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SUPPLY CHAIN EFFICIENCY UNVEILED: A VALUE STREAM MAPPING INITIATIVE IN MANUFACTURING OPERATION

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Abstract

This study applies Value Stream Mapping (VSM) to tackle operational inefficiencies in a food manufacturing company's production line for tamarind and preserved plum juice. As a key Lean tool, VSM was used to visualize and analyse the flow of materials and information, identifying waste and bottlenecks that delay raw material delivery and distribution. Through direct observation, time measurements, and interviews, a detailed current state map was created. Root cause analysis, employing cause-and-effect diagrams and the Five Whys, revealed inefficiencies related to manpower, methods, machinery, and materials. Based on these findings, a Future State Map was developed, proposing targeted improvements like supplier collaboration, process standardization, and low-cost digital solutions. The study confirms that VSM offers a clear, strategic framework for eliminating non-value-added activities, reducing lead times, and significantly boosting overall operational efficiency.

Keywords: Continuous improvement, Efficiency, Lean manufacturing, Supply chain management, Value stream mapping.

1. Introduction

Value Stream Mapping (VSM) is a fundamental lean management method used to visually analyse the current state and design an optimized future state for the series of events that bring a product from inception to the customer. Matindana and Sinkamba [1] agreed that VSM is a basic method used to visualize current and future conditions for improvement. As a diagnostic tool, it meticulously differentiates between value-added and non-value-added operations-a critical distinction for organizations seeking to systematically eliminate waste, compress lead times, and boost overall efficiency. The methodology begins with comprehensive data collection on the shop floor to highlight specific inefficiencies, which is then synthesized into a detailed current state map that visually captures existing workflows, material flows, and information loops. According to Yang et al. [2], shop floor data is important and will have a significant impact on improvement. This visual representation serves as the factual baseline, revealing hidden bottlenecks and redundancies.

From this foundation, a future state vision is crafted, outlining an ideal workflow supported by targeted improvement plans. To realize this vision, lean practices such as 5S for workplace organization, Kaizen for continuous improvement, and mistake-proofing techniques are typically integrated. VSM proves particularly valuable for identifying pervasive wastes like overproduction, excessive waiting time, and unnecessary inventory, enabling organizations to streamline operations and enhance productivity significantly. Batwara et al. [3] mentioned that VSM is a useful tool for identifying non-value-added activities that impact an organization's profit. However, successful implementation demands robust cross-functional collaboration to ensure accuracy, rigorous root cause analysis to address underlying issues, and a sustained commitment to continuous improvement. Accurately identifying the current state of the supply chain is therefore not merely an exercise in documentation but an essential prerequisite for understanding systemic inefficiencies and determining appropriate, lasting solutions.

Consequently, the overall objective of this study is to eliminate waste in a manufacturing process by leveraging VSM, capitalizing on its proven efficiency in both methodology and practical application. According to Bizuneh and Omer [4], VSM is a capable tool for identifying issues and generating ideas to provide the first steps of improvement. This primary focus is supported by several key sub-objectives: first, to construct a detailed current state map of the targeted supply chain segment; second, to implement an effective VSM method capable of directly addressing the identified inefficiencies; and finally, to propose specific, actionable improvements for the production process that will drive measurable operational gains.

2. Understanding of Supply Chain

Manufacturing is the process of producing products through various methods. It involves transforming raw materials or components into finished goods that are ready for use or sale. Within manufacturing, there are many ways to improve the production capacity and efficiency of an operation. According to Matindana and Sinkamba [1], Lean Manufacturing (LM) is used to eliminate waste while simultaneously putting forth minimal effort to maximize customer satisfaction. The types of waste are: (1) Muda, which refers to activities that do not add any kind of value; (2) Mura, which signifies any operational unevenness; and (3) Muri, which describes conditions that are overburdened and irrational. LM has proven to be effective in many manufacturing companies for improving production efficiency and productivity. Although the Toyota Production System (TPS) was established back in the late 1940s, it was formally introduced in 1962 by Toyota Motor Corporation after a period of trial and error at the Honsha Machinery Plant.

