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Operational Transformation of a Legacy Fast-Moving Consumer Goods Production System Toward Sustainable Manufacturing Excellence

A Case Study of a Production Line at Fast-Moving Consumer Goods Company

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Operational Transformation of a Legacy Fast-Moving Consumer Goods Production System Toward Sustainable Manufacturing Excellence

by

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Operativ Omvandling av Ett Äldre System för Snabbrörliga Konsumtionsvaror mot Hållbar Tillverkningsexcellens

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Abstract

Legacy production systems in fast-moving consumer goods (FMCG) manufacturing environments often experience operational instability, recurring rework generation, and limited process visibility despite the implementation of continuous improvement frameworks and performance monitoring systems. This study investigates how a legacy FMCG production system can be operationally transformed toward sustainable manufacturing excellence through structured operational learning routines integrated within daily production activities.

The research was conducted as a mixed-method case study with action research characteristics at a chocolate production line within an FMCG manufacturing company. The selected production line was characterized by aging equipment, unstable automation integration, recurring rework losses, and inconsistent production performance. To address these challenges, the study implemented a Root Cause Analysis (RCA)-based rework protocol integrated within a Plan–Do–Check–Act (PDCA) framework.

The findings showed improvements in key production performance indicators, including reduced rework rate and improved General Efficiency (GE) and Overall Equipment Effectiveness (OEE). Pareto analysis of the protocol data also enabled the production team to identify dominant defect categories and prioritize corrective actions more systematically. Qualitative findings further revealed improvements in operational awareness, cross-functional communication, and decision-making processes.

The study concludes that operational transformation in legacy FMCG systems is not solely dependent on large-scale technological upgrades. Instead, meaningful improvement can also emerge through structured operational learning routines that strengthen visibility, feedback mechanisms, and continuous improvement practices within existing production systems.

Keywords: Legacy production systems, FMCG manufacturing, operational transformation, sustainable manufacturing excellence, PDCA, root cause analysis, Lean Six Sigma, rework reduction.

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Sammanfattning

Äldre produktionssystem inom FMCG-industrin (Fast-Moving Consumer Goods) upplever ofta operativ instabilitet, återkommande omarbetning produkt (rework) och begränsad processynlighet trots implementeringen av ramverk för kontinuerliga förbättringar och prestationsuppföljningssystem. Denna studie undersöker hur ett äldre FMCG-produktionssystem kan genomgå operativ transformation mot hållbar tillverkningsexcellens genom strukturerade operativa läranderutiner integrerade i det dagliga produktionsarbetet.

Studien genomfördes som en mixed-method fallstudie med inslag av aktionsforskning på en chokladproduktionslinje inom ett FMCG-företag. Den valda produktionslinjen kännetecknades av åldrande utrustning, instabil automationsintegration, återkommande omarbetningsförluster av produkteroch ojämn produktionsprestanda. För att hantera dessa utmaningar implementerade studien ett RCA-baserat (Root Cause Analysis) protokoll för omarbetning av produkt, integrerat inom ett PDCA-ramverk (Plan–Do–Check–Act).

Resultaten visade förbättringar i centrala produktionsindikatorer, inklusive minskad omarbetningsgrad samt förbättrad General Efficiency (GE) och Overall Equipment Effectiveness (OEE). Paretoanalys av protokolldata gjorde det också möjligt för produktionsteamet att identifiera dominerande defektkategorier och prioritera korrigerande åtgärder på ett mer systematiskt sätt. De kvalitativa resultaten visade dessutom förbättringar i operativ medvetenhet, tvärfunktionell kommunikation och beslutsprocesser.

Studien drar slutsatsen att operativ transformation i äldre FMCG-system inte enbart är beroende av storskaliga teknologiska uppgraderingar. I stället kan meningsfulla förbättringar också uppstå genom strukturerade operativa läranderutiner som stärker synlighet, återkopplingsmekanismer och kontinuerliga förbättringsprocesser inom befintliga produktionssystem.

Nyckelord: Äldre produktionssystem, FMCG-tillverkning, operativ transformation, hållbar tillverkningsexcellens, PDCA, rotorsaksanalys, Lean Six Sigma, minskning av omarbetade produkt.

Contents

1. Introduction **1**

1.1 Background *1*

1.2 Problem Definition *2*

1.3 Purpose and Research Question *3*

1.4 Thesis Outline *3*

1.5 Expected Contributions *3*

1.6 Delimitations *4*

2. Literature **5**

2.1 Legacy Production Systems in FMCG Manufacturing *5*

2.2 Manufacturing and Operational Excellence *5*

2.2.1 Lean Manufacturing Philosophy 6

2.2.2 Lean Six Sigma 6

2.2.3 Sustainable Manufacturing Excellence 7

2.3 Performance Measurement Systems in Manufacturing *7*

2.4 Operational Transformation *8*

2.5 Research Gap *9*

2.6 Conceptual Framework *9*

3. Methodology **11**

3.1 Research Design *11*

3.2 Research Framework *11*

3.3 Case Study Context *12*

3.4 Data Collection *13*

3.5 Data Analysis *15*

3.6 Research Quality *16*

3.6.1 Reliability 16

3.6.2 Validity 16

3.7 Ethical Considerations *16*

3.8 Use of AI-Assisted Tools *17*

4. Empirical Results and Analysis **18**

4.1 Case Context and Production System Overview *18*

4.2 Current State Performance and Problem Characterization *19*

4.2.1 Process Flow and Rework Mechanism 20

4.2.2 Identification of Potential Causes (Exploratory Analysis) 20

4.3 Synthesis of Main Problem Findings *21*

4.4 RCA-Based Protocol Design *21*

4.5 PDCA Implementation *22*

4.6 Findings of Rework Protocol Implementation *23*

4.6.1 Quantitative Findings 23

4.6.2 Qualitative Findings 27

4.6.3 Operational Impact 31

5. Discussion **33**
5.1 Interpreting Operational Transformation in Legacy FMCG Systems *33*
5.2 From Performance Measurement to Operational Action Plan *34*
5.3 Integrating PDCA into Daily Operational Routines *34*
5.4 Behavioral and Cultural Dimensions of Transformation *36*
5.5 Supporting Sustainable Manufacturing Excellence *37*
5.6 Transferability to Other FMCG Manufacturing Contexts *37*
6. Conclusion **40**
6.1 Managerial Implications *41*
6.2 Limitations *41*
6.3 Future Research *42*
References **43**
Appendix **47**
Appendix A - Semi-Structured Interview Guideline *47*
Appendix B - Semi-Structured Interview Guideline (Swedish Version) *49*
Appendix C – RCA Based Protocol *51*

List of figures

Figure 1 Variant of Chocolate Products (Hartbeck, 2023) 2
Figure 2 Conceptual Framework for Operational Transformation in Legacy FMCG Production Systems 9
Figure 3 PDCA Cycle Framework 12
Figure 4 Simplified Chocolate Production Line of FMCG Company 18
Figure 5 Production Line GE Rate Week 7 to Week 15 23
Figure 6 Production Line OEE Rate Week 7 to Week 15 24
Figure 7 Production Line Rework Rate Week 7 to Week 15 25
Figure 8 Pareto Analysis of Rework Protocol Data Week 11 to Week 15 26

List of tables

Table 1 Summary of Collected Data 13
Table 2 Demographic Overview of Interview Participants 14
Table 3 Current State Performance of FMCG company's Chocolate Production 19
Table 4 PDCA Timeline 22

Foreword

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1. Introduction

1.1 Background

Fast-moving consumer goods (FMCG) manufacturing operates in highly competitive environments characterized by high production volumes, tight cost structures, and strict quality requirements. In such environments, operational efficiency, production stability, and waste reduction are critical factors in maintaining competitiveness and achieving sustainable manufacturing performance. Even small inefficiencies in high-volume production can accumulate into substantial operational losses in terms of material waste, energy consumption, labor costs, and lost production capacity (Shadid et al., 2025). Within FMCG production systems, waste occurs in multiple forms, including defects, rework, scrap, equipment downtime, and speed losses (Aljunaidi and Ankrak, 2014). These forms of waste reduce equipment effectiveness, disrupt production flow, and limit the ability of manufacturers to maintain stable operational performance over time (Fajembimo and Akpa, 2025).

To tackle these challenges, manufacturing companies have widely implemented continuous improvement frameworks and tools such as Lean, Six Sigma, and Total Productive Maintenance (TPM). These tools aim to systematically reduce waste, improve operational efficiency, reduce non-value-adding activities, minimize process variation, and improve equipment utilization (Costa et al., 2021; Widiwati et al., 2024; Le, 2025). As a result, these tools linked with the broader ambition and goal of achieving manufacturing excellence, typically understood as the ability to deliver high-quality products efficiently through standardized processes and continuous improvement practices. In recent years, the concept of manufacturing excellence has evolved toward a broader perspective of sustainable manufacturing excellence. This perspective emphasizes not only waste reduction and process optimization, but also long-term operational stability, resource efficiency, and the capability of production system to learn continuously learn and improve over time. In this sense, sustainability in manufacturing is not limited to environmental considerations, but also includes the ability of production system to stabilize performance and adapt to disturbances (Alanezi and Franchetti, 2025).

However, despite the availability of these frameworks, many manufacturing organizations continue to operate with legacy production systems characterized by aging and outdated equipment, historically developed operational routines, and limited integration between machines and digital control systems (Holmes, 2025). In such environments, production processes may experience frequent operational disturbances, equipment synchronization problems, and inconsistent automation performance. These technical and operational constraints often limit the effectiveness of improvement initiatives and contribute to recurring operational instability, for examples to add a new routines, protocol, and maintenance.

Within these legacy production environments, waste does not always originate solely from isolated technical defects but may arise from broader misalignments between equipment capabilities, automation systems, operational routines, and performance management practices. As a result, improvement frameworks may be formally implemented while production losses continue to happen in daily operations. This raises an important question regarding how legacy production systems can transition from fragmented improvement efforts toward more stable and sustainable manufacturing performance.

1.2 Problem Definition

In FMCG manufacturing, production waste frequently manifests in the form of product defects that require rework or scrap. While certain levels of rework are often integrated into manufacturing processes as a method of recovering materials and supporting sustainability objectives, excessive rework can create significant operational inefficiencies. Reprocessing defective products requires additional machine time, labor effort, and energy consumption, and therefore introduces hidden operational costs even when materials are recovered.

Figure 1 Variant of Chocolate Products (Hartbeck, 2023)

This challenge is evident in the case of a legacy production line at an FMCG company that manufactures chocolate, as shown in Figure 1. In this production process, product quality depends on several critical operations, including the chocolate depositor, which is a critical machine that affects chocolate production and formation. Instabilities in the production process may result in defects such as low-level filling, high-level filling, and even missing filling in chocolate production. Products with such defects cannot be released as finished goods and are therefore redirected into the rework stream for material recovery. Although rework contributes to reducing direct material waste by allowing defective products to be reprocessed, the system has a limited capacity to absorb reworked material into the production process. When the volume of rework exceeds this capacity, excess material must be discarded as scrap. In addition to material losses, high rework volumes also generate indirect operational costs due to increased labor requirements, additional machine utilization, and higher energy consumption.

In the production line studied, the average rework rate is approximately 7.8% of total production output, while the operational target is 3.5%, representing the maximum rework capacity that the system can sustainably manage (FMCG Company, 2026). This gap indicates recurring production instability within the legacy system.

One major contributing factor to this instability is the outdated production equipment and limited integration between machine automation systems. The production line is complex and consists of multiple machines that were installed and upgraded at different points in time, resulting in inconsistent automation capabilities and synchronization challenges. As a result, the production process frequently experiences unexpected short and long stop times with

various reasons, which disrupt production flow and increase the likelihood of product defects. Although the line sometimes achieves performance targets, production output often fluctuates and remains difficult to stabilize. Despite the presence of structured improvement frameworks such as Lean Six Sigma (LSS) and performance monitoring systems like Overall Equipment Effectiveness (OEE), achieving consistent operational performance and maintaining rework levels within the target range has remained a significant challenge. This situation illustrates a gap between the theoretical effectiveness of continuous improvement frameworks and their practical implementation within legacy manufacturing systems.

Therefore, the core problem addressed in this study is not merely the presence of production waste, but rather the limited understanding of how legacy production systems can operationally transform their management practices, daily execution routines, and performance monitoring mechanisms to stabilize production processes and reduce persistent waste.

1.3 Purpose and Research Question

The purpose of this study is to investigate how operational practices within a legacy FMCG production system can be reconfigured to improve production stability and reduce recurring waste. In particular, the study focuses on the role of daily execution routines, performance monitoring practices, and operational decision-making processes in supporting continuous improvement within a legacy manufacturing environment.

To achieve this objective, the study seeks to answer the following research question:

How can a structured continuous improvement initiative support operational transformation toward sustainable manufacturing excellence in a legacy FMCG production system?

1.4 Thesis Outline

This thesis is structured as follows. Chapter 1 introduces the research background, problem definition, research purpose, research question, and expected contributions of the study. Chapter 2 presents the theoretical framework, including literature on manufacturing excellence, Lean Six Sigma, performance measurement systems such as OEE, and the operational challenges associated with legacy manufacturing systems.

Chapter 3 describes the research methodology, including the Plan Do Check Act (PDCA)-based action research approach, the case study design, data collection methods, and analytical procedures used in the study. Chapter 4 presents the empirical findings from the case study conducted on the legacy FMCG production line. Chapter 5 discusses the findings in relation to the theoretical framework and explores their implications for operational transformation and sustainable manufacturing excellence. Finally, Chapter 6 concludes the thesis by summarizing the key findings, discussing limitations, and suggesting directions for future research.

1.5 Expected Contributions

This study contributes to both academic research and industrial practice. From an academic perspective, the study extends existing research on manufacturing excellence and continuous improvement by examining how improvement frameworks can be operationalized within legacy production systems characterized by technical constraints and automation limitations. While previous studies have demonstrated the effectiveness of Lean Six Sigma (LSS) initiatives in reducing waste (Dora and Gellynck, 2015), less attention has been given to the operational conditions required to sustain such improvements in complex legacy environments.

From an industrial perspective, the study provides practical insights into how production management practices, performance monitoring systems, and daily execution routines can be aligned to support waste reduction and operational stability. By applying a PDCA-based improvement approach within a real FMCG production line, the research aims to demonstrate how structured operational interventions can reduce rework levels, improve production stability, and support the broader objective of sustainable manufacturing performance.

1.6 Delimitations

This study is based on a study case within one legacy chocolate production line at FMCG company. While the case study approach enables rich contextual insight into operational execution and performance improvement mechanisms, it limits statistical generalizability. The findings should therefore be interpreted as analytically generalizable to similar production environments rather than universally applicable across all manufacturing contexts (Voss, Tsikriktsis & Frohlich, 2002). Furthermore, the research is conducted within a four-month thesis period, which restricts the ability to evaluate long-term sustainability of performance improvements and cultural or behavioural transformation effects.

