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Lean Six Sigma DMAIC Analysis for Process Improvement in Coffee Production

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Abstract

This study applies the Lean Six Sigma DMAIC (Define–Measure–Analyse–Improve–Control) methodology to examine operational inefficiencies and quality variation in the coffee production process at Sri Narasu's Coffee Company Private Limited, Salem. The process scope includes curing, roasting, grinding, degassing and packaging. Current-state process mapping and time analysis were used to identify waiting, work-in-progress (WIP), transportation, manual handling and quality-related losses.

The analysis identified degassing as the principal lead-time constraint, with approximately 480 minutes (eight hours) of waiting. The overall process was estimated at 158.395 minutes of processing time and 553 minutes of waiting time, giving a lead time of 711.395 minutes and a process cycle efficiency (PCE) of approximately 22.3%, excluding the separately stated transportation allowance. Quality observations highlighted granularity deviations, density/sorting failures and packaging defects, particularly weight and alignment variation.

Improvement proposals include blend-specific grinder settings and standard operating procedures, Poka-Yoke sieve mechanisms, automated bulk-density testing, a one-way degassing valve/high-vacuum approach, and packaging film-alignment guides with weight checks before sealing. These are proposed countermeasures; the projected benefits require validation through implementation and follow-up measurement.

Keywords: Lean Six Sigma; DMAIC; Value Stream Mapping; Poka-Yoke; Lead Time Reduction; Process Cycle Efficiency; Coffee Manufacturing

Introduction

Manufacturing performance depends on consistent quality, reliable process flow, efficient use of resources and timely delivery. Coffee production involves interconnected activities such as curing, roasting, grinding, degassing and packaging. Waiting or variation at one stage can increase lead time, create inventory between processes and affect product quality.

Lean management focuses on identifying and eliminating non-value-added activities, while Six Sigma uses data-driven analysis to reduce variation and defects. The DMAIC framework provides a structured

sequence for defining the problem, measuring current performance, analysing causes, developing improvements and establishing controls.

This project applies DMAIC to the coffee production process at Sri Narasu's Coffee Company Private Limited. The focus is on the long degassing wait, grinding granularity variation and packaging defects, alongside broader wastes involving inventory, transportation, motion and waiting.

Problem Statement

The production process experiences a prolonged degassing stage of approximately eight hours, contributing to increased lead time and WIP accumulation. Grinding operations show granularity variation, while packaging records include weight, alignment, coding and sealing defects. These conditions can contribute to rework, material waste and dependence on repeated manual checks.

Literature Review

Lean Six Sigma

Lean Six Sigma (LSS) integrates the principles of Lean manufacturing and Six Sigma to improve process flow, eliminate waste, and reduce process variation. Lean focuses on identifying activities that do not add value to the customer, while Six Sigma uses structured, data-driven analysis to reduce defects and inconsistencies. Costa et al. (2018), in their systematic literature review of Lean, Six Sigma, and Lean Six Sigma in the food industry, found that these approaches can improve productivity and reduce costs and inventory. Their review also identified challenges associated with food-industry characteristics and human factors, indicating that improvement methods must be adapted to the operating environment rather than applied uniformly.

Costa et al. (2020) further examined the relationship between Lean Six Sigma practices and food-industry performance. Their research reported a positive relationship between the adoption of these practices and organisational performance, while highlighting the importance of management awareness and experience with continuous improvement. These findings support the use of Lean Six Sigma in coffee manufacturing, where production efficiency depends on the coordination of processing stages, quality consistency, inventory flow, and packaging operations. In the present study, Lean Six Sigma provides the overall improvement framework for investigating production delays, quality-related issues, and non-value-added activities at Narasu's Coffee Company.

DMAIC Methodology

Define–Measure–Analyse–Improve–Control (DMAIC) is a structured problem-solving methodology used within Six Sigma to investigate process problems systematically. De Mast and Lokkerbol (2012) analysed DMAIC from the perspective of problem-solving theory and discussed how it structures the investigation of a problem, diagnosis of its causes, and development of corrective measures. The approach emphasises understanding the problem and its causes before selecting an improvement, rather than relying on assumptions or implementing changes without sufficient analysis.

Srinivasan et al. (2016), in their literature review of Six Sigma through the DMAIC phases, reported that DMAIC has been applied across manufacturing, service, and other sectors to support process improvement. The five phases provide a logical sequence: defining the problem and project scope, measuring current performance, analysing the causes of inefficiency, developing improvements, and establishing controls to sustain performance. For the present coffee-production study, the Define phase establishes the improvement scope; Measure records process times and observed defects;

Analyse investigates bottlenecks and recurring problems; Improve develops recommendations; and Control proposes monitoring measures to maintain future performance. As the recommendations in this study require implementation and validation, the Improve and Control phases should be interpreted as proposed actions rather than confirmed operational results.

Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is a Lean tool used to visualise the flow of materials and information across a process and distinguish value-adding activities from non-value-adding activities. It helps identify waiting time, bottlenecks, unnecessary movement, excess inventory, and delays between process stages. The systematic literature review by Applying Value Stream Mapping in Manufacturing (2017) examined published applications of VSM in manufacturing and discussed its use in analysing production systems and supporting improvement initiatives.

Dal Forno et al. (2014) reviewed the problems and challenges associated with VSM applications over a 15-year period. Their study highlighted that incorrect application or interpretation of value stream maps can lead to errors in identifying waste and selecting improvement measures. Therefore, process observations and reliable time data are important when preparing both current-state and future-state maps. In the present study, VSM can be used to represent the coffee-production stages, including curing, roasting, grinding, degassing, and packaging. Comparing processing time with waiting time helps identify stages that contribute disproportionately to overall lead time and provides a basis for prioritising improvement opportunities.

Lean Six Sigma in Food and Coffee Manufacturing

Food manufacturing presents specific operational challenges because production efficiency must be balanced with product quality, consistency, hygiene, and customer requirements. Costa et al. (2018) reviewed the application of Lean, Six Sigma, and Lean Six Sigma in the food industry and concluded that these approaches offer opportunities to improve productivity and reduce costs. Their findings also indicate that the particular characteristics of food processing can influence the selection and effectiveness of improvement tools. This is relevant to coffee manufacturing, where process parameters, raw-material characteristics, roasting conditions, grinding requirements, and packaging quality may affect the final product and production performance.