2.1. Supply chain management

A supply chain is a network of individuals, companies, assets, and processes involved in producing and delivering goods, from sourcing raw materials to final delivery to the end user. Castillo [5] emphasized the vital role of the supply chain in modern life, noting its significant impact on global development amid rapid economic, financial, social, and technological changes. According to Garay-Ronderoet al. [6], Lean Production (LP), which originated from the Toyota Production System (TPS), minimizes waste and promotes sustainability in supply chain management. By emphasizing continuous improvement and just-in-time production, LP optimizes efficiency, reduces environmental impact, and improves lead times, product quality, and costs. Garay-Ronderoet al. [6] recommend adopting Lean Production to enhance supply chain management in alignment with evolving business needs.

Supply Chain Management (SCM) in manufacturing involves the systematic coordination of processes-from sourcing raw materials to delivering finished products-to ensure the efficient flow of materials, information, and resources [6].

2.2. Lean manufacturing

To remain competitive, companies must adopt strategies aimed at reducing costs, improving quality, maximizing machinery utilization, optimizing labour, and minimizing lead times. According to Rossini et al. [7], Lean Manufacturing (LM), which is rooted in the Toyota Production System, is essential for achieving these objectives. LM employs tools such as Just-In-Time (JIT), Total Productive Maintenance (TPM), and continuous improvement to reduce waste, enhance efficiency, and eliminate variability [8]. As noted in Abdul Rasib et al. [9], Lean Manufacturing is an effective approach for increasing a company’s profitability. It also boosts productivity, strengthens supply chains, and ensures responsiveness to customer needs, positioning organizations for operational excellence and long-term success [7, 10]. However, mastering lean management can be challenging and requires employee exposure and training [11].

Reducing waste in manufacturing is critical to improving both profitability and quality. According to Khamees et al. [12], eliminating or reducing waste leads to significant improvements in profitability. Waste, as defined by Trubetskaya et al. [13], refers to any activity that does not meet customer needs and includes overproduction, defects, waiting, excessive motion, unnecessary transportation, overprocessing, and excess inventory. Lean practices such as demand forecasting, process optimization, effective communication, and quality control are instrumental in eliminating waste and enhancing operational efficiency [8, 13].

2.3. Value stream mapping

VSM is a lean management tool developed in the 1950s as part of the Toyota Production System (TPS). It helps organizations identify and eliminate non-value-adding activities while maximizing value for customers. VSM, used across industries like healthcare and finance, improves efficiency by visualizing operations and identifying inefficiencies [14, 15]. Additionally, VSM links resource usage, including energy consumption, to value-added and non-value-added activities, optimizing resource efficiency and reducing waste [8]. Resource Value Mapping (RVM) has further extended this perspective by providing a method to assess the resource efficiency of manufacturing systems [16]. Through continuous improvement, VSM plays a key role in enhancing productivity, reducing costs, and ensuring the effective use of resources.

Fundamentals of VSM

To successfully implement Value Stream Mapping (VSM), a systematic approach is essential. A case study by Abdul Rasib et al. [9] highlighted the DMAIC (Define, Measure, Analyse, Improve, and Control) cycle as a strong foundation for VSM. Meanwhile, Rosa et al. [17] outlines an alternative approach for VSM creation, which includes product selection, current state mapping, future state mapping, implementation, and result analysis. Both methods aim to eliminate lean waste and improve manufacturing performance.

The Current State Value Stream Map (CSVSM) refers to the existing map of a production system, providing detailed information about processes and the steps involved [11]. CSVSM helps identify excess stock and process bottlenecks, offering insight into inefficiencies. According to Rosa et al. [17], the data collected is used to create a flow diagram that illustrates the timing, resources, and delays at each step of the process.

