ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF PROJECT MANAGEMENT

Integrated Quality and Process Improvement Strategies in Manufacturing Crown Corks: The Case of Peniel Industry PLC

By

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February 2025

Addis Ababa, Ethiopia

INTEGRATED QUALITY AND PROCESS IMPROVEMENT STRATEGIES IN MANUFACTURING CROWN CORKS: THE CASE OF PENIEL INDUSTRY PLC

BY

TSEGAW HAILEMARIAM

A THESIS SUBMITTED TO ST. MARY'S UNIVERSITY, SCHOOL OF BUSINESS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF PROJECT MANAGEMENT

FEBRUARY, 2025

ADDIS ABABA, ETHIOPIA

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DECLARATION

I, the undersigned, declare that this thesis is my original work; prepared under the guidance of Temesgen Belayneh (PHD). All the sources used for the thesis have been dully acknowledged. I further confirm that this thesis has not been submitted either in part or in full to any higher learning institutions for the purpose of earning any degree.

Tsegaw Hailemariam ____________________________

Name Signature

St. Mary's university, Addis Ababa February, 2025

ENDORSEMENT

This thesis has been submitted to St. Mary's university, School of Graduate Studies for examination with my approval as a Thesis advisor.

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Name Signature & Date

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ACKNOWLEDGMENTS

First and foremost, I would like to thank God for helping me to complete this paper. My special and heartfelt gratitude to my advisor Temesgen Belayneh (PHD) for his advice, guidance and constructive feedback in the course of conducting this research study.

I am thankful to the Factory manager of Peniel industry PLC Mr. Anteneh Abebe who had a major contribution on this study.

ACRONYMS

ISO International Organization for Standardization

PLC Private Limited Company

JIT Just-In-Time

DMAIC Define, Measure, Analyze, Improve, Control

DPMO Defects Per Million Opportunities

IoT Internet of Things

SPC Statistical Process Control

UNIDO United Nations Industrial Development Organization

Abstract

This research examines Integrated Quality and Process Improvement Strategies in Manufacturing Crown Corks to enhance operational efficiency and product quality case study at Peniel Industry PLC, a crown cork manufacturing company in Ethiopia. The research employs a descriptive and explanatory research design, utilizing both quantitative and qualitative approaches. A structured survey questionnaire was distributed to employees, and interviews and direct observations were conducted to gather qualitative insights. Production records provided empirical data to assess defect rates, machine downtimes, and material waste. A stratified sampling technique was used to select employees from production and quality assurance departments, ensuring relevant expertise in the study. Findings indicate that high defect rates, inefficient machine utilization, and excessive material waste hinder the company's compliance with international quality standards such as ISO 9001. Statistical analysis, including correlation and regression, reveals that organizational readiness, structured implementation frameworks, and employee engagement are key determinants of successful Lean and Six Sigma adoption. The study concludes that integrating these methodologies can significantly reduce production inefficiencies, enhance product consistency, and improve customer satisfaction, thereby strengthening Peniel's market competitiveness. This research provides practical recommendations for manufacturing firms seeking continuous improvement through systematic quality and efficiency strategies.

Keywords: Lean Manufacturing, Six Sigma, Quality Improvement, Operational Efficiency, Crown Cork Manufacturing, Ethiopia, ISO 9001.

Chapter one: Introduction

1.1. Background of the study

As a sector manufacturing is a significant driver of economic growth, especially in developing countries. It plays a major role in the transformation of resources from low productivity sectors, such as agriculture, to high-productivity manufacturing activities, Hence accelerating GDP growth and job creation (UNIDO, 2015; World Bank, 2011). Historically, manufacturing has contributed to increased labor productivity and economic development, making it a backbone for sustainable industrialization (Economic Policy Institute, 2008; Su & Yao, 2017). Crown cork manufacturing is one of the subsector.

Crown cork manufacturing is part of the packaging industry. Ensures the secure sealing of bottled beverages, including soft drinks, beer, water and hair oil. However this industry is facing unique challenges, including the need for product consistency, quality assurance, and operational efficiency in the face of a rising competition and evolving customer demands (Womack & Jones, 2003). These challenges have been further magnified by the growing adoption of international quality standards, such as ISO 9001, which focuses on quality assurance, defect minimization, and process standardization (ISO 9001 Standard, 2015).

Peniel Industry PLC is one of the crown cork manufacturer in Ethiopia, established in 2014. The company supplies crown corks to the local beverage industry and operates two major production sites. The main production facility is located in the Lebu Industrial Zone, Addis Ababa, while an ongoing expansion project the printing section is located in Lemikura Sub-City, IPDC Phase 2. Peniel operates within this dynamic and competitive landscape. Recent pressures also emerged due to the entry of international brands and the global trend toward adopting international quality standards such as ISO 9001 (ISO 9001 Standard, 2015). These external demands initiates continuous improvement in quality management practices and operational efficiency to remain competitive in a market that increasingly values compliance with international standards (Shah & Ward, 2007)

To address these challenges, factories in manufacturing sectors worldwide have turned their head to methodologies like Lean Manufacturing and Six Sigma. Lean focuses on waste reduction and efficiency improvements, while Six Sigma emphasizes defect minimization and process variability reduction. Both methodologies have proven successful in enhancing performance across industries (Pyzdek & Keller, 2014; Antony, 2004). However, their specific application in crown cork manufacturing, particularly in the Ethiopian context, remains underexplored (Shah & Ward, 2007; UNIDO, 2015)

This study aims to narrow this gap by examining integrated quality and process improvement strategies for further recommendation the application of Lean Manufacturing and Six Sigma methodologies at Peniel Industry PLC. By analyzing the company's production processes, identifying inefficiencies, observing the current practice and proposing solutions, the research aims to enhance operational efficiency, reduce defect rates, and align Peniel Industry's practices with international standards. Enabling the company to meet and exceed the expectations of customers while maintaining its competitiveness in the marketplace.

1.2. Statement of the Problem

Peniel Industry PLC, a crown cork manufacturer in Ethiopia, faces persistent inefficiencies in its production processes, leading to high defect rates, excessive material waste, machine downtimes, and rising operational costs. Over the past two years, production data has shown consistent quality challenges, with 1,202,443 defective crown corks out of 517,550,000 produced last year (0.23%) and 1,573,000 defective crown corks from 358,960,000 produced the previous year (0.43%). While these percentages may appear small, they translate into significant material losses, increased production costs, and lower process efficiency. These inefficiencies not only impact profitability but also hinder the company's ability to meet international quality standards such as ISO 9001, which is increasingly demanded by global and regional markets.

One of the major challenges Peniel Industry faces is the lack of a structured, integrated approach to process optimization and quality management. While various quality control measures have been implemented, they remain reactive rather than preventive, failing to address root causes of defects and inefficiencies. Machine downtimes, unoptimized workflows, and variability in production processes further exacerbate these issues, leading to delays and additional costs. Without a robust strategy to streamline production and ensure consistency in product quality, the company struggles to enhance its competitive edge in the industry.

The growing presence of international competitors and the increasing adoption of global quality standards put additional pressure on Peniel Industry. Customers today demand higher quality products, faster delivery times, and compliance with strict regulatory requirements. The inability to meet these expectations can lead to customer dissatisfaction, potential loss of market share, and reduced business sustainability. As global brands enter the Ethiopian market with more efficient production processes, Peniel Industry must respond by adopting modern manufacturing strategies to improve both efficiency and quality.

To address these pressing challenges, this study proposes the implementation of Lean Manufacturing and Six Sigma methodologies at Peniel Industry PLC. Lean Manufacturing focuses on waste elimination, process flow optimization, and efficiency improvement, while Six Sigma targets defect reduction, process standardization, and quality enhancement. These methodologies, when applied together, offer a comprehensive framework that integrates both efficiency and quality improvement, ensuring sustainable manufacturing excellence.

Empirical research has demonstrated the effectiveness of Lean and Six Sigma in reducing defects, minimizing waste, improving machine utilization, and enhancing overall operational performance in various industries. Companies that have successfully implemented these methodologies have reported significant cost savings, increased productivity, and improved customer satisfaction. Given Peniel Industry’s current challenges, there is a need for a data-driven, structured approach to quality and process improvement, allowing the company to achieve consistent product quality, reduced waste, and enhanced competitiveness in the crown cork manufacturing sector.

This research aims examine integrated quality and process improvement strategies in addressing Peniel Industry’s production inefficiencies, providing practical recommendations for a systematic, evidence-based improvement strategy. By adopting these globally recognized approaches, the company can not only align itself with international quality standards but also secure a competitive advantage in the industry, ensuring long-term growth and sustainability.

1.3. Objectives of the Study

1.3.1 General Objective

To examine integrated quality and process improvement strategies for improving product quality and efficiency of production at Peniel Industry PLC, with the ultimate goal of reducing defect rates, minimizing waste, and aligning the company's operations with international quality standards.

1.3.2 Specific Objectives

1. To analyze the current production inefficiencies and defect rates at Peniel Industry PLC.
2. To assess the applicability of Lean Manufacturing principles for eliminating waste and optimization of workflows in crown cork manufacturing.
3. To assess the potential of Six Sigma methodologies in reducing defects and minimizing process variability within the production line.
4. To explore the alignment of Peniel Industry's quality assurance practices with global standards, Like ISO 9001, and meeting the expectations of international clients.

1.4. Research Questions

1) What are the key production inefficiencies and defects affecting Peniel Industry PLC, and how do they impact operational efficiency and product quality?
2) How can Lean Manufacturing and Six Sigma methodologies address these challenges to enhance efficiency and reduce defects?
3) What changes are necessary to align Peniel Industry PLC's operations with ISO 9001 standards and international benchmarks?

1.5. Significance of the Study

This study holds both practical and academic significance, particularly in the areas of quality assurance and process optimization within the crown cork manufacturing industry.

Practical Significance

For Peniel Industry PLC, the study provides actionable recommendations for improving product quality and operational efficiency by integrating Lean Manufacturing and Six Sigma methodologies. These strategies help eliminate waste, reduce defects, and optimize production processes, leading to:

- Lower production costs through waste reduction.
- Improved product consistency to meet international quality standards.
- Enhanced operational efficiency by minimizing machine downtime and material handling delays.
- Increased profitability through optimized workflow and better resource utilization.

By adopting these improvements, Peniel Industry PLC can strengthen its competitiveness and align its processes with ISO 9001 standards, ensuring compliance with multinational client requirements.

Academic and Industrial Significance

This study contributes to the existing body of knowledge on Lean Manufacturing and Six Sigma, specifically within crown cork manufacturing, an under-researched sector in the packaging industry. It provides empirical insights into how these methodologies can address challenges unique to bulk production environments.

Moreover, the findings offer valuable guidance for other manufacturing industries, particularly in developing economies like Ethiopia, where resource constraints make process optimization critical. The study serves as a reference for manufacturers aiming to implement globally recognized quality management practices in similar industrial settings.

Overall, this study provides practical solutions for Peniel Industry PLC while offering broader industrial and academic contributions, fostering continuous improvement, innovation, and alignment with international quality standards.

1.6. Scope of the Study

This study focuses on examining integrated quality and process improvement methodologies in the form of Lean Manufacturing and Six Sigma methodologies as a strategy for improving operational efficiency and product quality at Peniel Industry PLC, a crown cork manufacturer in Ethiopia. Specifically, the study examines production inefficiencies, defect rates, and quality challenges within the company.