More directly, Hernández et al. (2023), in Improving Productivity in a Coffee Production Company Through Six Sigma, examined the application of Six Sigma and industrial engineering tools in a coffee-producing company. The study focused on identifying the root causes of low productivity and developing strategies to improve production processes. Its direct relevance to coffee manufacturing supports the use of systematic problem-solving methods in the present study. However, findings from one coffee company should not automatically be assumed to apply to another, as equipment, process design, product mix, and operating conditions may differ.

Research on Lean Six Sigma in food manufacturing also provides a broader basis for waste reduction. A 2025 study, The Implementation of Lean Six Sigma Approach to Minimize Waste at a Food Manufacturing Industry, discusses the complementary role of Lean in improving process flow and eliminating waste and Six Sigma in identifying problems and improving quality consistency. This supports the combined use of process mapping, root-cause analysis, and defect analysis when investigating operational inefficiencies. For Narasu's Coffee Company, these principles are relevant to the analysis of production delays, work-in-progress accumulation, quality variations, and packaging defects.

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Overall, the reviewed literature supports the use of Lean Six Sigma, DMAIC, and VSM as complementary approaches to process improvement. Lean Six Sigma provides the overall improvement philosophy, DMAIC structures the investigation, and VSM helps visualise material flow and identify delays. Studies in food and coffee manufacturing establish the relevance of these methods to production settings. Building on this literature, the present study applies DMAIC-based analysis to the coffee-production process at Narasu's Coffee Company, using process-time observations and defect analysis to identify improvement opportunities and develop recommendations. The effectiveness of these recommendations must be established through subsequent implementation and measurement.

Study Objectives and Methodology

Objectives

Map the current process using Value Stream Mapping (VSM).

Classify activities as value-added (VA), non-value-added (NVA), or necessary non-value-added (NNVA).

Identify sources of waste, inventory accumulation, process delays, and bottlenecks.

Evaluate process performance through lead time, process cycle efficiency (PCE), and workflow analysis.

Analyse quality deviations and defect patterns using Pareto analysis.

Identify root causes using Fishbone (cause-and-effect) analysis.

Develop and evaluate solutions using Poka-Yoke, Jidoka, and standardization.

Research Design

This study adopts an observational case-study approach to examine operational inefficiencies and identify potential process-improvement opportunities in coffee manufacturing at Sri Narasu's Coffee Company Private Limited, Salem. The study was undertaken in the context of a summer internship and draws on direct observations of production activities and available company data. Lean Six Sigma and the DMAIC framework were used to organise the process analysis and develop improvement recommendations.

The study does not constitute a controlled experiment or a post-implementation evaluation. The proposed interventions were not implemented as part of the study; therefore, their effects on production performance, quality and cost have not been empirically established.

Data Sources and Collection

The analysis draws on two categories of information: observations made during the internship and production or quality information available from the company. Observations were used to examine process sequences, waiting, material movement, work-in-progress accumulation, manual handling and potential sources of operational waste. Available process-time and quality data were used where applicable to prepare process summaries and defect analyses.

The observation period, number of production cycles observed, measurement procedures and provenance of individual company figures should be documented wherever this information is available. Figures based on estimates or assumptions are distinguished from observed findings and company-record data. No additional measurements or sample sizes are inferred where supporting information is unavailable.

Analytical Framework

The DMAIC framework was used to structure the analysis. The Define phase established the process scope and the operational problems considered. The Measure phase examined available process-time information, process flow and reported quality deviations. The Analyse phase used process mapping, waste identification, Pareto analysis and cause-and-effect analysis, where supported by the available information, to identify potential improvement priorities.

The Improve phase developed proposed countermeasures based on the observed issues and Lean Six Sigma principles. The Control phase outlines suggested standard operating procedures, quality checks and performance indicators for future monitoring. Since the interventions were not implemented, the Improve and Control phases represent recommendations and a proposed monitoring framework rather than verified operational outcomes.

Limitations of the Method

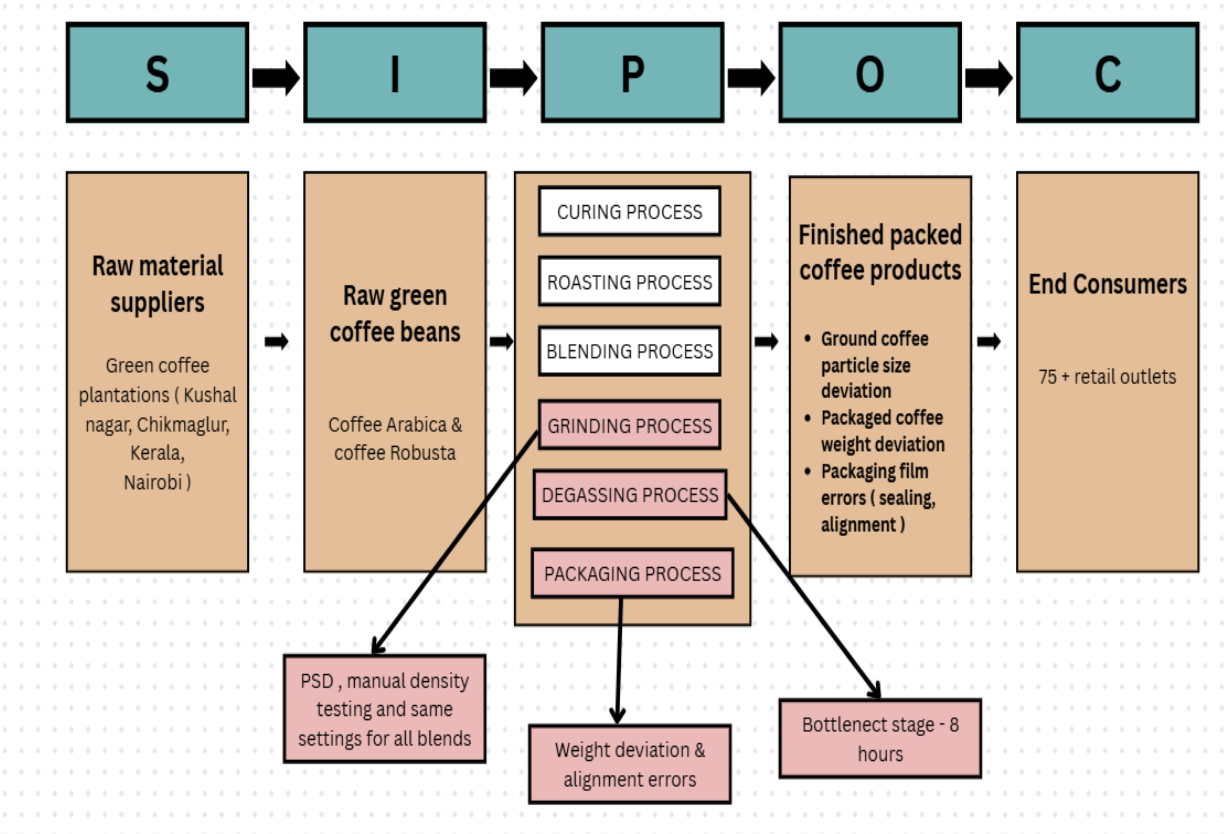
The study is limited by its observational design, reliance on the company information available during the internship and the absence of post-implementation measurements. Some future-state calculations depend on assumptions that require further verification. The findings are therefore intended to identify improvement opportunities in the process examined, rather than establish causal effects or demonstrate that the proposed interventions will achieve the projected benefits.