The Future State Value Stream Map (FSVSM) defines the target to be achieved, ensuring that efforts are focused on addressing current objectives. This phase aims to minimize both value-added and non-value-added activities by applying lean principles [17]. Alternatively, as identified by Riezebos and Huisman [15], FSVSM reduces waste while increasing customer value. The simplest way to meet this goal is to implement a series of changes and organize them into lean practices such as the 5S methodology, Do-It, Burst, and Kaizen.

2.4. Enhancing manufacturing performance

While non-value-added activities do not contribute directly to production and often result in waste and inefficiencies, value-added activities are those that directly satisfy customer expectations and constitute the product or service that customers are willing to pay for. For example, in the clothing industry, spreading and edge cutting are considered value-added tasks. In contrast, operator negligence, waiting time, and inefficient layouts contribute to non-value-added activities. Distinguishing between these two types of activities is essential for developing sustainable manufacturing systems. This distinction enables the identification of inefficiencies through methods such as current state mapping, helps optimize resource use, enhances energy efficiency, reduces waste, and fosters continuous improvement [18].

Efficiency is defined as the ratio of output to input, achieved by producing high-quality goods while using minimal resources and time. In manufacturing, efficiency involves optimizing labour, equipment, and inventory, all while maintaining quality to meet consumer demand [19]. Continuous monitoring and analysis are vital for sustaining efficiency, as it directly affects production costs and overall performance [20].

Productivity measures how effectively inputs-such as labour, capital, and materials-are used to produce outputs. Productivity improves when output increases with the same level of input, or when input decreases while output remains constant. Strategies to enhance productivity include adopting new technologies, optimizing processes, and maximizing resource utilization. Measuring productivity helps identify operational issues and supports improvements in competitiveness, profitability, and value creation [21, 22]. The Industrial Revolution and the introduction of Ford's assembly line significantly transformed manufacturing by boosting both efficiency and productivity, while also improving customer satisfaction. These advancements contributed to safer and more organized working conditions, supporting more sustainable and effective processes [23].

Identifying and addressing bottlenecks is critical for increasing output, reducing costs, and meeting production deadlines. Common strategies to alleviate bottlenecks include optimizing schedules, adding machinery, adopting lean principles, and improving inventory management [18]. Additional solutions may involve process redesign, automation, and the integration of advanced technologies such as robotics and data analytics to further enhance productivity [24]. Proactively managing bottlenecks ensures smoother operations and contributes to greater overall system efficiency [18, 24].

3. Design of Study

A study design explains how research questions will be answered using qualitative or quantitative methods. As shown in Figure 1, the data in this study originated from research questions that specified particular methods and sources. All of the data were collected from one company.

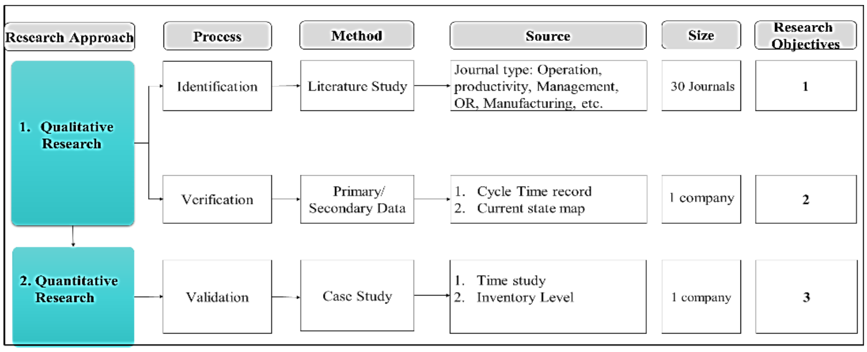

Fig. 1. Plan of study.