The research includes:

1. **Key Stakeholders:** The study involves employees from different roles, including machine operators, quality controllers, managers, and technical staff, who provide insights into the operational challenges and quality management practices.
2. **Data Scope:** Quantitative data, such as production down time and defect rates for the past two years taken from production and quality control records, and qualitative insights from interviews and observations, are analyzed to understand inefficiencies and identify opportunities for improvement.
3. **Methodological Focus:** The study investigates the current practices and readiness for the application of Lean Manufacturing for waste elimination and workflow optimization and Six Sigma for defect reduction and process variability control.
4. **Contextual Focus:** The research is conducted within the specific operational and market context of Peniel Industry PLC, with a focus on aligning quality management practices with international standards like ISO 9001.

1.7 Limitations of the study

First, the study is limited to a single case study focusing exclusively on Peniel Industry PLC, a crown cork manufacturing company in Ethiopia. Although the research provides an in-depth analysis of the company's operational inefficiencies and potential quality improvements, the findings may not be fully generalizable to other manufacturing firms with different product lines, production scales, organizational structures, and market conditions. The challenges faced by Peniel Industry, such as defect rates, material waste, and machine downtimes, might vary in significance across different manufacturing sectors, limiting the broader applicability of the recommendations.

Second, the successful implementation of Lean and Six Sigma methodologies often requires long-term commitment, cultural transformation, and sustained process monitoring. However, due to time constraints, this study may not be able to fully capture the long-term effects of integrating these methodologies at Peniel Industry. While the research will assess the initial impact and feasibility, certain key aspects, such as employee adaptability, continuous improvement cycles, and cost-benefit analysis over extended periods, might require further investigation beyond the study's scope.

Additionally, the study relies on quantitative and qualitative data collection methods, including surveys, interviews, and production records. These data sources are subject to respondent biases, measurement limitations, and data accuracy concerns, which could impact the reliability of findings. Employee perceptions of Lean and Six Sigma adoption may be influenced by preconceived notions, resistance to change, or lack of awareness, potentially affecting the interpretation of results.

Furthermore, external factors such as market dynamics, supply chain disruptions, regulatory changes, and technological advancements may influence the outcomes of Lean and Six Sigma implementation. Since the study focuses on internal operational improvements, external influences beyond the company’s control are not extensively examined.

Despite these limitations, the study seeks to provide a structured framework for quality and efficiency improvement, offering practical recommendations that can serve as a foundation for future research and real-world application. Future studies may expand on this research by conducting comparative analyses across multiple manufacturing firms, incorporating longitudinal data, and assessing industry-wide adoption strategies to provide a more comprehensive understanding of Lean and Six Sigma in manufacturing.

1.8 Operational Definition of Terms

Lean Manufacturing: A systematic approach to identifying and eliminating waste within a manufacturing process to improve efficiency and productivity. Waste in this context refers to activities that consume resources without adding value to the final product (Womack & Jones, 2003).

Six Sigma: A data-driven methodology aimed at achieving near perfection by reducing defects and minimizing variability in processes. It employs statistical tools and the DMAIC framework (Define, Measure, Analyze, Improve, Control) to enhance process capability (Pyzdek & Keller, 2014).

Quality Management: The coordinated activities and processes involved in achieving and maintaining a desired level of excellence. This includes quality assurance, quality control, and a focus on continuous improvement to meet customer expectations (Oakland, 2014).

Process Improvement: A systematic approach to enhancing the efficiency, effectiveness, and adaptability of organizational processes. This involves analyzing workflows to identify inefficiencies and implementing changes to achieve better outcomes (Deming, 1986).

Bottleneck: A constraint or point of congestion in a production system that limits the overall output and efficiency of the process. Bottlenecks often occur when production capacity at one stage is insufficient to meet the demand of subsequent stages (Shah & Ward, 2007).

Waste: In the context of Lean Manufacturing, waste refers to any resource-consuming activity that does not add value to the final product or service. The seven common types of waste include overproduction, waiting, transport, over processing, inventory, motion, and defects (Ohno, 1988).

Defect rate: refers to the percentage of defective items produced in a manufacturing process compared to the total number of items produced. It is a key metric in quality management that helps quantify the extent of inefficiencies and product inconsistencies. A lower defect rate indicates a more efficient and effective production process. Defect rates are typically calculated using the formula:

Defect Rate=(Number of Defective Items/Total Items Produced)×100

In the manufacturing industry, maintaining an acceptable defect rate is crucial for meeting customer expectations and minimizing operational costs. For instance, a defect rate below **0.1%** is generally considered acceptable in high-precision manufacturing industries, while higher defect rates often signal underlying issues such as poor quality control, equipment malfunctions, or inefficient workflows (Salah et al., 2010; Pyzdek & Keller, 2014).

1.9 Organization of the Study

Introduction: This chapter provides an overview of the research topic, including the background of the study, the problem statement, objectives, research questions, significance of the study, scope, limitations, and operational definitions.

Literature Review: This chapter presents a comprehensive review of existing literature related to quality management, Lean Manufacturing, Six Sigma, and process optimization in the manufacturing sector. It establishes a theoretical framework for the study.

Research Methodology: This chapter outlines the research design, population, sampling techniques, data collection methods, and analysis techniques employed in the study. It also discusses the reliability and validity of the instruments used.

Data presentation, Analysis and Interpretation: This chapter presents the findings of the study, analyzes the data collected, and discusses the results in relation to the research questions and objectives. The chapter also highlights key insights and implications for Peniel Industry PLC.

Conclusion and Recommendations: The final chapter summarizes the findings of the study and provides practical recommendations for Peniel Industry PLC based on the research. It also suggests potential areas for further research and concludes the study.

Chapter Two: Literature Review

2.1 Introduction

This chapter presents a review of literatures relevant to quality management and process improvement methodologies in manufacturing. The focus is primarily on Lean Manufacturing, Six Sigma, and their integration as Lean Six Sigma (LSS). These methodologies have been widely applied in various industries to enhance efficiency, minimize waste, and improve product quality. Additionally, this chapter contextualizes these frameworks within the crown cork manufacturing sector, particularly with reference to Peniel Industry PLC. By examining existing theoretical and empirical literature, this review establishes a foundation for understanding the significance of Lean and Six Sigma methodologies in optimizing production processes and ensuring competitive advantage.

2.2 Theoretical Literature Review

2.2.1 Lean Manufacturing Principles

Lean Manufacturing is a systematic approach aimed at eliminating waste ("muda") while ensuring value creation for customers. Introduced by Womack and Jones (2003), Lean focuses on reducing non-value-adding activities, optimizing workflows, and enhancing efficiency. The methodology is structured around core principles such as defining value from the customer's perspective, mapping value streams, and achieving a continuous flow in production processes. Lean emphasizes a pull-based production system where work is initiated based on customer demand rather than forecasts, reducing overproduction and inventory costs.

One of the foundational elements of Lean is the identification and elimination of the seven types of waste: overproduction, waiting, transportation, over-processing, excess inventory, motion, and defects. Various Lean tools and techniques have been developed to address these inefficiencies. Just-In-Time (JIT) focuses on producing only what is needed, when it is needed, minimizing excess inventory and associated holding costs. The 5S methodology (Sort, Set in order, Shine, Standardize, and Sustain) enhances workplace organization and operational efficiency. Kaizen, or continuous improvement, ensures that employees at all levels participate in incremental process improvements to enhance productivity and quality.

Lean principles have been widely applied across industries, including automotive manufacturing, healthcare, and consumer goods production. Studies indicate that Lean implementation significantly improves operational performance by reducing cycle times, enhancing productivity, and lowering defect rates (Womack & Jones, 2003). Despite these benefits, Lean faces challenges such as employee resistance to change, lack of management commitment, and difficulties in sustaining continuous improvement initiatives.

2.2.2 Six Sigma Framework

Six Sigma, developed by Motorola in the 1980s, is a data-driven methodology aimed at reducing process variation and eliminating defects. It employs statistical tools and rigorous problem-solving techniques to enhance quality and process efficiency. The methodology follows the DMAIC (Define, Measure, Analyze, Improve, Control) framework, which systematically identifies and addresses the root causes of inefficiencies.

- **Define**: Establish project goals and customer requirements.
- **Measure**: Collect and analyze data to determine baseline performance.
- **Analyze**: Identify root causes of defects and process variations.
- **Improve**: Implement solutions to optimize processes and reduce defects.
- **Control**: Maintain improvements through ongoing monitoring and process standardization.

Antony (2004) highlights that Six Sigma targets near-perfection, striving for a defect rate of less than 3.4 defects per million opportunities (DPMO). This focus on statistical process control and continuous improvement makes it highly complementary to Lean methodologies. Six Sigma relies on tools such as control charts, process capability analysis, failure mode and effects analysis (FMEA), and root cause analysis (RCA) to identify and mitigate inefficiencies.

2.2.3 Integration of Lean and Six Sigma

The integration of Lean and Six Sigma methodologies combines the waste elimination focus of Lean with the defect reduction emphasis of Six Sigma. This synergy, often referred to as Lean Six Sigma (LSS), enables organizations to achieve operational excellence by addressing both inefficiencies and quality issues. While Lean focuses on improving process flow and eliminating waste, Six Sigma emphasizes reducing variability and enhancing process control.

George (2002) argues that Lean Six Sigma offers a holistic approach to process improvement, leveraging the strengths of both methodologies to drive sustained improvements in efficiency, quality, and customer satisfaction. Organizations employing Lean Six Sigma have reported improvements in key performance indicators such as reduced cycle times, lower defect rates, and enhanced overall equipment effectiveness (OEE).

A key advantage of Lean Six Sigma is its structured approach to problem-solving, which combines qualitative and quantitative techniques to drive informed decision-making. The integration of Lean tools (e.g., value stream mapping, standardized work, and Kanban) with Six Sigma techniques (e.g., hypothesis testing, regression analysis, and design of experiments) enables organizations to address complex operational challenges effectively.

However, the successful implementation of Lean Six Sigma requires strong leadership commitment, a culture of continuous improvement, and a robust infrastructure for data-driven decision-making. Studies have shown that companies adopting Lean Six Sigma must invest in employee training and foster a collaborative environment to sustain long-term benefits (Salah et al., 2010).

2.3 Empirical Literature Review

2.3.1 Application of Lean and Six Sigma in Manufacturing

Empirical studies demonstrate the effectiveness of Lean and Six Sigma methodologies in improving manufacturing efficiency and product quality. Salah et al. (2010) analyzed their implementation in global manufacturing sectors, reporting significant reductions in defect rates and process variability. For instance, the application of Six Sigma in a packaging industry reduced misaligned products by 30%, while Lean practices minimized material handling losses by 25% (Pyzdek & Keller, 2014). In the automotive sector, Lean principles have improved assembly line efficiency by reducing lead times by up to 50% (Shah & Ward, 2007). Similarly, in food and beverage industries, the integration of Lean Six Sigma has been reported to enhance hygiene compliance, reduce waste, and optimize inventory levels, leading to a 20% improvement in overall productivity (George, 2002). These findings illustrate the broad applicability of Lean and Six Sigma methodologies across diverse manufacturing environments.

2.3.2 Defect Rate Management in Crown Cork Manufacturing

In crown cork manufacturing, maintaining low defect rates is critical for ensuring quality and operational efficiency. Industry benchmarks suggest acceptable defect rates range from 0.05% to 0.10% of total production, depending on the scale of operations and customer standards (Salah et al., 2010). Common defects, such as offset crown corks, incomplete liners, and bent corks, often stem from machine misalignment, improper liner application, and material handling inefficiencies. Addressing these issues through Six Sigma's DMAIC framework has proven effective in reducing defect rates by up to 40% (George, 2002). A case study on a leading crown cork manufacturer showed that implementing a data-driven quality control system, coupled with Lean tools like 5S and Kaizen, reduced scrap rates by 35% and improved production cycle times by 20% (Antony, 2014). These empirical insights highlight the potential of Lean and Six Sigma methodologies in enhancing process reliability and minimizing waste in the crown cork manufacturing sector.