DMAIC phases and tools

Phase	**Tools used**
Define	Project charter, problem statement, SIPOC diagram, CTQ parameters
Measure	Current state VSM, takt time, process and waiting times, PCE
Analyse	Pareto analysis, Fishbone diagram, waste identification tables
Improve	Poka-Yoke sieves, one-way degassing valve, SMED SOP, alignment jig, in-line weighing (Jidoka), automated bulk density testing
Control	SOPs, quality checkpoints, KPIs, periodic reviews, Gemba walks

DEFINE PHASE

SIPOC DIAGRAM



SIPOC diagram

CRITICAL TO QUALITY PARAMETERS (CTQ)

Granularity

Bulk Density

Package Weight

Seal Integrity

Film Alignment

MEASURE PHASE

Key Observations from VSM

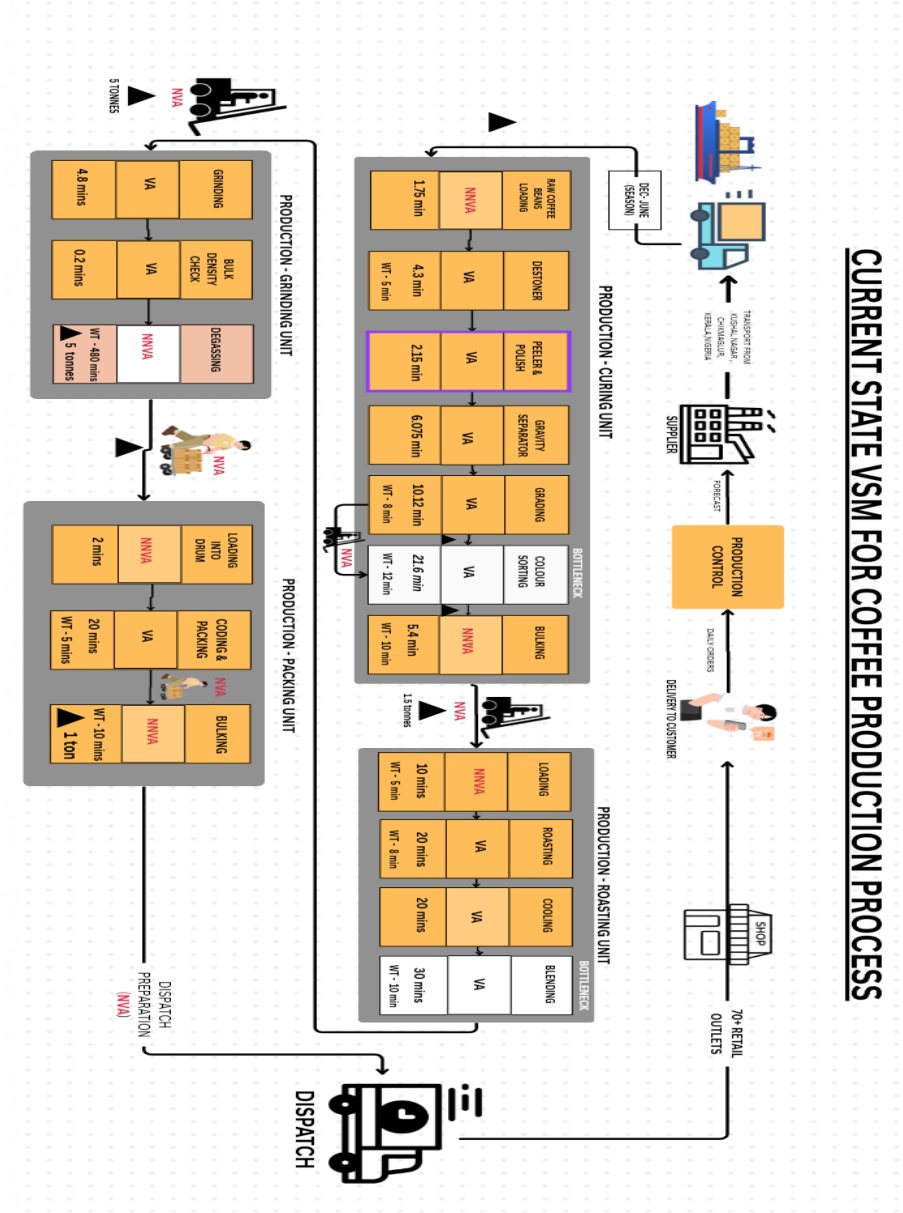
Colour sorting and degassing were recognized as the main bottlenecks.

Degassing adds considerably to the overall lead time.

There was a noticeable build-up of work-in-progress inventory between the roasting, grinding, and packaging stages.

