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Applying Lean Manufacturing to Enhance Operational Efficiency and Internal Logistics in Community-Based Rice Mills

Ganyarat TINNARAT[1], Kanjana HINTHAW[2]

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Abstract

Purpose: This investigation systematically implements Lean Manufacturing principles to substantially improve operational efficiency, optimize internal logistics, and reduce waste within community rice mills located in Kalasin Province, Thailand. These vital rural milling facilities frequently face inefficiencies caused by outdated processes and insufficient material flow. **Research design, data, and methodology:** A mixed-methods approach was employed, comprising surveys of 125 mills, in-depth interviews, and participatory action research (PAR). Lean tools, including 5S, Value Stream Mapping, and ECRS, were systematically implemented to optimize the milling process and enhance internal logistics. **Results:** The enhanced process resulted in a 22.73% reduction in processing time, a 10–15% drop in operational costs, and a lower broken rice rate from 10–12% to 7–8%. Overall Equipment Effectiveness (OEE) significantly increased from 59.94% to 80.47%, reflecting better machine availability, performance, and product quality. **Implications:** The findings demonstrate the effectiveness of participatory Lean implementation in boosting efficiency and internal logistics, which fosters socio-technical resilience in rural agro-industries. This study provides a replicable model that integrates technical efficiency with community knowledge for sustainable development. **Originality/value:** This research contributes to the literature on Lean Manufacturing in agriculture by offering a scalable framework to improve internal logistics and support grassroots development.

Keywords : Lean Manufacturing, Waste Reduction, Operational Efficiency, Rice Mills, Process Improvement, Internal Logistics

JEL Classification Code L66, Q13, O32, M11

1. Introduction

In recent years, the agricultural sector has encountered escalating demands to enhance both productivity and sustainability amid shifting economic, environmental, and technological circumstances. In Thailand, community-based rice mills constitute an essential component of the rural economy, offering income and employment opportunities to local inhabitants. Nevertheless, these enterprises frequently grapple with inefficiencies, including extended processing durations, surplus waste, antiquated workflows, and distribution bottlenecks. Lean Manufacturing—originally developed in the automotive industry—has demonstrated promising potential in optimizing operations and minimizing activities that do not add value within small-scale food processing sectors. In the context of rice milling, studies from Southeast Asia have indicated that Lean tools

1 First Author. Ph.D. candidate, Department, Business Administration and Digital Innovation, Department of Mahasarakham Business School, Mahasarakham University, Thailand.
Email: 64010997002@msu.ac.th
2 Corresponding Author. Academic Lecturer, Department of Mahasarakham Business School, Mahasarakham University, Thailand. Email: kanjana.h@acc.msu.ac.th

can markedly reduce cycle time and enhance overall processing efficiency in small-scale agro-industrial settings. Importantly, efficiency in logistics and distribution is crucial to ensuring that processed rice maintains its quality during transport and reaches trade channels in a timely and competitive manner (Thoucharee & Pitakaso, 2017).

In rural Thailand, rice mills are locally operated units responsible for processing rough rice obtained from regional farmers into consumable or marketable rice. These mills typically operate on a small to medium scale, with management practices that are often informal and heavily reliant on community resources such as family labor, basic machinery, and local networks (Dora et al., 2016). Community rice mills serve as vital infrastructure within the food system and contribute to the economic stability of surrounding regions because they facilitate value addition and income distribution, as well as help stabilize rice prices within the community (Hu et al., 2015; Rifatullah et al., 2022). Nevertheless, challenges such as inadequate transportation systems, limited storage capacity, and inefficient linkages to broader trade networks often impede their competitiveness (Pakdeenarong & Hengsadeekul, 2019). Therefore, enhancing the operational capacity of community rice mills—including optimizing logistics integration and developing trade-oriented distribution systems—represents a critical focus for both policy development and academic inquiry.

As one of Thailand's principal rice-producing provinces, Kalasin plays a pivotal role in ensuring national food security and bolstering the resilience of rural economies. The province is acclaimed for its extensive cultivation of glutinous and jasmine rice, which serve as essential commodities in domestic markets and are progressively integrated into global value chains. The significance of rice production in Kalasin has resulted in the establishment of a dense network of community-based rice mills that sustain local livelihoods and strengthen regional supply chains. Nevertheless, these rural enterprises often remain marginalized from technological, logistical, and managerial advancements that are prevalent in more industrialized regions.

Enhancing operational efficiency in Kalasin's rice mills represents both a local and global opportunity. Locally, it enables farming communities to retain more value within the province, minimize production losses, and strengthen distribution linkages. Globally, considering Thailand's status as a leading rice exporter, efficiency improvements in provinces such as Kalasin can collectively enhance the reliability and sustainability of rice supply in international trade (Wilasinee et al., 2010). This underscores the strategic significance of Kalasin as a case study for scalable innovation in rural agro-industrial transformation.

Numerous studies have validated that methodologies such as 5S, Value Stream Mapping (VSM), the ECRS principle, and Total Quality Management (TQM) significantly enhance operational performance, efficiency, and waste reduction across various industries. The systematic implementation of these tools promotes streamlined workflows and cultivates a culture of continuous improvement.

Furthermore, recent research emphasizes the growing importance of digital transformation within the fields of logistics and distribution for rural industries across Southeast Asia. The incorporation of Lean principles with digital technologies—such as Industry 4.0 solutions—has the potential to improve performance, traceability, cost-efficiency, and coordination of distribution, particularly when implemented through scalable, community-based strategies. These developments align with Thailand's national policies aimed at promoting smart agriculture, efficient logistics, and digital inclusion at the grassroots level.