Another limitation relates to the role of the researcher within the operational improvement activities. Although this positioning provides valuable access to internal processes and facilitates in-depth understanding of the company innovation tools execution practices, it may introduce potential bias in data interpretation or influence participant responses, as the company has unique approach with improvement tools. To mitigate this risk, methodological triangulation was applied through the integration of interviews, direct observations, operational documentation, and performance data. Additionally, interview data represent subjective perceptions from different hierarchical levels, which may be affected by individual experience or organizational dynamics. Cross-level comparison and validation against quantitative data were therefore used to strengthen interpretative credibility (Lincoln & Guba, 1985).

Although the findings indicate improvements in operational performance, visibility, and decision-making, the relatively short implementation period does not allow conclusions regarding long-term organizational transformation or sustainable cultural change. Therefore, the study should be interpreted as demonstrating how structured operational learning routines can support the early stages of operational transformation rather than representing a complete transformation process.

Finally, the study relies on operational performance data provided by the company. Any limitations in data accuracy, categorization consistency, or historical recording practices may affect the precision of quantitative analysis. Moreover, the scope of the study is limited to shopfloor-level operational execution and performance management within the framework, excluding broader strategic, financial, or supply chain considerations. These delimitations ensure analytical focus but constrain the extent of systemic conclusions beyond the direct production context.

2. Literature

2.1 Legacy Production Systems in FMCG Manufacturing

Legacy FMCG factories often run high-speed and high-volume processes that were designed decades ago or even more. Such aging production systems are prone to have rigid layouts, isolated data, and outdated controls. Legacy production systems with modern digital technologies are challenging, many existing machines and controls are incompatible, resulting in isolated data silos that hinder real-time data exchange and process optimization (Gomaa, 2024). Legacy FMCG lines may lack digital sensors or be inflexible, so any improvement must retrofit new capabilities around them. Recent studies on Industry 4.0 adoption highlight that old established production lines may be hesitant to adopt new technologies due to the significant capital investment required, and thus need low-cost retrofitting strategies (Holmes, 2025).

In many FMCG environments, legacy systems continue to operate because they still retain acceptable production capacity despite their technological limitations. However, maintaining older production systems often creates operational complexity due to the coexistence of manual processes, semi-automated systems, and fragmented information flows (Mojumder and Ruddro, 2023). As production demand increases, these limitations become more visible through unstable production performance, recurring stoppages, and difficulties in identifying the root causes of operational disturbances. Legacy production line constraints often lead to decision-making that remains hierarchical and slow, limiting organizational flexibility. In FMCG contexts, rework and scrap on the shop floor can persist because of these structural issues. Lean tools (like value-stream mapping) are applied in FMCG lines, the high-volume nature of production reveals waste-generating factors throughout the workflow (Aljunaidi and Ankrak, 2014).

Legacy FMCG lines face enduring operational inefficiencies due to outdated equipment, data fragmentation, and established mindsets, making transformation difficult without systemic change (Gomaa, 2024; Aljunaidi and Ankrak, 2014). Another important characteristic of legacy production systems is the tendency for operational knowledge to become experienced-based rather than system-based. In many older production environments, operators and technicians rely heavily on tacit knowledge accumulated through years of experience to manage machine instability and recurring defects (Nonaka, 2009).

2.2 Manufacturing and Operational Excellence

Manufacturing and operational excellence is commonly viewed as an enterprise-wide, continuous-improvement state where processes constantly result in high-quality output efficiently. Operational excellence is pursued by organizations aiming to deliver high-quality products efficiently while maintaining the ability to adapt to change (Le, 2025). Manufacturing excellence often couples Lean with disciplined standards (ISO, TPM, LSS, etc) (Ahmad et al., 2012).

Manufacturing excellence is also associated with the ability to sustain improvements over time rather than achieving isolated short-term performance gains. This means organizations must not only optimize technical processes, but also establish operational systems that continuously support learning, adaptation, and problem-solving (Carvalho et al., 2021). Overall, manufacturing excellence literature highlights leadership commitment, continuous

improvement, and standardized methodologies to create flow-state waste-free processes (Le, 2025; Schmidt and Lyle, 2010).

2.2.1 Lean Manufacturing Philosophy

Manufacturing excellence literature is rooted in Lean philosophy, pioneered by Toyota. Lean is a production management system aimed at systematically identifying the waste-generating factors in the organization and removing the waste through continuous improvement and synchronizing the product flow at the pull of the customer (Anvari et.al, 2011). At its core, Lean emphasizes the relentless pursuit of waste elimination (Johnson, 2020). Lean's objective is to optimize production value and flow by eliminating the seven wastes (overproduction, waiting, transport, inventory, motion, over-processing, and defects) (Dewi et al., 2021). The Toyota Production System saw Lean not just as tools, but as a cultural mindset of continuous improvement (kaizen) and respect for people. Indeed, production improvements under Lean (such as improved OEE or reduced setup times) are only sustained when accompanied by deep cultural change. For example, transitioning to Lean requires shifting from strict hierarchy to collaborative, feedback-driven work (Liker and Convis, 2012).

Empirical studies note that Lean transformations involve phased adoption of kaizen practices, standardized work, and daily management routines (Johnson, 2020; Lean Enterprise Institute, 2026). In practice, Lean initiatives start with value-stream analysis and pilot projects, then scale improvement practices while embedding PDCA learning loops (Lean Enterprise Institute, 2026). In sum, Lean manufacturing underpins excellence by driving waste reduction and embedding a continuous-improvement culture (Johnson, 2020). Furthermore, Lean thinking views problems not as failures to be hidden, but as opportunities for organizational learning. Continuous improvement therefore depends on the ability of frontline employees to identify, communicate, and respond to operational abnormalities in a structured manner (Moyano-Fuentes and Sacristán-Díaz, 2012). This perspective reinforces the importance of operator involvement and daily management practices within manufacturing excellence initiatives.

2.2.2 Lean Six Sigma

Lean Six Sigma (LSS) has been extensively studied in FMCG and food manufacturing. LSS is defined as a hybrid approach combining Lean's waste-elimination tools with Six Sigma's defect-reduction and statistical process-control methods (Costa et al., 2021). Previous research in FMCG and small medium enterprises illustrates that integrating Lean with Six Sigma achieves synergistic gains, for example, Dora and Gellynck (2015) state that a mid-size industry applied LSS to cut product overfilling and rework, yielding significant cost savings. The integration of Lean and Six Sigma is particularly relevant in FMCG manufacturing because production environments are often characterized by both high production speed and high process sensitivity. Small deviations in machine settings, material flow, or process synchronization can quickly generate large volumes of defects and rework (Ghelani, 2023).

The research emphasizes that Lean manufacturing eliminates waste and Six Sigma eliminates variation and that LSS integrates these two approaches into an effective hybrid (Dora and Gellynck, 2015). Another research also shows a Define, Measure, Analyze, Improve, Control (DMAIC)-based LSS project in a food factory, where Lean principles improved production flow and Six Sigma tools reduced defects, together diminishing waste (Widiwati et al., 2025). Empirical surveys further find industries that combine Lean and Six Sigma achieved 25–40% waste reduction, versus only 15–25% when using Six Sigma alone (Dora and Gellynck, 2015).

2.2.3 Sustainable Manufacturing Excellence

Beyond traditional Lean efficiency, modern literature emphasizes sustainability and resilience as pillars of manufacturing excellence. While LSS delivers cost and quality benefits, research highlights that long-term excellence requires integrating environmental and social goals. LSS is effective for reducing waste and variability, while Sustainable Manufacturing (SM) emphasizes resource conservation and environmental performance (Alanezi and Franchetti, 2025). The study proposes a unified framework embedding metrics like energy use, emissions, and waste into the DMAIC improvement cycle, yielding simultaneous gains in efficiency and environmental targets (Alanezi and Franchetti, 2025).

This means manufacturing excellence must also address ESG (environmental, social, governance) goals and supply-chain resilience, not just cost and quality. Conventional Lean systems optimized for quality/cost/time, but recent disruptions (pandemics, supply shocks) reveal the need to treat resilience as a first-class design target (Potthoff and Gunnemann, 2023). In practical terms, sustainable excellence implies stabilizing production while minimizing material and energy waste. For instance, manufacturing frameworks now stress circular-economy practices (reuse, remanufacture) and human-centered design to build robust, eco-efficient operations. Thus, manufacturing excellence today is holistic, it combines Lean waste elimination with long-term sustainability and adaptive capacity (Alanezi and Franchetti, 2025; Gomaa, 2024).

2.3 Performance Measurement Systems in Manufacturing

Systematic performance measures are crucial to control manufacturing excellence. The most common metrics are OEE with three factors: availability, performance, and quality (Bhosale and Jadhav, 2025). It delivers a proportion of productive time. In practice, OEE becomes a diagnostic tool to reduce a complex production problem into simple information and systematically classify potential issues affecting the machine utilization (Singh et al., 2013). Managers can focus on the largest losses by tracking OEE factors. Conventional frameworks classify losses into the Six Big Losses: breakdowns, setup, idling, reduced speed, start-up rejects, and rework. These losses map to the OEE factors. For example, a review explains that OEE improvement relies on analyzing six loss categories – e.g. downtime reduces availability, idling reduces performance, and rework reduces quality (Pereira et al. 2019).

A related concept is General Efficiency (GE), a broader ratio of actual output to maximum possible output over time; it serves as a simple shop-floor productivity indicator. These metrics provide visibility of production gaps: they tell managers how much capacity was lost to downtime or scrap. However, they have limitations. Importantly, OEE was never meant to be an end, it was devised as a ‘driver’ for improvement, not as a performance measure to be compared or benchmarked between equipment and sites (Pereira et al. 2019). In other words, OEE is most valuable as a trigger for problem-solving, not a final verdict. Critically, performance indicators alone do not explain root causes, but it reveals “what” happened (e.g. 10% downtime) but not “why” (the specific reason for each stoppage) (Andersson and Bellgran, 2015). Thus, literature notes that while OEE and similar KPIs (FPY, takt, etc.) are essential for monitoring factories, they must be complemented by problem-solving routines to interpret the data. As a result, many manufacturers use OEE as an early warning, but still rely on qualitative tools (fishbone diagrams, operator logs, root cause analysis) to diagnose underlying operational losses (Andersson and Bellgran, 2015).

In practice, manufacturing organizations often face difficulties translating performance measurements into operational action. While KPI dashboards may successfully visualize production losses, organizations frequently lack structured mechanisms to connect performance indicators with frontline problem-solving activities (Giovannoni and Pia Maraghini, 2013). As a result, performance measurement systems risk becoming passive reporting tools rather than active drivers of continuous improvement. This challenge is particularly visible in legacy production systems where operational disturbances occur frequently, but root causes remain poorly documented or inconsistently categorized (Giovannoni and Pia Maraghini, 2013).

2.4 Operational Transformation

Operational transformation means moving beyond one-off improvements to fundamentally alter how production works (Roden et al., 2017). This involves redesigning routines to enable continuous flows of data and learning at the frontline (Roden et al., 2017). A core idea is to integrate the PDCA cycle into daily operations: operators and leaders regularly identify issues (Plan), implement countermeasures (Do), measure the outcome (Check), and update standards (Act). This creates a culture where problems (e.g. a batch requiring rework) automatically trigger cause-analysis and follow-up actions. PDCA framework highlights that lasting change requires iterative learning over time (Lean Enterprise Institute, 2026). In legacy systems, transformation may also involve socio-technical changes (Geels, 2005). For example, empowering operators to log and analyze interruptions, or using digital dashboards to feed real-time KPIs into shop-floor groups. Some studies describe this as developing “dynamic capabilities”, which refers to the firms ability to reconfigure processes and knowledge in response to change (Ellonen et al., 2011).

Operational transformation therefore combines Lean thinking with learning infrastructures (Bell, 2016). It relies on routines (standardized problem-solving, cross-functional teams) that turn plant data into organizational knowledge. In short, it is not enough to measure losses. The system must be set up so that every loss (rework, downtime, defect) is captured, investigated, and looped back into practice. This perspective positions operational transformation as both a technical and behavioral process. Transformation does not only involve improving machines or production flow, but also changing how employees interact with operational problems and how organizations respond to production disturbances (Buschmeyer et al., 2016). Operational transformation therefore requires creating routines that challenge reactive behaviors and encourage systematic learning from operational deviations (Pagell et al., 2015).

The literature points out that sustainable improvement comes not from ad-hoc kaizen, but from disciplined operational management. Main elements include leader standard work, visual controls, daily accountability processes, and discipline (Poksinska, 2013; Mann, 2005). Leader standard work means each manager has a set of daily tasks (e.g. Gemba walk, KPI review) that ensure team routines are followed (Liker and Convis, 2012). Visual control is signing systems, information displays, and work organizational methods that are proposed to manage and control the processes and that provide direct understanding of a situation or condition (Mann, 2005; Liker and Convis, 2012). Daily accountability is structural meeting to ensure follow-up on task assignments made in response to emerging problems or opportunities for improvement. The meetings usually have fixed times and durations and follow a standardized agenda, Daily Management System (DMS) is a concrete example when it comes to daily accountability. Finally, discipline is required to complete the first three elements as designed and intended (Mann, 2005).

2.5 Research Gap

The previous literature provides valuable insights on Lean methods, performance metrics, and improvement cycles. However, there remains a notable gap regarding legacy FMCG operations. Much research treats Lean and Six Sigma tools or digital technologies in isolation, while assuming operational learning occurs. Few studies examine how frontline routines can be structured to capture the causes of deviations and feed continuous improvement in old production lines. Although Continuous Improvement (CI) initiatives such as Lean, Six Sigma, and PDCA are widely implemented in manufacturing environments, previous studies suggest that organizations often struggle to sustain their long-term benefits in practice (Gutierrez and Antony, 2020). This challenge is particularly visible in legacy production systems, where operational instability, fragmented information flow, and inconsistent execution routines may limit the effectiveness of continuous improvement efforts over time, implying a need to understand how learning happens on the shop floor. Similarly, Potthoff and Gunnemann (2023) highlight that traditional Lean systems prioritize cost/time, so resilience and tacit knowledge may be overlooked. In the FMCG context, where speed and volume amplify small losses, this gap is critical. In sum, while existing literature discusses what excellence looks like (Lean, OEE, PDCA) and why it is needed (efficiency, sustainability), it pays little attention to how legacy production teams operationally embed this learning. This study therefore addresses the gap by investigating how routine data capture and the implementation of PDCA practices at the operator level can enable a legacy FMCG plant to systematically learn from waste and rework, ultimately driving sustainable manufacturing excellence.

Additionally, much of the existing literature focuses either on high-level improvement frameworks or on technologically advanced manufacturing environments, while providing limited empirical insight into how operational transformation occurs within constrained legacy systems. There is still limited understanding regarding how relatively small operational interventions, such as structured data-capture routines or frontline escalation mechanisms, can influence organizational learning and production stability in practice. This creates a need for more empirical studies examining how operational routines can bridge the gap between performance measurement, problem-solving, and sustainable improvement within real manufacturing environments.

