waste reduction policies with overall operations	• Educate and train on waste reduction policies. • Implement monitoring and feedback tools to ensure policy compliance.
MG3	**Failure to set waste reduction audits and assessments**	Lack of awareness of the benefits of waste reduction audits	Limited expertise in conducting waste reduction assessments	Inadequate recognition of the role of audits in continuous improvement	Insufficient allocation of resources for waste reduction audits	Lack of accountability for the outcomes of waste reduction audits	Raise awareness about the benefits of waste reduction audits.

Table 15: Five Why Analysis for Supplier

Symbol	Issues	Why (1st)	Why (2nd)	Why (3rd)	Why (4th)	Why (5th)	Possible Solution
S1	**Inadequate communication with the supplier on material**	Lack of standardized communication channels with the supplier	Limited understanding of the importance of effective communication	Failure to establish regular communication protocols with the supplier	Insufficient monitoring and feedback mechanisms for communication	Absence of a dedicated role or responsibility for supplier communication	Increase understanding of the significance of good communication.
S2	**Lack of clear waste reduction policies and procedures**	Absence of a structured framework for waste reduction policies	Limited communication and training on waste reduction policies	Failure to establish enforceable procedures for waste reduction	Inadequate monitoring and feedback mechanisms for policy compliance	Lack of integration of waste reduction policies with overall operations	Communicate and train on waste reduction initiatives.
S3	**Lack of contingency plans for supply chain disruptions**	Insufficient risk assessment and identification of potential disruptions	Limited consideration of alternative supply chain scenarios	Failure to prioritize the development of contingency plans	Inadequate testing and simulation of contingency plans	Lack of cross-functional collaboration for contingency planning	Improve risk assessment and identify possible disruptions.

4.5 Improve Phase

4.5.1 Introduction

In the Measure and Analyse stages, the research aimed to identify the main causes of waste in the company's supply chain and analyse their influence on overall performance and efficiency. The study used the fishbone diagram to identify important elements contributing to waste. Building on these results, the study performed a comprehensive 5 Whys analysis for each root cause to go further into the underlying problems. The findings of this study were complemented by offered solutions. To systematically prioritize various alternatives, the study used a Prioritization Matrix. This matrix provides a systematic framework for analysing and ranking prospective solutions according to their relevance and practicality. By classifying and analysing the identified solutions, the Matrix of Prioritization enabled a thorough knowledge of the most impactful and practical tactics for addressing the core causes of waste in the company's supply chain.

4.5.2 5S Technique

The use of the 5S approach resulted in considerable increases in organizational efficiency and workplace order. With the use of the study of Michalska and Szewieczek [103], the 5S tool help to analyse and improve the workflow of the company. Before the research, the workplace was noticeably disorganized, with equipment and materials scattered throughout. Following deployment, a tremendous improvement was seen, demonstrating a methodical organization of tools, improved cleanliness, and simplified productivity.

The "sort" process resulted in the elimination of unneeded things, which reduced clutter and improved workplace functioning. The "Set in Order" step resulted in a systematic arrangement of tools and equipment, which improved accessibility and reduced time waste. "Shine" helped to make the workplace cleaner and more aesthetically pleasant, establishing a culture of cleanliness.

The "Standardize" phase implemented rules and established methods to provide uniformity in the management of the upgraded workplace. Lastly, the "Sustain" phase proved a continuous commitment to the 5S principles by implementing continual monitoring and reinforcing systems. Overall, the before-and-after study revealed in Table 17 measurable improvements in the operational efficiency or workflow of the company, confirming the 5S technique's favourable influence on organizational performance. Table 16 presents a detailed explanation of the before and after scenarios, while Table 17 provides photographic evidence of the changes..

Table 16: Before and after 5S implementation

Before	Action	Results
Material lying on the floor.	Implemented the NCR procedure to resolve material concerns originating with suppliers. Damages were recorded and written off in the system (SAP).	Clutter has been reduced and production spaces have become more organized.
Tools and packaging materials were thrown all around.	Racks with labelled sections were introduced to ensure correct storage.	Reduced the average damage to raw packing material.
The walls in the production area were not cleaned.	During the shutdown, the walls in the production area were painted.	The walls are now clean.
There was no audit undertaken to improve the workplace.	Trained the SHE teams to perform audits on Fridays.	The audit results are now given for continual improvement.

Table 17: 5S Implementation result

Before	After
	
	

4.5.3 Matrix Prioritisation

Following the 5-why analysis, the study used matrix prioritization to identify each cause or issue discovered in the fishbone diagram, boosting systematic knowledge and allowing focused improvement efforts. Bahill & Botta [104] effectively used the Prioritization Matrix to identify and prioritize waste reduction techniques in a manufacturing organization, easing the deployment of high-impact projects and resulting in considerable gains in operational efficiency. Notably, the data revealed a notable lack of concerns labelled as "Drop," suggesting that each root cause was significant and deserved attention. The bulk of the concerns were classified as "High Priority," indicating a need for focused efforts with a significant impact on waste reduction. This convergence of high-priority and low-effort needs indicated that smart waste management actions may produce considerable outcomes. The identification of these patterns using the Matrix Prioritization method highlighted the importance of focused and efficient mitigation solutions to address the identified concerns and improve waste reduction efforts within the examined environment. The symbols e.g. M1 represent possible solutions linked to the issue in Table 9.

Table 18: Matrix Prioritisation for Man

Symbol	Issues	Possible Solution
M1	Lack of awareness about waste reduction practices	Provide frequent training on waste reduction strategies
M2	High turnover and inexperienced workforce	Improve on-boarding procedures for new staff
M3	Poor communication among team members	Create efficient communication channels and team-building efforts
M4	Inefficient shift scheduling impacting material handling	Establish a strong planning mechanism for shift schedules to enable effective organization and coverage

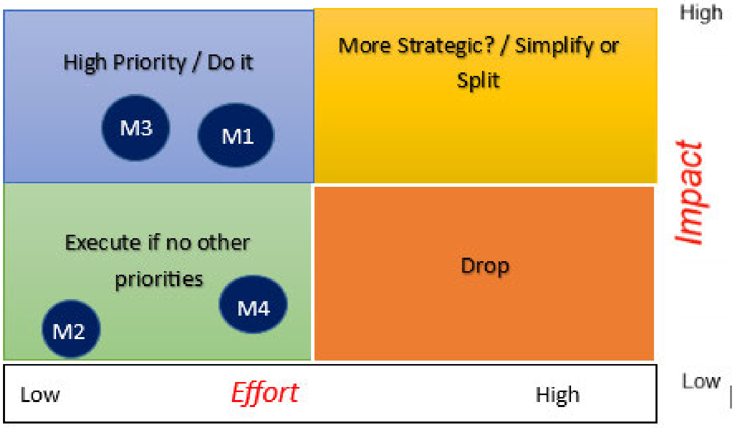


Figure 38: Impact and Effort diagram for Man.

To accomplish changes, adjustments were made to the communication systems among shift production controllers, especially in reporting the number of rejections created throughout their respective shifts. The absence of adequate shift handover protocols may have catastrophic consequences, underlining the crucial importance of trustworthy communication during shift changes, particularly in complicated and high-risk tasks, to protect safety [105]. This addition was useful since it alerted operators that management actively participates in waste reduction programs, instilling the awareness that every incidence of waste creation has an underlying reason. As a result, the research prompted the firm to have daily production meetings, which provided a forum for a thorough evaluation of all waste measures.

Table 19: Possible Solution Prioritisation for Method

Symbol	Issues	Possible Solution
MT1	Inefficient storage methods cause material spoilage	Reorganize storage spaces for efficiency and improve visibility with adequate labelling.
MT2	Lack of standard operating procedures for raw materials	Create standard operating procedures for handling raw materials and provide training on correct handling techniques.
MT3	Poorly designed workflow for material movement	Conduct workflow analysis to identify bottlenecks and improve communication for workflow changes.
MT4	Inadequate quality control checks during processing	Train people to conduct quality control inspections and invest in quality control equipment.

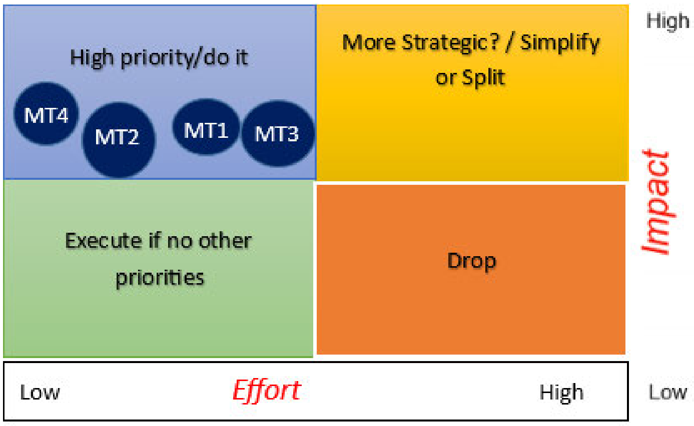


Figure 39: Impact and Effort diagram for Method.

The use of a First-In, First-Out (FIFO) method for material management resulted in a major improvement. Previously, materials lacked organized procedures and were kept on racks, risking harm during handling. The new arrangement, based on FIFO principles, avoided material damage by offering a systematic and ordered storage solution, therefore improving overall efficiency and avoiding waste.