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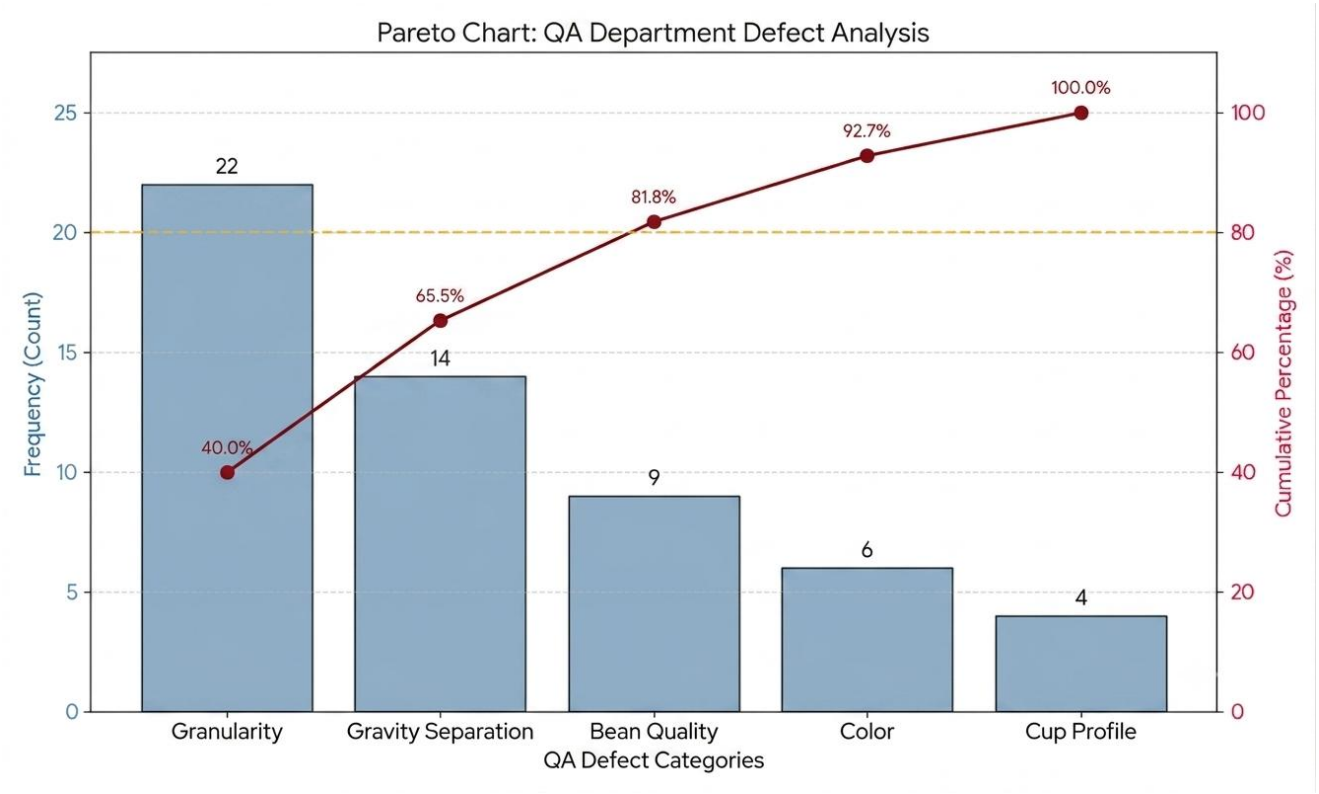
Transportation and manual handling contribute to increased motion waste. Packaging requires repeated manual handling and shows variability in quality



Current state value stream map of coffee production

ANALYSE PHASE

PARETO ANALYSIS



QA department Pareto chart

QUALITY DEFECTS IDENTIFIED

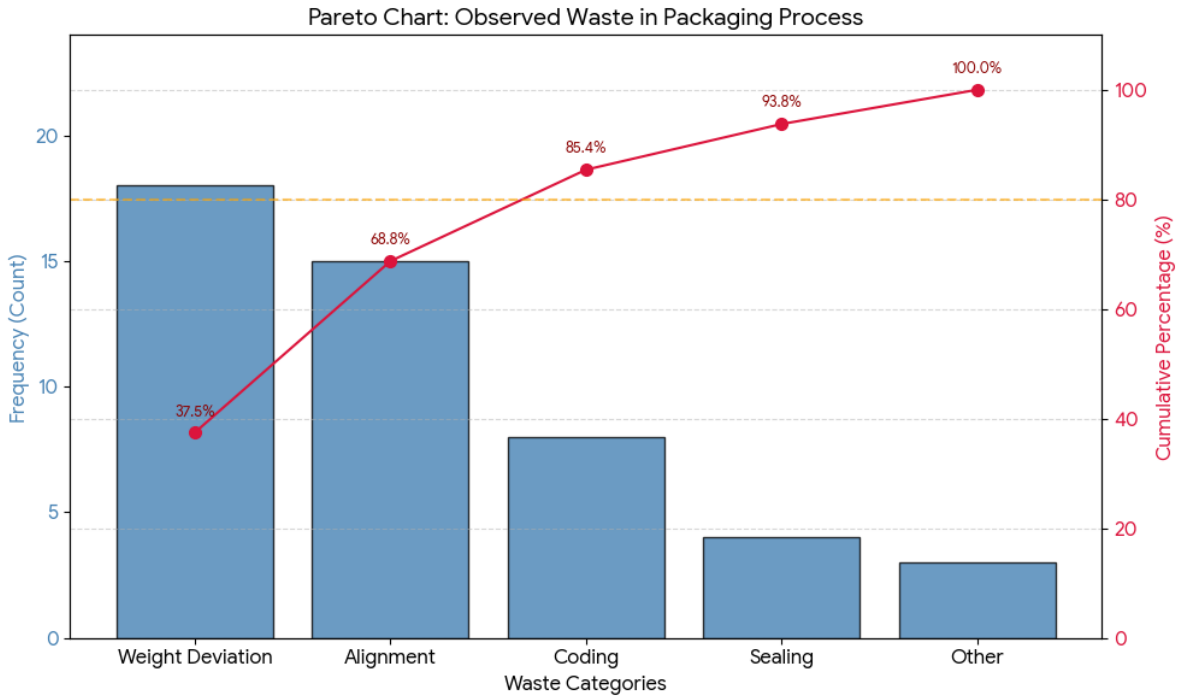
Particle size Distribution (PSD) deviation