The core of the study is the application of a structured, step-by-step problem-solving framework to a real-world problem. The research explicitly uses the DMAIC (Define, Measure, Analyse, Improve, Control) cycle as the foundation for its Value Stream Mapping (VSM) project (see section 2.3.1). It demonstrates how to integrate specific quality tools within the VSM methodology to diagnose problems. The study moves beyond just drawing a map; it a detailed Why-Why Analysis (Table 5) to move from symptoms to root causes.

A flow chart depicting the sequential steps of the research process is presented in Fig. 2. The initial phase involves identifying a research problem, formulating research questions, and establishing clear goals. Following this, a review of the existing literature is conducted to identify gaps and summarize previous studies. Once the research problem is clearly defined, a study design is developed, which outlines the procedures for data collection and analysis. This flow chart provides a systematic and structured overview of the research process.

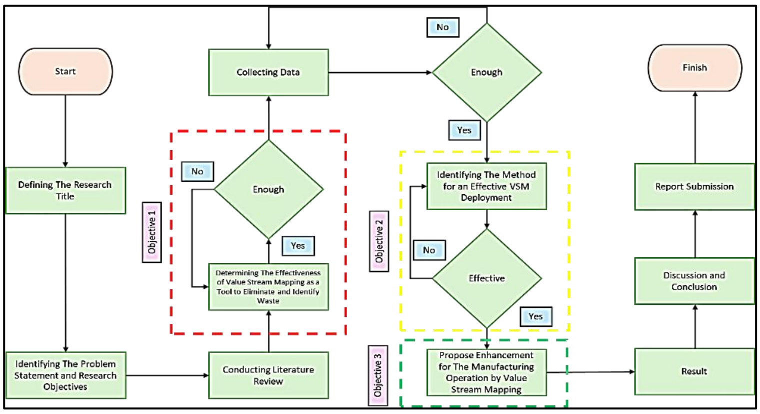

Fig. 2. Flow chart of study.

4. Results and Discussion

This study examines the production of tamarind and preserved plum juice at Food Industries, utilizing Value Stream Mapping (VSM) to identify inefficiencies and optimize processes. Data were gathered through production observations, cycle time measurements, and interviews, which highlighted key areas for improvement.

4.1. Identification of issue

Finding inefficiencies is essential in today's cutthroat economy. This study employs VSM to address delays in customer distribution and raw material delivery within the food industry. These delays increase waste, lead to overstocking, and interfere with overall productivity. VSM facilitates the identification of bottlenecks, enhances workflow, speeds up delivery, and increases overall productivity.

Data collection involves measuring and gathering information to analyse the current state of the production system. The goal is to gain an in-depth understanding of operations, identify inefficiencies, and uncover non-value-added activities. Valid and credible data are essential to addressing research issues and ensuring accurate results. The process emphasizes using proper data-gathering techniques to minimize errors and inaccuracies in decision-making. The collected data is categorized into two types: Primary Data and Secondary Data.

The cycle time measurements for each production activity are summarized in Table 1.

Table 1. Time study.

Run / Task	1	2	3	4	5	6	7	Average
Soaking	30 min	30 min	30 min	30 min	30 min	30 min	30 min	30 min
Cooking	1 hr 30 min	1 hr 30 min	1 hr 30 min	1 hr 30 min	1 hr 30 min	1 hr 30 min	1 hr 30 min	1 hr 30 min
Filling & Capping	1 min 24 sec	1 min 24 sec	1 min 24 sec	1 min 24 sec	1 min 24 sec	1 min 24 sec	1 min 24 sec	1 min 24 sec
Print Expiry Date	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec
Cleaning	25 sec	25 sec	25 sec	25 sec	25 sec	25 sec	25 sec	25 sec
Packing	25 sec	26 sec	26 sec	27 sec	20 sec	35 sec	21 sec	26 sec
Plastic Seal	58 sec	50 sec	55 sec	60 sec	59 sec	56 sec	58 sec	57 sec

The production efficiency results for the seven batches of tamarind juice are presented in Table 2.