Table 20: Matrix Prioritisation for Machine

Symbol	Issues	Possible Solutions
MC1	Insufficient budget for regular maintenance	Implement a maintenance monitoring and scheduling system.
MC2	Lack of calibration procedures for machines	Train operators on calibrating techniques and regularly verify machine calibration for correctness.
MC3	Lack of regular calibration for weighing scales or meters	Regularly calibrate weighing scales or meters.
MC4	Limited investment in automation technologies	Effectively communicate the benefits of automation and overcome opposition to change while using automation technology.

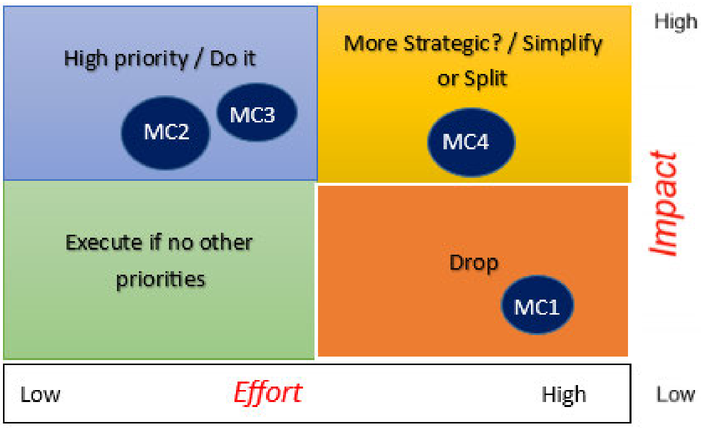


Figure 40: Impact and Effort diagram for Machine.

Improvements to the weighing system included the upkeep and enhancement of weighing equipment. The addition of a new scale with upper and lower boundaries aided the improvement. These adjustments made the weighing procedure more precise and efficient.

Table 21: Matrix Prioritisation for Material

Symbol	Issues	Possible Solutions
MM1	Poor quality or inconsistent raw materials from suppliers	Set defined quality criteria for raw materials and improve communication with suppliers.
MM2	Inadequate inspection and testing of incoming materials	Create consistent methods for material inspection and ensure accountability for material inspections.
MM3	Lack of supplier quality control agreements	Ensure unambiguous quality control agreements with vendors.
MM4	Lack of diversity in raw material suppliers	Diversify supplier base to lessen and offer incentives to diversify supplier base.

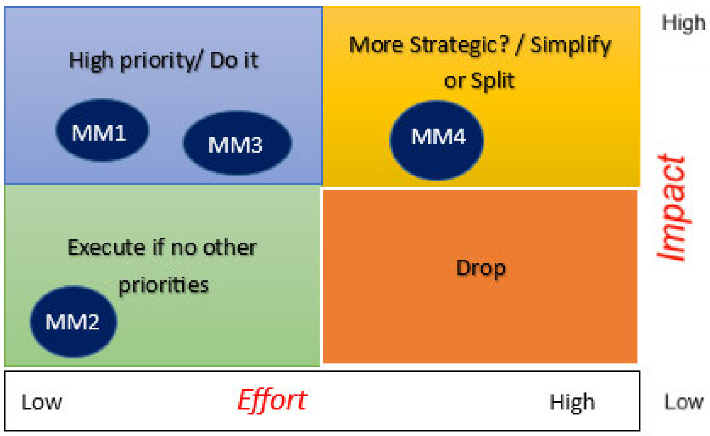


Figure 41: Impact and Effort diagram for Material.

Raising NCR engages suppliers in acknowledging errors or faults in their materials, as waste often results from defective materials identified during the production process.

Table 22: Matrix Prioritisation for Environment

Symbol	Issues	Possible Solutions
E1	Inadequate storage facilities exposing materials to the elements	Invest in covered storage for supplies and plan storage to account for weather concerns.
E2	Poorly designed storage areas for receiving material.	Use methodical planning to design storage places and prioritize workflow and accessibility in design.
E3	The inefficient layout of storage facilities causes material congestion	Optimize storage facility layouts by considering material movement.
E4	Insufficient security measures for material protection	Develop comprehensive security mechanisms for material protection.

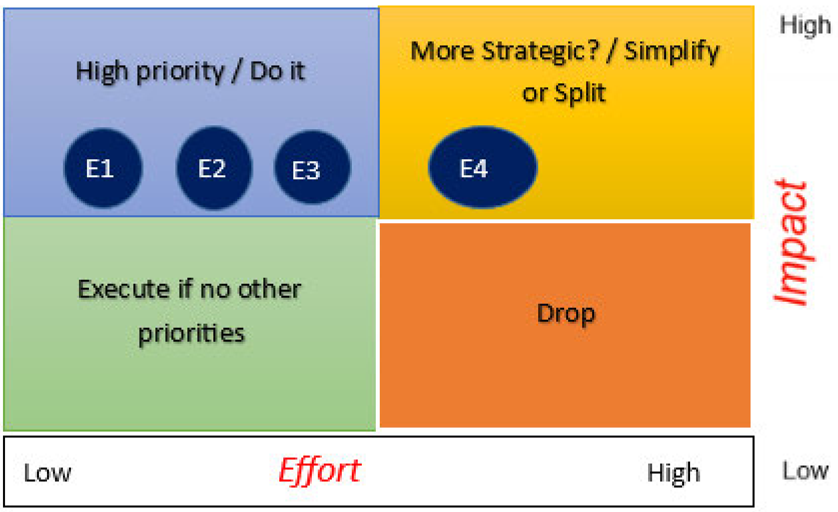


Figure 42: Impact and Effort diagram for Environment.

This improvement had a substantial influence on the project since it required the building and placement of a shelter appropriate for all weather situations to preserve supplies. The shelter was strategically placed at the site of unloading to ensure material safety and reduce exposure to harsh weather conditions.

Table 23: Matrix Prioritisation for Management

Symbol	Issues	Possible Solutions
MG1	Lack of designated personnel responsible for waste reduction	Establish defined roles and responsibilities for waste reduction.
MG2	Lack of clear waste reduction policies and procedures	Educate and train on waste reduction policies. Implement monitoring and feedback tools to ensure policy compliance.
MG3	Failure to set waste reduction audits and assessments	Raise awareness about the benefits of waste reduction audits.

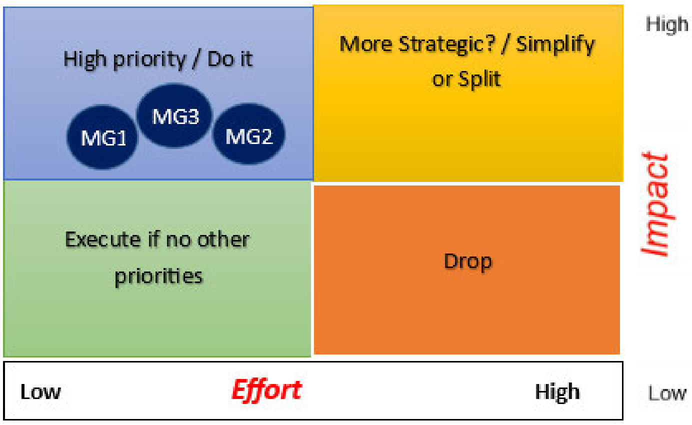


Figure 43: Impact and Effort diagram for Management.

Management improvements will include improving meeting procedures with an emphasis on waste reduction and strengthening production controllers' shift handover processes.

Table 24: Matrix Prioritisation for Supplier

Symbol	Issues	Possible Solutions
S1	Inadequate communication with the supplier on material	Share the NCR Report monthly
S2	Lack of clear waste reduction policies and procedures for suppliers	Communicate and train on waste reduction initiatives among suppliers and the company.
S3	Lack of contingency plans for supply chain disruptions	Improve risk assessment and identify possible disruptions.

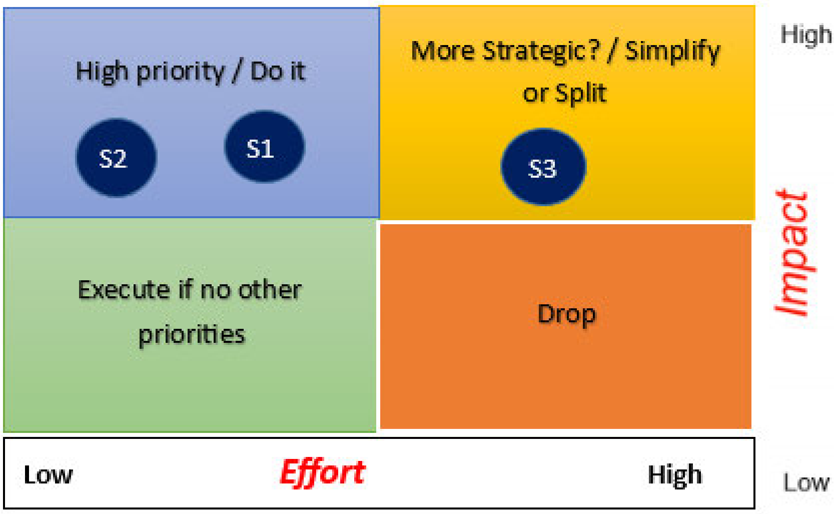


Figure 44: Impact and Effort diagram for Supplier.