Cup profile deviation

Bean quality defects

Roast colour variation

Density/sorting failure



Packaging department pareto chart (1660 PACKETS)

Packaging Defects Identified

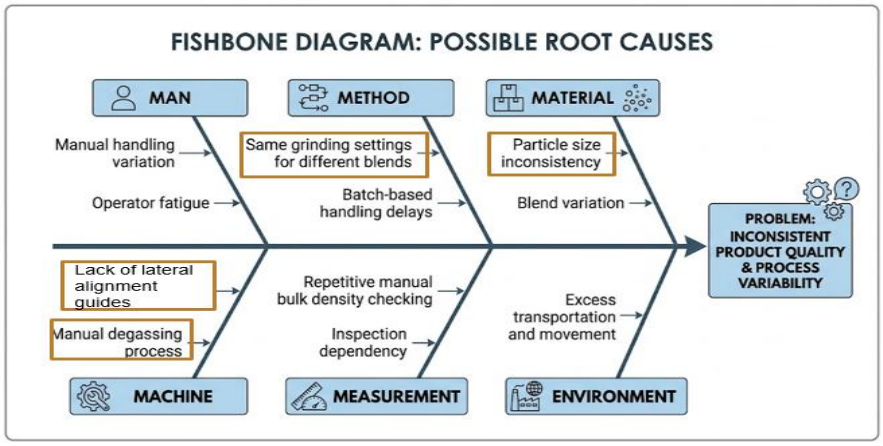
Weight deviation

Alignment variation

Coding defects

Sealing defects

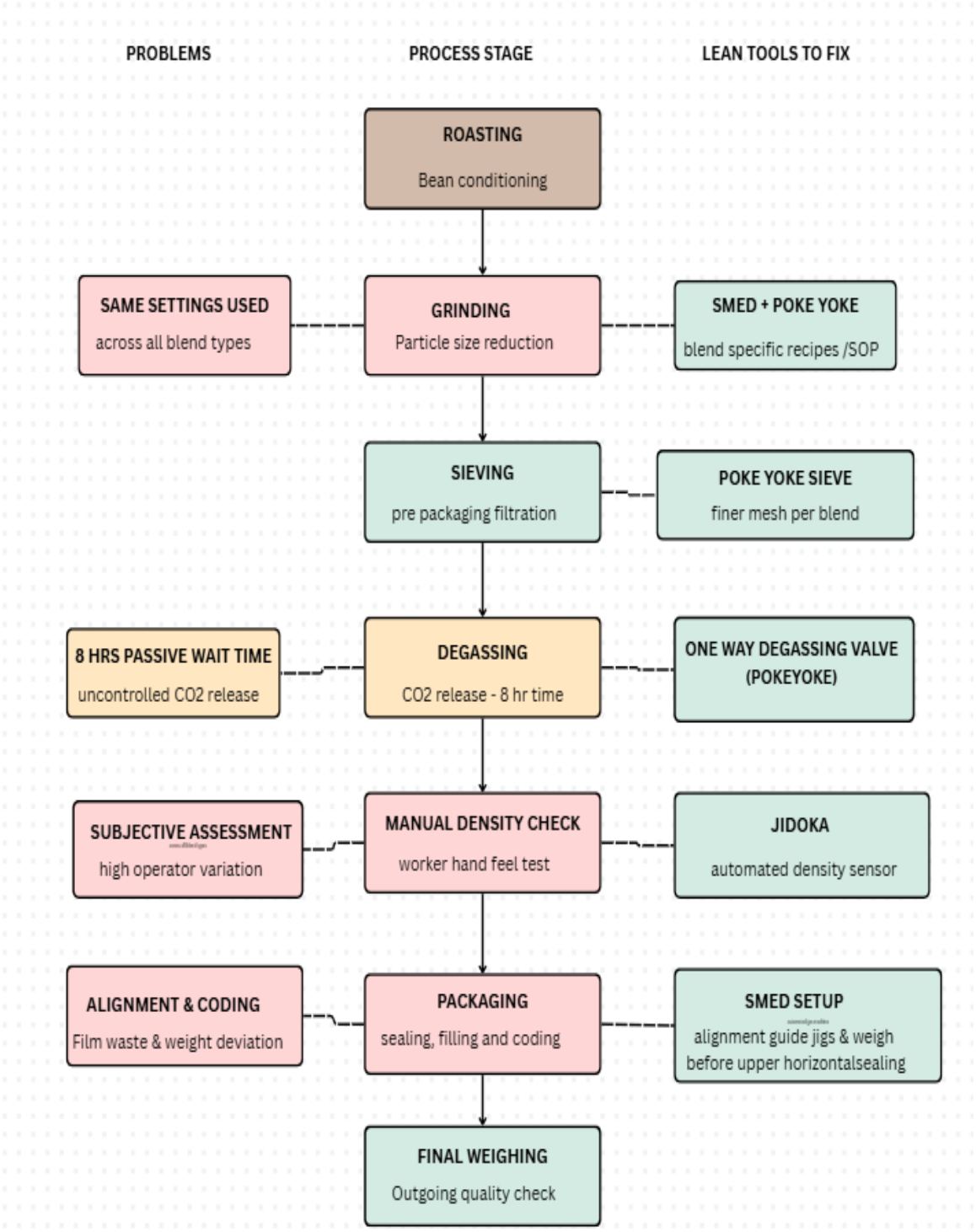
ROOT CAUSE ANALYSIS



Fish bone diagram

IMPROVE PHASE

Lean tools that can be applied to improve process efficiency in each step



Lean tools applied to each process steps

CONTROL PHASE

The Control phase aims to maintain the improvements achieved through Lean Six Sigma initiatives by standardizing processes, monitoring performance, and establishing regular review procedures. This ensures that identified inefficiencies and quality issues do not reoccur over time.

Control Measures for Grinding Process

To maintain consistent granularity and reduce variation, the following controls are recommended:

- Develop and implement blend-specific Standard Operating Procedures (SOPs) for grinder settings.
- Display grinder parameter charts and recipe cards at the grinding station.
- Conduct periodic calibration and verification of grinder settings.
- Perform routine inspection and maintenance of Poka-Yoke sieves.
- Monitor particle size distribution through scheduled quality checks.
- Document any deviations and record corrective actions taken.

