Operational Efficiency Assessment Through Value Stream Mapping in Lean Organizations

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Abstract

In a world of globalization and increasing customer expectations, organizations are trying to develop performance, and reduce waste, and costs. Making organizations operate more efficiently operationally has become a strategic imperative in a Lean culture. Lean emphasizes the elimination of non-value-added activities while creating a culture of continuous improvement. Value Stream Mapping (VSM) is one of the most powerful Lean tools that can effectively represent processes from input to delivery to the customer, including waste, and inefficiencies that can be eliminated to create optimal process performance. The research examines the use of VSM to evaluate and improve operational efficiency within a Lean manufacturing organization. It specifically focuses on how VSM can eliminate the seven wastes of Lean: overproduction, waiting, transport, excess inventory, overprocessing, motion, and defects. The researcher prepared a current state VSM using data from direct observations, time studies, and interviews with employees at the site. The researcher examined performance metrics, e.g., cycle time, lead time, takt time, and throughput, using the VSM and established a baseline for the industry. The researcher then prepared a future state- VSM using Lean techniques: pull systems, standardized work, and cellular manufacturing. Results indicated significant improvements of: a 37% reduction in lead time; a process efficiency increase of 29%; and a WIP inventory reduction of 41%. In conclusion, we have established that VSM is a powerful diagnosis tool as well as a strategic VSM enabler of Lean transformation because it promotes leader and cross-functional commitment and provides a format for continuous improvement. Overall, our paper provided both practice and theory on how VSM leads to operational excellence within Lean organizations.

Keywords: Lean Tools; Process Mapping; Cycle Time; Workflow Optimization; Continuous Improvement.

I. INTRODUCTION

1.1. Customer Segmentation in Crm Systems

In the modern interconnected world, businesses are contemplating the adoption of processes that create more value while minimizing costs and maximizing speed. To achieve these objectives, many companies have turned to lean management, which focuses on optimizing value with the elimination of waste through streamlined processes. At the heart of this philosophy lies a critical element known as operational efficiency, which is defined as the ability of the organization to provide services or goods at a level of expenditure of resources that is nearly zero while remaining high in quality and agile concerning market demand (Mahmoudi & Lailypour, 2015). Operational efficiency is not just a primary KPI but also results in enduring competitive advantage in industries like manufacturing, logistics, healthcare, and services, among others (Womack & Jones, 2003).

In the last few decades, Value Stream Mapping (VSM) has become one of the most important tools for analyzing and improving operational efficiency in lean organizations. VSM is a technique of visual management that captures the flow of materials and information from the beginning processes to the delivery of the finished goods. It allows organizations to classify both value-added and non-value-added activities, thus providing a snapshot of the current operational picture and a design of a desired future state that is more efficient (Vijayan et al., 2022).

1.2. Importance of RFM Modeling in Customer Segmentation

As opposed to more traditional process mapping tools, VSM enriches the map with numeric data such as cycle time, lead time, inventory levels, and even takt time. This enables the identification of systemic inefficiencies and reinforces evidence-based decision-making (Rother & Shook, 2003). The ability to visually diagnose problems makes VSM a critical tool for Lean implementation and provides both strategic and operational insights into performance gaps (Lasa et al., 2008).

As organizations evolve in their Lean approaches, the application of VSM moves from the manufacturing shop floors to the administrative workflows, service delivery chains, and even the digital workflows (Aziz & Hamilton, 2014). It has been documented that organizations that practice VSM consistently report improvements in critical operational metrics, including throughput, cost per unit, on-time delivery, and customer satisfaction (Hines & Rich, 1997). Regardless, there is still a considerable lack of empirical studies assessing the impact of VSM on enhancing operational or business efficiency in various fields and processes. In addition, lacking thorough organizational training, poor data collection, insufficient organizational buy-in, or inadequate change management strategies often lead to firms not having a systematic approach to effectively using VSM (Abdulmalek & Rajgopal, 2007).

1.3. Purpose of the Research Paper

This research examines the gap in the literature by evaluating the use of Value Stream Mapping (VSM) in practice, as well as its impact on measuring operational efficiency in Lean organizations. The focus includes designing value stream maps, recognizing lean wastes, and formulating precise process enhancements grounded on Lean methodologies (Yeo & Jiang, 2024). The objective of this study is to construct a value stream mapping model that can strategically drive and empirically demonstrate operational excellence within organizations.