4.5.4 Implementation Plan

Implementing effective ways to overcome operational inefficiencies is critical to the success of any company [106]. The analysis focuses on the "high priority" issues and provides an action strategy. The findings below only include the reasons that are of high priority. One such technique entails creating and executing an implementation plan targeted at identifying and resolving critical issues that impede productivity, quality, and overall performance. On the implementation plan the “how much” part will be excluded due to the privacy of the company.

In this regard, many researchers have investigated the use of implementation plans in diverse organizational settings, confirming their usefulness in producing beneficial outcomes. For instance, Forstag and Cuff [107] performed research on the deployment of quality control methods in a manufacturing plant, resulting in a considerable drop in defect rates and increased customer satisfaction. Similarly, Hegab *et al* [108] studied the impact of waste reduction activities in a logistics organization, which resulted in increased operational efficiency and cost savings. Based on the outcomes of these studies, the current study intends to build and implement an effective implementation strategy to solve operational difficulties inside the company.

Table 25: Implementation Plan

Symbol	Possible Solutions	What	Why	How	Where	Who
M3	Create efficient communication channels and team-building efforts	To improve team communication.	To improve teamwork and collaboration	Implement regular team meetings and team-building events	Production line	Team
MT4	Train people to conduct quality control inspections and invest in quality control equipment	To ensure accurate and quality control measures	Improve product quality and reduce defects	Provide training sessions and purchase necessary equipment	Production line	Quality Control Team
MT1	Reorganize storage spaces for efficiency and improve visibility with adequate labelling	To optimize storage areas for raw packaging material.	To improve efficiency and reduce material handling errors	Rearrange storage layout and label storage bins	Warehouse or stores	Operations Team
MC3	Regularly calibrate weighing scales or meters	To ensure accurate measurements on each pack size.	To maintain product quality and avoid customer complaints.	Schedule routine calibration checks	Production line	Quality Control Team
MM1	Set defined quality criteria for raw materials and improve communication with suppliers	To establish clear quality standards for raw materials	Ensure consistency and reliability in materials	Develop quality criteria and communicate with suppliers	Procurement Department	Quality Assurance Team
E1	Invest in covered storage for supplies and plan storage to account for weather concerns	To protect materials from weather damage	Prevent spoilage and maintain quality	Construct covered storage areas and implement weather-proofing measures	Stores for raw material	Operations Manager
MG1	Establish defined roles and responsibilities for waste reduction	To assign specific tasks and duties for waste reduction	Ensure accountability and efficiency	Develop job descriptions and allocate responsibilities	Production line	Management Team
MG2	Communicate and train on waste reduction initiatives	To educate employees on waste reduction practices	Increase awareness and participation	Conduct training sessions and distribute educational materials	Production line	Communicate and train on waste reduction initiatives

M1	Provide frequent training on waste reduction strategies	Provide personnel with the knowledge and skills necessary to adopt efficient waste reduction methods.	To increase employee knowledge and understanding of waste reduction benefits and strategies.	Hold regular workshops, seminars, and training sessions centred on waste reduction approaches and best practices.	Production line	Team
MT2	Create standard operating procedures for handling raw materials and provide training on correct handling techniques.	Establish clear material handling procedures to reduce waste and enhance resource use.	Ensure that raw materials are handled consistently and properly to reduce errors, waste, and quality issues.	Create extensive SOPs defining material handling procedures and hold training sessions to guarantee comprehension and compliance.	Production line	Operations Manager
MT3	Conduct workflow analysis to identify bottlenecks and improve communication for workflow changes.	Analyse existing workflows to streamline procedures, minimize inefficiencies, and increase productivity.	Identify and eliminate workflow bottlenecks to increase operational efficiency and reduce waste.	Use process mapping and data analysis tools to discover areas for improvement and create successful communication tactics.	Production line	Operations Manager
MC2	Train operators on calibrating techniques and regularly verify machine calibration for correctness.	Ensure that machines run efficiently, eliminating material waste and manufacturing errors.	Improve machine precision and consistency through accurate calibration, resulting in higher product quality and lower waste.	Provide hands-on training on calibration techniques and set up frequent verification plans for machine accuracy and performance.	Production line	Maintenance team
E2	Use methodical planning to design storage places and prioritize workflow and accessibility in design.	Optimize storage layouts to reduce material handling while increasing operational efficiency.	Improve material flow and accessibility to reduce congestion, damage, and waste in the material handling and storage operations.	Collaborate with supplier and design teams to plan and build effective storage solutions that meet workflow and accessibility requirements.	Receiving areas	Logistics/Operations team

E3	Optimize storage facility layouts by considering material movement.	Improve storage space layouts for better material flow and accessibility.	Optimizing storage layout and material transportation patterns can help to reduce material congestion, damage, and retrieval times.	Redesign storage layouts based on material flow analysis and operational team feedback to improve efficiency and reduce waste.	Stores or Warehouse	Raw Material Packaging Manager
MG3	Raise awareness about the benefits of waste reduction audits.	Promote the value of waste reduction audits to promote a culture of continuous improvement.	Improve accountability and commitment to waste reduction efforts by conducting regular audits and reviews.	Promote the positive effects of waste reduction audits through internal communications, training, and establishing clear waste reduction goals.	Production line	Management
S1	Share the NCR Report monthly	Improve supplier's understanding of quality expectations and encourage corrective measures.	Improve communication and coordination with suppliers to handle quality issues and minimize material waste.	Implement regular reporting and communication procedures to share (NCR) with suppliers and allow for rapid remedial actions.	Production line	Procurement team
S3	Improve risk assessment and identify possible disruptions.	Reduce supply chain risks to ensure uninterrupted operations and prevent material shortages.	Actively address potential interruptions and reduce their impact on material supply and production.	Conduct extensive risk assessments, create contingency plans, and establish communication channels with suppliers to resolve disruptions.	Production line	Operations Manager
S2	Communicate and train on waste reduction initiatives among suppliers and the company.	Align supplier processes with waste reduction targets to maximize resource utilization.	Encourage teamwork and shared accountability when implementing waste-reduction programs throughout the supply chain.	Establish and distribute waste reduction strategies to suppliers, collaborate on training programs, and set up feedback mechanisms to track progress and compliance.	Production line	Management

Organizations that want to enhance their operational performance must create and implement an effective implementation strategy. Organizations may solve operational inefficiencies and achieve good results by identifying core causes, creating clear objectives, and laying out specific procedures. The eight reasons listed in the implementation plan were high-priority issues, and all of them will be completed within six months. The success stories presented by researchers such as Forstag and Cuff [107] and Hegab *et al.* [108] demonstrate the ability of implementation plans to produce concrete benefits such as lower defect rates, more customer satisfaction, increased efficiency, and cost savings. As a result, utilizing the insights obtained from past investigations aided the research.

4.5.5 RASCI Analysis

Effective execution of organizational objectives and initiatives necessitates defined roles and responsibilities for team members. The RASCI analytical framework offers a systematic way to identify these responsibilities, assuring responsibility, and encouraging good team communication [109]. Companies may expedite decision-making processes and improve overall efficiency by clearly outlining who is responsible for carrying out tasks, who is ultimately accountable for their success, who should be engaged for feedback, who will assist, and who should be kept informed [109].

Suhanda and Pratami [110] performed a remarkable case study in which they used the RASCI framework to solve communication issues inside a global organization. The study discovered that poor communication among team members slowed project development and reduced overall productivity. The RASCI study identified the accountable parties as team leaders and managers, who were entrusted with planning frequent team meetings and maintaining open communication lines. The accountable parties, which included quality control teams and supervisors, oversaw the development of standardized communication processes and conducted routine inspections. The study indicated that by defining roles and duties using the RASCI framework, the company was able to increase communication, team cooperation, and, ultimately, project outcomes [111].