Control Measures for Bulk Density Testing

To ensure uniform bulk density measurements:

- Establish a standardized sampling frequency for each production batch.
- Maintain a calibration schedule for automated bulk density testing equipment. - Record density measurements digitally for traceability.
- Take immediate corrective actions when measurements fall outside specified limits.

Control Measures for Degassing Process

- Verify package integrity through leak tests and seal inspections of valves.
- Continuously monitor packaging throughput and overall process performance.

Control Measures for Packaging Process

To uphold packaging quality improvements:

- Perform daily inspections of alignment guides and film tracking mechanisms.
- Verify package weight before final sealing.
- Carry out periodic testing of seal strength.
- Standardize machine setup procedures for different product variants.
- Monitor and record packaging defects.
- Implement visual management tools to support operator performance.

Continuous Improvement Plan

- Review key performance indicators (KPIs) monthly.
- Conduct Periodic Lean audits and Gemba walks.

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- Provide ongoing employee training and awareness programs.
- Analyze Process Cycle Efficiency (PCE) and lead time performance regularly.
- Identify and eliminate waste continuously through Kaizen activities.

Analysis and Discussion

Process data (Measure phase)

Stage	Process time (min)	Waiting time (min)	Lead time (min)	PCE
Curing	51.395	35	86.395	59.5%
Roasting	80	23	103	77.7%
Grinding and degassing	5	480	485	1.03%
Packaging	22	15	37	59.5%

OVERALL PROCESS SUMMARY

Total Process Time	Total PT = 51.395+80+5+22 = 158.395 mins
Total Waiting Time	Total WT = 35+23+480+15 = 553 mins
Overall Lead Time	Total Lead Time = 158.395+553 = 711.395 mins
Overall Process Cycle Efficiency	Overall PCE = 158.395 / 711.395×100 **= 22.3%**
Overall PCE (including transportation time = 15+5+8+7)	Overall PCE = 158.395 / 746.395*100 **= 21.2 %**

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TAKT TIME CALCULATION

Customer demand = 10 tonnes/day
Available production time = 9 hrs/day = 540 mins

Takt Time = 540 mins /10 tonnes

=54 mins

WASTE IDENTIFICATION

ROASTING UNIT - WASTE IDENTIFICATION

S.No	Process/Area	Waste Type	Observation	Measurement	Impact
1	**Inter-unit Transfer**	**Transportation**	Forklift movement between roasting and grinding	100 metres	Increased transport waste
2	**Loading**	**NNVA (repeated - muri)**	Loading into roasting equipment	------	Additional handling activity
3	**Roasting**	**Waiting**	waiting for load	5 mins	Material idle time
4	**Cooling**	**Waiting / NNVA**	Cooling required before blending	20 mins	Increased lead time
5	**Roasting → Cooling**	**Waiting**	queue/wait	8 mins	Delayed downstream flow
6	**Blending**	**Bottleneck**	Highest roasting unit CT	30 mins	Restriction in throughput
		Waiting	waiting before blending	10 mins	Inventory buildup

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7	**Post-Roasting WIP**	**Inventory**	stored before grinding	5 tonnes	Excess inventory holding

GRINDING UNIT - WASTE IDENTIFICATION

S.No	Process/Area	Waste Type	Observation	Measurement	Impact
1	**Inter-unit Transfer**	**Transportation**	Manual transport using trolleys	100 metres	Increased transport waste
2	**Grinding**	**Motion**	Repetitive feeding and handling of 40 kg sacks	2.7 metres for one sack	Operator fatigue
3	**Bulk Density Check**	**Motion/ Process variability (defect)/**Repetitive	Manual sampling/checking process	Frequent deviation from granularity specification limit	Extra operator movement
4	**Degassing**	**Waiting**	480 min residence time	**480 mins (BOTTLENECK)**	Major contributor to lead time
		Inventory	5 tonnes WIP held during degassing	5 TONNES	Excess inventory accumulation
		NNVA	Necessary holding stage before packing		Increased total lead time

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SUMMARY OF CRITICAL WASTES IDENTIFIED

Waste Type	Frequency	Major Area
Waiting	High	Degassing, Colour Sorting
Transportation	High	Inter-unit movement
Motion	Medium	Packing, Grinding
Inventory	High	Post-roasting storage
Defects	Medium	Packing section

Quality analysis (Analyse phase)

Item	Value (from report)
QA defects (total)	55
Granularity defects	22 (40% of QA defects)
Packaging defects (1,660 packets)	48 (weight 18, alignment 15, coding 8, sealing 4, other 3)
Packaging DPMO	5,783
Sigma level	4.0

GRINDING STAGE SETTINGS

BLENDS	RPM	GRIND SIZE
Premium blend	1800	500 – 600 µm
N. Spl	1800	500 – 600 µm
Royal extra bold	1800	500 – 600 µm

GROUND POWDER DISCHARGE OUTLET DIMENSION – 24.4 cm * 21 cm

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QA Defect Category	Frequency	Calculation	Individual %	Cumulative %
Granularity	22	0.4	40.0%	40.0%
Density/sorting failure	14	0.25	25.5%	65.5%
Bean quality	9	0.163	16.3%	81.8%
Roast bean colour	6	0.109	10.9%	92.7%
Cup profile	4	0.07	7.3%	100.00%

Total Observations : 55

Individual Frequency Percentage:
Percentage =(Category Frequency/Total Observations) * 100

Granularity defects/ Particle Size Distribution (PSD) deviation contributes 40% to the total QA defects

PACKAGING UNIT

Packaging defects Category	***Frequency***	**Calculation**	**Individual %**	**Cumulative %**
Weight Deviation	*18*	0.375	37.50%	37.50%
Alignment	*15*	0.3125	31.30%	68.80%
Coding	*8*	0.166666667	16.70%	85.50%
Sealing	*4*	0.083333333	8.30%	93.80%
Other	*3*	0.0625	6.20%	100.00%

DPMO CALCULATION FOR PACKAGING UNIT

15 defects are caused due to alignment errors out of 1660 units (packets)

18 defects are caused due to weight deviation out of 1660 units (packets)

$$\text{DPMO} = \frac{\text{Total Defects} \times 10,00,000}{\text{No. of units} \times \text{No. of opportunities/unit}}$$

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DPMO calculation before implementation (all defects)

Total defects = 15 + 18 + 8 + 4 + 3 = **48 defects**

Units = 1660

Opportunities per unit = 5

$$DPMO = \frac{48 \times 1{,}000{,}000}{1660 \times 5}$$

DPMO = **5,783.133**

Sigma level ≈ 4.0

Projected improvements (Improve phase)

Based on the process observations and available quality information, several Lean Six Sigma countermeasures are proposed to address the identified improvement opportunities. These include blend-specific grinding standardisation, Poka-Yoke sieves, a review of the degassing method, packaging-film alignment guides and in-line weight verification.