2.6 Conceptual Framework

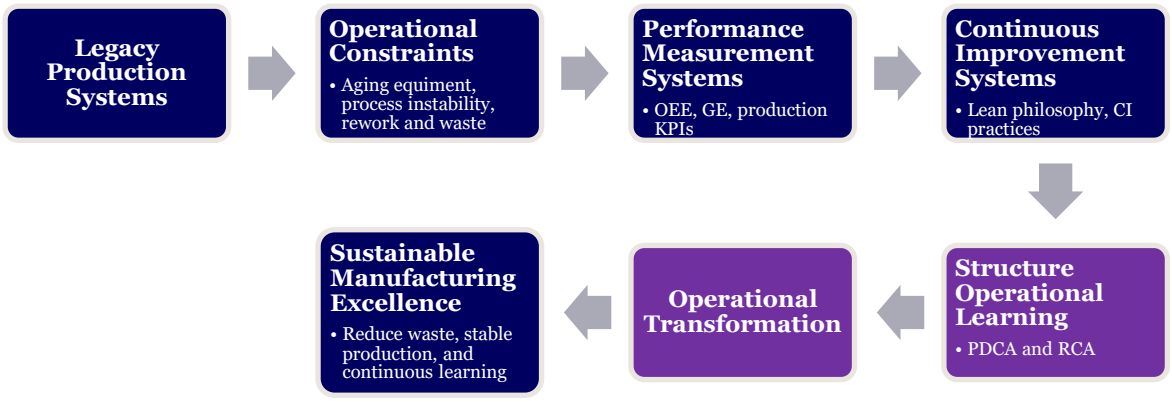

Figure 2 Conceptual Framework for Operational Transformation in Legacy FMCG Production Systems

Based on the reviewed literature, Figure 2 shows a conceptual framework that is proposed to illustrate the relationship between legacy production constraints, performance measurement systems, continuous improvement practices, and structured operational learning mechanisms. The framework highlights how structured problem-solving routines, particularly those aligned with the PDCA cycle combine with Root Cause Analysis (RCA), enable organizations to translate performance data into operational learning and sustained improvement. In this study, it focuses on structured operational learning to achieve sustainable manufacturing excellence by operational transformation. The framework serves as an analytical lens to examine how frontline operational routines can support operational transformation toward sustainable manufacturing excellence.

3. Methodology

3.1 Research Design

This study adopts a mixed-method case study research design to investigate how legacy fast-moving consumer goods (FMCG) production systems can be operationally transformed toward sustainable manufacturing excellence. The research focuses on a single production line within an existing FMCG manufacturing facility, examining how targeted operational improvements can enhance production efficiency and support sustainable manufacturing practices.

A mixed-method approach is selected to enable a comprehensive evaluation of the operational transformation process, and several studies use this approach in a manufacturing context (Antony et al., 2023; Sony et al., 2022). The integration of qualitative and quantitative data enables the study to evaluate both measurable operational performance changes and the organizational processes underlying those changes. Quantitative operational data are used to measure changes in production performance following the implementation of an improvement initiative, while qualitative insights from production personnel provide contextual understanding of operational challenges and improvement opportunities within the legacy production system (Antony et al., 2023; Sony et al., 2022). A key challenge of a mixed-method approach is the potential difficulty in integrating quantitative and qualitative findings, as well as ensuring consistency and objectivity across different data sources. To address this, a clear triangulation strategy is applied, systematically aligning performance data with insights from production personnel to enhance validity and ensure a coherent interpretation of results.

The study also incorporates elements of action research, where the researcher actively participates in diagnosing operational inefficiencies, implementing improvement actions, and evaluating their outcomes within the real production environment (Coughlan and Coghlan, 2002). This design allows the research to generate both practical industrial insights and academically relevant findings regarding operational transformation in manufacturing systems.

3.2 Research Framework

This study applies a PDCA (Plan–Do–Check–Act) cycle as the operational improvement framework guiding and evaluating the implementation within the production system (Realyvásquez-Vargas et al., 2018). While the overall research design follows a mixed-method case study approach with action-research characteristics, the PDCA cycle is used specifically to structure the operational improvement process conducted during the study.

PDCA framework is widely used in manufacturing and operational excellence initiatives to support systematic problem-solving and continuous improvement, one of the issues to reduce the defects and waste (Pecas et al., 2021). Figure 3 shows the PDCA Cycle also known as the Deming or Shewhart cycle, is a four-step, iterative management method used for continuous improvement of processes, products, or services. It supports industries to solve problems, implement changes on a small scale, and standardize successful improvements to drive long-term efficiency. In this study, the PDCA cycle structures the research process as follows:

1. Plan:
   The planning phase involves identifying inefficiencies or operational challenges within the existing production line. This stage includes direct process observation, discussions with production staff, and preliminary analysis of operational performance indicators.

Based on these findings, a minor routine operational change is proposed to improve production efficiency or reduce operational waste.

2. Do:
   During this phase, the proposed operational change is implemented within the selected production line. The intervention is conducted under normal production conditions to ensure that the improvement reflects realistic operational practices and does not disrupt regular manufacturing activities.

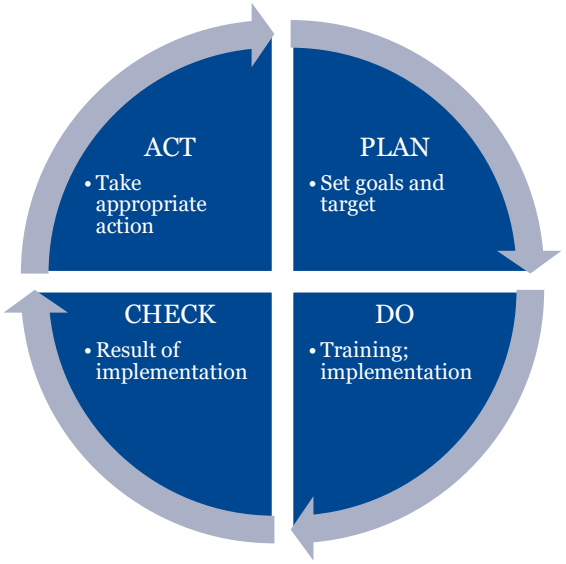

Figure 3 PDCA Cycle Framework

3. Check:
   Following implementation, production performance data are collected and compared with baseline data obtained prior to the intervention. This phase evaluates whether the implemented change results in measurable improvements in operational performance.

4. Act:
   The final stage evaluates the effectiveness and sustainability of the improvement. Feedback from production personnel and analysis of operational outcomes are used to determine whether the implemented change should be standardized, modified, or further developed as part of ongoing improvement initiatives.

3.3 Case Study Context

The research is conducted within a chocolate production line of FMCG company. The selected production line represents a legacy production system, characterized by established operational routines, existing process constraints, and opportunities for efficiency improvement through operational adjustments. The goal of PDCA implementation is to reduce defects (waste and rework) of the products, while the research is to understand the process of daily transformation that could support sustainable manufacturing excellence.

The study focuses on personnel directly involved in the production process. Participants include operators, production coordinators, line leaders, continuous improvement engineers, process engineers, cost analyst and the manufacturing manager responsible for overseeing production performance. Approximately 15 to 20 production line staff members are included

in the study to capture a diverse range of operational perspectives across different functional roles within the manufacturing environment. This multi-level participation allows the research to explore both operational realities on the production floor and managerial perspectives on process improvement and sustainability initiatives. In this study, sustainable manufacturing excellence is operationalized through improvements in operational stability, waste reduction, production efficiency, and structured operational learning. Accordingly, indicators such as rework rate, GE, and OEE are used as measurable proxies representing these dimensions rather than attempting to assess manufacturing excellence in its entirety.

3.4 Data Collection

Data for this research are collected using multiple methods to ensure a comprehensive understanding of the operational system and the impact of the implemented improvement initiative. The primary data collection methods include direct observation, semi-structured interviews, operational performance data, and rework protocol data analysis. Table 1 summarizes the type and scope of data collected throughout the study. The qualitative data consist of semi-structured interviews and direct shopfloor observations, while the quantitative data consist of operational production data collected before and after the implementation period and rework protocol records.

Table 1 Summary of Collected Data

Data Type	Source	Amount/Duration	Purpose
Direct observation	Shopfloor production activities	Week 7 – Week 18	Identify process inefficiencies and operational routines impact
Semi-structured interviews	Operators, coordinators, engineers, managers	8 interviews	Understand operational challenges and implementation feedback
Operational production data	Internal production records	40 production days (Week 7 – Week 15)	Evaluate production performance changes
Rework protocol data	Decision point robot station	Week 11 – Week 15	Capture RCA-based defect and rework information

1. Direct Observation:
   Observations are conducted on the production line to examine workflow processes, operator activities, machine utilization, and potential inefficiencies within the existing operational system. Table 1 already mentioned direct observation will conduct from week 7 until week 18. These observations help identify operational bottlenecks, process interruptions, and sources of waste that may affect production performance.

2. Semi-Structured Interviews:
   Eight semi-structured interviews are conducted with production personnel to gather insights into operational practices, challenges associated with the legacy production system, and perceptions of improvement initiatives. The interview format allows participants to share their experiences while also enabling the researcher to explore specific themes related to operational transformation and sustainability. Table 2 shows the demographic of the interviewee, ranging from shop floor staff to the managerial level. The semi-structured interviews were conducted using predefined interview guidelines tailored to each organizational role. The complete interview guidelines are presented in Appendix A (English version) and Appendix B (Swedish version).

Table 2 Demographic Overview of Interview Participants

Interviewee Coding	**Interviewee Capability/Area of Expertise**	**Format of the Interview**	**Date**	**Language**	**Duration**
Interviewee A	Operator Shift I of Decision Point Robot	On-site	April 2026	Swedish	39 minutes
Interviewee B	Operator Shift II of Decision Point Robot	On-site	April 2026	Swedish	44 minutes
Interviewee C	Coordinator Shift I of Production Line	On-site	April 2026	Swedish	52 minutes
Interviewee D	Coordinator Shift II of Production Line	On-site	April 2026	English	40 minutes
Interviewee E	Senior Process Engineer of Production Line I, II, and III	On-site	April 2026	English	42 minutes
Interviewee F	Cost Conversion Analyst	Online	April 2026	English	49 minutes
Interviewee G	Section Manufacturing Manager of Production Line I, II, and III	On-site	April 2026	English	40 minutes
Interviewee H	Section Controller and Continuous Improvement Engineer of the Production Line	On-site	May 2026	English	40 minutes

3. Operational Production Data:
   Quantitative operational data are collected from production records and internal monitoring systems. To evaluate the impact of the implemented protocol, operational

performance data were compared across three different time frames: full-year 2025 performance, week 11 to week 15 of 2025, and week 7 to week 15 of 2026. The primary comparison focused on week 7 to week 10 of 2026 (pre-implementation baseline) and week 11 to week 15 of 2026 (post-implementation period) (See Table 1).
The selected periods were chosen to ensure comparable production conditions and equal production duration. Although the week ranges differed slightly, the total number of production days remained consistent due to planned maintenance activities and holidays occurring during weeks 14 and 15. Additionally, the inclusion of week 11 to week 15 of 2025 provided historical context for seasonal and operational comparison. Key performance indicators may include rework rate, GE rate, OEE rate, and cost loss.

4. Rework Protocol Data:
   As part of the implementation, structured rework protocol records were collected during the implementation period from Week 11 to Week 15. These records provided detailed operational data regarding recurring defects, machine-related disturbances, and process instability within the production line. The protocol records served both as an operational improvement tool and as a research data source, enabling the study to trace recurring waste patterns and evaluate how structured data capture could support root cause analysis and operational learning.

The combination of qualitative and quantitative data sources enables a comprehensive evaluation of both the technical and human aspects of operational transformation. Although the researcher participated in the development and implementation of the protocol, several measures were taken to reduce researcher bias. Operators completed the protocol independently during routine production without researcher supervision. Production performance data were extracted from the company's official production monitoring systems, reducing the possibility of subjective interpretation. Interview participants were informed that participation was voluntary and that both positive and negative opinions regarding the intervention were encouraged. Furthermore, the protocol and its implementation were reviewed together with production management and engineering personnel before deployment to ensure operational relevance and consistency.

3.5 Data Analysis

The collected data are analyzed using a combination of process analysis, qualitative thematic analysis, and comparative operational analysis.

1. Process Analysis:
   Observational data are used to analyze workflow patterns, process inefficiencies, and operational bottlenecks within the production line. These insights provide contextual understanding that supports both the quantitative performance analysis and the qualitative findings from interviews.

2. Thematic Analysis:
   Interview data are analyzed using thematic analysis to identify recurring patterns and insights related to operational challenges, improvement opportunities, and employee perspectives on the implemented change. Interview transcripts are reviewed and coded to identify key themes that contribute to understanding the operational transformation process.

3. Comparative Operational Analysis:
   Operational performance metrics collected before and after the implementation are compared to evaluate the effectiveness of the implemented improvement. This analysis focuses on identifying measurable changes in rework rate, GE rate, OEE rate, and relevant production performance measures.

4. Rework Pattern Analysis:
   The structured rework protocol records were analyzed to identify recurring defect categories, operational disturbances, and potential root causes contributing to rework generation. The analysis use pareto analysis to focused on detecting patterns in defect occurrence, frequency of specific rework reasons, prioritizing the action plan, and their relationship to operational instability within the production system. This analysis supported the evaluation of whether the protocol improved operational visibility and strengthened the production line's ability to systematically learn from recurring waste events.

By integrating these analytical approaches, the study provides a comprehensive assessment of how targeted operational interventions can contribute to the transformation of legacy manufacturing systems.

3.6 Research Quality

To ensure the credibility and robustness of the research findings, this study addresses research quality through considerations of reliability and validity.

3.6.1 Reliability

Reliability refers to the consistency and dependability of the research procedures and findings (Kimberlin & Winterstein, 2008). To enhance reliability, standardized procedures are used for data collection, including structured observation approaches and consistent interview protocols (William, 2024). Operational performance data are obtained from official production records to ensure accuracy and consistency in measurement. Additionally, documentation of the PDCA implementation process helps ensure transparency in how the operational intervention is conducted and evaluated.

3.6.2 Validity

Validity refers to the extent to which the research accurately reflects the operational phenomena being studied (Blomqvist & Hallin, 2015). This study enhances validity through data triangulation, which involves combining multiple sources of data including observations, interviews, and operational performance metrics. Triangulation allows the researcher to cross-verify findings from different perspectives, thereby strengthening the credibility of the results (Jonsen and Jehn, 2009). The interview also includes several roles and level, as it increases validity of the research. Furthermore, conducting the study within a real manufacturing environment improves the practical relevance and validity of the research.