2.3.3 Waste Management in Lean Manufacturing

Waste, defined as any non-value-adding activity, is a central focus of Lean Manufacturing. The seven types of waste identified by Lean (overproduction, waiting, transportation, over-processing, inventory, motion, and defects) account for significant resource losses in manufacturing systems (Womack & Jones, 2003). Shah and Ward (2007) highlight that implementing Lean tools like 5S and JIT can reduce waste by 15–25%, enhancing material flow and reducing operational costs. For example, a study on the beverage packaging industry found that optimizing production scheduling and implementing automated material handling systems reduced transportation waste by 18% (Pyzdek & Keller, 2014). Additionally, reducing excess inventory through Just-In-Time (JIT) principles has been shown to lower storage costs by up to 30%, improving cash flow and operational efficiency. These empirical findings emphasize the critical role of waste reduction strategies in driving cost savings and enhancing competitiveness in manufacturing.

2.3.4 Challenges in Implementing Lean and Six Sigma in Developing Economies

While Lean and Six Sigma are widely adopted in developed economies, their application in developing economies faces unique challenges. UNIDO (2015) identifies resource constraints, lack of skilled personnel, and limited access to advanced technologies as major barriers. In the African context, studies reveal gaps in employee training and inconsistent quality management practices as significant obstacles to achieving sustainable process improvement (Su & Yao, 2017). For example, a study on Ethiopian manufacturing industries found that only 35% of surveyed firms had formally implemented any Lean or Six Sigma principles, largely due to financial and infrastructural limitations (UNIDO, 2015). Moreover, resistance to change and inadequate leadership support have been cited as key impediments to the successful adoption of Lean Six Sigma in resource-constrained environments. Tailored approaches, considering local realities, are essential for overcoming these challenges and ensuring successful implementation.

2.4 The Role of Technology in Process Improvement

2.4.1 Technology as an Enabler of Lean and Six Sigma

The integration of technology plays a vital role in facilitating the implementation of Lean and Six Sigma methodologies. IoT-enabled sensors, predictive maintenance systems, and SPC software provide real-time data for monitoring and improving production processes (Antony, 2014). These tools enable proactive defect detection, reduce downtime, and enhance operational efficiency. In the crown cork industry, automated liner dispensers and high-precision cutting tools have significantly reduced defects related to misalignment and material inconsistencies (Pyzdek & Keller, 2014). The adoption of real-time production monitoring systems has also enhanced decision-making capabilities, allowing manufacturers to respond swiftly to deviations from quality standards. However, their adoption in resource-constrained environments, such as Ethiopia, remains limited (UNIDO, 2015).

2.4.2 Empirical Evidence on Technological Integration

Case studies from global manufacturing industries show that integrating technology with Lean and Six Sigma can yield substantial benefits. For example, automated quality inspection systems have reduced defect rates by 30%, while predictive analytics tools have decreased machine downtime by 40% (Pyzdek & Keller, 2014). In crown cork manufacturing, technologies such as automated liner dispensers and high-precision cutting tools have been instrumental in achieving process standardization and reducing defects. A case study conducted on a South African beverage packaging plant reported that digital twin simulations of production lines improved workflow efficiency by 25% and significantly reduced unexpected machine failures. Similarly, advanced data analytics in supply chain management has enhanced demand forecasting accuracy, leading to optimized inventory levels and reduced waste (Shah & Ward, 2007). These empirical examples underscore the potential of technology-driven process improvements in enhancing quality management practices.

2.5 Conceptual Framework

The conceptual framework of this study seeks to address the operational and quality challenges at Peniel Industry PLC by integrating Lean Manufacturing, Six Sigma, and quality management practices. This framework highlights the relationships between key variables and demonstrates how the systematic implementation of these methodologies can enhance operational efficiency and stproduct quality.

1. Independent Variables

- **Current Practices:** Existing workflows, quality control measures, and production processes at Peniel Industry PLC, which provide the baseline for identifying inefficiencies.
- **Gaps in quality and efficiency:** Specific shortcomings, such as machine downtime, high defect rates, and material handling inefficiencies that hinder productivity and quality.
- **Lean Manufacturing Practices:** Strategies aimed at reducing waste, streamlining workflows, and optimizing operational performance.
- **Six Sigma Practices:** Data-driven methodologies designed to minimize defects, reduce process variability, and improve decision-making through statistical analysis.

2. Dependent Variables

- **Operational Efficiency:** Enhanced production cycle times, minimized machine downtime, improved throughput, and streamlined workflows.
- **Product Quality:** Reduced defect rates, consistent production outputs, adherence to international standards like ISO 9001, and improved customer satisfaction.

2.5.1 Diagram

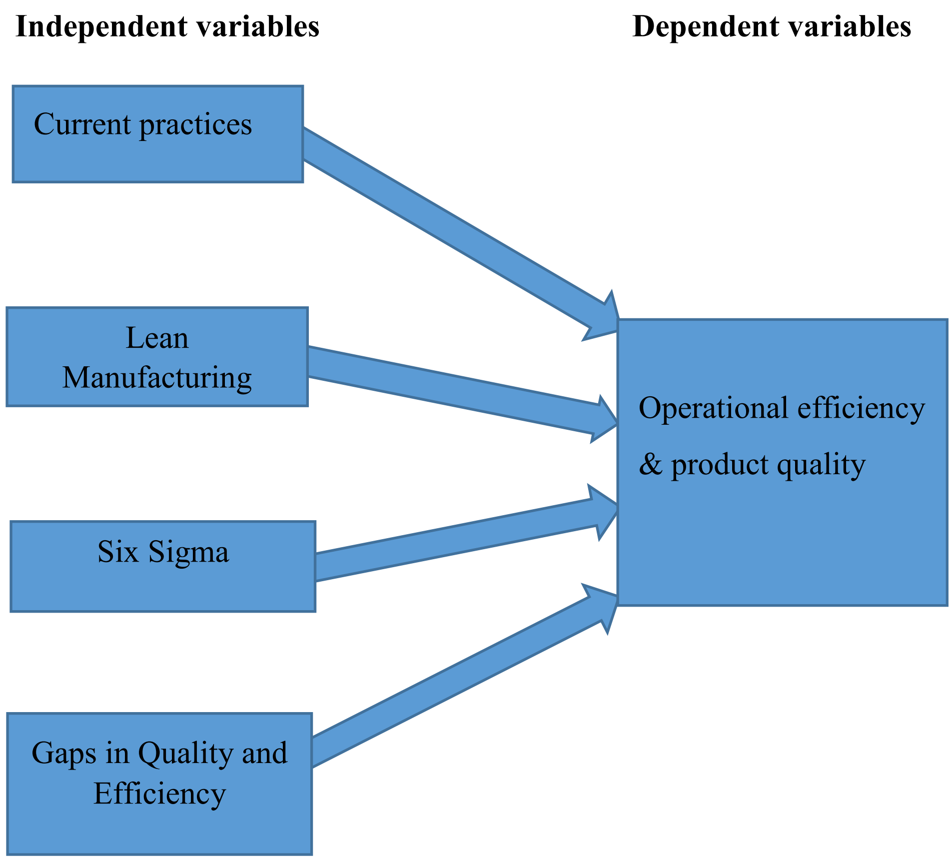

Fig 1. Conceptual framework diagram

Source: Adapted from literature (developed by the researcher, 2024).

Chapter Three: Research Methodology

3.1 Description of the Study Area

This study was conducted at Peniel Industry PLC, focusing on analyzing the manufacturing processes within its production lines. The research targeted areas of inefficiencies, production bottlenecks, and quality control challenges to identify opportunities for enhancing operational efficiency, reducing waste, and improving product quality. This chapter outlines the research design, population, sampling methods, data collection instruments, and analytical tools employed in the study to provide a clear understanding of the methodology used.

3.2 Research Design

This research employs a descriptive and explanatory research design to analyze integrated quality and process improvement strategies at Peniel Industry PLC. The descriptive aspect of the study focuses on systematically outlining the current operational conditions, including defect rates, machine downtimes, material waste, and employee perspectives. This allows for a comprehensive understanding of existing inefficiencies and how they impact production quality and efficiency.

The explanatory component seeks to identify and analyze the relationships between various factors contributing to these inefficiencies. By using quantitative data analysis (such as defect rate trends and production performance metrics) alongside qualitative insights (employee feedback and operational observations), the study aims to explain the root causes of these inefficiencies. This approach helps establish causal links between operational challenges and the effectiveness of Lean and Six Sigma methodologies in addressing them.

3.3 Population

The population for this study comprises employees directly involved in the production process at Peniel Industry PLC. This includes individuals from key operational and quality roles essential to the crown cork manufacturing process. The total population of employees in these departments is 55 individuals, distributed as follows:

Table 3.1 population of the study (source: own survey data)

Job Role	Number of Employees	Sex Distribution (Female: Male)
Factory Manager	1	0:1
QA Manager	1	0:1
Technical Manager	1	0:1
Production Manager	1	0:1
Data Analysts	2	0:2
Quality Controllers	6	3:3
Senior Machine Operators	6	0:6
Junior Machine Operators	10	0:10
Warehouse Manager	1	0:1
Assistant Warehouse Manager	1	0:1
Spare Part Store Keeper	1	0:1
Packers	12	0:12
Manual Sorters	12	12:0

This population was chosen because it includes all employees with direct involvement in production, quality control, and operations, ensuring the study captures diverse insights from key stakeholders.

3.4 Sampling

To ensure representativeness and diversity in perspectives, a stratified random sampling method was employed. Each stratum corresponds to a job role, and the sample will proportionally represent each role's population size.

Using the finite population correction formula, the sample size is calculated as 35 participants based on a 95% confidence level and a ±10% margin of error. Proportional representation was applied to determine the number of participants selected from each job role, ensuring all roles are adequately represented.

Table 3.2 stratified sample (source own survey data)

Job Role	Population	Proportional Sample Size	Sex Distribution in Sample
Factory Manager	1	1	0:1
QA Manager	1	1	0:1
Technical Manager	1	1	0:1
Production Manager	1	1	0:1
Data Analysts	2	1	0:1
Quality Controllers	6	4	2:2
Senior Machine Operators	6	4	0:4
Junior Machine Operators	10	6	0:6
Warehouse Manager	1	1	0:1
Assistant Warehouse Manager	1	1	0:1
Spare Part Store Keeper	1	1	0:1
Packers	12	7	0:7
Manual Sorters	12	6	6:0

3.5 Sampling Methods

A stratified random sampling approach was used to make sure all key job roles and their different perspectives are represented in the study. The population was divided into strata based on their job roles, and individuals were randomly selected from each stratum based on their proportional representation.

This approach ensures that:

1. Each role contributes insights reflective of its significance in the production process.
2. The unique experiences of underrepresented groups, such as women (e.g., quality controllers and manual sorters), are included to provide a holistic view of the challenges and opportunities within the company.

For example, since manual sorters and packers together constitute a significant portion of the workforce (44%), approximately 13 participants selected from these roles. Managers, who play a critical decision making role, represented with a 100% sample to capture their strategic insights.

3.6 Data Collection Tools

3.6.1 Questionnaires

Structured questionnaires of 25 Likert scale questions were distributed to employees selected through stratified random sampling. These questionnaires collected quantitative data on employees' experiences with production processes, quality control practices, and perceptions of inefficiencies and bottlenecks. A Likert scale was employed to measure attitudes towards the adoption of Lean Manufacturing and Six Sigma methodologies. This method ensured the collection of measurable and comparable responses.