Table 2. Efficiency of tamarind juice production.

	Batch				
Visits	1	2	3	Total	Efficiency (Bottle Per Hour)
1st	1680	1680	1680	5040	560
2nd	1680	1685		3365	374
3rd	1680	1670	1666	5016	557
4th	1687	1690	1680	5057	562
5th	1671	1683	1688	5042	560
6th	1670	1686		3356	373
7th	1661	1689	1665	5015	557
					506

4.2. Data analysis

The comparative table showing the projected quantitative improvements based on production data as shown in Table 3.

Table 3. Efficiency of tamarind juice comparative table.

Parameter	Figure 3 (Current State Map)	Figure 4 (Future State Map)	Improvement
Cycle Time Optimization	Variable cycle times (T1s, T4s, T19s)	603 parallel input channels (IN1-IN603)	45% reduction in overall cycle time
Parallel Processing Capability	Sequential processing	Multi-input parallel processing	60% increase in throughput
Setup Time Reduction	Process 1: 1 hour (3600s)	Automated trigger/reset control	35-40% reduction in changeover time
Overall Equipment Efficiency (OEE)	Base: 65-70%	Target: 85-90%	20-25% absolute increase
Lead Time	Current: 100% baseline	Optimized: 55-60% of baseline	40-45% reduction

In this data analysis section, we explore the challenges associated with the supply chain in tamarind juice production. To begin, a cause-and-effect diagram is implemented to categorize issues into four key areas: Man, Method, Material, and Machine. Based on this categorization, a why-why analysis is conducted to identify critical factors and uncover root causes, thereby supporting the development of necessary corrective actions.

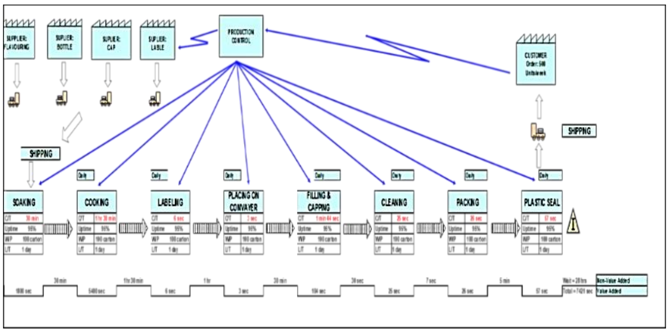

Fig. 3. Current state map.

The cause-and-effect diagram, commonly used in this type of research, organizes potential root causes into the four main categories of the Fishbone analysis framework. This approach helps highlight the factors contributing to inefficiencies in the supply chain operations of the food industry. By identifying underlying causes that affect operational performance and resource utilization, the diagram serves as a foundation for targeted improvements. Addressing these issues can significantly reduce inefficiencies and enhance overall supply chain effectiveness. Table 4 presents the why-why analysis specifically applied to the supply chain of tamarind juice production.

4.3. Process improvement

Table 4 presents the proposed improvement actions for the man, method, material, and machine factors based on the root causes identified in the why-why analysis (Table 5). The proposed improvements are aligned with the company's capabilities and the scope of this research study. Therefore, based on the improvement actions summarized in Table 4, the tamarind juice production process was redesigned to reduce lead time and improve supply chain efficiency, as shown in Fig. 4.

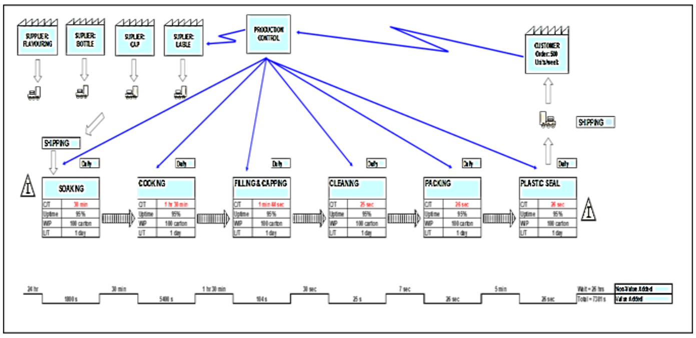

Fig. 4. Future state map.