3.7 Ethical Considerations

Ethical considerations are addressed throughout the research process to ensure responsible research practices and the protection of participants. Participation in interviews is voluntary, and participants are informed about the objectives and purpose of the study prior to data collection. Confidentiality and anonymity are maintained by ensuring that individual responses

are not directly linked to specific participants in the reporting of findings, which is essential to encourage honest and unbiased input without fear of repercussions. Organizational data related to production performance and operational processes are treated as confidential and are used solely for academic research purposes. All data are securely stored and handled in accordance with data protection principles to prevent unauthorized access and ensure confidentiality. AI-assisted tools were used solely to support language refinement and improve clarity of expression, while all analysis, interpretations, and conclusions remain the independent work and responsibility of the author. The operational improvement implemented as part of the PDCA cycle is designed as a minor routine adjustment that does not compromise production safety, employee well-being, or operational stability within the manufacturing environment.

3.8 Use of AI-Assisted Tools

AI-assisted tools were used in a limited and supportive capacity during the writing process of this thesis. The tools were utilized primarily for language refinement, grammar correction, sentence clarity, and improvement of academic writing structure. AI-generated suggestions were carefully reviewed, edited, and validated by the author before inclusion in the thesis. The development of the research design, literature analysis, data collection, interpretation of findings, discussion, and conclusions remain the independent intellectual work and responsibility of the author. No AI tools were used to generate research data, conduct interviews, perform data analysis autonomously, or produce findings without critical evaluation by the author. The use of AI-assisted tools was therefore limited to writing support and does not replace the author’s academic judgment, analytical reasoning, or original contribution throughout the research process.

4. Empirical Results and Analysis

4.1 Case Context and Production System Overview

This chapter presents the empirical findings from the legacy chocolate production line studied at the FMCG company. The product quality depends on stable coordination between chocolate formation throughout every chocolate depositor. The line represents a legacy production system characterized by aging equipment, multiple digital machine interfaces, and varying levels of automation integration across the production flow. These characteristics make the line operationally complex and sensitive to disturbances, particularly when one machine is not fully harmonized with others in terms of automation and control logic.

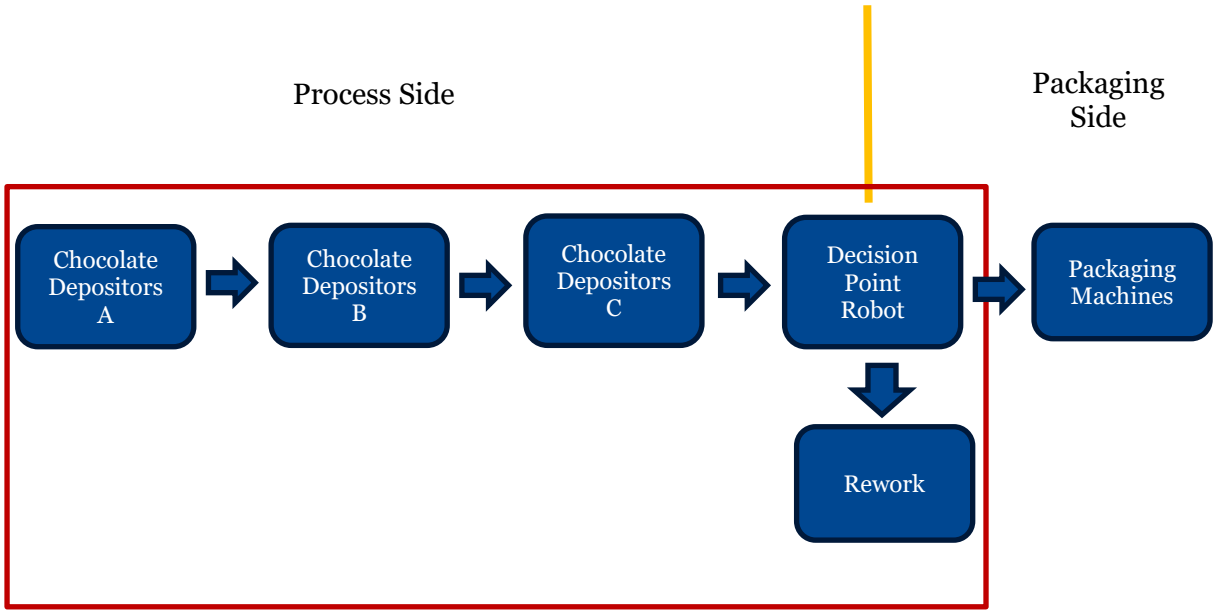

Figure 4 Simplified Chocolate Production Line of FMCG Company

Figure 4 shows a simplified chocolate production line of FMCG company, which is divided into a process side and a packaging side. On the process side, chocolate depositor A, B, and C are responsible for chocolate formation before the product is transferred to a specific machine, referred to as the decision point robot. The production system includes this decision point robot, where products can either continue to the packaging side or be redirected to rework. This point is critical because it determines whether a product will be released as finished output or returned to the process for recovery.

At this decision point, the robot autonomously transfers chocolate to the packaging line and detects visible defects. However, operators also can manually redirect products into the rework bin when defects are identified. In practice, this station accounts for approximately 70% of all reworks generated in the production line, making it the most significant contributor to the rework stream. This stage therefore represents a critical operational point where waste becomes visible and where the present study is implemented. Rather than focusing on technical modifications to directly reduce rework at the robot station, the study aims to improve organizational learning from rework by systematically capturing the reasons behind product diversion decisions. The study assumes that the root causes of defects may originate not only at the robot station itself but also from upstream process machines. Consequently, identifying

and understanding these root causes is considered more important than implementing immediate technical interventions to reduce rework volumes.

The line is therefore a suitable case for studying operational transformation in a legacy FMCG environment because it combines a measurable waste problem, recurring performance instability, and a clear opportunity for improvement through structured daily routines or protocols. The case also provides access to multiple stakeholder perspectives, including operators, technicians, coordinators, line leaders, engineers, and management, making it possible to analyze the problem from both technical and organizational perspectives.

4.2 Current State Performance and Problem Characterization

As explained in the previous chapter, recurring waste is one of the main issues. Table 3 shows the current state performance of FMCG company's chocolate production. Rework rate, cost loss, OEE (Overall Equipment Efficiency), and GE (General Efficiency) are the FMCG company's key production KPIs. The current state performance includes three-time frames: the full year of 2025, a partial period from week 11 to week 15 in 2025, and week 7 to week 10 in 2026.

Table 3 clearly shows that the rework rate is approximately 7.8% of total production output in 2025, while the target level is 3.5%, which represents the maximum rework capacity. Improvement is evident in week 7 to week 10 of 2026, where the rework rate decreases to 5.7%. The total cost loss in 2025 is €445,311, while the fraction of week 11 to week 15 of 2025 accounts for 16% of the total cost loss.

Table 3 Current State Performance of FMCG company's Chocolate Production

KPI	2025	W11-W15 2025	W7-W10 2026
Rework rate	7.8%	7.9%	5.7%
Cost Loss	€ 445,311	€ 71,224	€ 51,405
OEE	30%	33%	35%
GE	28%	29%	32%

From this table, there is a clear relationship between the rework rate and both OEE and GE. As the rework rate decreases, OEE and GE increase. This is because higher rework indicates reduced production quality, performance, and availability, as well as ineffective utilization of planned production time. Consequently, week 7 to week 10 of 2026 represents the "best" current state performance, with the lowest rework rate and OEE and GE values of 35% and 32%, respectively. Therefore, week 7 to week 10 of 2026 will be used as the baseline for comparison with the new implementation.

The rework rate gap relative to the target is significant because it indicates that the system regularly produces more defective output than it can efficiently absorb through rework. When rework exceeds system capacity, some material is eventually diverted to scrap, increasing both direct material losses and indirect operational costs such as labor, machine time, and energy consumption.

From an operational perspective, the production line also experiences frequent short and long stop times. These interruptions reduce stability and contribute to unpredictable output. Although the line may occasionally perform within target, the process is not consistently stable, and performance fluctuates across shifts and production periods. As a result, the production environment is characterized by a strong interconnection between waste and instability, rather than isolated issues.

4.2.1 Process Flow and Rework Mechanism

The flow of the production system can be understood as a sequence of value-adding and non-value-adding steps. Value-adding activity in this case starts with products being formed, filled from the chocolate depositors, and then either approved for packaging or diverted to rework depending on whether quality standards are met. For non-value-adding, it is divided by two, necessary and waste. Examples for necessary non-value-adding steps in this case are inspections (metal and plastic detections and weight inspections). Waste non-value-adding examples are scrap and rework. Scrap is a defective product that can't be recovered. In the rework loop, defective products are reprocessed so that the material can be recovered and reintroduced into production. This rework system supports resource efficiency and is aligned with the company's sustainability objectives because it reduces direct disposal of materials.

However, the rework mechanism also has an operational limit. When the quantity of rework becomes too high, the system loses flexibility and excess material is no longer recoverable. At that point, the material is classified as scrap. This means that rework is not simply a beneficial recovery process; it is also a signal of process instability. The more frequently the system relies on rework, the more likely it is that the line is operating outside its stable range. For this reason, the study treats rework as both a sustainability mechanism and a performance indicator. Rework is valuable because it recovers products, but it is also costly because it consumes additional resources and may still result in scrap if the system is overloaded. The empirical analysis therefore focuses not only on the rework quantity itself, but also on the conditions that lead to repeated use of the rework stream.

4.2.2 Identification of Potential Causes (Exploratory Analysis)

To understand the underlying causes of the rework problem, the author did Gemba walk, a Lean management tool to observe processes, identify waste, and support employees by observe directly at the shop floor level. Throughout the Gemba walk, the study maps the possible source categories using a structured problem analysis approach. The preliminary cause mapping suggests that the rework issue is not caused by one factor alone, but rather by a combination of machine-related, method-related, man-related, and organizational factors.

The most prominent technical cause is the aging and outdated equipment structure of the line. Different machines were installed or upgraded at different points in time, and this has led to uneven automation capability across the processes. As a result, the machines become more vulnerable to automation problems and unexpected stoppages. These disturbances increase the likelihood that products are formed incorrectly or incompletely, which then leads to rework.

A second cause category is the operational method itself. In a legacy environment, daily routines and protocols may be inconsistent or not fully standardized, especially when operators respond to defects based on experience rather than a structured decision logic. If the system does not require the operator to record why a product was sent to rework, the organization loses the opportunity to learn from recurring defects.

A third cause category is measurement and feedback. While production data exists, the data may not always capture the detailed reason for each rework decision. In this case, the production line only captures how much rework that was produced in a day. This means that the line may know how much rework occurred, but not always why it occurred. Without that information, recurring problems remain difficult to isolate and address systematically.

4.3 Synthesis of Main Problem Findings

The empirical analysis indicates that the rework problem is driven by both technical instability and organizational learning gaps. On the technical side, aging machines and weak automation integration create unexpected stop times and process interruptions. On the organizational side, the absence of a structured reason-capture routine limits the ability of the line to convert rework events into actionable knowledge.

This finding is important because it shifts the focus from waste reduction as a purely technical problem to waste reduction as a learning and governance problem. The line does not only need better equipment performance; it also needs a better mechanism for understanding what the equipment and the operators are experiencing when rework occurs. In this sense, supporting operational transformation is not only about fixing the process, but also about improving how the process is observed, discussed, and learned from.

4.4 RCA-Based Protocol Design

Based on the findings above, the study introduces an RCA (Root Cause Analysis)-based protocol at a critical decision point robot in the production line. The protocol is not designed to directly reduce rework by changing the product or machine configuration. Instead, it aims to make rework more visible and traceable by requiring operators to record the cause of each rework decision (see Appendix C).

In Appendix C, the protocol consists of a rework form as its core element, where the operator at the decision point robot records the reason and quantity of products sent to the rework bin. In addition, an instruction table is provided to facilitate learning for other staff or operators, including problem codes, explanations, and the possible machines associated with each issue. This is why the protocol is based on RCA—it is not merely about recording volume and defect type, but also about identifying why the problem occurs and which machine may be responsible. Furthermore, instructions are provided on how and when operators should complete the protocol. Finally, guidelines are included for line leaders and coordinators on how to escalate the information into DMS (Daily Management System) level 2/shop floor level for verification and root cause resolution planning (see Appendix C).

The protocol is implemented at the intersection between the packaging flow and the rework stream, where the operator decides whether a batch should proceed forward or be diverted. At this point, the operator is required to complete a short, structured log containing the reason for rework, the defect type, the affected quantity, and any additional context needed to explain the event. The Problem Code Instruction Table in Appendix C also enables the documentation of defect categories, including issues such as defect 1, defect 2, defect 3, and so on, while the operator is also required to record the corresponding problem code to support the rework analysis process. These codes and defect categories are linked to possible machine-related causes, enabling more advanced root cause analysis. The protocol also allows flexibility for recording other reasons that may not fit within the predefined categories.

This protocol is intentionally narrow in scope. It is applied to one machine and one operator station as a pilot trial for approximately one month. This limited scope enables the practicality of the protocol to be tested before considering its extension to other parts of the line. The purpose is to evaluate whether structured logging can improve visibility, support root cause analysis, and create a stronger feedback loop for daily operational improvement.

4.5 PDCA Implementation

The research follows the PDCA cycle, as shown in Table 3, which illustrates the timeline of the study from Week 7 to Week 22, progressing through the Plan, Do, Check, and Act phases. The study begins with the Plan phase, where Gemba walks are conducted to identify recurring rework issues, the lack of structured cause capture, and the need for a more systematic learning routine. Engaging with operators and directly observing problems on the shop floor are essential for formulating a well-grounded plan. Based on this diagnosis, the protocol is designed and introduced for use at the selected decision point robot.

Table 4 PDCA Timeline

Week	W07	W08	W09	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22
Plan																
Do																
Check																
Act																

In the Do phase, the protocol is implemented during regular production operations. Operators record the reason for rework and associate defect information whenever a batch is manually directed to the rework bin. This enables the system to collect structured data in real time without significantly interrupting the production flow. Data was collected from Week 11 to Week 15, although the implementation continues until Week 22 and beyond, particularly if the protocol proves effective in helping the production line better understand the causes of rework.

In the Check phase, the data collected during the trial period are compared with the baseline situation. The baseline covers Week 7 to Week 10, representing the period immediately before protocol implementation. The comparison focuses on whether the protocol improves the clarity of rework reasons, whether the data are usable for analysis, whether the operational team perceives the protocol as practical and relevant, and whether production performance improves (e.g., OEE, GE, and rework rate). Interviews with operators, line leaders, and engineers are conducted to support this evaluation.

In the Act phase, the protocol is assessed for potential standardization. Feedback from the production team is used to determine whether the routine should be refined, simplified, or integrated into regular operational practice. If the protocol proves useful, it can become part of the line's daily execution system and serve as a foundation for further improvement.

4.6 Findings of Rework Protocol Implementation

4.6.1 Quantitative Findings

This section presents the quantitative findings from the implementation of the RCA-based rework protocol within the selected legacy FMCG production line. The quantitative evaluation aims to assess whether the implementation contributed to measurable operational improvements and increased visibility of rework generation during production activities.