3.6.2 Interviews

Semi-structured interviews were conducted with key personnel, exclusively managers. The interviews aimed to gather some quantitative records and qualitative insights into operational challenges, perceptions of process inefficiencies, and recommendations for improvement. The semi-structured format facilitated an in-depth exploration of key themes and reviewing some records while allowing flexibility to find additional details.

3.6.3 Observations

Direct observations of production processes were carried out by the researcher to identify inefficiencies, bottlenecks, and areas for improvement. Observations provided firsthand insights into the dynamics of the manufacturing floor, complementing the data collected through questionnaires and interviews.

3.7 Data Analysis

Data analysis combined both quantitative and qualitative techniques to reflect the whole understanding of the operational issues at Peniel Industry PLC.

3.7.1 Quantitative Data Analysis

Data from the questionnaires were analyzed using descriptive statistics to summarize key metrics, including defect rates, production cycle times, and waste levels. Statistical analyses, such as correlation analysis, were performed using SPSS software to identify relationships between variables. Also while interviewing some data records also reviewed focusing majorly on defect rates, production downtime and quality records.

3.7.2 Qualitative Data Analysis

Interview data were analyzed using thematic analysis to identify recurring themes and patterns related to challenges and improvement opportunities. The qualitative data helped contextualize the quantitative findings, offering deeper insights into finding solutions. Observational data were also integrated into the analysis to validate and enhance the themes identified.

3.8 Reliability

Reliability refers to the consistency and stability of the research instrument in measuring the intended variables. A reliable instrument ensures that the collected data is dependable and can produce consistent results if the study were to be repeated under similar conditions. To evaluate the reliability of the questionnaire used in this study, Cronbach's alpha coefficient was employed. Cronbach's alpha is a widely accepted statistical measure used to assess internal consistency, indicating how closely related a set of items are as a group.

A Cronbach's alpha value of 0.7 or higher is generally considered acceptable, signifying that the questionnaire items are sufficiently correlated and measure the same underlying construct. In this study, the calculated Cronbach's alpha exceeded 0.7, confirming the internal reliability of the instrument. This suggests that participants' responses were consistent and that the questionnaire effectively measured perceptions of quality management and process improvement. Ensuring high reliability in data collection enhances the credibility of the research findings, allowing for accurate analysis and interpretation.

Table 3.4 Test of reliability

Section	Number of Items	Cronbach's Alpha
Current Production Practices	5	0.79
Awareness of Lean Manufacturing	5	0.81
Awareness of Six Sigma	5	0.74
Identified Gaps in Quality and Efficiency	5	0.88
Implementation of Lean and Six Sigma	5	0.72

Source: own survey questionnaire

3.9 Validity

Validity determines the extent to which a research instrument accurately measures what it is intended to measure. In this study, different forms of validity were considered to ensure the accuracy and relevance of the questionnaire. Content validity was established through expert evaluation, where the academic advisor reviewed the questionnaire for clarity, comprehensiveness, and alignment with the research objectives. This review process ensured that all essential aspects of quality management and process improvement were adequately covered.

Additionally, face validity was assessed by presenting the questionnaire to a small sample of participants before full-scale data collection. This helped identify any ambiguities, unclear wording, or potential misinterpretations. The feedback obtained was used to refine the instrument, improving its clarity and effectiveness in capturing reliable responses. By ensuring strong validity, the research findings are more likely to be meaningful, accurately reflecting the studied phenomena.

3.10 Ethical Considerations

Ethical integrity is a fundamental aspect of conducting research, ensuring that participants' rights and well-being are safeguarded throughout the study. Several ethical measures were taken to uphold the highest standards of research ethics.

Informed Consent

Before participating in the study, individuals were provided with a clear explanation of the research objectives, methodology, and potential implications. This included details on how the collected data would be used and the measures taken to ensure privacy. Participants were given the opportunity to ask questions and seek clarifications before providing their consent. Only those who voluntarily agreed to participate were included in the study, ensuring compliance with ethical research practices.

Confidentiality and Data Security

To maintain the confidentiality of participants, all responses were anonymized, ensuring that individual identities could not be linked to the data. Personal identifiers were removed, and responses were stored securely in password-protected digital files. Only the researcher and authorized personnel had access to the data, minimizing the risk of unauthorized disclosure. These measures protected participants' privacy and encouraged honest and unbiased responses.

Voluntary Participation and Right to Withdraw

Participants were explicitly informed that their involvement in the study was entirely voluntary. They were assured that they had the right to withdraw from the study at any stage without facing any negative consequences. This approach reinforced the principle of autonomy, allowing participants to make informed decisions about their participation.

By integrating these ethical considerations, the study upheld the principles of honesty, transparency, and respect for participants' rights, ensuring the reliability and validity of the research findings.

Chapter 4: Data presentation, Analysis and Interpretation

4.1 Introduction

This chapter presents the findings and analysis of the data collected during the study. The analysis is structured around the research objectives and questions, focusing on identifying production inefficiencies, exploring waste and defect patterns, and examining integrated quality and process improvement strategies also assessing the potential for implementing Lean Manufacturing and Six Sigma at Peniel Industry PLC.

The data collected from survey responses, interviews, and observational records are systematically analyzed using both quantitative and qualitative approaches. Quantitative data, derived from structured questionnaires, are statistically examined to measure the extent of inefficiencies, defect rates, and employee awareness of Lean and Six Sigma principles. Meanwhile, qualitative data from open-ended responses and interviews provide deeper insights into operational challenges, employee perceptions, and managerial perspectives on process improvement.

The objective of this analysis is to provide data-driven insights that will guide decision-making at Peniel Industry PLC. By identifying key challenges and assessing the feasibility of Lean and Six Sigma methodologies, the findings will contribute to formulating practical recommendations for enhancing production efficiency and ensuring consistent quality standards.

4.2 Demographic Information of Respondents

The demographic profile of respondents highlights the workforce composition at Peniel Industry PLC. This section presents a breakdown of respondents by gender, work experience, education level, and job role, offering insights into their backgrounds and contributions to the company's operations. Below is a table which shows Summary of Respondent Demographics.

Table 4.1: Summary of Respondent Demographics

Source: own survey data (December 2024)

Gender		
	Frequency	Percentage%
Male	27	77.1%
Female	8	22.9%
Work experience		
	Frequency	Percentage%
<1	5	14.3%
1-3	6	17.1%
4-6	11	31.4%
>6	13	37.1%
Education level		
	Frequency	Percentage%
Diploma	Diploma	Diploma
BA Degree	BA Degree	BA Degree
MA Degree	MA Degree	MA Degree
Job role		
	Frequency	Percentage%
Machine operator	10	28.6%
QC staff	4	11.4%
Managerial	6	17.1%
Other	15	42.9%

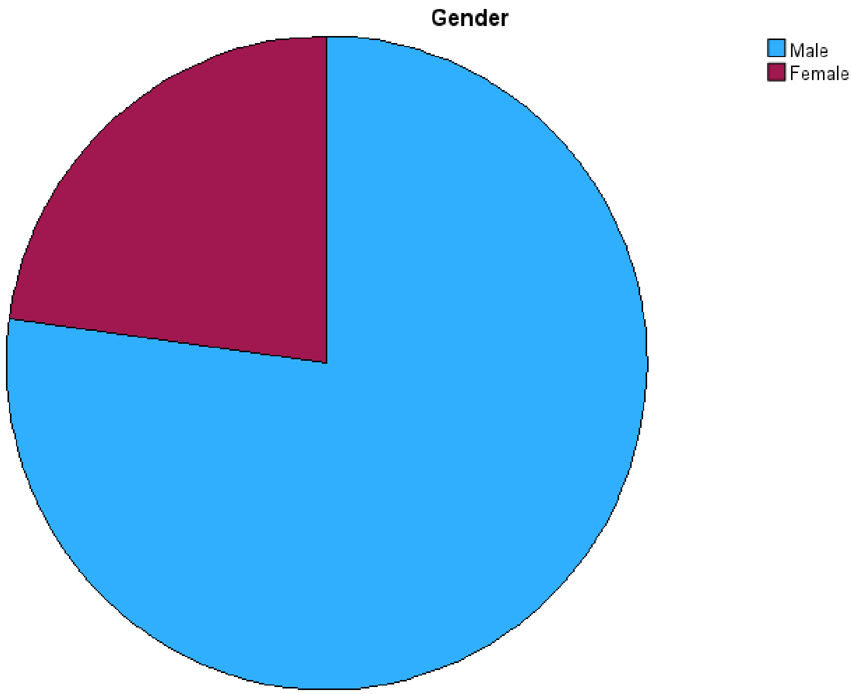

Figure 4.1 Gender chart

The demographic profile of respondents offers key insights into the workforce composition at Peniel Industry PLC. The majority, 77.1%, were male, while 22.9% were female, highlighting a gender disparity commonly observed in manufacturing industries, where labor-intensive roles are often male-dominated. This distribution suggests that gender representation in technical roles may be skewed, potentially impacting workplace diversity and inclusion efforts. Understanding this trend can help the company develop strategies to promote gender balance, particularly in roles requiring specialized skills and leadership positions.

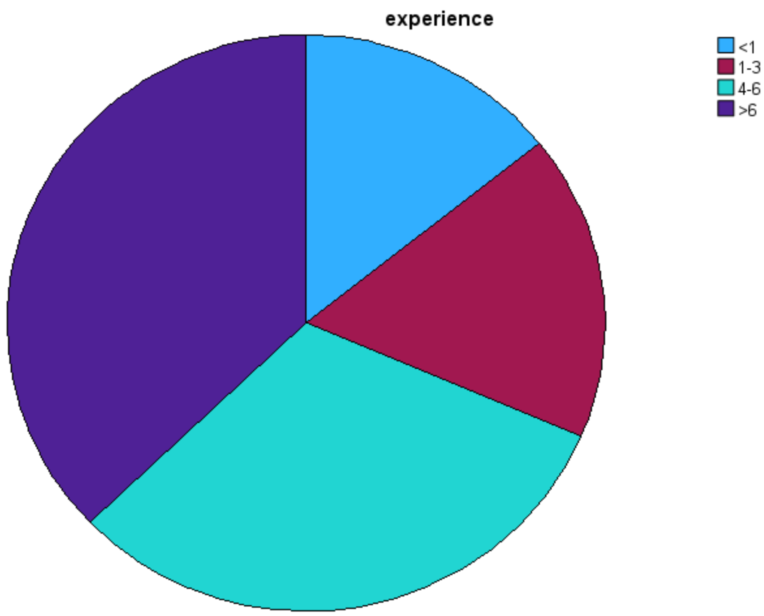

Figure 4.3 work experience chart

Regarding work experience, a substantial portion of respondents demonstrated significant familiarity with the industry. Those with more than six years of experience constituted the largest group at 37.1%, followed by those with 4–6 years at 31.4%. Respondents with 1–3 years of experience made up 17.1%, while 14.3% had less than one year of experience, indicating a mix of seasoned and newer employees.

Also Educational qualifications among the participants were diverse, including diploma holders, bachelor's degree holders, and individuals with master's degrees, showcasing a wide range of educational backgrounds contributing to the workforce's skillset. In terms of job roles, the respondents were well-distributed across various categories. The largest group fell under "Other" roles, accounting for 42.9%, followed by machine operators at 28.6%, managerial staff at 17.1%, and quality control staff at 11.4%. This diverse representation of roles and expertise provided a comprehensive perspective on the company's operational and quality management practices, supporting the study's objectives effectively.