Table 26: RASCI Analysis

Issues	Symbol	Responsible	Accountable	Consulted	Supported	Informed
Poor communication among team members	M3	Production Controllers, Managers	Production Controller	Team members	Management	All team members
Inadequate quality control checks during processing	MT4	Production floor staff	Quality control team, Production Controllers	Process engineers	Production manager, Quality manager	All relevant departments
Inefficient storage methods cause material spoilage	MT1	Packaging Raw Material Manager	Packaging Raw Material Manager	Procurement department	Operations Manager	Production and warehouse team
Lack of regular calibration for weighing scales or meters	MC3	Mechanical team, Maintenance operators	Quality control team, Production Controller	Operations Manager	Mechanical Engineer	Production and quality control staff
Poor quality or inconsistent raw materials from suppliers	MM1	Packaging Raw Material Manager, Quality team	Procurement manager, Quality manager	Operations team	Production manager, Quality manager	All relevant departments
Inadequate storage facilities expose materials	E1	Packaging Raw Material Manager	Operation manager, Packaging Raw Material manager	Logistics team	Operations Manager	All warehouse and store team
Lack of designated personnel responsible for waste reduction	MG1	Production Controller	Production floor team, Operations team	Management	Operations Manager	All production and operations staff
Lack of clear waste reduction policies and procedures	MG2	Quality manager	Production Controller	Quality team	Quality manager	All employees, the Quality control team
Lack of awareness about waste reduction practices	M1	Operations Manager	Quality Manager	Production Team	SHE Department	All Employees
Lack of standard operating procedures for raw materials	MT2	Production Manager	Quality Manager	Operations Team	Packaging Raw Material Manager	All Employees
Poorly designed workflow for material movement	MT3	Warehouse Manager	Production Manager	Operations Team	Process Engineer	All Employees
Lack of calibration procedures for machines	MC2	Maintenance Manager	Quality Manager	Operations Team	Process Engineer	All Employees

Poorly designed storage areas for receiving material	E2	Warehouse Manager	Logistics Manager	Operations Team	Process Engineer	All Employees
The inefficient layout of storage facilities causes material congestion	E3	Logistics Manager	Warehouse Manager	Operations Team	Process Engineer	All Employees
Failure to set waste reduction audits and assessments	MG3	Environmental Specialist	Quality Manager	Operations Manager	Production Team	All Employees
Inadequate communication with the supplier on material	S1	Supply Chain Manager	Procurement Manager	Quality Manager	Operations Manager	All Employees
Lack of clear waste reduction policies and procedures for suppliers	S2	Environmental Specialist	Supply Chain Manager	Quality Manager	Operations Manager	All Employees
Lack of contingency plans for supply chain disruptions	S3	Supply Chain Manager	Operations Manager	Quality Manager	Procurement Manager	All Employees

The RASCI analysis offers a methodical strategy for dealing with diverse organizational difficulties by explicitly identifying roles and responsibilities. Suhanda and Pratami [110] conducted a case study to demonstrate the efficacy of adopting the RASCI framework to address organizational communication difficulties. By carefully defining roles and responsibilities, the RASCI analysis supported the implementation of focused communication efforts, resulting in real improvements in team cooperation and project results. The study emphasizes the significance of explicit responsibility and support structures in promoting organizational transformation. Overall, the findings indicate that using the RASCI framework can improve communication effectiveness and contribute to the overall success of corporate projects.

4.5.6 Summary of Results

The full improvement of “High Priority/Do It” issues has a major impact on waste reduction and overall corporate performance. The study initially adopted the "high priority/do it" strategy taken from 4.5.3 since these reasons are easy to resolve and do not need considerable financial or strategic resources. The adoption of this strategy was implemented for four weeks, and the improvement audit was done in week 21, beginning on November 13th, 2023. The following weeks, from week 21 to week 29, were the improvement period. However, this phase saw a two-week production pause, coinciding with the December holidays. The comprehensive audit process gave significant insights into the effectiveness of the made modifications, resulting in a more efficient and streamlined operational environment within the defined high-priority areas.

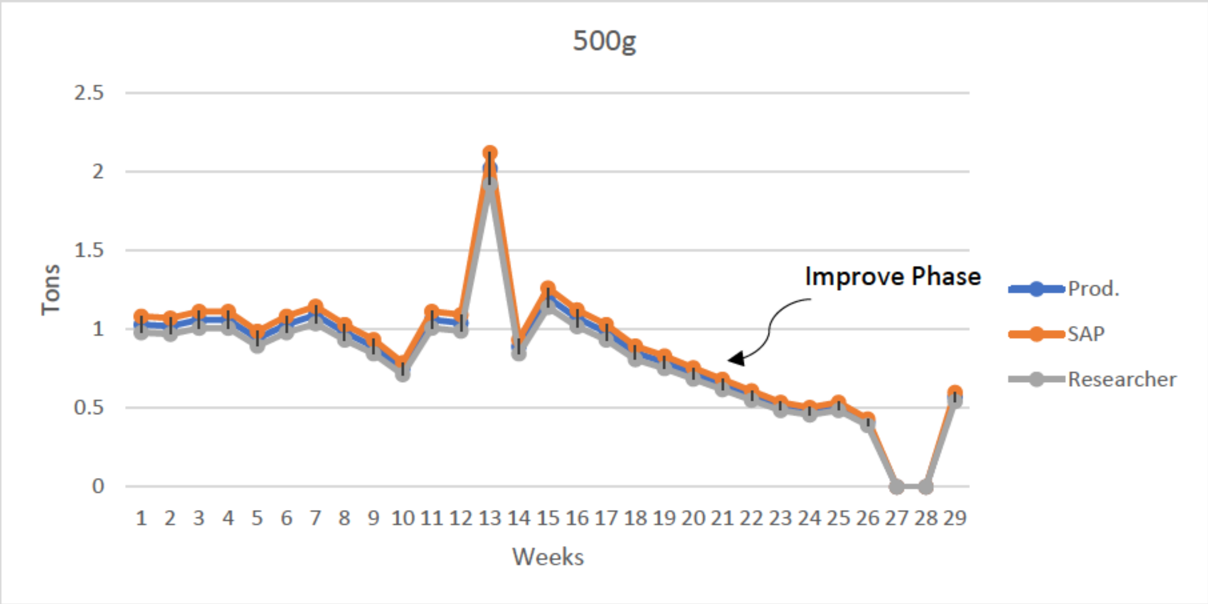


Figure 45: Improve Phase for waste numbers for 500g.

Figure 45 shows that the 500g segment's performance has improved significantly after 15 weeks. Waste levels are gradually approaching the company's target of 0.5 tons each week. However, on Week 29, waste levels exceeded the 0.5-ton threshold. This can be linked to the first manufacturing run of the year, which included off-spec sugar. This problem emerged because of the flushing operation, which left residual sugar within the beans.

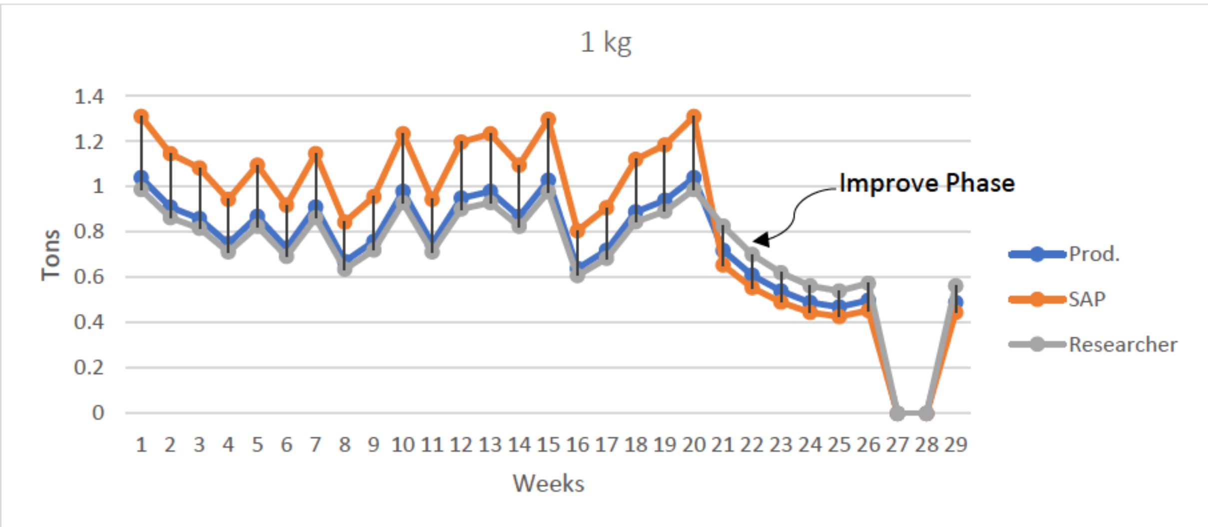


Figure 46: Improve Phase for waste numbers for 1kg.

Figure 47 illustrates the performance of the 1 kg metric, demonstrating significant improvements. However, it also demonstrates an important change in the Bill of Materials (BOM) for this measure throughout the company. To rectify the observed BOM discrepancy, a comprehensive assessment of the material requirements followed by retesting is advised. Despite the waste reduction, meeting the company's aim of 0.5 tons remains difficult, with weeks 24 to 26 showing significantly better outcomes. During the improvement phase, researchers faced high tonnage, which was attributable to the updating of SAP with study results.