To provide a structured analysis, the quantitative findings are divided into two parts. The first part, *Operational Production Data*, evaluates changes in key production performance indicators before and after the implementation of the protocol. This includes indicators such as General Efficiency (GE), Overall Equipment Effectiveness (OEE), and rework rate. The comparison is conducted using production data collected across equivalent production periods to ensure consistency and comparability.

The second part, *Rework Protocol Data*, focuses on the structured operational data generated through the protocol itself. The protocol records provide detailed information regarding rework reasons, defect categories, operational disturbances, and machine-related issues captured during the implementation period. This analysis aims to identify recurring patterns and improve understanding of how rework is generated within the production system. These quantitative findings provide both performance-based and operational-level insights into how structured daily routines and RCA-based data collection can support operational transformation within a legacy FMCG manufacturing environment.

4.6.1.1 Operational Production Data

After the protocol had been implemented for five weeks, production data were collected to evaluate whether the intervention improved the performance of the production line. The quantitative evaluation is based on three key performance indicators (KPIs): General Efficiency

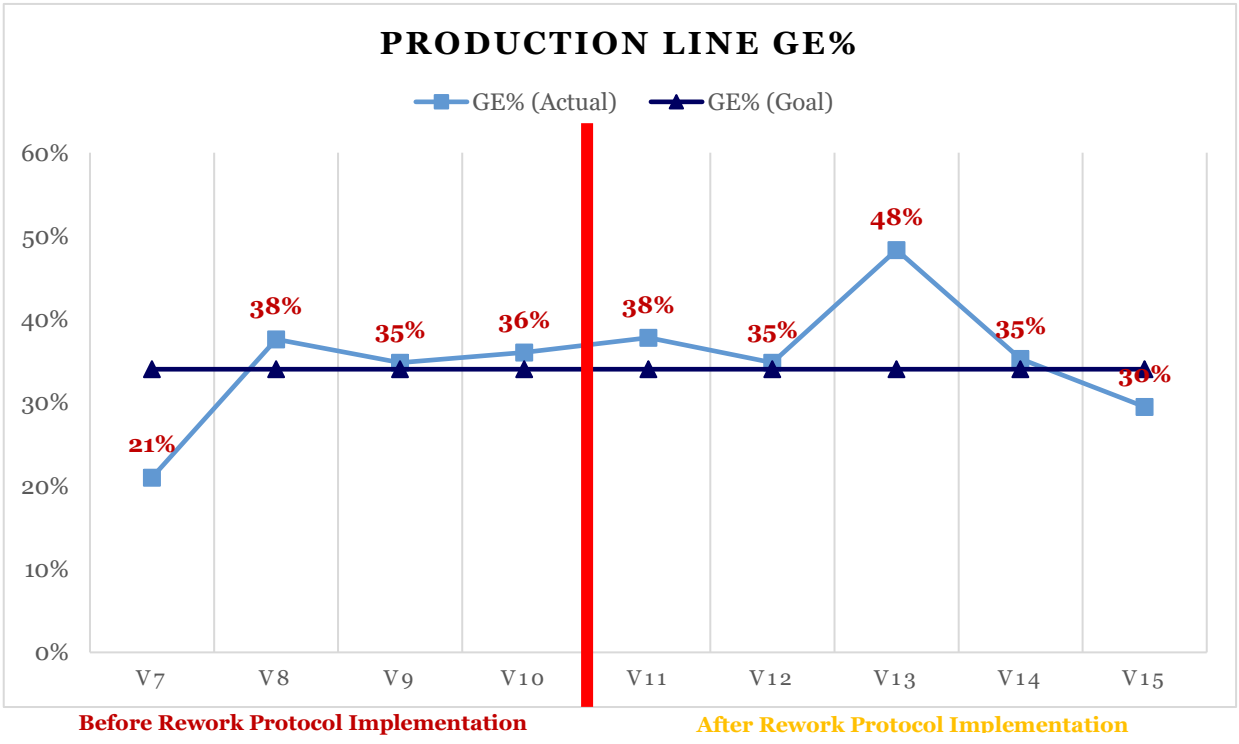

Figure 5 Production Line GE Rate Week 7 to Week 15

(GE), Overall Equipment Effectiveness (OEE), and rework rate. The comparison is conducted using a before-and-after scenario with an equivalent number of production days. Although the comparison spans slightly different calendar weeks, the total number of production days remains consistent to ensure comparability. The dataset consists of 40 production days, with 20 days before and 20 days after implementation.

First, as illustrated in Figure 5, the General Efficiency (GE) rate appears relatively similar before and after implementation, although a notable peak occurs in Week 13, where GE reaches 48%. GE represents the proportion of planned production time that is effectively utilized. Therefore, frequent short and long stoppages negatively affect GE, as they reduce the line's ability to utilize scheduled production time. During Weeks 7 to 10, the average GE rate is approximately 32%. After implementation, the average GE increases by around 5%, with the highest performance observed in Week 13. Both the pre- and post-implementation periods include one week in which the target was not achieved. This improvement suggests that the protocol may contribute to reducing unstructured interruptions or improving responsiveness to disturbances, even though it does not directly target machine availability.

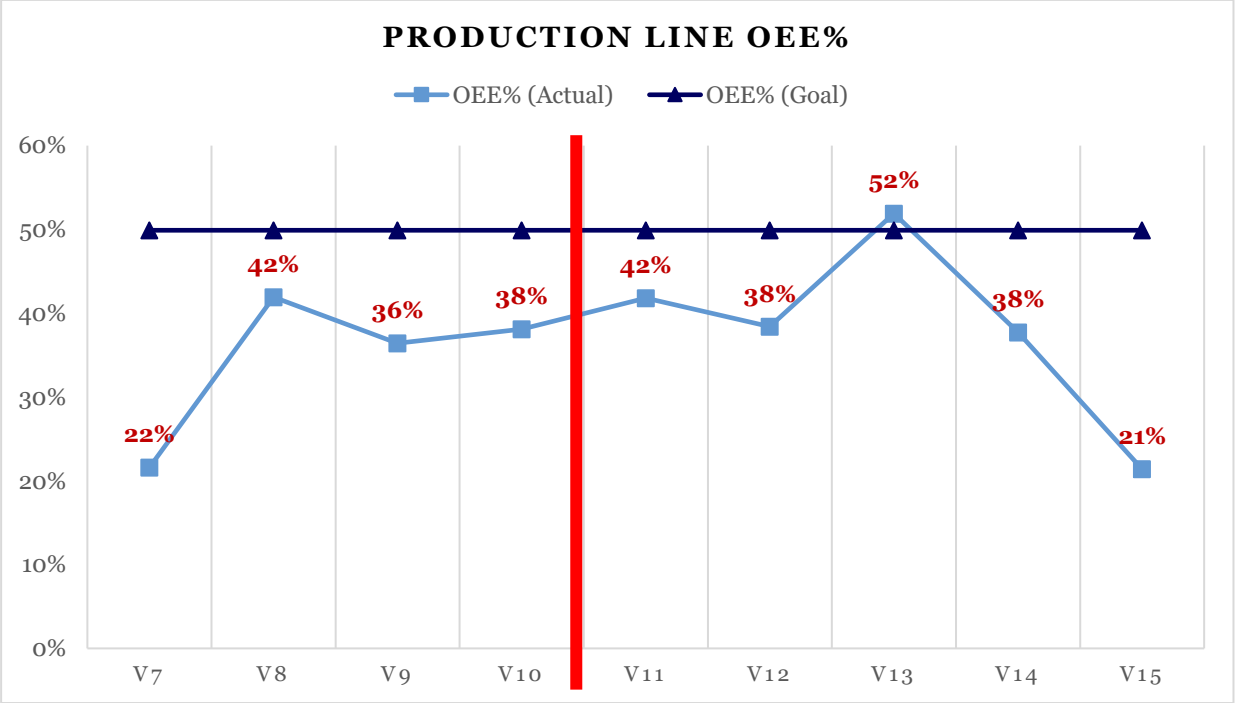

Figure 6 Production Line OEE Rate Week 7 to Week 15

In contrast, Figure 6 shows that the OEE rate of the production line does not reach the target level of 50%, except in Week 13 after implementation. OEE is a composite metric consisting of availability, performance, and quality, making it more difficult to improve, especially in a legacy production environment characterized by outdated equipment and operational instability. While similar performance levels are observed before implementation, Week 13 demonstrates a significant improvement, allowing the production line to meet the target. On average, OEE increases by approximately 3% after implementation. Although a 3% increase may appear modest, it is significant given that OEE reflects the combined effect of three performance dimensions. This improvement can be associated with enhanced quality (through reduced rework), improved performance (higher actual output), and better availability (linked to reduced downtime, as also reflected in GE). GE is a simpler metric compared to OEE, as it

primarily reflects availability. It is also important to note that Week 7 and Week 15 show the lowest OEE and GE values. Week 7 represents a start-up period with frequent machine issues, while Week 15 includes one public holiday, and two days affected by raw material shortages. These external factors contribute to reduced performance during those weeks. This indicates that while the protocol supports operational improvement, external constraints such as supply disruptions and start-up conditions continue to influence overall system performance.

The final and most critical KPI is the rework rate, as reducing rework is the primary objective of this study. Figure 7 shows a clear downward trend in rework rate following implementation, with performance approaching the target level. Notably, the target is achieved in Weeks 11 and 15. It is also worth highlighting that near-zero rework rate was achieved on three production days within the 40-day observation period. Historically, the production line has not experienced near-zero rework rate in a single day, making this an important observation. These occurrences took place twice in Week 14 and once in Week 15. Before implementation, the average rework rate was 5.7% (Weeks 7–10). After implementation, it decreased to 3.8%, representing a substantial improvement toward the 3.5% target. This result indicates that the protocol contributes to reducing rework, even though it does not directly eliminate the root causes. More importantly, the findings suggest that increasing the visibility and traceability of rework enables the production system to better understand underlying causes. This supports more targeted interventions, such as maintenance prioritization and process adjustments, thereby strengthening the feedback loop for continuous improvement.

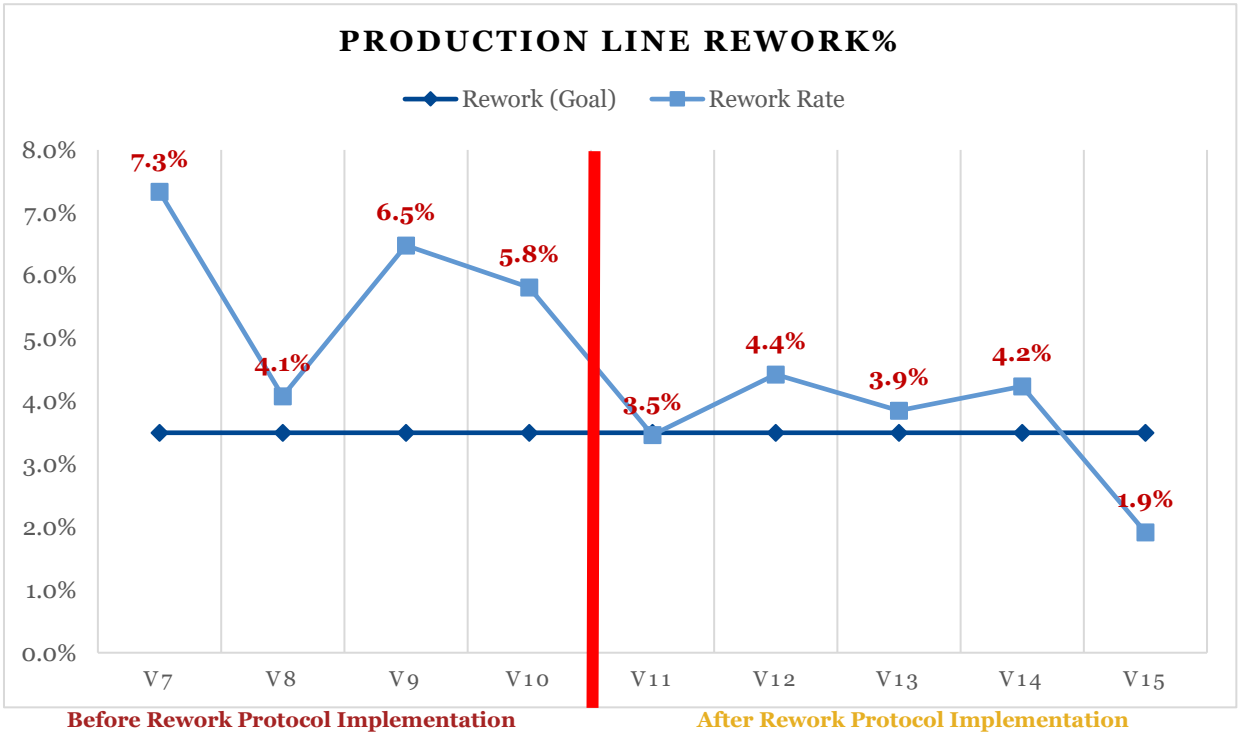

Figure 7 Production Line Rework Rate Week 7 to Week 15

4.6.1.2 Rework Protocol Data

The implementation of the RCA-based protocol generated a new layer of operational data that previously did not exist within the production system. Prior to implementation, the production line primarily monitored total rework volume without systematically documenting the specific reasons or defect categories contributing to rework generation. Through the protocol, operators were required to record the defect type, estimated quantity, and suspected operational cause whenever products were manually diverted into the rework stream. This enabled more detailed tracking and classification of recurring production losses.

Figure 8 presents a Pareto analysis of the recorded rework categories during the implementation period. The analysis shows that a limited number of defect categories contributed disproportionately to the total rework volume, with Defect 2 and Defect 4 representing the most dominant contributors. The Pareto visualization therefore helped the production line identify which operational problems required the highest priority for investigation and corrective action.

Beyond identifying dominant defects, the protocol also strengthened operational visibility and root cause analysis capabilities. By connecting recurring defect categories with potential machine-related sources, the production team was able to escalate specific issues into the Daily Management System (DMS) for further verification and action planning. This improved the ability of engineers, coordinators, and operators to focus discussions on the most significant production losses rather than relying only on general rework volume data.

The findings demonstrate that the protocol not only functioned as a data collection tool, but also as an operational learning mechanism that supported prioritization, cross-functional communication, and more structured problem-solving within the legacy production system.