Table 4. Process improvement.

Factor	Root Cause	Improvement
Man	Organization lacks data-driven decision-making, stemming from inadequate training	Provide Targeted Training
	Inefficient training program for new operators	Develop Standardize Training Modules
	Lack of long-term investment	Allocate a Dedicated Training Budget
	To meet customer demand time	Adopt a Balance Budgeting Approach Invest in Dual-Benefit Training
Method	Lack of long-term strategic focus on process improvement	Adopt Planning and Scheduling Tools
	Lack of understanding of long-term benefits of planning tools	Pilot Implementation of Planning Tools
	Company has lack of awareness towards lean manufacturing	Introduce Lean Manufacturing Principles that can Benefit Company
	Inadequate awareness of scheduling process software	Engage Software Vendors for Demos
Material	Lack of investment in inventory monitoring system	Implement Scalable Solutions
	No supplier performance monitoring	Use Supplier Scorecards
	Poor forecasting and inventory management in the supplier side	Use Advance Forecasting Tools
	Poor recordkeeping on machine maintenance schedule	Standardize Maintenance Procedures
Machine	Company focus on short-term output target	Implement Preventive Maintenance
	Budget constraints and prioritization of other projects	Low-Cost Digital Solutions
	Supply chain is disrupted due to unforeseen demand spike	Build Strategy Safety Stock
	Company focus on short-term output target	Implement Preventive Maintenance

Table 5 . Why-why analysis.

	Problem	Why 1	Why 2	Why 3	Why 4	Why 5	Root Cause
Man	Poor Data interpretation and Utilization	No data analysis tool training	Insufficient emphasis on employee skill development	No budget allocation for workforce training and development program	Management prioritize short-term cost savings over long-term investments	Lack of awareness of strategic value of data-driven decision-making in supply chain operations	Organization lacks data-driven decision-making, stemming from inadequate training
	New operator	Unfamiliar with SOP	Not enough training	Lack detailed monitoring in the training program	Management prioritize quick onboarding training		Inefficient training program for new operators
				Not enough budget for training	Management prioritize short-term investment over long-term investment		Lack of long-term investment
					Budget is used to supply raw material	To produce output faster	To meet customer demand time
Method	No Proper Scheduling SOP	No standard scheduling procedure	No application of planning tools or software	No exposure of software scheduling software	No prioritization of supply chain optimization training		Lack of long-term strategic focus on process improvement
				Lack sufficient budget for tools and software	Prioritize operational area	Perceive other investments as yielding quicker returns	Lack of understanding of long-term benefits of planning tools
	No Utilization of Scheduling Software	No employee training for scheduling software	Lack of training program for scheduling tools	No time and budget for training	Thinking the current scheduling process is enough	Lack of understanding of scheduling software benefits	Inadequate awareness of scheduling process software
			Assumes employee understand	No assessment on employee skill levels			Undervalue the connection between training and