The proposed measures are intended to address potential sources of process variation, waiting and defects. The future-state calculations presented in this study are illustrative scenarios based on stated assumptions rather than measured post-implementation results. Their technical feasibility, operational impact and financial benefits require further evaluation before implementation. Accordingly, the proposed improvements are recommendations for future testing and are not presented as demonstrated performance gains.

POKE YOKE one-way valve for Degassing

Coffee continues to release CO2. If a bag were hermetically sealed without a release mechanism, the "error" of bag swelling or bursting would inevitably occur. The one-way valve acts as a passive, fail-safe mechanism that allows CO2 to escape while preventing oxygen from entering. This ensures the physical integrity of the package, preventing the defect of package failure during transit or storage. A one-way valve changes the open-air waiting stage to an in-package curing stage

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One-way degassing valve

Total PT = 5 mins

Total WT = 20 mins

Lead Time

Lead Time = 5+20
= 25 mins

Process Cycle Efficiency

PCE = 5 / 25 ×100
= 20 %

LEAD TIME REDUCTION = 480 – 25 / 480 x 100

= 94.7 %

- The process cycle efficiency of grinding unit is projected to increase from 1.03 % to **20 %** with reduction in lead time by **94.7 %** (480 mins to 25 mins)

IMPROVEMENT

20 / 1.03 = 19.4

The grinding unit becomes approximately **19 times** more efficient in terms of PCE

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The proposed system can also be integrated with existing Nichrome VFFS (Vertical Form Fill Seal) packaging equipment with minor modifications, reducing implementation complexity and capital expenditure.

POKE YOKE Sieves for granularity control

A Poka-Yoke (error-proofing) sieve system is proposed for installation at the grinder discharge outlet to automatically filter oversized coffee particles before they proceed to the next processing stage. The sieve serves as a physical control that prevents particles outside the specified size from moving downstream.

Working Principle

Ground coffee exits the grinder.

Coffee passes through a fixed mesh sieve mounted below the grinder outlet.

Particles meeting the required size pass through the sieve.

Oversized particles are retained and redirected for regrinding.

Only acceptable granularity proceeds to bulk density testing and packaging.

Proposed Sieve Specification

The sieve frame should be designed to fit the existing grinder discharge outlet dimensions (24.4 cm * 21 cm)

Recommended mesh ranges for different blend categories are:

Coffee blend category	Recommended mesh size	Property
Premium blend	25- 30 mesh	Coarser grind
N. Spl blend	30-35 mesh	Medium grind
Royal extra bold	40-45 mesh	Finer grind

Mesh – Number of holes per inch (app.)

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Poke yoke sieves

Current state

From pareto analysis

Granularity defects = 22

Total quality defects = 55

Contribution to total defects = 40 %

Granularity is the largest quality issue contributing to 40 % of all QA defects

Future state (After implementation of the poke yoke sieve)

Assuming 60 % reduction in granularity defects

Granularity defects = 8 (reduced by **63.64 %)**

Contribution to total QA defects = **19.5 %**

The Poka-Yoke sieve system is projected to reduce granularity-related defects from 22 occurrences to 8 occurrences. This represents a **63.64% reduction in particle size distribution (PSD) deviations**. The contribution of granularity defects to total quality deviations is expected to decrease from **40% to 19.5%**

SMED-Based Standard Operating Procedure (SOP) for Blend Changeover & grinding parameter standardization

To reduce setup variation and changeover time, a standardized operating procedure (SOP) based on SMED principles is proposed. This SOP includes predefined grinder settings, blend-specific recipe cards, and visual controls that allow operators to switch between coffee blends quickly without repeated trial-and-error adjustments. The standardization aims to shorten setup time, limit process variation, and enhance grinding consistency, which reduces granularity deviations and improves overall product quality.

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VMS

Blend-specific grinding parameter chart displayed near the grinder.

Colour-coded blend identification and recipe card system. (VMS)

SOP for predefined grinder RPM and calibration settings.

Standardised changeover procedure to reduce setup time.

Current state setup time for grinding machine - 20 mins

Future state after applying SMED - < 10 mins

Annual hours saved = $\frac{\text{10 mins saved x 1setup/day x 312 days/year}}{60}$

= 52 hours / year

Annual capacity reclaimed

Save 1 hour per week (10 mins x 6days) and 52 hours / year, which increases daily available grinding capacity to 1.85 %

Time taken to grind 1 tonne of roast coffee beans = 2 hours

i.e. 8.3 kg of roast coffee bean can be grinded in 1min

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83.3 kg in 10 mins, 0.5 tonnes in an hour and 26 tonnes in 52 hours

By implementing SMED and standardizing it via an SOP, the facility's output will be scaled up by **26 tonnes of coffee a year** purely by eliminating 10 minutes of machine setup waste each day and saving **52 hours** annually

Packaging Process Improvement Using Poka-Yoke and Jidoka

Alignment Jig for Film Positioning (Poka-Yoke)

An alignment jig is proposed for film positioning within the packaging machine to reduce film waste and sealing defects. Acting as a Poke-Yoke mechanism, the jig guides the film along a fixed path and prevents lateral movement during operations.



Film alignment guide

In-Line Weight Verification Before Final Sealing (Jidoka)

An in-line weighing verification system is proposed to reduce weight variation defects before the final sealing stage. This system automatically measures package weight after filling and prior to sealing.

Working Principle

Coffee powder is filled into the pouch, which then passes through an electronic weighing station.

The package weight is compared to predefined specifications, allowing identification of non-conforming packages before sealing.

Only packages meeting the criteria proceed to final sealing.