4.3 Quantitative Data Analysis

This section presents the findings from the questionnaires, interview review on production and quality records at Peniel Industry PLC, focusing on current practices, awareness on lean and six sigma methodologies, operational inefficiencies, defect rates, and waste levels. The analysis highlights all the quantitative aspects of the study, gaps and improvement for opportunities, directly aligning with the study's objectives.

4.3.1. Descriptive analysis:

Through descriptive analysis, this section evaluates employee perceptions of current production practices, six sigma awareness, Lean Manufacturing awareness and identified gaps. Below there are tables of descriptive analysis and their interpretation.

Table 4.2 Descriptive statistics of current production practices

Source: Own Survey Data (December, 2024)

Current Production Practices			
	N	Mean	Std. Deviation
Production processes are running efficiently.	35	4.14	.601
The current workflow prioritize reducing unnecessary waste.	35	4.31	.676
Quality control measures in place are improving defect rates.	35	3.77	.731
Employees are fully equipped in training to identify production inefficiencies.	35	4.29	.622
The factory's operational practices align with international quality standards like ISO 9001.	35	4.20	.632
Valid N (listwise)	35		

The analysis of production practices at Peniel Industry PLC reveals positive employee perceptions, with strong agreement on several key aspects. Employees generally believe that production processes are running efficiently, as evidenced by a mean score of 4.14 and a low standard deviation of 0.601, indicating consistency in responses. Waste reduction is seen as a priority in the current workflow, achieving the highest mean score in this section (4.31) with a slightly higher standard deviation of 0.676, reflecting minor variability in opinions. Although quality control measures are viewed as improving defect rates, this item recorded the lowest mean score (3.77) and the highest standard deviation (0.731) within this section, suggesting room for improvement and diverse perspectives on the effectiveness of current quality measures. On the positive side, employees feel well-trained to identify inefficiencies, supported by a high mean of 4.29 and a low standard deviation of 0.622, signifying consensus on the adequacy of training programs. Additionally, confidence in the factory's alignment with international quality standards like ISO 9001 is reflected in a mean score of 4.20 and a standard deviation of 0.632, reinforcing the company's commitment to maintaining globally recognized operational practices

Table 4.3 Descriptive statistics of awareness of lean manufacturing

Source: Own Survey Data (December, 2024)

Awareness of Lean Manufacturing			
	N	Mean	Std. Deviation
Employees believe Lean Manufacturing can enhance the company's alignment with ISO 9001 standards.	35	4.23	.598
Lean Manufacturing is essential to addressing bottlenecks in the crown cork production process.	35	4.09	.562
Employees believe adopting Lean Manufacturing will speed up processes.	35	4.20	.632
Lean Manufacturing principles, such as waste elimination, can save costs.	35	3.83	.453
Lean Manufacturing fosters a culture of continuous improvement within the organization.	35	4.31	.583
Valid N (listwise)	35		

The analysis of employee perceptions regarding Lean Manufacturing highlights its recognized value in enhancing operational efficiency and addressing production challenges at Peniel Industry

PLC. Employees strongly agree that Lean Manufacturing can facilitate alignment with ISO 9001 standards, as reflected by a mean score of 4.23 and a low standard deviation of 0.598, indicating consistent agreement. Similarly, Lean Manufacturing is considered essential for resolving production bottlenecks (Mean = 4.09, Std. Deviation = 0.562), and respondents share a common understanding of its importance. The belief that Lean Manufacturing can accelerate production processes also garnered high agreement (Mean = 4.20, Std. Deviation = 0.632), though the slightly higher variability suggests some differences in the degree of enthusiasm. While Lean principles, such as waste elimination, are acknowledged for their cost-saving potential (Mean = 3.83, Std. Deviation = 0.453), this item scored the lowest in the section, potentially reflecting less awareness or emphasis on financial benefits among the primarily technical respondents. Notably, the highest mean score (4.31) was attributed to the belief that Lean Manufacturing fosters a culture of continuous improvement, with a low standard deviation of 0.583 demonstrating uniform agreement. Overall, the findings underscore strong employee recognition of Lean Manufacturing's benefits, with opportunities to further emphasize its financial advantages during training or implementation.

Table 4.4 descriptive statistics of Awareness of Six Sigma

Source: Own Survey Data (December, 2024)

Awareness of Six Sigma			
	N	Mean	Std. Deviation
Employees believe Six Sigma can significantly reduce defect rates in crown cork production.	35	3.60	.881
Employees see Six Sigma as a methodology that aligns to achieve international quality standards like ISO 9001.	35	4.03	.857
Employees believe Six Sigma can help address variability issues in production.	35	4.11	.718
The help of statistical tools enhance production capability.	35	4.20	.677
Six Sigma data-driven decisions will improve operational performance.	35	4.06	.684
Valid N (listwise)	35		

The analysis of employee perceptions regarding Six Sigma highlights its recognized potential to enhance quality and process optimization at Peniel Industry PLC. Employees generally agree that Six Sigma can significantly reduce defect rates in crown cork production, as reflected by a mean score of 3.60, though the relatively lower mean and higher standard deviation (0.881) indicate variability in opinions and an area for improved awareness. Respondents also affirm that Six Sigma aligns with achieving ISO 9001 standards (Mean = 4.03, Std. Deviation = 0.857), with general agreement but some differences in perception. Strong consensus is evident in the belief that Six Sigma can address variability issues in production (Mean = 4.11, Std. Deviation = 0.718) and that statistical tools enhance production capability, which achieved the highest mean score in the section (Mean = 4.20, Std. Deviation = 0.677). Additionally, employees agree that data-driven decisions improve operational performance (Mean = 4.06, Std. Deviation = 0.684), with consistent responses across participants. Overall, the results demonstrate a positive perception of Six Sigma's role in improving production capability and operational performance, with an opportunity to strengthen employee understanding of its impact on defect reduction.

Table 4.5 descriptive statistics of Identified Gaps in Quality and Efficiency

Source: Own Survey Data (December, 2024)

Identified Gaps in Quality and Efficiency			
	N	Mean	Std. Deviation
The current defect rate significantly impacts operational efficiency and customer satisfaction.	35	4.06	.639
Equipment downtime is a major challenge in meeting production targets.	35	3.71	.667
The factory lacks a structured framework for process improvement and quality management.	35	3.71	.710
Existing resources are insufficient to address production inefficiencies.	35	4.20	.632
Current practices need significant improvement to align with international benchmarks.	35	4.29	.667
Valid N (listwise)	35		

The analysis highlights critical gaps in operational practices and resources at Peniel Industry PLC that significantly impact efficiency and customer satisfaction. Employees strongly agree that the current defect rate negatively affects operational performance and customer satisfaction, as reflected by a mean of 4.06 and a low standard deviation of 0.639, indicating a shared understanding of its critical role. Equipment downtime is also identified as a challenge (Mean = 3.71, Std. Deviation = 0.667), though it is perceived as less pressing compared to other issues. The lack of a structured framework for process improvement (Mean = 3.71, Std. Deviation = 0.710) further underscores the need for systematic measures to address inefficiencies. Insufficient resources are another major concern, with one of the highest mean scores (4.20, Std. Deviation = 0.632) reflecting strong agreement on the inadequacy of current tools and systems. The highest mean (4.29, Std. Deviation = 0.667) underscores a consensus that significant improvements are needed to align practices with international benchmarks. These findings emphasize the urgency for targeted interventions, particularly through structured methodologies like Lean Manufacturing and Six Sigma, to enhance resource utilization, address process inefficiencies, and meet global standards.

Table 4.6 descriptive statistics of Implementation of Lean and six sigma

Source: Own Survey Data (December, 2024)

Implementation of Lean and six sigma			
	N	Mean	Std. Deviation
Management is supportive of adopting new methodologies like Lean and six sigma.	35	4.20	.797
Employees are willing to participate in trainings to effectively apply Lean and Six Sigma.	35	4.26	.611
The organizational culture supports continuous improvement and innovation.	35	4.23	.731
Integration of Lean and Six Sigma would improve both quality and efficiency.	35	4.34	.591
The implementation of lean and six sigma is essential for ensuring competitiveness in the international market	35	4.37	.547
Valid N (listwise)	35		

The results from Section 5 demonstrate a robust organizational readiness and alignment for implementing Lean and Six Sigma methodologies at Peniel Industry PLC. The high mean score of 4.20 for management support highlights employees' perception of strong managerial backing, though the slightly higher standard deviation (0.797) suggests some variability in experiences with managerial priorities. Employee willingness to participate in training programs, reflected by a mean of 4.26 and a low standard deviation of 0.611, indicates a high level of readiness for capacity-building initiatives. Similarly, the organizational culture is seen as supportive of continuous improvement and innovation (Mean = 4.23, Std. Deviation = 0.731), although moderate variability suggests pockets of skepticism that may need to be addressed.

The strongest consensus emerged regarding the transformative potential of integrating Lean and Six Sigma, with a mean score of 4.34 (Std. Deviation = 0.591) indicating widespread belief in its ability to enhance both quality and efficiency. The highest mean score (4.37, Std. Deviation = 0.547) underscores a unified view that these methodologies are essential for maintaining international competitiveness. The low variability across most items suggests consistent agreement among respondents, both employees and management, about the value and necessity of adopting these practices.

Overall, the findings reveal strong foundational support and cultural readiness for Lean and Six Sigma implementation at Peniel Industry PLC. This alignment provides an excellent platform for addressing the identified gaps in quality and efficiency, ensuring the organization can leverage structured methodologies to drive sustainable improvements and competitiveness in the global market.

4.3.2. CORRELATION ANALYSIS

Pearson Correlation Analysis Interpretation is presented in the next table, Pearson correlation measures the strength and direction of linear relationships between variables, expressed as a coefficient ranging from -1 to 1. In this context, it helps identify significant associations among production practices, quality gaps, and readiness for Lean and Six Sigma implementation. Strong positive correlations indicate aligned variables, such as operational efficiency and quality improvements, which are critical for driving strategic outcomes.

Correlations						
		A	B	C	D	E
A	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	35				
B	Pearson Correlation	.788**	1			
	Sig. (2-tailed)	<.001				
	N	35	35			
C	Pearson Correlation	.654**	.659**	1		
	Sig. (2-tailed)	<.001	<.001			
	N	35	35	35		
D	Pearson Correlation	.659**	.613**	.690**	1	
	Sig. (2-tailed)	<.001	<.001	<.001		
	N	35	35	35		
E	Pearson Correlation	.763**	.681**	.755**	.877**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	
	N	35	35	35	35	35
**. Correlation is significant at the 0.01 level (2-tailed).						

Table 4.7. Pearson Correlations summary

Source: Own Survey Data, SPSS (December, 2024)

The Pearson correlation matrix examines the relationships between five variables (A, B, C, D, and E). The correlation coefficients (r) range from -1 to 1, where 1 indicates a perfect positive correlation, 0 indicates no correlation, and -1 indicates a perfect negative correlation. The results suggest strong relationships between variables and alignment with theoretical expectations. Strong positive correlations were observed between A and E (r = 0.763), indicating that current production practices significantly influence the implementation of Lean and Six Sigma, and between D and E (r = 0.877), highlighting that addressing gaps in quality and efficiency is the strongest predictor for adopting these methodologies. Moderate positive correlations, such as between B and C (r = 0.659), reflect the overlapping but distinct contributions of Lean Manufacturing and Six Sigma awareness to quality and efficiency improvements. All correlations were statistically significant ($p < 0.001$), reinforcing the validity of these findings.

4.3.3. Regression Analysis

Model Summary [b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.919[a]	.845	.824	1.179
a. Predictors: (Constant), D, B, C, A				
b. Dependent Variable: E				

Table 4.8 model summary

Source: Own Survey Data, SPSS (December, 2024)

R= 0.919 indicates a very strong relationship between predictors and the dependent variable. R^2= 0.845 suggests that 84.5% of the variance in Lean and Six Sigma implementation is explained by the independent variables. Adjusted R^2= 0.824 confirms the model's stability, even when accounting for additional predictors.