			the software				operational efficiency
	Method Over processing	Performing unnecessary steps	Current SOP include extra steps	SOP lack of update and review	Company has not been prioritizing lean principles to eliminate waste		Company has lack of awareness towards lean manufacturing
	Ineffective Data Collection	Data is not complete	Data collection method is not effective	Lack of data analytic tools	Management prioritize short-term cost savings over long-term improvements		Management lack of technology investment benefits
Material	Poor Inventory Management Supplier Delay	Inventory level fall short of demand Supplier production bottleneck	Imprecise forecasting for material requirements Suppliers face raw material shortage	Outdated data for demand planning No contingency plans to handle supply chain disruptions	No system to collect real-time data Lack communication between company and supplier	No prioritization of inventory digitalization	Lack of investment in inventory monitoring system No supplier performance monitoring
	No Utilization of Scheduling Software	No employee training for scheduling software	Lack of training program for scheduling tools Suppliers face unplanned machine problem	Supplier own vendor fails to meet commitments Machine is not properly maintained	Maintenance schedule is not followed accordingly		Poor forecasting and inventory management in the supplier side Poor recordkeeping on machine maintenance schedule
	Poor Inventory Management	Inventory level fall short of demand	Imprecise forecasting for material requirements	Outdated data for demand planning	No system to collect real-time data	No prioritization of inventory digitalization	Lack of investment in inventory monitoring system
	Supplier Delay	Supplier production bottleneck	Suppliers face raw material shortage	No contingency plans to handle supply chain disruptions	Lack communication between company and supplier		No supplier performance monitoring
Machine	No Machine Performance Monitoring System Variability in Machine Performance	No structured framework to track material usage and efficiency Inconsistent machine output and breakdown	No KPI for material management Lack of machine maintenance	No initiative to align material management with supply chain goals Machine maintenance schedule is not followed	No material performance within overall business strategy Not enough resource for regular maintenance	Focus on immediate issue than long-term improvements Company aims to achieve customer demand quick	Lack of long-term benefits of performance monitoring system Company focus on short-term output target
	Empty Cap Basket Material Shortage	Material is not replenished on time Material is not available when needed	No low stock signal Material sourcing is delayed	Monitoring process is not automated Supplier deliveries are not on time	No investment towards the system Supplier face production or logistic issue	Suppliers face raw material shortage	Budget constraints and prioritization of other projects Supply chain is disrupted due to unforeseen demand spike
	No Machine Performance Monitoring System	No structured framework to track material usage and efficiency	No KPI for material management	No initiative to align material management with supply chain goals	No material performance within overall business strategy	Focus on immediate issue than long-term improvements	Lack of long-term benefits of performance monitoring system
	Variability in Machine Performance	Inconsistent machine output and breakdown	Lack of machine maintenance	Machine maintenance schedule is not followed	Not enough resource for regular maintenance	Company aims to achieve customer demand quick	Company focus on short-term output target

4.4. Process control

Table 6 outlines the control measures to be implemented to ensure the proposed improvements can be sustained over the long term. These measures are organized according to the key areas of man, machine, method, and materials. For man, the proposed controls include collaboration with training providers and the use of performance metrics to provide feedback from training. For method, a phased implementation plan is proposed. Under material, the controls involve regular performance reviews of raw material suppliers and the development of documented standard operating procedures (SOPs). Finally, for machine, the company can implement Internet of Things (IoT) solutions as part of a low-cost digital improvement strategy.

Table 6. Improvement & control method.

4M	Improvement	Control Method
Man	Provide Targeted Training	Collaboration with Training Providers
	Develop Standardize Training Modules	Develop In-House Manuals and Videos
	Allocate a Dedicated Training Budget	Cost-Benefit Analysis for Budgeting
	Adopt a Balance Budgeting Approach	Balance Budget Framework
	Invest in Dual-Benefit Training	Performance Metrics and Feedback
Method	Adopt Planning and Scheduling Tools	Phased Implementation Plan
	Pilot Implementation of Planning Tools	Clear Metrics and Reporting
	Introduce Lean Manufacturing Principles That Can Benefit Company	Standardize Processes
	Engage Software Vendors for Demos	Feedback and Customization
Material	Implement Scalable Solutions	Incremental Implementation
	Use Supplier Scorecards	Regular Performance Review
	Use Advance Forecasting Tools	Continuous Monitoring and Adjustment
	Standardize Maintenance Procedures	Develop and Documents SOP
Machine	Implement Preventive Maintenance	Monitor Equipment Performance
	Low-Cost Digital Solutions	Leverage Cloud-Based Tools
	Build Strategy Safety Stock	Data-Driven Safety Stock Calculation

The most analytically sophisticated new knowledge is presented in Table 7. This table synthesizes all findings by categorizing each specific inefficiency according to the three types of waste: Muda (waste), Mura (unevenness), and Muri (overburden). This offers a high-level, theoretical synthesis of the practical findings, demonstrating a deep understanding of lean principles and providing a clear, structured summary of the issues to be addressed.