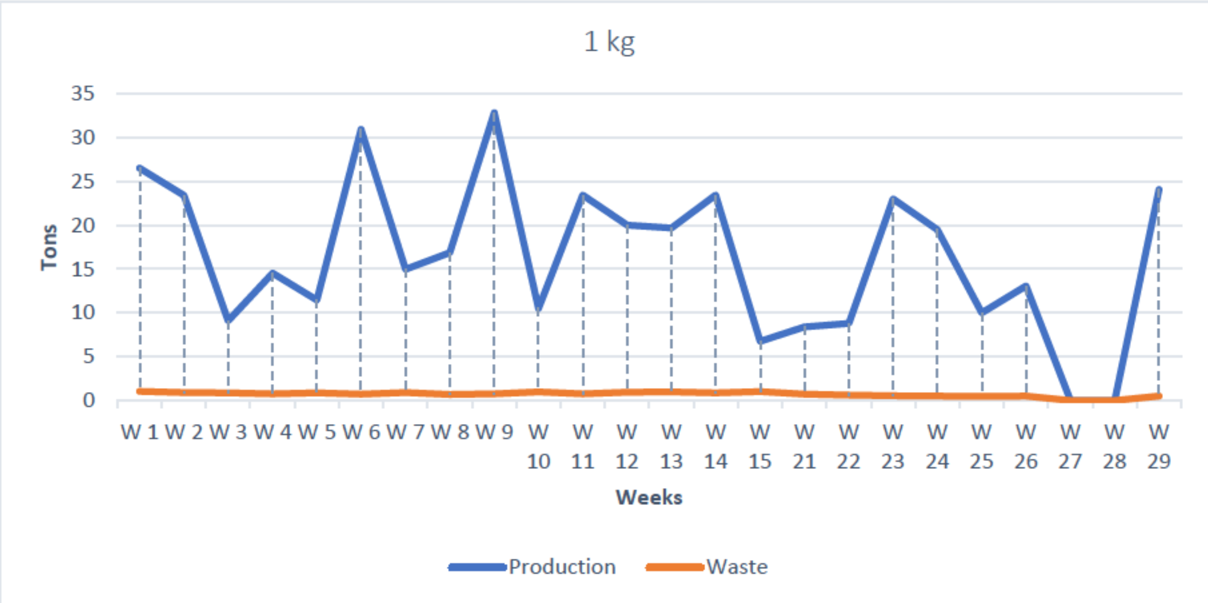


Figure 47: Improve Phase: Production vs Waste for 1kg.

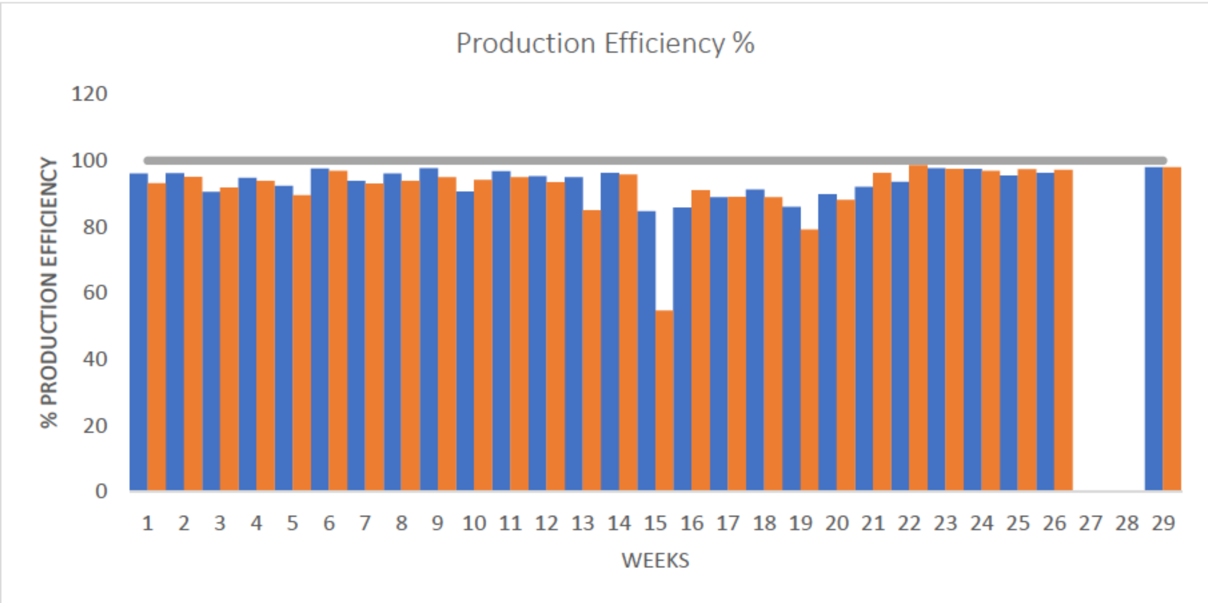


Figure 48: Improve Phase of Production Efficiency

The production efficiency of both SKUs has not yet achieved 100%. However, throughout the improvement stage, it is worth noting that the efficiency of 500g output outperforms that of 1 kg production, as opposed to the first 15 weeks of the specified period. While the results did not approach 100% efficiency, they improved dramatically after 15 weeks, with values ranging from 95% to 99%.

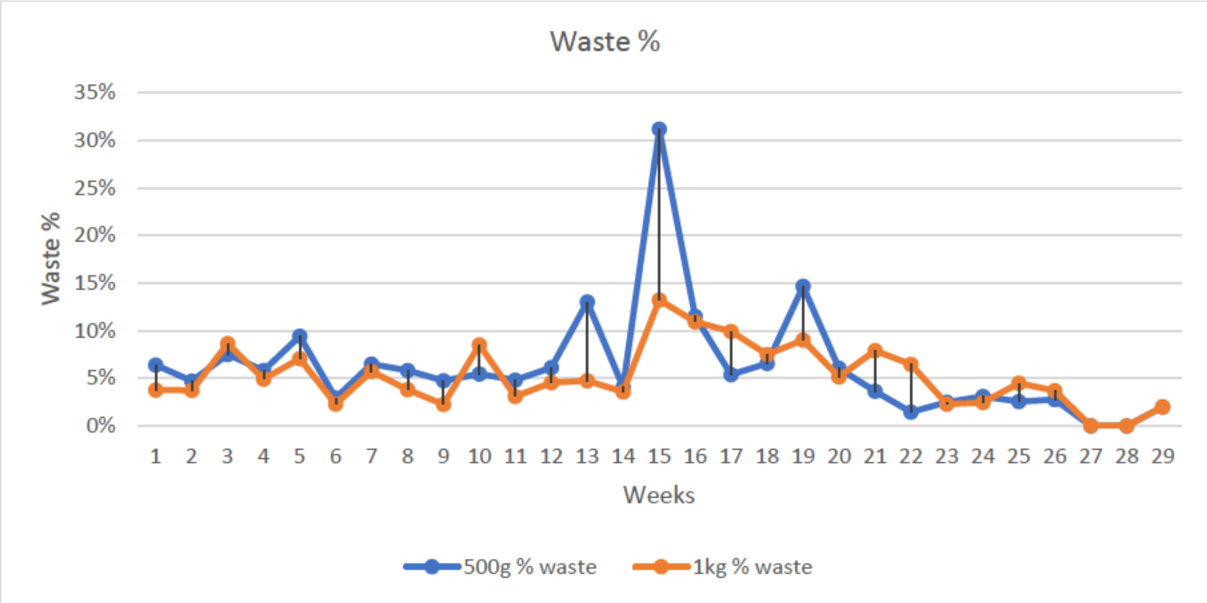


Figure 49: Improve Phase of Waste%

Figure 49 shows a considerable improvement in the 500g category against 1 kg. The statistics reveal a significant reduction in waste % for 500g, while 1 kg also shows a decrease, but not as strong as the 500g category. The difficulties encountered by the 1 kg category are attributable to material and Bill of Materials (BOM) concerns.

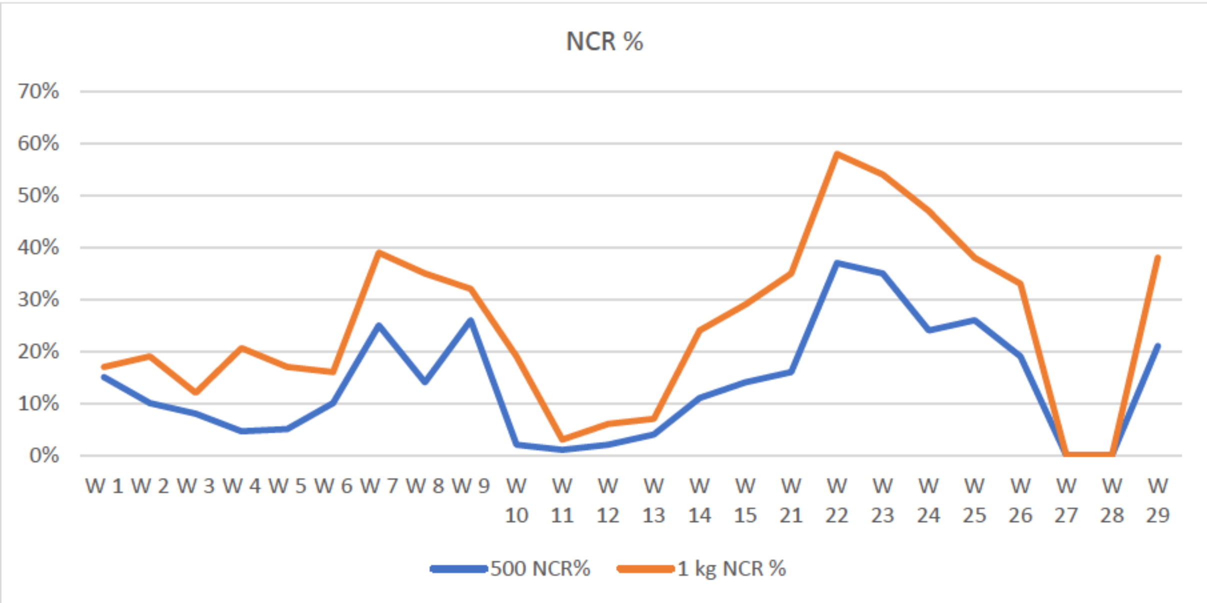


Figure 50: Improve Phase of NCR % for both 500g and 1kg.