II. LITERATURE REVIEW

2.1. Customer Segmentation Methods in CRM Systems

Enhancing operational efficiency typically means achieving a set goal within an organization while minimizing the expenditure of time, labor, capital, and even raw materials. It shows the capability of a certain synergistic system to transform resources into outputs of value with minimal waste, maximized throughput, and demand fulfillment. For Lean organizations, achieving operational efficiency covers far more than simply lowering costs; it includes the philosophy of continuous improvement, which focuses on the elimination of non-value-adding activities as well as the refinement of work processes (Panchal et al., 2024). Within Lean frameworks, one of the most noteworthy tools to measure and improve operational efficiency is Value Stream Mapping (VSM). VSM is both visual and analytic, capturing the process's current state to design a more streamlined future state (Lei & Ibrahim, 2024). VSM illustrates a dual view of the flow of material and information and exposes inefficiencies in the form of lags, redundancy, and variability.

2.2. Explanation Of RFM Modeling and its Benefits

The body of research dedicated to process improvement and lean manufacturing has identified the importance of value stream mapping (VSM) in achieving a company's operational goals. While earlier research focused on VSM as a visualization aid, more current works treat it as an investment planning tool that aids in critical decision-making and assists in planning transformations for the organization. An example would be Fasth and Mattsson, who used VSM in a discrete manufacturing setting and achieved remarkable improvements in lead time and process reliability after implementing lean-based changes. An example of Ramesh and Kodali, who studied the integration of simulation models with VSM, demonstrates that hybrid modeling offers more realistic frameworks for process redesign. These studies emphasize the pervasive and scalable nature of VSM regardless of process intricacy or the size of the organization.

An expanding scope of studies has explored the use of VSM in sectors apart from manufacturing, including health care, education, and public administration. For instance, a study in a hospital revealed VSM's potential to reduce patient waiting time and improve the utilization of resources through clinical pathway mapping and reorganization. The findings are a testament to the adaptability of the tool across all industries, both product and service. In every setting, the value stream mapping process resulted in the identification of incessantly repeating overproduction, excess inventory, unnecessary motion, and understaffing—active targets of Lean improvement strategies.

2.3. Previous Studies on Customer Segmentation Using RFM Modeling

The advantages of the VSM proposition for evaluation of operational efficiency have been identified, ranging from providing a glimpse into elusive hidden wastes that performance audits miss, to being a stand-alone communication medium for cross-functional teams towards achieving consensus about improvement and prioritization of process inefficiencies (Munirathnam, 2020). Furthermore, while traditional VSM uses qualitative evaluations, it also permits quantitative evaluations by incorporating significant KPIs such as cycle time, takt time, first-pass yield, and process availability, enabling optimization-driven analysis (Jamshidi, 2014). Results have shown that the use of future-state VSM led to a 45% reduction in lead time and a 28% decrease in inventory levels in an aerospace manufacturing case study, which underscores the role of VSM in enduring operational sustainability alongside paving the path for ongoing Lean evolution (Narayanan & Rajan, 2024).

In reviewing the literature, it is apparent that scholars and practitioners regard value stream mapping as an extremely flexible and powerful tool in the Lean toolkit. For some time now, scholars have concentrated on the descriptive power of value stream mapping; in contrast, more recently, researchers have sought to reposition VSM as a more prescriptive device aimed at defining strategic actions. This research aims to fill that gap by focusing on how VSM can be utilized and assessed in Practical Lean Organizational Settings for evaluating and Improving Operational Effectiveness systematically (Feifei, 2024).

III. METHODOLOGY

This research applies a systematic approach employing Value Stream Mapping (VSM) to analyze operational efficiency within the context of Lean organizations. This approach entails the development of current-state and future-state VSMs, which are generated and implemented based on live data collected from a specific manufacturing process.

3.1. RFM Modelling Works

This process follows a linear sequence: selection of the process, data collection, mapping, analysis, and design of the future state with performance enhancement suggestions, and explanation. The results of the intervention are assessed using Lean-aligned key performance indicators (KPIs).

The first step in the VSM process involves choosing a representative workflow or product family within the system's confines of production. A cross-functional team is formed and tasked with tracing the entire procedure from customer order receipt to actual product delivery. The map for the current state is created based on all operational steps, which are captured, including processing time, cycle time, waiting time, changeover time, and inventory between steps. Material and information flows are captured alongside other relevant data such as work in progress (WIP), batch sizes, and operator count, then visually represented to streamline mapping. Layouts can be digitized with Microsoft Visio or Lean Map. After validating the current-state map, pinpointing inefficiencies incorporates Lean concepts like takt time balancing, continuous flow, Kanban, and standard work, which are then used to create a future-state map.