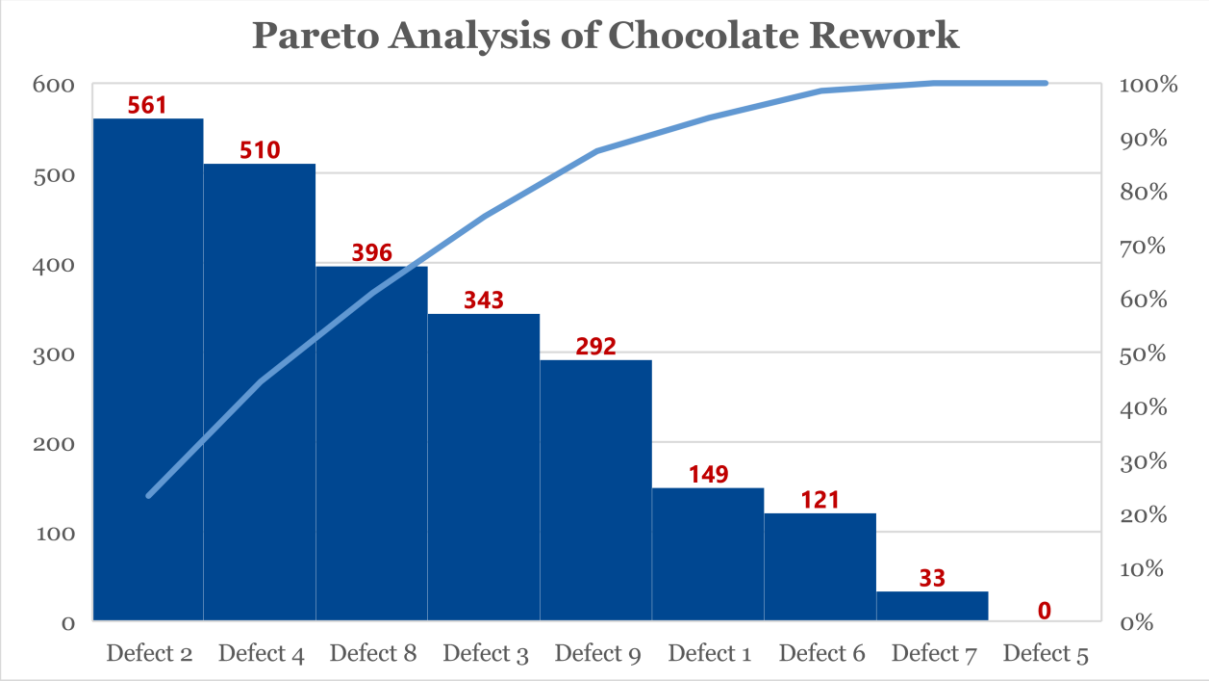

Figure 8 Pareto Analysis of Rework Protocol Data Week 11 to Week 15

4.6.2 Qualitative Findings

To complement the quantitative evaluation, qualitative findings were collected through semi-structured interviews with employees from multiple organizational levels within the production environment. A total of eight interviews were conducted, involving operators, production coordinators, a senior process engineer, a cost conversion analyst, a continuous improvement engineer, and a manufacturing manager. The purpose of the interviews was to understand how the implemented protocol was perceived in practice, how it influenced operational routines and decision-making, and whether it contributed to improved visibility and learning regarding rework generation.

The interview findings provide insights beyond measurable production performance indicators by capturing the human and organizational dimensions of operational transformation within the legacy production system. Through thematic analysis, several recurring themes emerged regarding operational visibility, behavioral change, communication, root cause identification, and the role of structured routines in supporting continuous improvement. These findings help explain how the protocol influenced not only production performance, but also the daily operational practices and learning processes within the production line.

4.6.2.1 Visibility and Understanding of Rework

I. Lack of cause visibility prior to implementation

Before the implementation, rework was primarily monitored in terms of volume, with limited insight into the underlying causes. This restricted the ability of the production team to identify recurring issues or patterns across the line. As a result, rework was often treated as a general outcome rather than a diagnosable problem. The absence of structured cause data limited systematic learning and hindered targeted improvement efforts.

> *"We only knew how much we reworked and not really documented why it happened." – Interviewee C*

II. Structured identification of defect types and sources

The protocol enables operators to categorize rework based on defect types and link them to specific process stages or machines. This structured approach improves the traceability of problems and allows the production team to better understand where defects originate. By connecting defects to their potential sources, the system moves from general observation to more precise diagnosis. This creates a stronger foundation for root cause analysis and targeted interventions.

> *"Now we can actually see if it's coming from chocolate depositor A or from the chocolate depositor B." – Interviewee B*

III. Creation of traceable and usable data

The introduction of structured logging transforms rework data from simple volume tracking into actionable information. The data becomes more detailed, consistent, and suitable for analysis across time and shifts. This enhances the ability of engineers and coordinators to detect trends and recurring issues. As a result, rework is no longer just monitored but actively used as an input for improvement.

“Before, the data was just numbers. Now it’s something we can actually use.” – Interviewee E

“Now we can see patterns instead of just total rework.” – Interviewee H

“It’s easier to understand what is happening in the line now.” – Interviewee G

4.6.2.2 Impact on Daily Operational Behavior

I. Increased awareness during rework decisions

The requirement to document rework reasons encourages operators to reflect on defects before making decisions. This reduces automatic or habitual actions and promotes more conscious evaluation of product quality. Operators become more attentive to the nature of defects and their possible origins. This shift contributes to a more proactive approach to waste handling.

“Now you think more before sending it to rework because you need to explain why and count the total molds.” – Interviewee A

II. Shift from reactive to more conscious actions

The protocol supports a transition from reactive handling of defects toward more deliberate operational behavior. Instead of simply removing defective products, operators engage in identifying and understanding the issue. This fosters a mindset where problems are recognized as signals rather than interruptions. Such behavioral change is essential for embedding continuous improvement practices at the shopfloor level.

“Before, we didn’t always investigate the problem in detail. Now we try to understand what’s actually wrong.” – Interviewee B

“Now we try to understand what caused the problem, not just remove it.” – Interviewee A

“You can see operators are more aware of what is happening in the process.” – Interviewee C

III. Perceived additional workload under high pressure

Despite its benefits, the protocol introduces an additional task during production, which can be challenging during high workload periods. Operators may prioritize maintaining production flow over completing the protocol in detail. This creates a tension between operational efficiency and data accuracy. Managing this balance is critical for ensuring consistent implementation.

“When it’s stressful and there hectic situation on the shop floor, it’s harder to write everything.” – Interviewee A

4.6.2.3 Decision-Making and Prioritization

I. Transition toward data-supported decision-making

The protocol introduces structured data that supports more informed decision-making at the operational level. Previously, decisions were largely based on experience or assumptions due to limited data availability. With clearer insights into rework causes, teams can base decisions on actual operational evidence. This reduces uncertainty and improves the quality of decision-making.

"We used to guess which problem was biggest. Now we can see it more clearly." – Interviewee D

"It helps us justify why we focus on certain problems." – Interviewee H

II. Improved prioritization of recurring losses

The availability of categorized rework data enables teams to identify and prioritize the most frequent and impactful issues. This allows resources to be allocated more effectively toward high-impact problems. Instead of addressing issues reactively, the team can focus on systematic improvements. This enhances the efficiency of continuous improvement efforts.

"It helps us focus on the problems that happen most often." – Interviewee G

4.6.2.4 Cross-Functional Collaboration

I. Development of a shared understanding of problems

The standardized structure of the protocol creates a common language for describing defects and issues across roles. This reduces ambiguity and improves clarity in communication between operators, coordinators, and engineers. A shared understanding enables more efficient collaboration and alignment. It also supports more consistent interpretation of production problems.

"Now everyone describes the problem in the same way." – Interviewee D

II. Improved input for engineering and CI functions

Engineers and CI personnel benefit from clearer and more structured problem descriptions. The improved quality of input data enables more efficient analysis and faster identification of root causes. This reduces the time required to investigate issues and supports more targeted solutions. As a result, cross-functional problem-solving becomes more effective.

"The information we get now is much clearer, so it's easier to find the cause." – Interviewee E

"Before, it was difficult to know where the problem came from." – Interviewee H

4.6.2.5 Operational Learning and Feedback Loop

I. Systematic capture of operational problems

The protocol ensures that rework events are recorded at the moment they occur, reducing the loss of critical information. This allows problems to be captured systematically rather than

being overlooked or forgotten. The availability of detailed data supports more structured analysis over time. This is a key step toward building a learning-oriented production system.

"Now the problems are not just forgotten, they are recorded." – Interviewee F

II. Integration with existing improvement routines

The collected data can be integrated into existing routines such as daily management meetings and continuous improvement processes. This strengthens the connection between shopfloor observations and higher-level decision-making. The protocol provides a consistent input for discussions and follow-up actions. As a result, improvement efforts become more structured and data driven.

"It gives better input for our daily meetings because we have actual reasons behind the numbers." – Interviewee C

III. Strengthening of the feedback loop

The protocol contributes to a stronger feedback loop by linking operational events with follow-up actions. Problems identified at the shopfloor can be escalated, analyzed, and addressed systematically. This reduces the likelihood of recurring issues being ignored. Over time, this supports more sustainable performance improvement.

"Now we can actually follow up on problems instead of just seeing them once." – Interviewee G

"We can bring real issues into the daily, weekly and yearly meetings." – Interviewee E

4.6.2.6 Cost Awareness and Financial Impact

I. Recognition of indirect costs of rework

The findings highlight that rework involves not only material recovery but also significant indirect costs. These include labor, energy consumption, and machine utilization, which are often less visible. The protocol helps make these costs more apparent by linking rework events to their causes. This reinforces the importance of reducing rework beyond material considerations.

"Even if we reuse it, we still lose time and energy." – Interviewee F

"It affects efficiency even if the material is reused." – Interviewee G

II. Improved linkage between operational losses and cost drivers

By connecting operational data with specific causes, the protocol enhances understanding of cost drivers within the production system. This allows financial and operational perspectives to be better aligned. Decision-makers can more clearly see how operational inefficiencies translate into financial losses. This supports more informed and economically grounded improvement decisions.

"Now it's easier to understand what is actually causing the cost." – Interviewee F

4.6.2.7 Challenges and Limitations

I. Dependence on operator consistency

The effectiveness of the protocol depends on how consistently operators apply it during production. Variations in interpretation, attention, or experience can lead to inconsistencies in the recorded data. This may affect the reliability and comparability of the information over time. Continuous guidance and alignment are therefore necessary to maintain data quality.

"If people don't fill it in properly, the data won't be reliable." – Interviewee C

II. Risk of declining usage over time

Sustaining the protocol requires ongoing reinforcement and integration into daily routines. Without visible follow-up or perceived value, it may be seen as an additional administrative task. This can reduce motivation and consistency in its use over time. Embedding the protocol into standard practices is therefore essential for long-term effectiveness.

"If no one follows up, it might stop being used after a while." – Interviewee G

4.6.3 Operational Impact

Beyond quantitative and qualitative evaluation, the implementation of the protocol has generated significant operational impacts on how the production line manages, interprets, and responds to rework.

One of the most immediate outcomes is the development of structured visibility through a rework dashboard. Previously, the production line only recorded the total volume of rework, without systematically capturing its causes. With the introduction of the protocol, rework data now include both quantitative and qualitative dimensions, such as defect type, associated process step, and affected quantity. This enables the creation of a more informative dashboard that supports the Continuous Improvement (CI) function. As a result, CI engineers can utilize this structured dataset to identify recurring issues, prioritize improvement initiatives, and monitor performance trends over time. In addition, the protocol has contributed to the standardization of operational routines on the shop floor. Recording rework reasons has increasingly become part of daily execution, rather than an additional or optional task. Operators and line leaders now follow a consistent process when handling rework decisions, indicating the early institutionalization of structured problem identification within daily operations.

A key operational impact is the improvement in decision-making processes. Prior to implementation, decisions regarding production losses were often based on experience or intuition, with limited supporting data. With the protocol in place, rework information now serves as a first stage in decision-making, enabling teams to prioritize losses based on actual frequency and impact. This shift allows for more targeted and justified actions, particularly in maintenance planning and process improvement initiatives.

The protocol also enhances cross-function communication across the production system. Improved communication between operators, line leaders, engineers, and CI personnel has been observed, as all stakeholders now refer to a shared and structured dataset. Engineers benefit from clearer and more traceable problem descriptions, allowing them to link defects to specific machines or process conditions. Similarly, CI teams receive more reliable input for analysis, strengthening their ability to design effective improvement actions.

Another critical impact is the strengthening of the operational feedback loop. Before implementation, rework events were recorded only at an aggregate level, limiting the ability to systematically learn from recurring issues. With structured cause-capture integrated into daily routines, each rework event now contributes to a continuous learning process. Problems are identified, recorded, analyzed, and can be escalated through existing systems such as Daily Management Systems (DMS). This reflects the practical application of a PDCA-based approach, where operational data are continuously fed back into improvement activities.

Finally, the protocol contributes to a shift in the role of operators within the production system. Rather than acting solely as executors of predefined tasks, operators now actively participate in identifying and documenting problems. This increases their involvement in the improvement process and supports a more engaged and knowledge-driven shop-floor environment.

Overall, these operational transformations demonstrate that the protocol does not only improve performance metrics but also transforms how the production system learns from waste. By embedding structured data capture, standardized routines, and feedback mechanisms into daily operations, the protocol supports the transition from reactive problem-solving to a more systematic and sustainable approach to manufacturing excellence.

5. Discussion

5.1 Interpreting Operational Transformation in Legacy FMCG Systems

The findings of this study demonstrate that supporting operational transformation within legacy FMCG production systems can occur without extensive technological replacement. Instead, the transformation emerged through changes in operational routines, information visibility, and structured learning processes embedded within daily execution. This finding is particularly important in the context of legacy manufacturing systems, where aging equipment, fragmented automation, and limited digital integration often constrain large-scale modernization efforts (Gomaa, 2024; Holmes, 2025).

The studied chocolate production line reflects many of the characteristics commonly associated with legacy production environments. The production process depends on multiple interconnected machines with varying automation capabilities, creating operational instability and unpredictable performance. Frequent short and long stop times, combined with recurring product defects contributed to a rework rate significantly above the organizational target. These conditions align with previous studies suggesting that legacy systems struggle with operational flexibility, fragmented data flow, and persistent waste generation (Aljunaidi and Ankrak, 2014; Gomaa, 2024).

However, the findings suggest that supporting operational transformation should not be understood solely as a technological challenge. While existing Industry 4.0 literature frequently emphasizes digitalization and automation as primary drivers of transformation, this study indicates that meaningful improvement can also emerge through structured operational learning mechanisms. The RCA-based protocol introduced in this study did not alter the technical configuration of the production system. Instead, it transformed how operational disturbances were captured, interpreted, and escalated within the organization. The protocol created a more structured information flow between operators, coordinators, engineers, and management. Previously, rework was primarily measured in terms of volume, providing limited insight into the causes behind production losses. Following implementation, rework events became traceable through standardized categorization and documentation. This shifted the operational system from reactive handling of waste toward a more systematic understanding of process instability. This finding supports the argument that operational transformation in legacy systems can emerge through changes in organizational routines and decision-making structures rather than through technological replacement alone. Roden et al. (2017) argue that operational transformation requires redesigning organizational routines so that information and learning continuously circulate within daily operations. Similarly, the present study demonstrates that even relatively small interventions at the shopfloor level can significantly improve organizational learning capability when integrated into operational workflows.