The data given shows a significant difference in material-related concerns between the 1 kg and 500g categories, as seen by the higher NCR percentages during the improvement stage for 1 kg versus 500g. Both SKUs had elevated levels of NCR, indicating a link between supplier-provided off-spec materials and higher waste output. Interestingly, a drop in waste corresponded with an increase in NCR cases, showing a possible relationship between strict quality control procedures, supplier responsibility, and waste reduction initiatives within the production process.

4.5.7 Improve Phase Conclusion

The collected data show a significant link between a rise in NCR % and a decrease in waste percentage throughout the improvement phase (Weeks 21–29). This finding highlights the significant contribution of packaging raw materials to overall waste productivity. Material-related variables are identified as the most significant contributors to waste. Discrepancies in Production, SAP, and researcher data throughout the improvement weeks highlight the importance of changing the Bill of Materials (BOM). Waste reduction has improved manufacturing efficiency, increasing the overall efficacy of the supply chain. This emphasizes the interdependence of processes and the importance of addressing material-related concerns with the supplier to reduce waste inside the company.

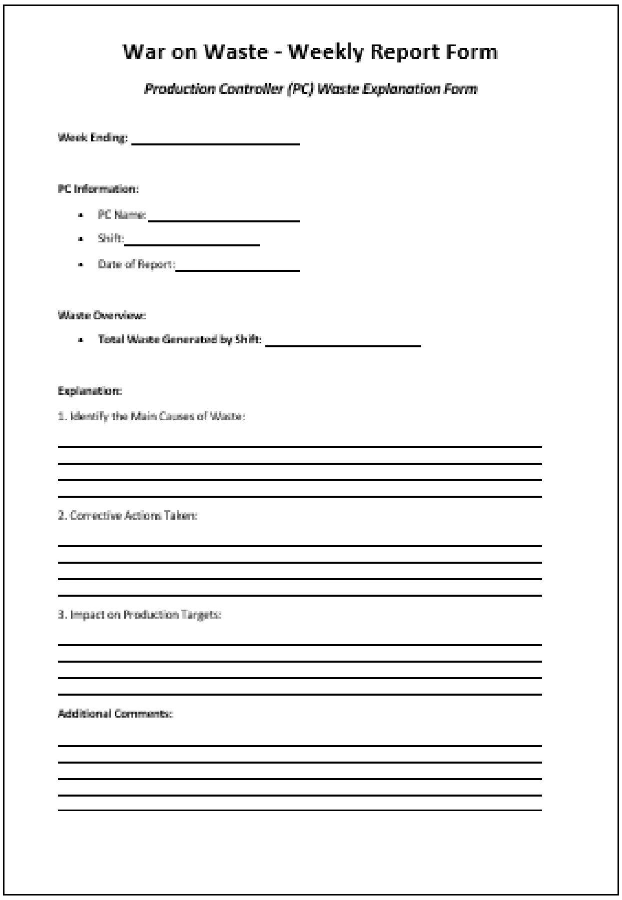
4.6 Control Phase

Following a complete 29-week analysis, the study chose to keep the processes used from week 21 to week 29, resulting in reduced waste and increased productivity. Efficient control over handover levels and NCR reporting to the Packaging Material Manager proved critical, with an inverse relationship seen between increased NCR reporting and reduced waste. The introduction of a new form in week 25 resulted in favourable outcomes, with 1kg waste quantities consistently < 0.8 tons after DMAIC adoption. In addition, a 5S method audit was implemented on week 21, analysing workflow adherence and waste, and NCR reporting audits for continuous improvements [112]. The purpose of this phase is to retain the improvements made during the study. Some techniques that were deployed to maintain the gains made during the improvement phase were:

- Monitor the workflow of the company by monitoring 5S principles.
- Audit Waste by shift and report if any have occurred the causes and solution.
- Audit NCR report that involves the performance of the suppliers.

4.6.1 Shift Report Form

The form presented below in Figure 51 was created by the researcher to improve shift handover processes and track waste every shift, allowing the firm to discover reasons for inefficiencies and handle problems that arise along the manufacturing line, including NCR. This tool is useful in providing a thorough knowledge of changes that have occurred on the production line since the previous shift, ensuring a seamless transition between shifts for both personnel and management and sustaining continuous production operations. Randell et al. [113] revealed the efficiency of implementing a shift report template for managing waste and handover procedures in a production facility, leading to improved communication between shifts, improved waste monitoring, and reduced manufacturing processes. This strategic approach emphasizes the value of organized communication and process monitoring in reducing inefficiencies and increasing operational effectiveness in industrial environments.



War on Waste - Weekly Report Form

Production Controller (PC) Waste Explanation Form

Week Ending: ____________

PC Information:

- PC Name: ____________
- Shift: ____________
- Date of Report: ____________

Waste Overview:

- **Total Waste Generated by Shift:** ____________

Explanation:

1. Identify the Main Causes of Waste:

2. Corrective Actions Taken:

3. Impact on Production Targets:

Additional Comments:

Figure 51: Weekly Report Form

4.6.2 5S Audits

The graphic shown in Figure 52 summarizes the results of the 5S performance evaluation by combining the individual scores assigned to each of the five "S" components into a complete overview. Beginning in week 21, the researcher performed a rigorous internal audit of the 5S procedures once a week within the manufacturing plant. This technique is praised for its universal applicability in boosting company productivity and satisfaction among staff members, acting as a basic component of Total Quality Management (TQM) programs. Furthermore, its successful adaption to the Hong Kong corporate environment is shown by customized training programs and case studies staged by the industry department, demonstrating its adaptability and efficacy in varied operating situations [114].

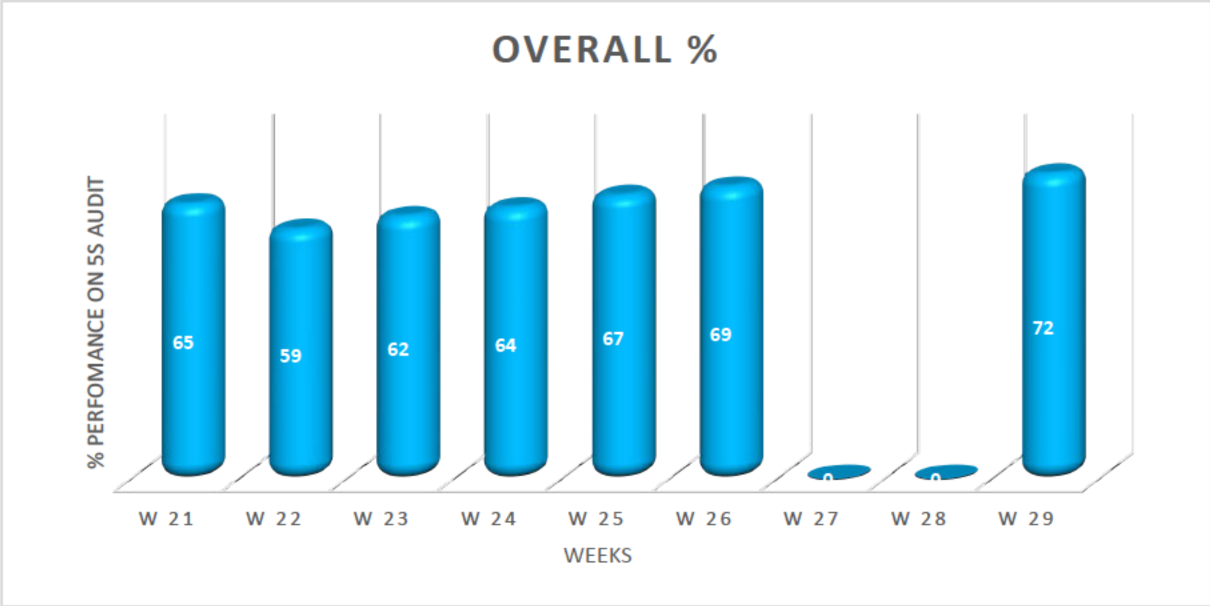


Figure 52: 5S Weekly Performance

Figure 48 displays 5S performance, showing a continuous improvement trend while not achieving an ideal condition. The data indicates an approximate 80% score based on the researcher's most recent audit. However, audits were not done during Weeks 27 and 28 owing to the company's December holiday shutdown. Despite these occasional gaps in evaluation, there is a noticeable trend toward improved 5S compliance across the firm over time.

4.7 Chapter Conclusion

During the Define Phase (weeks 1-15), the company did not reach its waste reduction objective of ≤0.5 tons per week. The define phase, discovered inefficiencies mostly because of insufficient supplier engagement in the company's manufacturing procedures, particularly in the delayed filing of NCRs. The inquiry found various potential solutions, with many labelled as "High Priority/Do It" activities to directly address these difficulties. Implementing these measures resulted in a significant drop in waste, exposing poor communication and insufficient NCR reporting as the primary sources of inefficiency [101].