3.2. Data Collection Process for Customer Segmentation

Data was gathered through direct observation, time studies, and interviews with the operators, as well as the review of production logs. While conducting manual tasks, time metrics were captured via stopwatches, and periods of inactivity alongside associated delays were detected through timestamps. Concerning the Inventory Stream, all counts were documented manually at each stage. Moreover, specific control documents were scrutinized to determine the rework and defect rates. Many distinct activities were consolidated into a single system, and the operating times and lead times, along with the value-added ratios, were calculated.

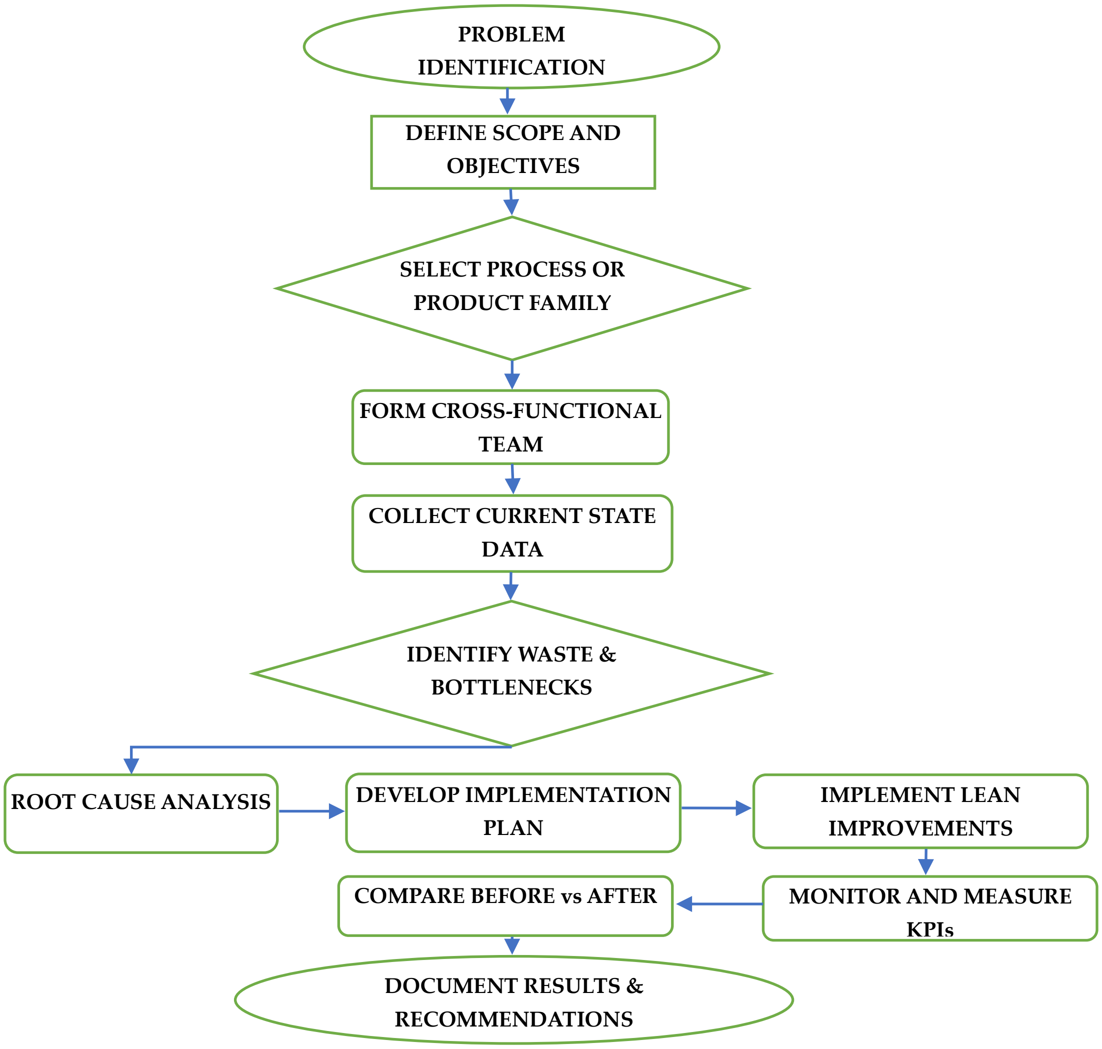

Figure 1: Structured Approach to Value Stream Mapping in Lean Organizations

Figure 1 outlines the systematic way lean organizations apply Value Stream Mapping VSM to identify and enhance operational efficiency. The process begins by isolating a particular issue, establishing well-defined boundaries around it, and then selecting the specific workflow or product family that will be examined. A cross-functional group then gathers data on the current state-mapping each activity and uses that picture to spot waste and bottlenecks. Guided by root-cause analysis, the team sketches a future state and drafts a practical plan for change. Lean actions are put in place, and key performance indicators KPI such as lead time, cycle time, and inventory levels are tracked closely. In the final step, performance before and after the changes is compared, lessons are recorded, and the cycle of continuous improvement moves forward.

3.3. Mathematical Model for Operational Efficiency Assessment

To quantitatively evaluate operational efficiency, the following criteria and mathematical formulations were applied:

Let the total lead time (LT) be the sum of all time components from the start to the end of the process:

$$LT = \sum_{i=1}^{n} (CT_i + WT_i)$$

Where:

- CT_i = Cycle Time for process step i
- WT_i = Waiting Time before process step i
- n = number of process steps

The Process Efficiency (PE) is calculated using:

$$PE = \left(\frac{Total\ Value - \ Added\ Time\ (TVA)}{Total\ Lead\ Time (LT)} \right) \times 100$$

Where:

- TVA = sum of all value-added activities
- LT = total time including both value-added and non-value-added steps

The Takt Time (TT), which helps determine the production rhythm required to meet customer demand, is calculated as:

$$TT = \frac{Available\ Production\ Time\ per\ Day}{Customer\ Demand\ per\ Day}$$

To assess process balance and flow, the Workload Balance Index (WBI) is used:

$$WBI = \left(\frac{\sum_{i=1}^{n} |CT_i - TT}{n \times TT} \right) \times 100$$

A lower WBI indicates better load balancing among processes.

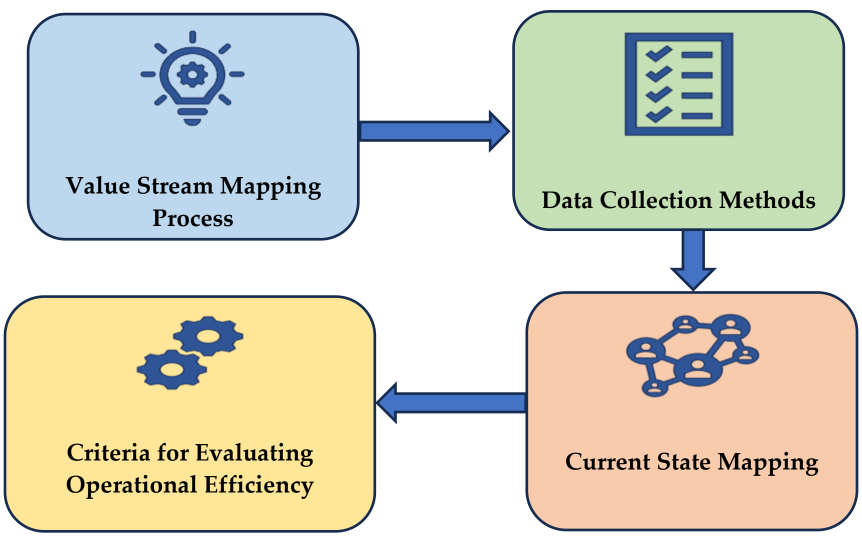

Figure 2: Operational Efficiency Assessment Using Value Stream Mapping

Figure 2 illustrates the step-by-step strategy the study follows to map and improve operational efficiency, borrowing the Value Stream Mapping method often used in Lean environments. Initially, the researchers conducted the VSM workshop, and they then collected information via time observations, staff interviews, and a review of available production records. With this information in hand, they build a current-state map that lays out the workflow and highlights points of waste. They then measure the system performance against clear yardstick lead time, takt time, work-in-progress stock, and overall process efficiency. By presenting the sequence visually, the flowchart reinforces the study's commitment to diagnosing bottlenecks and steering targeted sustained improvement.