Furthermore, the findings also reflect the socio-technical perspective of transformation proposed by Geels (2005), where operational systems are shaped not only by technological infrastructure but also by routines, behaviors, and coordination mechanisms. In this case, the intervention altered how production losses were socially interpreted and operationally managed, thereby strengthening the production line's capability to respond to recurring disturbances. Therefore, the study suggests that operational transformation in legacy FMCG systems should be viewed as the development of structured learning capability under constrained technological conditions. The transformation observed in this study was not driven

by replacing machines, but by improving how the organization learns from the instability generated by those machines.

5.2 From Performance Measurement to Operational Action Plan

The findings also highlight the limitations of relying solely on traditional manufacturing performance metrics such as OEE and GE without mechanisms that connect those metrics to operational learning and root cause analysis. Prior to the implementation of the protocol, the production system already monitored several key performance indicators, including rework rate, OEE, GE, and production losses. However, although these metrics provided visibility into the existence of operational losses, they did not sufficiently explain the underlying causes behind those losses. This observation strongly aligns with existing literature on performance measurement systems in manufacturing. Andersson and Bellgran (2015) argue that metrics such as OEE primarily explain what happened within the production process rather than why it happened. Similarly, Pereira et al. (2019) emphasize that OEE was originally designed as a driver for continuous improvement rather than as a standalone performance indicator. Without structured problem-solving mechanisms, performance metrics risk becoming passive monitoring tools rather than actionable learning systems.

The protocol implementation introduced in this study partially addressed this limitation by linking quantitative performance data with structured operational context. Rather than documenting only the amount of rework generated, the protocol captured defect categories, possible machine origins, and operational circumstances associated with each rework event. As a result, the production system gained a more detailed understanding of how specific operational disturbances contributed to waste generation. This transformation is significant because it shifts the role of performance measurement from descriptive reporting toward operational decision support. Engineers and coordinators were no longer required to rely solely on aggregated performance numbers when identifying production priorities. Instead, they gained access to more granular operational information that improved the ability to prioritize maintenance activities, identify recurring machine disturbances, and escalate issues within the Daily Management System (DMS). The findings therefore suggest that performance measurement systems become substantially more valuable when integrated with structured operational routines that support interpretation and learning. In this sense, the protocol functioned as a bridge between measurement and operational action. Rather than replacing existing KPIs, the protocol implementation enhanced their usefulness by providing contextual information that enabled more informed decision-making. At the same time, the findings also reveal important limitations. Since the protocol relies on manual operator input, the consistency and quality of the collected data remain dependent on human discipline and engagement. Variations in operator interpretation, workload pressure, or inconsistent categorization may affect data reliability over time.

Consequently, while the protocol improved visibility and traceability, it did not fully eliminate the challenges associated with manual production reporting systems. Nevertheless, the study demonstrates that even relatively simple data-capture mechanisms can significantly strengthen operational learning capability when integrated into existing performance management structures.

5.3 Integrating PDCA into Daily Operational Routines

Another important finding of this study is the role of the PDCA cycle as a practical operational routine rather than merely a conceptual improvement framework. While PDCA is widely

discussed within Lean and continuous improvement literature, organizations often struggle to operationalize the cycle consistently within day-to-day production activities. The findings from this study suggest that the protocol implementation successfully integrated PDCA principles into daily operational execution through the structured handling of rework events.

The planning phase began with direct observation of recurring rework patterns, production instability, and the absence of structured root cause documentation. Through Gemba observations and discussions with operators, the study identified that the production line lacked sufficient visibility regarding why products were diverted to rework. This diagnosis phase reflects the Lean principle of understanding problems directly at the source before implementing corrective actions.

The doing phase involved the implementation of the RCA-based protocol during normal production operations. Importantly, the intervention did not interrupt the production flow significantly because it was integrated into an already existing operational decision point. This integration into routine execution appears to be one of the reasons why the protocol was perceived as practical and usable by operators and coordinators.

The checking phase extended beyond purely quantitative evaluation. In addition to comparing KPI before and after implementation, the study incorporated qualitative feedback from operators, coordinators, engineers, and management. This broader evaluation approach strengthened the learning aspect of the PDCA cycle by assessing not only performance outcomes but also operational usability and organizational acceptance.

Finally, the acting phase focused on refining and potentially standardizing the protocol as part of the production line's daily management routines. The findings indicate that several stakeholders viewed the protocol as useful for long-term operational improvement because it increased process visibility and improved escalation capability.

This operationalization of PDCA supports previous research emphasizing that continuous improvement requires disciplined routines embedded into daily management practices (Mann, 2005; Poksinska, 2013). The findings also align with Lean philosophy, where improvement should occur continuously through iterative learning cycles rather than isolated improvement projects (Liker, 2004). Most importantly, the study demonstrates that PDCA became embedded into the operational workflow itself. Rework events were transformed from isolated production disturbances into learning opportunities capable of generating actionable operational knowledge. This finding strengthens the argument that sustainable improvement depends not only on identifying waste, but on developing organizational routines capable of continuously learning from waste.

Beyond daily operational use, the protocol also demonstrates potential for integration into broader production management routines. The structured rework data generated through the protocol could support weekly, monthly, and yearly review forums by enabling more systematic discussions around recurring defects, production losses, and prioritization of corrective actions. At the weekly level, Pareto-based reviews may support rapid escalation and short-term maintenance prioritization, while monthly and yearly reviews could contribute to longer-term continuous improvement planning and investment decision-making. Integrating the protocol into formal review structures would strengthen organizational learning by connecting frontline operational data with managerial decision-making processes across multiple organizational levels.

However, sustaining such routines over time may require ongoing managerial reinforcement. Without consistent follow-up, leadership engagement, and integration into broader management systems, there is a risk that the discipline associated with structured data capture gradually weakens.

5.4 Behavioral and Cultural Dimensions of Transformation

Beyond operational and technical improvements, the findings also indicate early behavioral and cultural shifts within the production environment. While the intervention itself was relatively simple from a technical perspective, its implementation influenced how operators and production staff interacted with production disturbances and process deviations. Prior to the implementation, rework handling was largely reactive. Products identified as defective were diverted to rework primarily as an immediate operational response, with limited reflection regarding the underlying process conditions causing the defects. Following implementation, operators reported becoming more aware of the causes behind rework decisions and more attentive to recurring process disturbances. Rather than simply removing defective products from the line, operators began associating defects with specific machine conditions, operational patterns, or recurring disturbances.

This finding reflects an important Lean principle emphasizing frontline involvement and organizational learning. According to Liker (2004), sustainable improvement requires not only technical process optimization but also active engagement from operators who directly interact with the production process. The findings suggest that the protocol increased operator participation in the improvement process by encouraging more conscious observation and documentation of production problems. Additionally, the protocol appeared to strengthen communication between functions. Engineers, coordinators, and CI personnel gained access to more detailed operational information, reducing ambiguity during problem escalation and supporting more focused discussions regarding production losses. This improved communication contributed to stronger alignment between operational and technical perspectives.

The findings also suggest that the intervention strengthened feedback loops within the organization. By documenting the causes behind rework events, the production system improved its ability to connect production disturbances with operational responses. This created a more structured mechanism for learning from recurring issues rather than repeatedly reacting to symptoms without sufficient root cause visibility. However, it is important not to overstate the extent of cultural transformation achieved during the study period. The intervention lasted only several weeks, which limits the ability to evaluate long-term behavioral sustainability. Furthermore, several interviewees highlighted that the effectiveness of the protocol remains dependent on operator discipline and consistency. If operators stop documenting accurately or perceive the protocol as an administrative burden, the quality of the learning system may deteriorate over time.

Therefore, the findings should be interpreted as evidence of early behavioral shifts rather than full organizational cultural transformation. Nevertheless, these early shifts are significant because they demonstrate how relatively small operational routines can influence organizational awareness, communication, and problem-solving behavior within legacy manufacturing systems.

5.5 Supporting Sustainable Manufacturing Excellence

The findings of this study also contribute to a broader understanding of sustainable manufacturing excellence within legacy FMCG environments. Traditionally, manufacturing excellence has often been associated with achieving high levels of productivity, quality, and efficiency through Lean, TPM, and Six Sigma practices (Le, 2025; Ahmad et al., 2012). However, contemporary literature increasingly emphasizes that manufacturing excellence must also incorporate sustainability, resilience, and long-term operational adaptability (Alanezi and Franchetti, 2025; Potthoff and Gunnemann, 2023).

The studied production line illustrates why this broader perspective is necessary. Although rework serves as a recovery mechanism that allows defective chocolate products to be reused rather than immediately discarded, excessive rework still generates significant operational waste. Rework consumes labor time, machine utilization, electricity, and production capacity, even when materials are partially recovered. When rework volumes exceed the system's recovery capacity, portions of the material eventually become scrap, creating additional environmental and economic losses.

From this perspective, reducing rework is not only a productivity objective but also a sustainability objective. The reduction of rework observed during the intervention contributed to more efficient utilization of materials, production time, and operational resources. Improvements in OEE and GE similarly reflect more stable and effective use of manufacturing capacity. Importantly, however, the findings suggest that sustainable manufacturing excellence should not be interpreted solely as achieving lower waste levels or higher KPI performance. Instead, sustainability emerges through the system's capability to continuously identify, understand, and respond to operational instability over time. In this study, the RCA-based protocol strengthened that capability by enabling the production system to learn more effectively from recurring disturbances. This finding aligns with recent literature emphasizing resilience and adaptability as central dimensions of modern manufacturing excellence (Potthoff and Gunnemann, 2023). The ability to systematically capture operational problems, escalate them appropriately, and integrate learning into daily execution contributes to a more resilient production system capable of adapting to recurring disturbances despite technological limitations.

Nevertheless, the study does not claim that sustainable manufacturing excellence was fully achieved. Rather, the findings indicate that the intervention supported movement toward more sustainable operational practices by strengthening learning capability, improving resource utilization, and increasing operational visibility. Long-term sustainability would require continued reinforcement, broader organizational integration, and potentially further technological support.

5.6 Transferability to Other FMCG Manufacturing Contexts

The findings of this study indicate that the implemented RCA-based protocol may be transferable to other FMCG manufacturing environments characterized by recurring waste, manual operational decisions, and legacy production constraints. Although the intervention was developed within a chocolate production line, many of the operational challenges identified in this study are not unique to confectionery manufacturing alone. FMCG industries commonly operate under high-volume, high-speed, and efficiency-driven production conditions where even small operational disturbances can generate significant material losses, production instability, and cost inefficiencies. As a result, recurring rework, limited operational visibility,

and reactive problem-solving practices are challenges that may also exist across other FMCG sectors.

One of the main strengths of the protocol implementation is its relatively low implementation complexity. Unlike large-scale automation or digital transformation projects, the protocol does not require substantial capital investment, major equipment modification, or extensive system redesign. Instead, the intervention relies primarily on structured operational routines, standardized data capture, frontline participation, and RCA-based learning practices. This makes the approach particularly relevant for FMCG manufacturers operating legacy production systems with aging equipment, limited automation integration, or restricted modernization budgets. In many legacy environments, operational instability is often accepted as unavoidable because technical upgrades are costly or difficult to implement. The findings of this study suggest that operational improvements may still be achieved by strengthening how production teams capture, interpret, and respond to operational disturbances within existing systems.

The transferability of the approach is also supported by the broader operational similarities shared across FMCG industries. Sectors such as confectionery, bakery, dairy, beverage, frozen food, and packaging-intensive manufacturing frequently involve repetitive production cycles, strict production targets, and multiple process interdependencies where defects and waste can propagate rapidly throughout the production flow. In many cases, operators are required to make real-time decisions regarding product rejection, rework handling, or process continuation. However, while production losses are often quantitatively measured through KPIs such as OEE, downtime, or scrap volume, the operational causes behind those losses may remain insufficiently documented or poorly categorized. The implemented protocol directly addresses this visibility gap by transforming rework events into traceable operational information that can support root cause analysis and prioritization of corrective actions.

Another important aspect of transferability lies in the protocol's role as a socio-technical operational improvement mechanism rather than a purely technical solution. The effectiveness of the intervention was not dependent solely on data collection itself, but also on the interaction between operators, coordinators, engineers, and management within the daily operational system. The protocol strengthened communication, supported escalation into the Daily Management System (DMS), and improved alignment between frontline observations and engineering decision-making. This suggests that successful transferability depends not only on technical compatibility, but also on organizational factors such as operator engagement, management support, continuous improvement maturity, and execution discipline.

At the same time, the transferability of the intervention is not without limitations. Production systems that are already highly automated, digitally integrated, or equipped with advanced real-time defect tracking technologies may require a modified or partially digitalized version of the protocol. Similarly, industries operating under significantly different production logics or regulatory requirements may not experience the same operational benefits from manual RCA-based routines. Therefore, while the core principles of structured operational learning and rework traceability may remain applicable, the implementation approach itself should be adapted according to the technological maturity, organizational structure, and operational characteristics of each manufacturing environment.

Finally, the protocol may also serve as a transitional operational mechanism for companies moving toward more advanced digital manufacturing systems. By creating structured and categorized operational data at the shopfloor level, the intervention establishes a foundation

that could later support digital dashboards, predictive maintenance systems, automated defect analytics, or Industry 4.0-based continuous improvement initiatives. In this sense, the study suggests that supporting operational transformation in legacy FMCG systems does not necessarily begin with advanced technology adoption but may first require the development of structured operational learning routines capable of converting production disturbances into actionable organizational knowledge.

6. Conclusion

This study investigated how a legacy FMCG production system could be operationally transformed toward sustainable manufacturing excellence through the implementation of a structured root-cause-analysis (RCA)-based protocol integrated within a PDCA improvement approach. The research focused on a chocolate production line at FMCG company characterized by aging and outdated equipment, unstable operational performance, recurring rework generation, and limited visibility regarding the causes of production losses. Rather than introducing a major technical modification, the study examined how structured daily operational routines could improve organizational learning and operational decision-making within the existing production environment.

The findings demonstrate that the implemented protocol contributed to both operational and organizational improvements. Quantitatively, the production line experienced improvements in rework rate, General Efficiency (GE), and Overall Equipment Effectiveness (OEE) during the implementation period. The protocol increased visibility of rework generation by enabling operators to systematically document defect categories, quantities, and suspected machine-related causes whenever products were diverted into the rework stream. This created a more structured understanding of operational disturbances that previously remained undocumented or difficult to trace.

Beyond performance improvements, the findings also revealed important qualitative impacts on operational behavior and communication. Operators became more aware of production conditions before making rework decisions, while engineers and coordinators gained clearer information for identifying recurring process disturbances and prioritizing corrective actions. The protocol strengthened communication between production roles and supported a more proactive approach toward operational problem-solving. Rather than treating rework solely as an unavoidable production outcome, the system gradually began to treat rework as a source of operational learning and continuous improvement.