From weeks 21 to 29, further analysis was undertaken to assess the efficacy of these selected therapies. This testing phase verified that increasing the frequency of NCR submissions or rejecting inferior raw materials resulted in waste reduction. As a result, the study identified supplier communication as a crucial area for improvement, emphasizing the need for more frequent and effective contact with suppliers to address waste concerns related to this specific SKU.

Furthermore, using the 5S model greatly enhanced organizational workflow, with performance indicators above the 60% mark. To improve communication and guarantee a smooth transfer between shifts, the researcher created a special handover form. This application is intended to monitor shift changes and track waste each shift, hence easing the detection and resolution of production inefficiencies and NCR-related issues, highlighting the vital role of organized communication in improving operational efficiency [113]. Table 27 below focuses on optimizing shift handovers and 5S compliance through shift report forms and weekly audits. Table 28 below outlines actions such as improving communication, investing in quality control, and optimizing storage, with controls to ensure KPI impacts like enhanced efficiency and reduced waste.

Table 27: Control Plan

Control Point	Description
Shift Report Form	Use the shift report form provided by the researcher to optimize shift handover operations and measure waste during each shift.
	Ensure that all modifications made to the production line since the previous shift are thoroughly documented for a smooth transition and continuing production operations.
	Use the form to identify reasons for inefficiencies, address issues like NCRs, and improve communication between shifts and management.
	Conduct frequent training and reinforcement of the shift report forms used among personnel to ensure successful implementation.
5S Audits	Conduct weekly internal audits of the production plant's 5S procedures to ensure compliance and identify areas for improvement.
	Utilize the audit results to evaluate and measure progress toward workplace organization, cleanliness, and efficiency.
	Provide specific training programs based on audit results to address areas for improvement and maintain compliance with 5S principles.
	Ensure continual improvement by eliminating audit gaps and incorporating 5S principles into Total Quality Management (TQM) programs.

Table 28: Operational Efficiency and Waste Reduction: Actions, Controls, and KPI Impacts

Action implemented/ possible solution	Symbol	How will be controlled going forward	Impact on the KPI
Create efficient communication channels and team-building efforts	M3	Regular meetings and questionnaires help to monitor teamwork and feedback.	Improved cooperation and communication, resulting in faster problem resolution and more output.
Train people to conduct quality control inspections and invest in quality control equipment	MT4	Conduct frequent audits and performance evaluations to verify compliance with standards.	Increased product quality, fewer defects, and more customer satisfaction.
Reorganize storage spaces for efficiency and improve visibility with adequate labelling	MT1	Conduct regular inspections and audits of storage facilities to ensure order and cleanliness.	Improved material handling time, decreased mistakes, and improved inventory accuracy.
Regularly calibrate weighing scales or meters	MC3	Establish a calibration program and perform routine equipment checks.	Consistent measurement accuracy means less waste owing to measurement inaccuracies.
Set defined quality criteria for raw materials and improve communication with suppliers	MM1	Implement quality assurance methods and conduct frequent supplier assessments.	Improved product standardization, decreased rework, and strengthened supplier relationships.
Invest in covered storage for supplies and plan storage to account for weather concerns	E1	Monitor storage conditions and adjust plans depending on weather projections.	Reduced material damage and wastage while improving inventory management.
Establish defined roles and responsibilities for waste reduction	MG1	Create performance indicators and conduct frequent assessments of waste-reduction initiatives.	Clear responsibility for waste reduction activities, with increased progress and outcome tracking.
Communicate and train on waste reduction initiatives	MG2	Evaluate training program participation percentages.	Employees have become more conscious of and have adopted waste-reduction techniques.
Provide frequent training on waste reduction strategies	M1	Evaluations administered after training are used to test employee competency.	Increased adoption of waste reduction methods, resulting in less waste creation.
Create standard operating procedures for handling raw materials and provide	MT2	Conduct frequent audits and spot inspections to verify procedures are followed.	Reduced material waste, increased operating efficiency, and decreased material handling mistakes.

training on correct handling techniques.			
Conduct workflow analysis to identify bottlenecks and improve communication for workflow changes.	MT3	Conduct frequent evaluations of workflow procedures and request input from team members.	Streamlined operations, shorter lead times, and more efficient resource usage.
Train operators on calibrating techniques and regularly verify machine calibration for correctness.	MC2	Conduct performance reviews and spot checks on machine calibration.	Improved machine performance, fewer production mistakes, and higher product quality.
Use methodical planning to design storage places and prioritize workflow and accessibility in design.	E2	Conduct regular reviews of storage efficiency and process optimization.	Improved material movement, reduced congestion, and increased accessibility to materials.
Optimize storage facility layouts by considering material movement.	E3	Monitor storage efficiency indicators and solicit comments from operations teams.	Reduced material handling expenses, increased space utilization, and better inventory management.
Raise awareness about the benefits of waste reduction audits.	MG3	Track participation rates in reducing waste audit programs and do post-audit reviews.	Waste reduction measures have been enhanced, resource efficiency has increased, and the environmental effect has decreased.
Share the NCR Report monthly	S1	Monitor the timely dissemination of NCR reports and the rates at which remedial actions are completed.	Improved supplier partnership, increased product quality, and decreased non-conformances.
Improve risk assessment and identify possible disruptions.	S3	Create risk monitoring processes and carry out frequent risk assessments.	Increased supply chain resilience, less disruption effect, and better company continuity planning.
Communicate and train on waste reduction initiatives among suppliers and the company.	S2	Establish frequent contact routes with suppliers and evaluate training efficacy.	Waste reduction initiatives were aligned across the supply chain, supplier relations improved, and waste creation was decreased.

4. Chapter Five: Recommendation, Conclusion, and Future Research Work

5.1 Introduction

The study uses the DMAIC problem-solving approach to improve supply chain efficiency at the AXY Company in South Africa's sugar sector. The research covers difficulties associated with exceeding waste objectives and material inefficiencies, with a special emphasis on the 1kg and 500g product categories. Chapter 4 contains recommendations from the Improve phase, such as the adoption of a shift control form that will control the handovers and the adoption of 5S audits. The study provides answers to all the important research issues. Future work stresses the importance of digitization and embracing Fourth Industrial Revolution (4IR) technology in driving continual supply chain improvement. This research aims to improve operating processes and foster innovation in the sugar industry.

5.2 Recommendations

This section outlines recommendations for improving the existing status of the engineering company, which requires change to meet its operating needs. Based on the successful deployment of different solutions targeted at improving supply chain efficiency and minimizing material waste, many critical suggestions may be made to maintain and improve these good outcomes. Review Table 25.

Creating and maintaining effective communication channels as well as team-building activities (M3) through frequent meetings and feedback, is important. This strategy should be continued to promote better cooperation and communication inside the organization, resulting in faster issue resolution and enhanced production. Furthermore, continuous training programs on waste reduction efforts (MG2) should be addressed to ensure that personnel stay aware of and dedicated to waste reduction practices, thereby fostering a culture of waste minimization and resource efficiency.

Furthermore, continuing to invest in covered storage for supplies and establishing weather-responsive storage strategies (E1) would help to limit material damage and waste while enhancing overall inventory management. Finally, implementing regular audits and assessments to ensure compliance with quality control standards (MT4) and standard operating procedures (MT2) for raw material handling will be critical to maintaining high product quality, reducing defects, and strengthening supplier relationships. These ideas are consistent with the ideals of continuous improvement and proactive supply chain management, as well as industry best practices and new Fourth Industrial Revolution (4IR) technology.

The present difficulties, notably those related to material waste and sugar production, demand strategic solutions. Implementing a FIFO system would increase material use, batch tracking, and delivery monitoring. Shelters for material receiving would protect from weather-related harm. Introducing a weekly NCR for suppliers would increase transparency and speed up issue resolution. The FIFO system promotes efficient stock movement, minimizes waste, and improves bookkeeping. This method optimizes warehouse space, improves order fulfilment, and increases overall operational efficiency. These approaches are consistent with best practices for addressing material waste concerns and improving supply chain efficiency in the sugar company.

5.3 Conclusion

In conclusion, this thesis systematically implemented the DMAIC technique, a key component of Six Sigma, to address and improve supply chain efficiency. This study discovered major inefficiencies in the company's supply chain, notably in waste management and operational procedures, after conducting a thorough review of its operations. The research used a mix of observational data collecting, SAP data analysis, and statistical representation using Microsoft Excel to offer a thorough picture of the status of operations and indicate crucial areas for improvement.

The Define phase of the DMAIC process showed the first issues in achieving its waste reduction objectives, which were mostly due to insufficient supplier cooperation and delayed NCRs. The ensuing Measure and analysis stages allowed for a detailed examination of the core causes of waste in the company's supply chain, using techniques such as the fishbone diagram and 5 Whys analysis. The adoption of a Prioritization Matrix enhanced the strategic ranking and selection of solutions, stressing those classed as "High Priority/Do It" for urgent execution [104].

The Improve phase saw the successful implementation of these solutions, resulting in a significant reduction in waste and emphasizing the critical role of efficient communication and NCR management in improving operational efficiency. Furthermore, the study revealed the usefulness of the 5S technique in considerably improving organizational workflow, with a special focus on sustaining these benefits through the development of a shift handover form designed to guarantee smooth communication and waste monitoring throughout shifts. The key findings show that after implementing efficiency improvement methods, waste generation remained under the specified limit of 0.5 tons per week. After 15 weeks of defining, measure, and analysis, the implementation phase lasted from week 16 to week 20. The findings were then audited from week 21 to week 29, and waste levels were regularly reported to be less than the prescribed goal range of 0.5 tons.