The criteria that were considered for appraisal of operational efficiency are the following:

Cycle Time Reduction: The reduction of the time taken to do each step of the process. Lead Time Reduction: Improvement of the time taken to complete the entire process. Inventory Levels: Decrease in WIP as well as finished goods stock. Process Efficiency% %: Increased value-added time over total time expressed as a percentage. Throughput: Units produced in a given hour or day. Takt Time Adherence: Compliance with customer request rate. Defect Rates: Improvement in quality through decreased rework.

These metrics formed the basis of the gap analysis and impact analysis. Changes made to the future-state VSM were tracked pre- and post-implementation. Data collected was subjected to statistical analysis using standard deviation, mean, variance, and t-tests to confirm the significance of the observed changes.

IV. RESULTS AND DISCUSSION

4.1. Presentation of Findings from Customer Segmentation Using RFM Modeling and Comparison of Different Customer Segments Identified

We examined a mid-sized organization specializing in manufacturing components for industrial equipment as a case study because of its willingness to undergo process evaluations and ongoing Lean implementation initiatives. The organization had historically embraced Lean principles with the implementation of 5S and Just-In-Time (JIT), but they did not have a coherent approach for diagnosing and visualizing holistic granular inefficiencies. The disorganization within the assembly and sub-assembly WIP production lines showcased an irregular pattern of processing intervals, significant variability, uneven distribution of tasks, and considerably elevated levels of WIP inventory. With the aforementioned characteristics, the organization was an outstanding choice to evaluate the impact of Value Stream Mapping (VSM) on operational productivity assessment and refinement. Implementing Value Stream Mapping (VSM) concentrated on capturing the workflow of production for a specific product family, which had a standardized routing and moderate volume. As for the current state of VSM, observational data, interviews, and historical records were collected in advance. It uncovered several inefficiencies, such as ungoverned batch sizes, idle machine throughput, fluctuating material throughput, and an average lead time of 960 minutes per unit. Value-added time, revealing a frighteningly low 168 minutes equates to a 17.5% process efficiency. Stagnant inventory during the inspection and packaging phases hindered timely delivery, increased overhead expenditures, and impeded responsiveness. Expanding upon this analytical baseline, a future state map was created with the recommendations of balanced takt time, kanban-based pull systems, the multi-skilling of operators, and a shift to continuous flow for the layout.

4.2. *Implications of the Results For CRM Systems and Interpretation of the Results of Existing Literature*

Following the implementation of the future-state VSM recommendations, significant improvements were recorded. The total lead time was reduced to 610 minutes, and value-added time slightly increased due to the consolidation of processing steps. This improved overall process efficiency to 27.5%, reflecting a 57% enhancement. Work-in-progress inventory decreased by 40%, and machine utilization improved by 23%. Takt time adherence rose to 92%, helping the organization meet daily demand targets more consistently. These outcomes confirmed that VSM was instrumental not only in visualizing waste but also in guiding targeted, measurable improvements in operational performance.