As the research question of the study is: "How can a structured continuous improvement initiative support operational transformation toward sustainable manufacturing excellence in a legacy FMCG production system?"

To answer this research question, the study suggests that operational transformation in legacy FMCG systems is not solely dependent on large-scale technological upgrades or advanced automation investments. While technical limitations remain important contributors to instability, the findings indicate that meaningful transformation can also emerge through structured operational learning routines embedded within daily production activities. In this case, the RCA-based protocol functioned as a mechanism that connected frontline observations, operational data, and management decision-making into a more continuous improvement-oriented system. The PDCA structure further supported this transformation by creating a systematic process for identifying problems, implementing interventions, evaluating outcomes, and standardizing successful practices.

Furthermore, the study contributes to the understanding of sustainable manufacturing excellence within legacy production environments. Sustainable manufacturing excellence was not achieved merely through short-term efficiency gains, but through the development of a more transparent, traceable, and learning-oriented operational system capable of continuously identifying and responding to recurring production losses. The findings support the view that

sustainable operational excellence requires not only performance measurement systems such as OEE and GE, but also organizational routines capable of translating performance data into actionable operational knowledge.

Overall, this study concludes that legacy FMCG production systems can move toward sustainable manufacturing excellence by strengthening structured daily execution routines, improving visibility of operational losses, integrating RCA practices into frontline activities, and embedding continuous learning mechanisms within existing production systems. The research highlights that supporting operational transformation in legacy environments is both a technical and organizational process, where sustainable improvement depends on the ability of the production system to continuously learn from its own operational disturbances.

6.1 Managerial Implications

This study provides several managerial implications for FMCG manufacturers operating legacy production systems. First, the findings demonstrate that operational improvements do not always require major capital investment or full-scale automation upgrades. Although aging equipment and technological limitations contribute to instability, meaningful improvements can still be achieved through relatively simple operational interventions that strengthen visibility and learning on the shop floor.

Second, the study highlights the importance of structured operational data capture at the frontline level. Many manufacturing systems measure production losses quantitatively but lack detailed operational information explaining why losses occur. The implemented protocol showed that involving operators directly in documenting rework reasons can improve traceability, strengthen root cause analysis, and support more informed decision-making processes. This suggests that operators should not only be viewed as production executors, but also as important contributors to operational learning and continuous improvement activities.

Third, the findings emphasize the importance of integrating performance measurement systems with daily management routines. Metrics such as OEE and GE become more valuable when they are connected to structured RCA practices and cross-functional communication processes. Managers should therefore ensure that operational KPIs are not treated solely as reporting tools, but as inputs for systematic problem-solving and continuous improvement discussions.

Finally, the study indicates that sustainable manufacturing excellence depends heavily on organizational routines and behavioral alignment. Building a learning-oriented operational culture requires consistent execution, accountability, and communication across different production roles. Structured protocols and daily routines can therefore serve as important mechanisms for stabilizing operations and improving long-term production performance within legacy manufacturing environments.

6.2 Limitations

This study has several limitations that should be acknowledged. First, the research was conducted within a single production line in one FMCG manufacturing facility, limiting the generalizability of the findings across other industries or production environments. While the case study approach provided rich operational insights, the findings should primarily be interpreted within the context of legacy FMCG manufacturing systems with similar operational characteristics.

Second, the implementation period of the protocol was relatively short. Although measurable operational improvements were observed during the study period, the research could not fully evaluate the long-term sustainability of the intervention or its long-term influence on organizational behavior and operational culture. Future operational conditions may also influence the consistency of protocol execution over time. Third, the protocol was implemented only at one critical decision point within the production line. While this focused approach allowed detailed evaluation of the intervention, it also limits understanding of how the protocol would function if implemented across multiple machines, production areas, or production lines simultaneously.

Finally, the study relied partially on interview-based qualitative findings, which may be influenced by participant subjectivity, operational perspectives, and organizational dynamics. Although triangulation between interviews, observations, and operational data was applied to strengthen credibility, some interpretations remain context dependent.

6.3 Future Research

Future research could extend this study in several ways. Longitudinal studies would be valuable to evaluate whether the observed operational and behavioral improvements can be sustained over longer implementation periods. Future research could also investigate how RCA-based operational routines evolve over time and how they influence organizational culture, employee engagement, and continuous improvement maturity.

Additionally, future studies could replicate the research across different FMCG sectors, production technologies, or manufacturing environments to assess the broader applicability of the findings. Comparative studies between legacy and digitally integrated production systems may also provide deeper understanding regarding the relationship between operational learning routines and technological maturity. Further research may also explore the integration of digital technologies into structured rework tracking systems. For example, digital dashboards, automated defect logging, or Industry 4.0-based monitoring systems could strengthen the scalability and responsiveness of RCA-based operational learning processes.

Finally, future studies could investigate how structured operational learning routines interact with broader sustainability objectives, including energy efficiency, material circularity, and waste minimization strategies, to further strengthen the connection between operational transformation and sustainable manufacturing excellence.

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Appendix

Appendix A - Semi-Structured Interview Guideline

(Multi-Level Stakeholder Perspective)

The interviews aim to understand how rework decisions are made, how waste is currently interpreted, and how structured protocol/routines can support operational learning and transformation in a legacy production system.

Interviews are semi-structured to allow flexibility while ensuring comparability across roles.

1. **Operators and Technicians (Frontline Level)**
   Objective: Understand decision routines, informal practices, and visibility of causes.

   A. Daily Operational Routines and Decision-Making
      1. How do you decide whether a batch should go to rework?
      2. Are these decisions guided by formal procedures or mainly by experience?

   B. Understanding of Rework
      3. What are the most common reasons products go to rework?
      4. How are reasons for rework documented before this protocol?
      5. Do you feel the root cause of defects is clearly identified?
      6. Do you think rework is predictable or random? Why?

   C. Current Challenges
      7. What makes it difficult to maintain stable production?
      8. Are there situations where you are unsure why defects happen?

   D. Evaluation of the Protocol and Feedback
      9. How easy or difficult is it to use the rework logging protocol?
      10. Do you feel it improves communication with supervisors or engineers?
      11. Do you think tracking reasons for rework is useful? Why?
      12. Do you have any feedback for improvement about the protocol?

2. **Coordinators and Line Leaders (Supervisory Level)**
   Objective: Understand coordination, escalation, and accountability mechanisms.

   A. Line Performance and Stability
      1. How would you describe the current performance stability of the line?
      2. What are the main contributors to rework and production?

   B. Decision-Making and Control
      3. How are rework decisions monitored or controlled at your level?
      4. How do you ensure consistency between different operators?

   C. Problem-Solving Practices before the Protocol
      5. How are recurring problems typically addressed?
      6. Are root causes systematically identified and followed up?

   D. Evaluation of the Protocol and Operational Routines
      7. Does the rework protocol provide useful insights for managing the line?
      8. Has it improved visibility of rework causes? Does it support better decision-making?
      9. How are daily meetings (e.g., DMS) used to discuss performance issues?
      10. Do you have any feedback for improvement about the protocol?

3. Engineers (Process, Project, Sr. Process, and CI)
Objective: Explore technical instability and feedback loops

A. Technical Drivers
1. What are the main technical causes of rework and defects?
2. Are failures typically reactive or predictable?

B. Information Flow
3. What data do you currently use for root cause analysis?
4. Is the information detailed enough to conduct effective root cause analysis?

C. System Constraint
5. How does machine integration or automation system constrain affect performance?
6. What are the challenges of improving a legacy production line?

D. Evaluation of the Protocol
7. Can the collected data support deeper root cause analysis?
8. Does the protocol provide more actionable data?
9. Could this protocol be scaled to other machines or lines?
10. What improvements and feedback would you suggest?

4. Production Manager and Cost Analyst
Objective: Connect operations to strategy and sustainability ambition

A. Performance and Business Impact
1. How does rework impact production cost and efficiency?
2. How critical is the rework problem for overall performance?

B. Current Improvement Approach
3. How are Lean Six Sigma initiatives currently implemented?
4. What challenges exist in sustaining improvements?

C. Legacy System Challenges
5. What are the main limitations of legacy production systems?
6. How do these limitations affect long-term performance?

D. Evaluation of the Protocol and Strategic Perspectives
7. Do you see value in structured rework data collection?
8. Can this approach support long-term improvement?
9. How could this initiative contribute to manufacturing and operations excellence?
10. What would be required to sustain this approach long-term?

Appendix B - Semi-Structured Interview Guideline (Swedish Version)

(Flernivåperspektiv för intressenter)

Intervjuerna syftar till att förstå hur beslut om returvara fattas, hur spill tolkas för närvarande och hur strukturerade protokoll/rutiner kan stödja operativt lärande och transformation i ett äldre produktionssystem.

Intervjuerna är semistrukturerade för att möjliggöra flexibilitet samtidigt som jämförbarhet mellan roller säkerställs.

1. **Operatörer och tekniker (frontlinjenivå)**
   Mål: Förstå beslutsrutiner, informella metoder och synlighet av orsaker.

   A. Dagliga operativa rutiner och beslutsfattande
   1. Hur bestämmer du om en sats ska gå till returvara?
   2. Styrs dessa beslut av formella procedurer eller huvudsakligen av erfarenhet?

   B. Förståelse för returvara
   3. Vilka är de vanligaste anledningarna till att produkter går till returvara?
   4. Hur dokumenteras orsakerna till returvara före detta protokoll?
   5. Känner du att grundorsaken till fel är tydligt identifierad?
   6. Tror du att returvara är förutsägbar eller slumpmässig? Varför?

   C. Nuvarande utmaningar
   7. Vad gör det svårt att upprätthålla en stabil produktion?
   8. Finns det situationer där du är osäker på varför fel uppstår?

   D. Utvärdering av protokollet och feedback
   9. Hur lätt eller svårt är det att använda protokollet?
   10. Tycker du att det förbättrar kommunikationen med handledare eller ingenjörer?
   11. Tycker du att det är användbart att spåra orsaker till returvara? Varför?
   12. Har du någon feedback för förbättring av protokolle?

2. **Koordinatorer and Linjeledare (övervakningsnivå)**
   Mål: Förstå mekanismer för samordning, eskalering och ansvarsskyldighet.

   A. Linjens prestanda och stabilitet
   1. Hur skulle du beskriva linjens nuvarande prestandastabilitet?
   2. Vilka är de viktigaste bidragsgivarna till returvara och produktion?

   B. Beslutsfattande och kontroll
   3. Hur övervakas eller kontrolleras beslut om returvara på din nivå?
   4. Hur säkerställer du konsekvens mellan olika operatörer?

   C. Problemlösningsmetoder före protokollet
   5. Hur hanteras återkommande problem vanligtvis?
   6. Identifieras och följs grundorsaker systematiskt upp?

   D. Utvärdering av protokollet och operativa rutiner
   7. Ger returvarasprotokollet användbara insikter för att hantera linjen?
   8. Har det förbättrat synligheten av orsaker till returvara? Stödjer det bättre beslutsfattande?
   9. Hur används dagliga möten (t.ex. DMS) för att diskutera prestandaproblem?
   10. Har du någon feedback för förbättringar gällande protokollet?

3. Ingenjörer (Process, Projekt, Senior Process och CI)
Mål: Utforska teknisk instabilitet och återkopplingsslingor

A. Tekniska drivkrafter
1. Vilka är de främsta tekniska orsakerna till returvara och defekter?
2. Är fel vanligtvis reaktiva eller förutsägbara?

B. Informationsflöde
3. Vilka data använder ni för närvarande för grundorsaksanalys?
4. Är informationen tillräckligt detaljerad för att genomföra en effektiv grundorsaksanalys?

C. Systembegränsning
5. Hur påverkar maskinintegration eller automatiserings prestandan?
6. Vilka är utmaningarna med att förbättra en äldre produktionslinje?

D. Utvärdering av protokollet
7. Kan den insamlade datan stödja djupare rotorsaksanalys?
8. Ger protokollet mer handlingsbar data?
9. Kan detta protokoll skalas till andra maskiner eller linjer?
10. Vilka förbättringar och feedback skulle du föreslå?

4. Produktionschef och kostnadsanalytiker
Mål: Koppla verksamheten till strategi och hållbarhetsambition

A. Prestanda och affärspåverkan
1. Hur påverkar returvara produktionskostnader och effektivitet?
2. Hur kritiskt är returvaraproblemet för den totala prestandan?

B. Nuvarande förbättringsmetod
3. Hur implementeras Lean Six Sigma-initiativ för närvarande?
4. Vilka utmaningar finns för att upprätthålla förbättringar?

C. Utmaningar med äldre system
5. Vilka är de största begränsningarna med äldre produktionssystem?
6. Hur påverkar dessa begränsningar långsiktig prestanda?

D. Utvärdering av protokollet och strategiska perspektiv
7. Ser du värde i strukturerad insamling av returvarasdata?
8. Kan denna metod stödja långsiktig förbättring?
9. Hur skulle detta initiativ kunna bidra till tillverkningskvalitet?
10. Vad skulle krävas för att upprätthålla denna strategi på lång sikt?

Appendix C – RCA Based Protocol

This protocol helps the production line understand not only how many that rework is produced but also learn why is it happen and which machine having a problem, this protocol helps in data collection for engineers that want to conduct Root Cause Analysis.

1. Rework Protocol Form

DECISION POINT ROBOT – Rework Protocol					
Date	Shift	Number of Molds	Problem Code	Reason	Big Problem

2. Problem Code Instruction Table

Problem Code	Explanation	Possible Machine Problem
C	Defect 1	Chocolate Depositor A1 Chocolate Depositor A2
F	Defect 2	Chocolate Depositor B1 Chocolate Depositor B2 Chocolate Depositor B3 Chocolate Depositor B4
S	Defect 3	Chocolate Depositor C1 Chocolate Depositor C2
G	Defect 4	Chocolate Machine D
O*	Others Cause (Defect 5, Defect 6, …)	Another machine that mentioned before (e.g. Decision Point Robot)

*: If other causes will become common problems, it is possible to add other problem codes. The problem code comes from common problems, which is the result of discussions with the CI engineer, process engineer, operator, and technician.

3. Instructions for the operator to fill out protocols

1. When the operator sees defects chocolate and chooses to reject the current molds for rework bin, the operator should fill out the protocol.
2. The operator should write the date, shift, number of molds, problem code, and reason.
    a. If the problem is a defect 2 problem, the operator should write the specific pieces that has a problem to identify which chocolate depositor has a problem.
3. At the end of the shift, the operator can make a cross for the 1-3 biggest problems that the shift has, depending on how many molds go to rework bin. (A significant number can be >30 molds.)

4. Instructions for line managers and coordinators for escalating protocols to DMS2

1. For line managers and coordinators to identify and escalate the problem to DMS2, it is recommended to first look in the "Biggest Problem" column yesterday.
2. Investigate the problem and how many molds there are, link the possible machine problems (see instructions for the problem code table) that have problems with it.
3. Verify the problem with technicians in DMS2.

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