ANOVA Results

ANOVA [a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	226.727	4	56.682	40.805	<.001[b]
	Residual	41.673	30	1.389		
	Total	268.400	34			
a. Dependent Variable: E						
b. Predictors: (Constant), D, B, C, A						

Table 4.9. Anova results

Source: Own Survey Data, SPSS (December, 2024)

The F-statistic (40.805, $p < 0.001$) confirms that the regression model is statistically significant, indicating the predictors collectively explain the variance in the dependent variable.

Regression Coefficients and Their Interpretation

Coefficients [a]											
Model		Unstandardized Coefficients		St.Coefficient	T	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.573	1.953		.294	.771					
	A	.276	.134	.262	2.069	.047	.763	.353	.149	.323	3.095
	B	-.002	.157	-.002	-.013	.990	.681	-.002	-.001	.341	2.931
	C	.165	.097	.187	1.700	.099	.755	.297	.122	.426	2.348
	D	.593	.111	.576	5.349	<.001	.877	.699	.385	.447	2.239
a. Dependent Variable: E											

Table 4.10. Regression coefficient

Source: Own Survey Data, SPSS (December, 2024)

The regression analysis reveals key insights into the factors influencing the implementation of Lean and Six Sigma at Peniel Industry PLC. Current production practices ($\beta = 0.262$, $p = 0.047$) show a statistically significant positive relationship with Lean and Six Sigma implementation, suggesting that a one-unit improvement in production practices is associated with a 0.262-unit increase in implementation. Awareness of Lean Manufacturing ($\beta = -0.002$, $p = 0.990$) is not statistically significant, indicating that awareness alone does not directly predict implementation, emphasizing the need for a more integrated approach. Awareness of Six Sigma ($\beta = 0.187$, $p = 0.099$) is marginally significant, reflecting a positive but less pronounced impact compared to other factors. Identified gaps in quality and efficiency ($\beta = 0.576$, $p < 0.001$) emerge as the most critical predictor, highlighting the necessity of addressing inefficiencies to ensure the successful adoption of these methodologies. These findings align closely with the operational efficiency metrics, defect rate, and waste analysis derived from quality and production records, reinforcing the importance of tackling inefficiencies to enhance the overall effectiveness of Lean and Six Sigma initiatives.

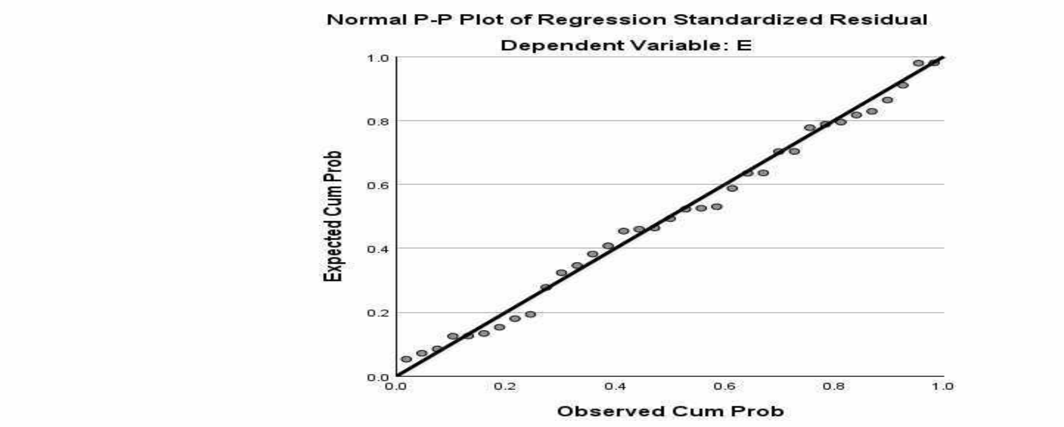

Figure 4.4 Normal P-P plot of regression

Source: Own Survey Data, SPSS (December, 2024)

Normal P-P Plot of Regression Standardized Residual: The data points closely follow the diagonal line, indicating that the residuals are approximately normally distributed. This supports the assumption of normality in regression, which is important for valid statistical inferences.

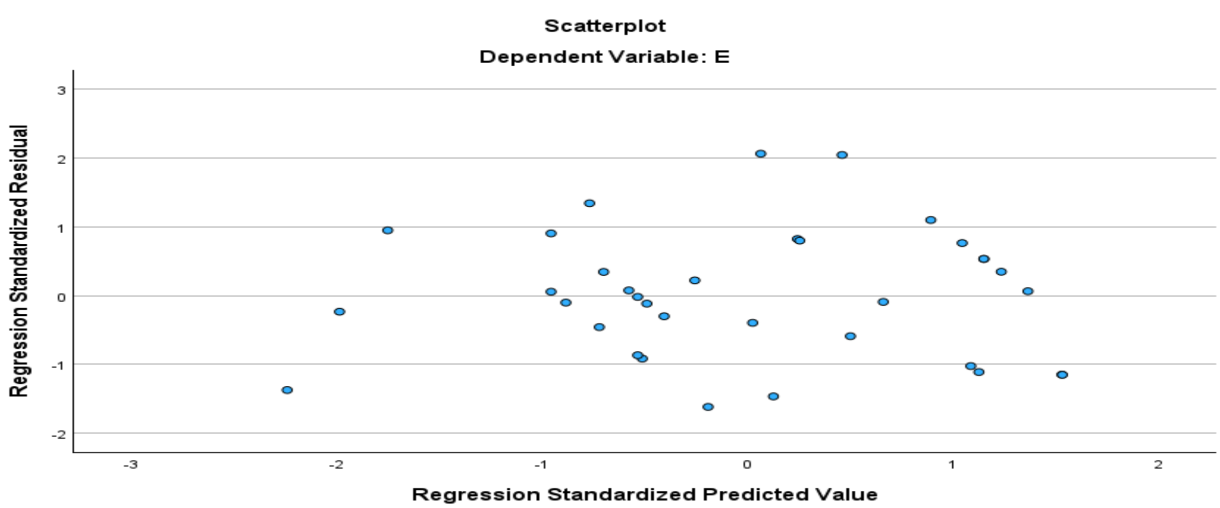

Figure 4.5 Scatterplot dependent variable: E

Source: Own Survey Data, SPSS (December, 2024)

Scatterplot of Regression Standardized Residual vs. Predicted Values: The residuals are scattered randomly around zero, with no discernible pattern. This randomness suggests that the assumptions of linearity and homoscedasticity (constant variance of residuals) are likely satisfied. However, there appears to be slight clustering or non-randomness in certain regions, which could warrant further investigation for potential outliers or non-linearity.

4.3.5. Operational Inefficiencies

This section identifies key areas where operational inefficiencies affect productivity at Peniel Industry PLC. Metrics like machine downtime, production cycle time, and output rate reveal significant gaps from target levels, underscoring the need for process improvements in maintenance and workflow optimization.

Metric	**Target**	**Actual (2024)**	**Gap**	**Observation**
Machine Downtime (hours/day)	< 2 hours	3.8 hours	+1.8 hours	Caused by reactive maintenance and delayed repairs.
Production Cycle Time (minutes)	<5 minutes	6.5 minutes	+1.5 minutes	Delays in material handling and setup processes.
Output Rate (units/hour)	500 units	410 units	-90 units	Bottlenecks in cutting and lining processes.

Table 4.11: Operational efficiency metrics

Source: Production records of Peniel industry

As shown on the above table downtime of machines equals an average of 3.8 hours/day of downtime, exceeding the target by 1.8 hours. This shows inadequate preventive maintenance and delays in sourcing replacement parts. Production Cycle Time is another issue Extended cycle times (6.5 minutes/unit) result from inefficient material handling and process running and long setup processes. Output Rate also Falling short by 90 units/hour, the output rate highlights inefficiencies in critical production stages, including majorly cutting and lining.

4.3.6. Defect Rates and Quality Control

This section analyzes defect rates. High occurrences of offset crown corks and incomplete liners highlight inefficiencies in machine alignment and material application, emphasizing the need for enhanced quality control practices.

Defect Type	Occurrence (% of output)	Target (% of output)	Gap	Observation
Offset Crown Corks	2.6%	< 1%	+1.6%	Improper machine alignment during cutting.
Incomplete Inner Liner	1.2%	< 0.5%	+0.7%	Irregular dispensing in lining machines.
Incomplete Liner	1.1%	< 0.5%	+0.6%	Inconsistent liner material application.
Bent Crown Corks	0.8%	< 0.3%	+0.5%	Mishandling during transfers and storage.

Table 4.12: Defect rate analysis

Source: Quality records of Peniel industry

As shown on the defect rate analysis, offset crown corks represents the most frequent defect (2.6%), resulting from reactive maintenance of cutting machines. Another recurring issue incomplete liner & incomplete inner liner at 1.1% and 1.2% respectively this defect highlights irregular dispensing of liner material contribute to the defect rate, often caused by inconsistencies of the puncher in the lining process. Finally bent crown corks occur less frequently (0.8%) but underscore material handling inefficiencies. The defect rates (0.23% in 2024 and 0.43% in 2023) represent a significant loss of resources, with 1,202,443 defective crown corks in 2024 and 1,573,000 in 2023.

4.3.7. Waste Analysis

This section examines waste generated during production, focusing on defective products, material handling losses, and overproduction discards. The analysis highlights the impact of inefficiencies on resource utilization and provides a foundation for waste reduction strategies.

Waste Source	Waste (kg/day)	Target (kg/day)	Gap (kg/day)	Observation
Defective Corks	9 kg	< 5 kg	+4 kg	High defect rates in cutting and lining stages.
Material Handling Loss	7.5 kg	< 3 kg	+4.5 kg	Spillage and damage during material transfers.
Overproduction Discards	4.5 kg	< 2 kg	+2.5 kg	Excess units produced to cover defects.

Table 4.13: Material waste metrics

Source: Quality records of peniel industry

For the waste analysis Defective Corks Account for the largest portion of waste (9 kg/day), reflecting the impact of high defect rates. Material Handling Loss Spillage and mishandling contribute significantly to waste (7.5 kg/day).Overproduction Discards Producing additional units to compensate for defects adds 4.5 kg/day to waste.

4.4. Qualitative Data Analysis

This section presents the qualitative findings derived from interviews with key personnel at Peniel Industry PLC, as well as observations conducted within the factory environment. The analysis explores recurring themes related to operational inefficiencies, quality management challenges, and opportunities for implementing Lean Manufacturing and Six Sigma.

4.4.1 Themes Identified from Interviews

One of the recurring challenges in current production practices was machine downtime. Employees highlighted that equipment failures often stem from the lack of a preventive maintenance schedule, leading to delays and missed production targets. As one employee stated, "The machines often break down because we don't follow a proper maintenance schedule. Repairs take too long, causing delays and missed production targets." Another employee echoed these sentiments, noting, "Most of the downtime issues stem from reactive maintenance rather than preventive measures. This leads to interruptions in the workflow."

Material handling inefficiencies were also emphasized as a critical bottleneck. Staff members pointed out delays in material delivery to production lines and mishandling during transfers, which often resulted in damaged raw materials. Observations confirmed these findings, revealing instances of improper storage practices contributing to inefficiencies. Additionally, some finished products were mishandled, compounding these issues.

Awareness and readiness for Lean Manufacturing varied among employees. While some displayed limited awareness of its principles, particularly in waste reduction, others expressed optimism about its potential benefits. One employee remarked, "We have not been trained on Lean Manufacturing, but I think it could help us eliminate unnecessary steps in the process." Conversely, a senior employee expressed, "Streamlining workflows through Lean could save significant time and resources."