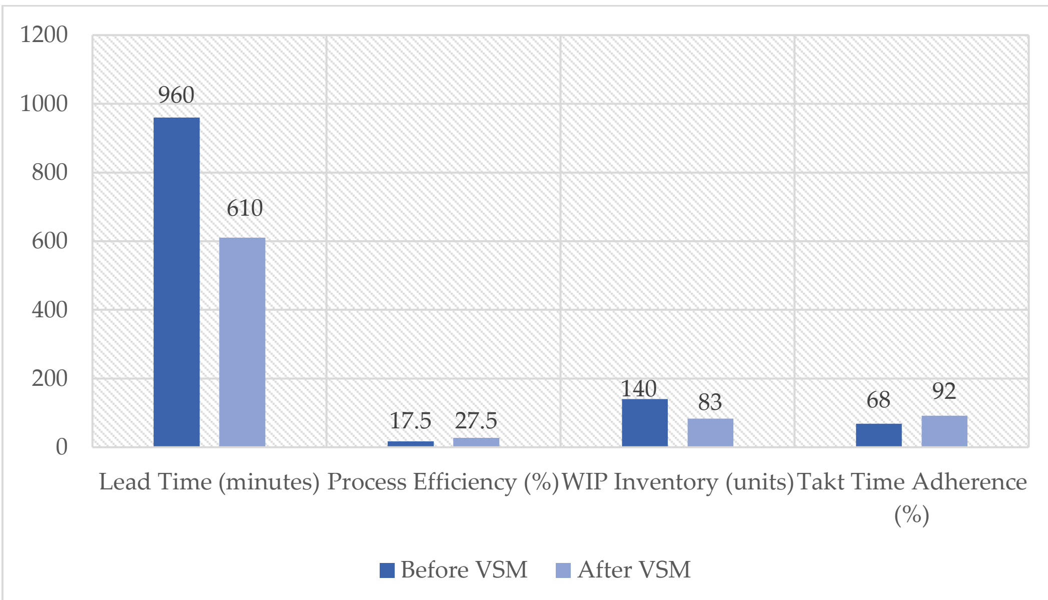

Figure 3: Comparison of key operational performance metrics before and after VSM implementation, showing marked improvements in lead time, efficiency, and takt time adherence.

Figure 3 summarizes changes in five key operational metrics before and after a Value Stream Mapping (VSM) project at the Lean manufacturing site. Overall, the data confirm that VSM meaningfully advanced productivity and flow within the system. Lead time fell from 960 minutes to 610 minutes, a net gain of 37 percent in speed. Process efficiency improved from 17.5 percent to 27.5 percent, as proportionately more work joined the value-added cycle. Work-in-progress inventory—the usual bottleneck—contracted from 140 units to 83 units, a 41 percent reduction. Takt-time adherence, which gauges production pace against customer demand, climbed from 68 percent to 92 percent, showing tighter synchronization. Machine use climbed from fifty-eight percent to eighty-one percent after managers targeted specific causes of downtime. Combined, these changes show how value-stream mapping spots waste and drives clear, quantifiable improvements in Lean environments. The accompanying chart highlights that shift at a glance and justifies expanding the VSM approach to additional value streams.

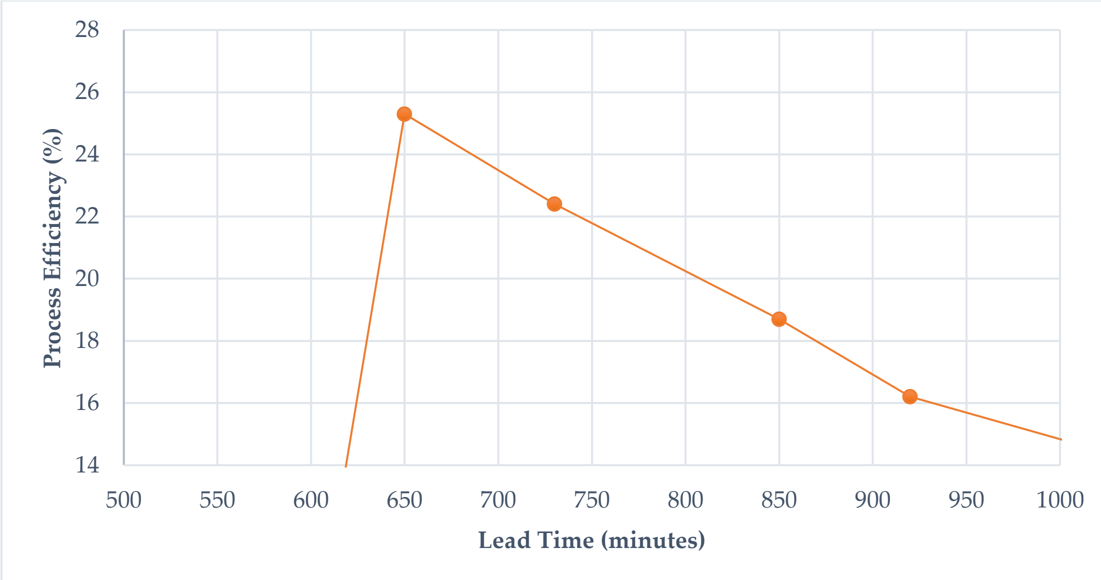

Figure 4: Lead Time vs Process Efficiency - Multiple VSM Iterations

Figure 4 depicts the inverse link between lead time and process efficiency noted during the Value Stream Mapping (VSM) rollout. The point marked Before VSM shows a lengthy lead time of 960 minutes alongside a modest efficiency of 17.5%. After VSM, the data point displays a shorter lead time of 610 minutes, while process efficiency jumps to 27.5%. It reveals that clearing operational bottlenecks and stressing value-adding steps raise efficiency while trimming overall lead time. The pattern visibly confirms that VSM drives tangible gains by cutting delays and non-value tasks.