This study not only provided significant insights into AXY Company's particular operational inefficiencies but also demonstrated the flexibility and usefulness of the DMAIC technique in addressing complex supply chain difficulties. The insights and approaches presented here add considerably to a greater knowledge of supply chain management and operational efficiency, providing a reproducible foundation for comparable businesses experiencing similar difficulties. Based on the information and analysis offered, AXY Company and similar organizations should adopt a culture of continuous improvement, employing DMAIC and tools like the 5S technique to systematically eliminate inefficiencies and improve overall supply chain performance.

This thesis is a comprehensive effort to apply academic theories and methodology to real-world operational difficulties, providing actionable insights and a solid platform for additional study and practical applications in the domain of supply chain management and operational efficiency. By effectively tying together the findings and recommendations, this study underscores the importance of a systematic approach to supply chain optimization and highlights potential areas for future research and development in this field.

5.4 Research Questions and Answers

- **How have case studies involving the application of Lean management produced insights and recommendations for reducing inefficiencies in the supply chain being studied?**

  The analysis went into Lean management case studies, gathering significant insights and solutions for decreasing inefficiencies in the supply chain under study. These case studies provided practical views on best practices and a road map for adopting efficient ways to improve overall operational efficiency and reduce waste. The research in Chapter 2 reveals that most of the studies on the use of DMAIC are largely in use of production.

- **What is the current waste and performance levels?**

  The research extensively examined the current waste and performance levels within the studied supply chain. Through a detailed analysis, the study identified key areas of inefficiency and operational challenges, providing a comprehensive understanding of the existing situation. The study looks at all the SKUs in terms of waste and selects the two that are the highest. The performance level demonstrated that the Company was underperforming in terms of its waste target of 0.5 tons per week.

- **Which SKU is contributing to the high wastage?**

  The selected SKUs 500g and 1kg are the most contributors to waste in the company. The study has revealed that was running at the highest level of waste which was targeted at≥0.5 tons per week. The performance in terms of reporting the NCR was below 30% per week for the duration of the defined phase (15 Weeks).

- **What are the strategies that can be implemented to improve supply chain efficiencies?**
  The methods that were used included the 5 Whys analysis following a thorough evaluation of the fishbone diagram, which identified the underlying fundamental causes. This research indicated prioritized "High-priority" solutions, particularly those addressing difficulties with changeover communication and NCR reporting. The use of these methods significantly led to waste reduction, although an increase in NCR reporting was noted as a result.

5.5 Future Work

The study's findings point to major prospects for improving BOM management in the engineering and industrial sectors. Specifically, the antiquated BOM software, which was last updated in 2014, presents issues in aligning with current material needs, as indicated by disparities between prescribed materials and those recorded in the SAP system on the manufacturing line. This exposes significant quality control concerns and emphasizes the need for better communication with suppliers.

The study's future work should focus on digitalization activities and include 4IR technology to achieve continuous supply chain improvement. Upgrading BOM management systems to current digital technologies may improve material traceability, expedite contact with suppliers, and provide real-time changes to keep inventory data correct. Embracing 4IR technology such as Internet of Things (IoT) sensors and Artificial Intelligence (AI) analytics can help to enhance supply chain processes by allowing predictive maintenance and proactive inventory management. Integrating these improvements will be critical for establishing long-term operational efficiency and quality control in the changing company efficiencies.

By effectively tying together the various aspects of this study, from initial problem identification to practical recommendations and future directions, this chapter underscores the cohesive narrative of the research and its implications for both theory and practice in supply chain management.

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Appendix 1: Bill of Material for SKU's

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
20	15 x 500g BALER	Sugar Refined H1	KG	1 000,99	9,99	9 999,87
20	15 x 500g BALER	Paper Pre-print Belched 500g 90Gsmx264Mm NEW	KG	9,975	44,14	440,3
20	15 x 500g BALER	Wrap Shrink 15x500g 50Mic Plastic Brown NEW	KG	2,44	39,36	96,04
20	15 x 500g BALER	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	0,988	5,359	5,29
20	15 x 500g BALER	Film Stretch-Wrap 20Mic 500Mmx1500M Reel KG	KG	0,247	95,188	23,51
						10 565.01

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
13	20 x 250G BALER	Bag belched KRFT 250Gr 75Gr NEW	EA	4 375,00	0,43	1 881,25
13	20 x 250G BALER	Wrap Shrink 20x250G 50Mic plastic Blue NEW	KG	4,063	39,362	159,93
13	20 x 250G BALER	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	1,042	5,359	5,58
13	20 x 250G BALER	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,26	95,188	24,75
						12 078.37

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
1	25KG BAG	Sugar Refined H1	KG	1 000,40	9,99	9 994,00
1	25KG BAG	Bag Sack Kraft 25kg W/Ultrasonic Valve	EA	41	7,38	302,58
1	25KG BAG	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	1	5,359	0,18
1	25KG BAG	Pad Layer Cardboard for Pallet	EA	1	6,4	6,4
1	25KG BAG	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,25	95,188	23,8
1	25KG BAG	Adhesive Anti Slip Jowar for Palletising	EA	0,005	3 144,17	15,72
						10 342,67

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
21	10 x 1kg BALER	Sugar Refined H1	KG	1 001,00	9,99	9 999,99
21	10 x 1kg BALER	Paper Pre-print belched 1kg 75Gsmx320Mm NEW	KG	6,857	44,14	302,67
21	10 x 1kg BALER	Wrap Shrink 10x1kg 60Mic Plastic 2Barc NEW	KG	2,352	39,36	92,57
21	10 x 1kg BALER	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	0,952	5,359	5,1
21	10 x 1kg BALER	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,238	95,188	22,65
						10 422,99

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
15	8 x 2.5KG BALER	Sugar Refined H1	KG	1 001,00	9,99	9 999,99
15	8 x 2.5KG BALER	Paper Pre-printed Bleached Sig 437Mm NEW	KG	6,9	45,33	312,78
15	8 x 2.5KG BALER	Film Shrink 8X2 5Kg 70Mic Brown White NEW	KG	2,36	43,49	102,64
15	8 x 2.5KG BALER	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	1	5,359	5,36
15	8 x 2.5KG BALER	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,25	95,188	23,8
						10444,56

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
16	4 x 5KG BALER	Sugar Refined H1	KG	1 000,42	9,99	9 994,17
16	4 x 5KG BALER	Bag S O White Sugar 5Kg NEW	EA	204,167	1,3	265,42
16	4 x 5KG BALER	Film Shrink 4X5Kg 70Micx1080Mm Grin NEW	KG	2,563	39,361	100,88
16	4 x 5KG BALER	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	1,042	5,359	5,58
16	4 x 5KG BALER	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,26	95,188	24,75
						10 390,80

SKU	SKU Description	Material	UOM	Qty/Rate	Price	Tot Value per ton
6	10KG BAG	Sugar Refined H1	KG	1 000,40	9,99	9 994,00
6	10KG BAG	Bag Sack Kraft 10kg Bay white	EA	103	4,36	449,08
6	10KG BAG	Sheet Plastic 1200x1350Mm 50Micr Re Plastic	EA	1	5,359	5,36
6	10KG BAG	Pad Layer Cardboard for Pallet	EA	1	6,4	6,4
6	10KG BAG	Film Stretch-Wrap20Mic 500Mmx1500M Reel KG	KG	0,25	95,188	23,8
6	10KG BAG	Adhesive Anti Slip Jowar for Palletising	EA	0,005	3 144,17	15,72
						10 494,35

Appendix 2: Production vs Waste vs Yield for 1kg %

	1 Kg		
Weeks	**Production**	**Waste**	**Yield %**
W 1	26,49	1,04	96,07
W 2	23,41	0,91	96,11
W 3	9,08	0,86	90,53
W 4	14,51	0,75	94,83
W 5	11,44	0,87	92,40
W 6	30,93	0,73	97,64
W 7	14,96	0,91	93,92
W 8	16,86	0,67	96,03
W 9	32,82	0,76	97,68
W 10	10,51	0,98	90,67
W 11	23,42	0,75	96,80
W 12	20,01	0,95	95,25
W 13	19,67	0,98	95,02
W 14	23,42	0,87	96,29
W 15	6,75	1,03	84,74

Appendix 3 Production vs Waste vs Yield % for 500g

	500g		
Weeks	**Production**	**Waste**	**Yield %**
W 1	15,1125	1,03	93,18
W 2	20,67	1,02	95,07
W 3	13,04	1,06	91,87
W 4	17,18	1,06	93,83
W 5	9,02	0,94	89,58
W 6	34,03	1,03	96,97
W 7	15,68	1,09	93,05
W 8	15,81	0,98	93,80
W 9	17,87	0,89	95,02
W 10	12,98	0,75	94,22
W 11	20,98	1,06	94,95
W 12	15,98	1,04	93,49
W 13	13,47	2,02	85,00
W 14	20,977	0,89	95,76
W 15	2,6475	1,2	54,67