Lean Principle Applied

Jidoka (Automation with Built-in Quality)

The weighing system automatically detects deviations and prevents defective packages from progressing to downstream operations.

DPMO CALCULATION FOR PACKAGING UNIT

15 defects are caused due to alignment errors out of 1660 units (packets)

18 defects are caused due to weight deviation out of 1660 units (packets)

$$DPMO = \frac{\text{Total Defects} \times 10,00,000}{\text{No. of units} \times \text{No. of opportunities/unit}}$$

After Implementation (50% reduction in alignment + weight)

Reduced alignment defects = 8

Reduced weight defects = 9

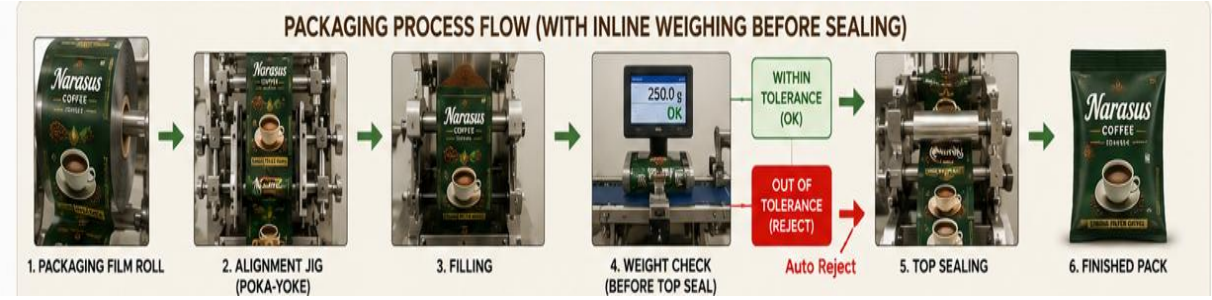
Total defects after = 8 + 9 + 8 + 4 + 3 = **32 defects**

$$DPMO = \frac{32 \times 1,000,000}{1660 \times 5}$$

DPMO = **3855.422**

Sigma level ≈ 4.2

Proposed Poka-Yoke and Jidoka improvements are projected to reduce total packaging defects from 48 to 32 per 1,660 packets, lower DPMO by **33.3%** (from 5,783 to 3,855), and increase the sigma level from **4.0 to 4.2**



Packaging process flow with inline weighing before sealing

Improvement	Projected result (from report)
Degassing valve (one-way)	Stage lead time 480 to 25 min; overall lead time about 251 min; grinding PCE 1.03% to 20%
Poka-Yoke sieves	Granularity defects 22 to 8 (63.6% reduction)
SMED blend changeover SOP	Grinder setup 20 to under 10 min; about 52 hours and 26 tonnes capacity per year
Alignment jig and in-line weighing	Packaging defects 48 to 32; sigma 4.0 to 4.2

Cost-benefit analysis

Proposed Improvement	Lean Tool Applied	Estimated Cost (INR)	Expected Benefits
Blend-Specific SOP and Recipe Cards	SMED	₹2,000 – ₹5,000	26 tonnes of extra annual production, potential revenue increase via capacity optimization
Blend-Specific Poka-Yoke Sieves	Poka-Yoke	₹5,000 – ₹15,000	79.5 % reduction in annual rework costs (From Rs. 10L to Rs. 2.05L)
Alignment Jig for Packaging Film	Poka-Yoke	₹5,500 – ₹12,000	Considering 2 g overfill, 0.002 kg × 100,000 bags = 200kg of coffee saved. If coffee costs ₹950/kg, that is ₹1,90,000 saved annually
In-Line Weight Verification Before Sealing	Jidoka	₹25,000 – ₹50,000	

Conclusion and Scope for Further Study

This study examined operational inefficiencies and quality-related issues in the coffee production process at Sri Narasu's Coffee Company Private Limited, Salem, using Lean Six Sigma concepts and the DMAIC framework. Based on observations made during a summer internship and the analysis of available company information, the study used process mapping, process-time analysis, waste

identification and quality-defect analysis to identify potential areas for improvement across curing, roasting, grinding, degassing and packaging.

The available process-time summary indicates a total processing time of 158.395 minutes, waiting time of 553 minutes and estimated lead time of 711.395 minutes, corresponding to a process cycle efficiency of approximately 22.3%, subject to confirmation of the process scope and treatment of transportation time. The available quality data identify granularity variation, density/sorting failures, weight deviation and film alignment as issues warranting further investigation. These findings suggest opportunities to examine waiting, process variation and packaging accuracy more systematically.

Based on the analysis, the study proposes several countermeasures, including blend-specific grinding standardisation, Poka-Yoke sieves, a review of the degassing method, packaging-film alignment guides and in-line weight verification. These recommendations are intended to address the operational issues identified during the study. However, the proposed interventions were not implemented as part of the internship study, and their effects on lead time, defect rates, capacity and cost have therefore not been empirically established. Any projected improvements should be interpreted as conditional scenarios requiring further evaluation.

The study demonstrates how Lean Six Sigma concepts can be applied in an internship-based observational case study to structure process analysis and identify potential improvement opportunities in coffee manufacturing. Its findings are specific to the process examined and are subject to limitations arising from the observational approach, the availability of company data and the assumptions used in future-state calculations

Future work could extend the present study in the following areas:

Implementation and validation: Pilot the proposed interventions and compare measured process times, lead time, process cycle efficiency and defect rates with a documented baseline.

Statistical process analysis: Collect repeated observations across production cycles and use suitable statistical process control and capability methods where the data and measurement system permit.

Cost-benefit evaluation: Obtain verified implementation and operating costs and evaluate actual savings, capacity utilisation and return on investment.

Grinding and product quality: Evaluate blend-specific grinding parameters and sieve specifications against established product-quality requirements.

Degassing process evaluation: Assess alternative degassing arrangements under appropriate technical and product-quality requirements before establishing revised residence times.

Inventory and material flow: Extend the analysis to work-in-progress, transportation and storage to investigate additional opportunities for reducing non-value-added time.

Future studies supported by documented measurements and post-implementation data would help establish the effectiveness and financial viability of the proposed improvements. Such work could also provide a stronger empirical basis for assessing the application of Lean Six Sigma in coffee and other food-processing operations.

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