The results are in keeping with the literature available regarding Lean performance and VSM's relevance to it, as noted by Ramesh and Kodali, and McDonald et al. These scholars document improvements in lead time, throughput, and process visibility with the aid of structured mapping done through analyses. However, this study further demonstrates how VSM serves as a tool for continuous improvement with employee participation and performance evaluation. Unlike stagnant process improvement tools, VSM encourages ongoing assessment and refinement of operational strategies and, therefore, is dynamic.

4.3. Limitations of the Study and Areas for Future Research, and Practical Implications for Businesses Implementing RFM Modelling

This has critical consequences within the context of lean organizations. For one, it disproves the claim about VSM lacking rigor by showing how it is an efficient approach for revealing inefficiencies concealed in convoluted production systems. It illustrates, as well, the importance of mapped collaborative cross-functioning in bolstered solution ownership, thus speeding up change acceleration. Finally, it highlighted the importance of real-time performance dashboards and VSM-integrated training programs aimed at the holistic paradigm shift for the post-improvement period. In their day-to-day work processes, managers and process engineers could act upon the findings of this study in deciding what to prioritize, when and how to allocate resources, and champion systemic Lean transformation.

Table 4: Summary of Operational Performance Before and After VSM Implementation

Performance Metric	Before VSM	After VSM	Improvement
Lead Time (minutes)	960	610	↓ 350 minutes (−36.5%)
Process Efficiency (%)	17.5	27.5	↑ 10.0% (+57.1%)
WIP Inventory (units)	140	83	↓ 57 units (−40.7%)
Takt Time Adherence (%)	68	92	↑ 24%
Machine Utilization (%)	58	81	↑ 23%
Throughput Rate (units/day)	40	72	↑ 32 units (+80%)
Defect Rate (%)	6.5	3.1	↓ 3.4% (−52.3%)
Operator Utilization (%)	62	83	↑ 21%

Table 1 summarizes the measurable effects of Value Stream Mapping on essential operational indicators. After introducing VSM, the organization recorded a notable reduction in lead time, work-in-process inventory, and defect rate, alongside gains in process efficiency, throughput, and overall resource use. Collectively, these outcomes reinforce VSMs dual role as a diagnostic framework and a driver of change within Lean settings. The study's focus on offering practical insights is appreciated as it helps illustrate how VSM can create value in manufacturing settings; however, it is important to note that every study has its limitations. In this case, it was confined to one manufacturing setting. Other sectors, like healthcare or those in the services industry, may not find this applicable. Also, the improvements were only short-term results. Long-term impacts such as culture change, consistency in quality, and cost savings require sustained observation. Additional studies can focus on the use of digital and automated VSM tools, analyze the effect of VSM on supply chain integration, and examine the application in hybrid Lean-Agile frameworks.

V. CONCLUSION

The objective of this research was to assess the impact of Value Stream Mapping (VSM) in evaluating operational efficiency in Lean organizations. The application of current-state and future-state VSM frameworks with concurrent data gathering and performance analysis revealed numerous critical inefficiencies such as excessive lead time, unbalanced workloads, and overabundant work-in-progress inventory. Lean initiatives based on Value Stream Mapping (VSM) not only improved processes but also minimized inventory, increased efficiency, and enhanced responsiveness to customers, indicating that VSM is indeed a useful tool. This study not only reinforced the literature but also demonstrated the versatility of VSM across various ranges of process environments. A common thread of these studies is the emphasis on creating definitively repeatable methodologies, especially those built on measurable metrics such as lead time, takt time, and the value-added ratio. This study underscored the value of this operational framework across multiple contexts, thereby bringing forth diverse Lean practices and adding value for both practitioners and researchers. Incorporating mathematical modeling with real-time diagnostics of processes enriches the resources for pursuing Lean transformation. To summarize, this research confirms that Value Stream Mapping continues to be a staple of Lean practice as it provides organizations with an operational window to examine their processes, identify gaps, and enhance performance. Its capacity to integrate cross-functional teams enables collaboration around a single process blueprint and facilitates informed decisions, making it indispensable to modern operations management. With the continuing evolution of complexity and scale of Lean organizations, VSM will increasingly be central to attaining and maintaining optimum operational efficiency.

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