Similarly, awareness and readiness for Six Sigma were noted. Discussions with quality control staff revealed a basic understanding of Six Sigma as a methodology to reduce defects and enhance process control. However, they acknowledged the lack of practical training and resources. As one staff member noted, "We need to use more statistical tools to analyze defects. Right now, we rely mostly on visual and manual checks, which are not always accurate."

Gaps in current quality management practices were also highlighted. Managers and quality control staff emphasized the absence of a structured framework for process improvement. As one manager explained, "We address problems when customer complaints or a major inefficiency happens, but there is no systematic way of identifying and solving inefficiencies."

4.4.2 Observational Findings

Observations within the factory confirmed several challenges highlighted in interviews. Equipment maintenance schedules were found to be irregular, with some machines visibly worn and prone to frequent stoppages. Material handling practices also contributed to inefficiencies, with spillage and improper storage commonly observed, leading to waste and increased handling times.

Defect and quality control practices were primarily manual, with minimal use of advanced statistical tools. Defects such as offset crown corks and incomplete liners were observed, consistent with quantitative findings. Despite these challenges, employees appeared motivated to improve production processes but lacked structured training opportunities. Several workers expressed enthusiasm for participating in Lean and Six Sigma training initiatives.

4.4.3 Integration with Quantitative Findings

The qualitative insights align closely with the quantitative results, reinforcing key challenges:

1. Machine downtime: Interview responses about reactive maintenance mirror operational data showing excessive downtime (3.8 hours/day).
2. Material waste: Observational findings of spillage and mishandling correlate with the high material handling loss (7.5 kg/day).
3. Defect management: Interviews and observations highlight gaps in quality control, consistent with defect rate data (e.g., offset crown corks at 2.6%).
4. Awareness and training: Employee interest in Lean and Six Sigma aligns with survey findings, where training needs were strongly emphasized (mean = 4.26).

These findings collectively provide a comprehensive understanding of the challenges and opportunities for implementing Lean Manufacturing and Six Sigma at Peniel Industry PLC, highlighting the alignment between employee perceptions, observed practices, and quantitative data.

Chapter 5 Summary, Conclusions and Recommendations

5.1 Introduction

This chapter presents the key findings from the study and offers actionable recommendations to address the operational inefficiencies and quality challenges identified at Peniel Industry PLC. By integrating the principles of Lean Manufacturing and Six Sigma, the company can tackle these challenges effectively and lay the groundwork for operational excellence and global competitiveness. The chapter also discusses the implications of these methodologies and suggests areas for future research to build on the study's findings.

5.2 Summary of Key Findings

The study's primary objective was to examine integrated quality and process improvement strategies to recommend Lean Manufacturing and Six Sigma in improving operational efficiency and product quality at Peniel Industry PLC. Below are the major findings categorized by key focus areas.

5.2.1 Survey Findings

The survey findings provide critical insights into the perceptions and readiness of employees at Peniel Industry PLC regarding current production practices and the potential implementation of Lean Manufacturing and Six Sigma methodologies. The results indicate a strong foundation of employee awareness and a clear recognition of the need for improvement in operational efficiency and quality management.

In terms of current production practices, employees expressed positive views, with a mean score of 4.14 indicating that production processes are generally perceived as running efficiently. However, the lower mean score of 3.77 for quality control measures highlights a critical area requiring improvement, as employees see room for more effective defect rate management. Notably, the highest mean score of 4.31 in this section reflects a strong focus on waste reduction, aligning with the principles of Lean Manufacturing.

Regarding awareness of Lean Manufacturing, employees demonstrated a robust understanding of its potential benefits. A mean score of 4.31 underscores the belief that Lean fosters a culture of continuous improvement. Similarly, high scores for its role in aligning with ISO 9001 standards (4.23) and accelerating production processes (4.20) reveal consistent recognition of its operational advantages. However, the relatively lower mean of 3.83 for its cost-saving potential suggests an opportunity to emphasize the financial benefits of Lean principles in future training sessions.

Awareness of Six Sigma was similarly positive, with employees acknowledging its value in addressing variability and enhancing production capabilities. The highest score of 4.20 was attributed to the belief that statistical tools enhance production, reflecting confidence in data-driven approaches. However, the lower mean of 3.60 for defect reduction highlights a gap in understanding its full potential, underscoring the need for targeted training to bridge this gap.

The survey also identified significant gaps in quality and efficiency, with employees strongly agreeing (mean = 4.29) that current practices require substantial improvement to meet international benchmarks. Equipment downtime and the lack of a structured framework for quality management were highlighted as critical challenges, with mean scores of 3.71 each. These findings point to the urgency of implementing structured methodologies like Lean and Six Sigma to address these inefficiencies effectively.

Finally, the findings reveal strong organizational readiness for implementing Lean and Six Sigma. A mean score of 4.26 indicates high employee willingness to participate in training programs, while the highest score of 4.37 reflects unanimous agreement on the importance of these methodologies for maintaining international competitiveness. These insights underscore the alignment between employee perceptions, organizational goals, and the strategic adoption of Lean and Six Sigma to drive sustainable improvements at Peniel Industry PLC.

5.2.2 Defect Rates and Quality Control

The analysis revealed several recurring quality issues. Offset crown corks, caused by improper machine alignment, accounted for 2.6% of total defects. Incomplete liners and inner liners contributed 1.1% and 1.2% respectively, highlighting inconsistencies in material application during the lining process. Bent crown corks, caused by mishandling during transfers, added another 0.8% to the defect rate. These defects collectively underscored the need for better calibration and maintenance of equipment, as well as improved handling practices.

5.2.3 Waste Management

Significant waste was generated daily due to defects and inefficiencies. Defective corks alone accounted for 9 kg/day, surpassing the target of less than 5 kg/day. Material handling losses, including spillage and damage during transfers, contributed 7.5 kg/day to the waste total. Overproduction to compensate for defects added another 4.5 kg/day, further straining resources and highlighting the need for process optimization.

5.2.4 Operational Inefficiencies

Machine downtime emerged as a critical issue, with an average of 3.8 hours/day, significantly exceeding the target of less than 2 hours. The primary causes included delayed repairs and a reliance on reactive maintenance practices. Production cycle times were also inefficient, with units taking 6.5 minutes compared to the target of 5 minutes. These delays were attributed to material handling inefficiencies and lengthy setup processes. Additionally, output rates fell short by 90 units/hour, indicating bottlenecks in critical processes such as cutting and lining.

5.3. Conclusion

This study underscores the critical need for operational and quality improvements at Peniel Industry PLC. High defect rates, significant machine downtime, and excessive material waste hinder the company’s ability to meet customer expectations and align with international standards. However, these challenges also present opportunities for transformative change.

The integration of Lean Manufacturing and Six Sigma offers a comprehensive framework for addressing these challenges. Lean focuses on eliminating waste and optimizing processes, while Six Sigma targets defect reduction and variability control. Together, they create a synergistic approach that drives continuous improvement and aligns operations with strategic goals.

By adopting the recommendations outlined in this study, Peniel Industry PLC can achieve substantial gains in efficiency, quality, and competitiveness. Improved machine maintenance, streamlined workflows, and enhanced employee training will foster a proactive approach to quality management. Aligning with ISO 9001 standards will further solidify the company's reputation in global markets.

Moreover, this research contributes to the broader discourse on quality management in manufacturing, demonstrating that Lean and Six Sigma principles can be effectively adapted even in resource-constrained environments like Ethiopia. As a case study, it provides valuable insights for other manufacturers facing similar challenges.

While the journey towards operational excellence requires commitment, investment, and cultural change, the potential benefits far outweigh the costs. For Peniel Industry PLC, embracing Lean Manufacturing and Six Sigma represents not just a pathway to overcoming current inefficiencies but also a strategy for long-term growth and resilience in an increasingly competitive market.

5.3 Recommendations

Based on the findings, the following recommendations are proposed to address the identified challenges at Peniel Industry PLC. The recommendations are categorized by relevant departments to ensure effective implementation.

Operations & Maintenance Department

- Implement a preventive maintenance program by scheduling regular machine inspections to reduce unexpected downtime.
- Maintain an inventory of critical spare parts to minimize production disruptions.
- Optimize material handling through the adoption of automated systems where feasible.
- Conduct targeted training programs for machine operators to improve efficiency and minimize equipment-related defects.

Quality Assurance Department

- Regularly calibrate and maintain production equipment to ensure consistent product quality.
- Establish quality checkpoints at critical stages of production to detect and address defects early.

- Adopt Six Sigma tools such as Pareto charts and control charts to monitor defect trends and implement corrective actions based on data.

Production & Process Improvement Department

- Apply Lean Manufacturing principles such as value stream mapping to identify and eliminate waste in production.
- Align production scheduling with actual demand to prevent overproduction and inventory excess.
- Improve storage and material handling practices to minimize raw material waste, spillage, and damage.

Human Resources & Training Department

- Organize workshops and training programs on Lean and Six Sigma methodologies, focusing on practical tools like DMAIC (Define, Measure, Analyze, Improve, Control).
- Foster a continuous improvement culture by encouraging employee participation in problem-solving initiatives.
- Establish a recognition and incentive program to reward employees for contributions to process efficiency and quality enhancement.

Compliance & Standards Department

- Regularly review and update quality policies to ensure alignment with international standards such as ISO 9001.
- Engage external consultants and auditors to assess the company's readiness for ISO certification.
- Develop a customer feedback system to systematically collect and analyze product satisfaction data, enabling proactive improvements.

These recommendations, when effectively implemented across their respective departments, will contribute to enhanced efficiency, reduced waste, improved product quality, and stronger alignment with global manufacturing standards at Peniel Industry PLC.

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Appendix

Descriptive Statistics			
	Mean	Std. Deviation	N
E	21.40	2.810	35
A	20.71	2.663	35
B	20.66	2.209	35
C	20.00	3.190	35
D	19.97	2.728	35

Correlations						
		E	A	B	C	D
Pearson Correlation	E	1.000	.763	.681	.755	.877
	A	.763	1.000	.788	.654	.659
	B	.681	.788	1.000	.659	.613
	C	.755	.654	.659	1.000	.690
	D	.877	.659	.613	.690	1.000
Sig. (1-tailed)	E	.	<.001	<.001	<.001	<.001
	A	.000	.	.000	.000	.000
	B	.000	.000	.	.000	.000
	C	.000	.000	.000	.	.000
	D	.000	.000	.000	.000	.
N	E	35	35	35	35	35
	A	35	35	35	35	35
	B	35	35	35	35	35
	C	35	35	35	35	35
	D	35	35	35	35	35

Variables Entered/Removed[a]			
Model	Variables Entered	Variables Removed	Method
1	D, B, C, A[b]	.	Enter
a. Dependent Variable: E			
b. All requested variables entered.			