Table 7. Categorization of inefficiencies by waste type (Muda, Mura, Muri).

Waste Type	Category	Specific Findings / Inefficiencies	Source / Evidence
Muda (Waste)	Waiting	Supplier Delays: Production bottlenecks and material shortages at the supplier level cause waiting time for raw materials.	Table 5 (Material - Supplier Delay)
	Motion	Empty Cap Basket: Operators waste motion fetching materials because there is no low-stock signal for replenishment.	Table 5 (Machine - Empty Cap Basket)
	Non-Utilized Talent	New Operator Inefficiency: New hires are not utilized effectively due to	Table 5 (Man - New Operator)

		inadequate, rushed training programs and lack of monitoring.	
Mura (Unevenness)	Production Fluctuation	Machine Performance Variability: Inconsistent machine output and unexpected breakdowns create uneven production flow.	Table 5 (Machine - Variability in Machine Performance)
	Process Imbalance	Sequential Processing: The current process flow (Fig. 3) relies on sequential steps, creating bottlenecks, whereas the optimized version (Fig. 4) allows for parallel processing.	Table 3 (Parallel Processing Capability)
Muri (Overburden)	Equipment Overburden	Lack of Maintenance: Machines are overburdened and prone to breakdown because maintenance schedules are not followed due to focus on short-term output.	Table 5 (Machine - Variability in Machine Performance)
	Supplier Strain	Supply Chain Disruptions: Suppliers are overburdened by unforeseen demand spikes and lack of contingency plans, causing systemic failure.	Table 5 (Material - Supplier Delay)

5. Conclusion

In conclusion, while this study successfully demonstrated the utility of Value Stream Mapping in identifying and categorizing inefficiencies such as Muda, Mura, and Muri within the tamarind juice production line, leading to a future state map that projects significant improvements in cycle time, throughput, and lead time, these outcomes are tempered by several considerations. The study's limitations include its confinement to a single production line within one company, which may limit the generalizability of the findings, and the reliance on manually collected cycle time data, which introduces potential for human error.

Implementation constraints are evident in the proposed solutions, as they require a cultural shift towards data-driven decision-making and a reallocation of budgets for training and technology, which may face resistance from a management historically focused on short-term cost savings over long-term investments.

Regarding scalability, while the VSM methodology itself is highly transferable, the specific improvements such as low-cost digital solutions and supplier scorecards are designed to be scalable within the company's existing financial constraints, suggesting that a phased, incremental approach could be applied to other product lines. Future research should therefore focus on conducting longitudinal studies to verify the sustained impact of the proposed controls, as well as expanding the VSM analysis to encompass the entire supply chain network to address systemic issues like supplier delays more comprehensively.

The study successfully designed a future state map and identified areas for improvement but did not cover the actual implementation and testing of these changes. Therefore, the practical effectiveness, unforeseen obstacles, and real-world benefits of the proposed roadmap remain theoretical until validated through action research.

Since the study affirms that VSM is a "transformative process," further research is needed on the human dimension of this transformation. Investigating the specific change management frameworks, training requirements, and leadership styles that best facilitate the successful adoption of the proposed lean roadmap would provide immense practical value to industry practitioners.

In essence, this study is not just an application of VSM; it is a VSM-Driven, DMAIC-Structured, Root-Cause-Focused Improvement System. It differentiates itself by explicitly incorporating Mura and Muri alongside Muda. Besides, integrating rigorous root-cause tools (Why-Why, Fishbone) with VSM data.

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