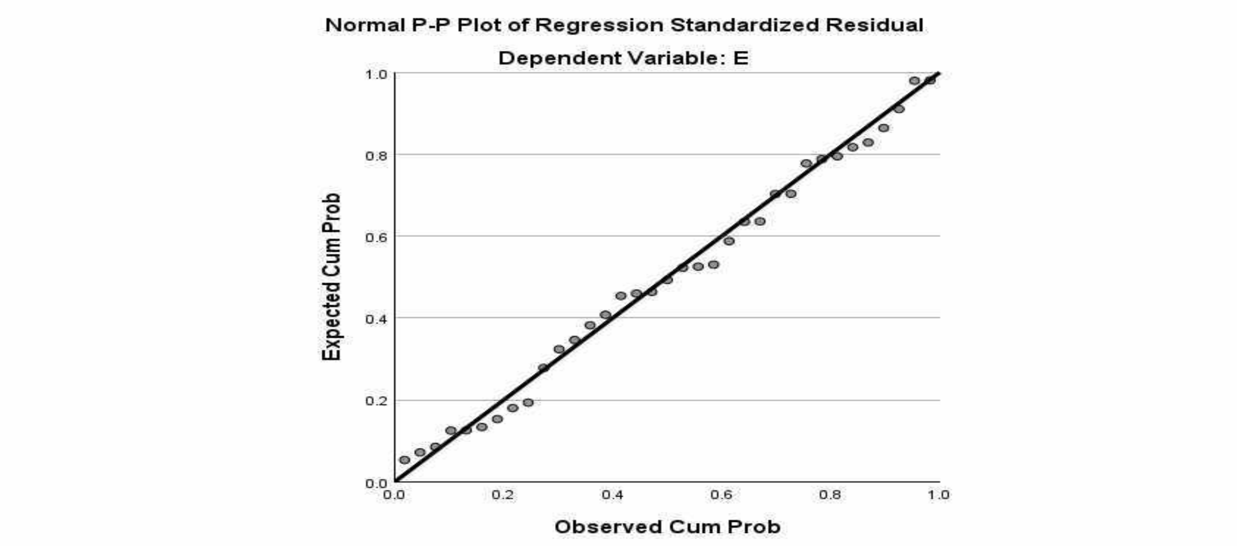
Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.919[a]	.845	.824	1.179
a. Predictors: (Constant), D, B, C, A				
b. Dependent Variable: E				

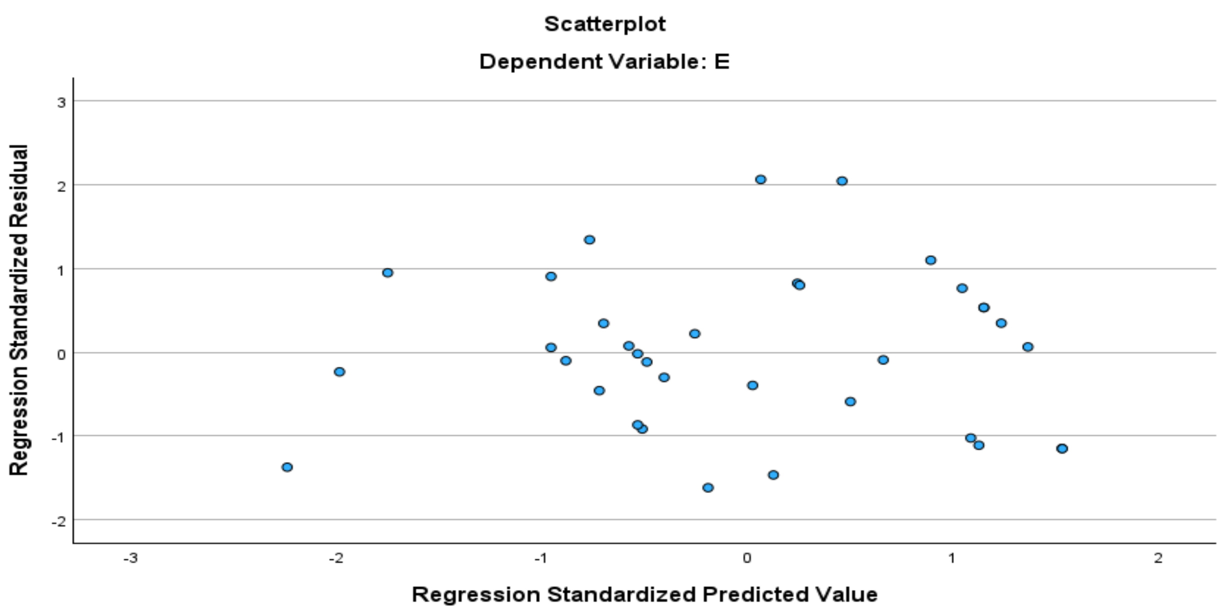
ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	226.727	4	56.682	40.805	<.001[b]
	Residual	41.673	30	1.389		
	Total	268.400	34			
a. Dependent Variable: E						
b. Predictors: (Constant), D, B, C, A						

Coefficients[a]											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	.573	1.953		.294	.771					
	A	.276	.134	.262	2.069	.047	.763	.353	.149	.323	3.095
	B	-.002	.157	-.002	-.013	.990	.681	-.002	-.001	.341	2.931
	C	.165	.097	.187	1.700	.099	.755	.297	.122	.426	2.348
	D	.593	.111	.576	5.349	<.001	.877	.699	.385	.447	2.239
a. Dependent Variable: E											

Collinearity Diagnostics[a]								
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions				
				(Constant)	A	B	C	D
1	1	4.972	1.000	.00	.00	.00	.00	.00
	2	.013	19.818	.43	.00	.01	.33	.03
	3	.006	27.687	.29	.38	.08	.14	.14
	4	.006	28.339	.07	.01	.01	.50	.80
	5	.003	43.870	.20	.61	.90	.03	.02
a. Dependent Variable: E								

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	15.62	25.36	21.40	2.582	35
Std. Predicted Value	-2.239	1.532	.000	1.000	35
Standard Error of Predicted Value	.255	.689	.431	.113	35
Adjusted Predicted Value	16.13	25.65	21.36	2.585	35
Residual	-1.906	2.432	.000	1.107	35
Std. Residual	-1.617	2.064	.000	.939	35
Stud. Residual	-1.699	2.382	.016	1.039	35
Deleted Residual	-2.132	3.269	.041	1.361	35
Stud. Deleted Residual	-1.757	2.600	.024	1.078	35
Mahal. Distance	.624	10.659	3.886	2.479	35
Cook's Distance	.000	.404	.049	.092	35
Centered Leverage Value	.018	.314	.114	.073	35
a. Dependent Variable: E					


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: E
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0


Scatterplot
Dependent Variable: E
Regression Standardized Residual
Regression Standardized Predicted Value
3
2
1
0
-1
-2
-3

SCHOOL OF GRADUATE STUDIES

PROJECT MANAGEMENT PROGRAM

Name of student: Tsegaw Hailemariam

Telephone: 0904153582

Email address: tsegaw2144@gmail.com

Dear Participant,

Thank you for taking your time to participate in this research study, which focuses on improving quality and efficiency in crown cork manufacturing at Peniel Industry PLC. The primary objective of this study is to examine integrated quality and process improvement strategies in crown cork manufacturing.

Your insights and responses are important to this research. The information you provide will help in better understanding of the current practices, challenges, and potential areas for improvement in the manufacturing process. By participating, you are contributing to practical solutions that benefit both the company and the broader manufacturing sector.

All responses will be kept strictly confidential and will only be used for academic purposes.

Please indicate your choice by putting a tick mark (□) among the given alternatives.

Part 1: Demographic Information

1. What is your job title?

☐ Machine Operator

☐ Quality Control Staff

☐ Managerial Role

☐ Other (Please specify): __________

2. Gender:

☐ Male

☐ Female

2. How many years have you worked in this company?

☐ Less than 1 year

☐ 1–3 years

☐ 4–6 years

☐ More than 6 years

3. What is your highest level of education?

☐ High School

☐ Diploma

☐ Bachelor's Degree

☐ Master's degree or above

Part 2: Likert scale questions

No	Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Section 1: **Current Production Practices**						
1.	Production processes are running efficiently.					
2.	The current workflow prioritize reducing unnecessary waste.					
3.	Quality control measures in place are improving defect rates.					
4.	Employees are fully equipped in training to identify production inefficiencies.					
5.	The factory's operational practices align with international quality standards like ISO 9001.					
Section 2: **Awareness of Lean Manufacturing**						
6.	Employees believe Lean Manufacturing can enhance the company's alignment with ISO 9001 standards.					
7.	Lean Manufacturing is essential to addressing bottlenecks in the crown cork production process.					
8.	Employees believe adopting Lean Manufacturing will speed up processes.					
9.	Lean Manufacturing principles, such as waste elimination, can save costs.					
10.	Lean Manufacturing fosters a culture of continuous improvement within the organization.					
Section 3: **Awareness of Six Sigma**						

11.	Employees believe Six Sigma can significantly reduce defect rates in crown cork production.					
12.	Employees see Six Sigma as a methodology that aligns to achieve international quality standards like ISO 9001.					
13.	Employees believe Six Sigma can help address variability issues in production.					
14.	The help of statistical tools enhance production capability.					
15.	Six Sigma data-driven decisions will improve operational performance.					
Section 4: **Identified Gaps in Quality and Efficiency**						
16.	The current defect rate significantly impacts operational efficiency and customer satisfaction.					
17.	Equipment downtime is a major challenge in meeting production targets.					
18.	The factory lacks a structured framework for process improvement and quality management.					
19.	Existing resources are insufficient to address production inefficiencies.					
20.	Current practices need significant improvement to align with international benchmarks.					
Section 5: Implementation of Lean and six sigma						
21.	Management is supportive of adopting new methodologies like Lean and six sigma.					
22.	Employees are willing to participate in trainings to effectively apply Lean and Six Sigma.					
23.	The organizational culture supports continuous improvement and innovation.					

24.	Integration of Lean and Six Sigma would improve both quality and efficiency.					
25.	The implementation of lean and six sigma is essential for ensuring competitiveness in the international market					

Thank you for your time and input. Your feedback is very important to this research and will also contribute to improving the quality and efficiency of Peniel production processes.

Research interview questions for Respondents

Introduction:

Thank you for agreeing to participate in this interview. The purpose of this study is to explore opportunities for improving quality and efficiency in the crown cork manufacturing process at Peniel Industry PLC by applying Lean Manufacturing and Six Sigma methodologies. Your insights and experiences are invaluable to this research.

Section 1: Background and Role

1. Could you briefly describe your role at Peniel Industry PLC and your responsibilities in the production process?
2. How long have you been working in the crown cork manufacturing industry and also in Peniel industry?

Section 2: Current Practices and Challenges

3. What are the quality management practices currently implemented at Peniel Industry PLC?
4. In your opinion, what are the main challenges in the crown cork production process?
5. How do these challenges impact product quality, operational efficiency, or customer satisfaction, can we see some records for quality and production records?

Section 3: Lean Manufacturing Awareness and Practices

6. Are you familiar with Lean Manufacturing principles? If so, how do you think these principles can be applied to improve the manufacturing process?
7. What types of waste (e.g., overproduction, defects, waiting) do you observe in the production line?
8. Can you identify specific areas in the production process where efficiency can be improved?

Section 4: Six Sigma Awareness and Practices

9. Are you familiar with Six Sigma methodologies? If so, have you observed any efforts to apply these techniques in the company?
10. How do you currently identify and address defects or inconsistencies in the production process?

11. What role does data play in decision-making and process improvement at Peniel Industry PLC?

Section 5: Employee Engagement and Training

12. How do you feel about the current level of training and support provided to employees in improving quality and efficiency?
13. Do you think additional training in Lean Manufacturing or Six Sigma would benefit employees and improve processes?

Section 6: Recommendations and Future Improvements

14. What changes would you suggest to improve quality and efficiency in the crown cork production process?
15. In your opinion, how can Lean Manufacturing and Six Sigma be effectively integrated into Peniel Industry's operations?
16. Are there any other strategies or tools you believe could be beneficial for process improvement and quality management?

Closing:

Thank you for sharing your insights. Your interview responses will contribute significantly to this research and help identify practical solutions for improving production processes at Peniel Industry PLC. If you have any additional thoughts or suggestions, please feel free to share them.