Notwithstanding these advancements, a significant research gap persists regarding the integration of Lean manufacturing with logistics and trade-oriented distribution strategies in Thai community-based rice mills. This inquiry aims to address this gap by examining the impact of Lean tools on not only operational efficiency and waste reduction but also on distribution performance within Kalasin Province. The insights obtained from this study are intended to enrich the existing literature on Lean manufacturing and agribusiness distribution, while providing practical guidelines for sustainable productivity enhancements, optimized logistics systems, and strengthened trade networks within rural agricultural processing sectors.

2. Research Objectives

2.1. Identify Key Inefficiencies and Sources of Waste in Traditional Rice Milling Processes

This objective involves a systematic evaluation of wast e within rice milling operations at community-based rice mills. The study will categorize various types of waste, including overproduction, waiting times, unnecessar y transportation, excess inventory, defects, and underutiliza tion of workforce skills. To effectively identify inefficienci es in the milling process, this research employs established Lean analytical tools such as Fishbone Diagrams, which as sist in classifying inefficiencies into primary factors (e.g., workforce, machinery, methods, and materials), and Pareto Analysis, which highlights the most significant contributor s to waste (Kumar et al., 2023; Hu et al., 2015). Recent sch olarly work also underscores the importance of the 5S meth odology in enhancing operational efficiency through works pace organization, waste reduction, and the promotion of a safer working environment, particularly within small-scale food processing establishments (Hu et al., 2015). This comprehensive approach facilitates a thorough understand ing of the critical areas requiring intervention.

2.2. Evaluate the Effectiveness of Lean Manufacturing Principles in Reducing Waste and Improving Productivity

This objective emphasizes evaluating the implementation of Lean tools such as Value Stream Mapping (VSM), 5S, Kaizen, and the ECRS framework within rice milling processes to reduce waste, enhance operational efficiency, and improve productivity. A comparative analysis will be performed by measuring key performance indicators (cycle time, defect rates, energy consumption, and overall equipment effectiveness (OEE) before and after the implementation of Lean practices. Recent scholarly literature indicates that Kaizen and 5S methodologies can engender significant advancements in both quality and productivity within food production systems, especially in rural environments. (Hu et al., 2015).

2.3. Develop a Sustainable Framework for Lean Process Optimization in Community Rice Mills

This objective aims to develop a practical, scalable framework that integrates Lean Manufacturing with sustainability practices in community-based rice mills. The proposed model emphasizes waste reduction, resource optimization, and community collaboration. It incorporates tools such as the 5S and ECRS frameworks, augmented with feedback mechanisms, to facilitate long-term process improvement without reliance on high-cost technologies. By adapting Lean methodologies to accommodate the constraints of small-scale rice mills—such as limited capital, manual labor, and reliance on local resources—the framework promotes continuous improvement, environmental responsibility, and economic resilience in rural areas. This approach aligns with recent scholarly findings regarding the role of Lean in advancing sustainable efficiency within small-scale agricultural enterprises (Kumar et al., 2023; Hu et al., 2015).

3. Theoretical Framework

Lean Manufacturing constitutes a comprehensive philosophy and methodology that systematically emphasizes maximizing customer value while concurrently minimizing all forms of waste within the production system. The foundational theoretical framework is predominantly attributed to Taiichi Ohno (1988), who pioneered the Toyota Production System (TPS), and was subsequently elaborated upon by Womack and Jones (1996). Fundamentally, Lean focuses on identifying value strictly from the customer's perspective and the rigorous elimination of seven types of waste (Muda): overproduction, waiting, transportation, over-processing, inventory, motion, and defects. These wastes represent activities that do not add value, consume resources, and prolong lead times, which Lean seeks to eliminate to enhance operational efficiency and responsiveness (Ohno, 1988; Womack & Jones, 1996). The core principles that underpin Lean Manufacturing are Value, which is what the customer is willing to pay for, serving as the compass for all improvements (Womack & Jones, 1996). Value Stream: Mapping all processes that deliver this value, enabling visualization of waste and bottlenecks (Rother & Shook, 2003). Continuous Flow: Ensuring smooth, uninterrupted production flow to minimize delays and inventory buildup (Womack & Jones, 1996). Pull System: Producing goods based on actual customer demand rather than forecasts to avoid overproduction and excess inventory (Womack & Jones, 1996). Moreover, Continuous Improvement (Kaizen) is a cultural and operational philosophy promoting incremental improvements through active employee participation (Imai, 1986).

The implementation of Lean principles within small-scale agro-industries, such as community-based rice mills, requires careful contextualization due to intrinsic limitations, including constrained financial resources, diverse levels of labor proficiency, and reliance on manual or semi-manual processes (Parmar & Desai, 2019). Lean tools, including the 5S methodology (workplace organization), Value Stream Mapping (VSM), the ECRS framework (Eliminate, Combine, Rearrange, Simplify), and Kaizen, have been empirically validated to improve productivity, reduce waste, and standardize processes in environments with similar resource constraints (Bhamu & Sangwan, 2014; Hu et al., 2015). Recent empirical research broadens the scope of Lean's impact to encompass sustainability and resilience within agro-industrial sectors, emphasizing the integration of Lean principles with environmental stewardship and social responsibility. For instance, Kumar et al. (2023) illustrate how waste reduction through Lean methodologies supports sustainability objectives by decreasing resource consumption and enhancing economic resilience in rural enterprises. Hu et al. (2015) further underscore the environmental benefits driven by Lean, including lowered carbon footprints and improved waste recycling practices.

Furthermore, the successful implementation of Lean principles is inherently linked to change management frameworks that facilitate the overcoming of cultural and organizational obstacles to Lean adoption. Kotter's (1996)

8-step change model has been utilized to guide Lean transformation initiatives, emphasizing the importance of effective leadership, active employee engagement, an articulated vision, and ongoing communication to maintain Lean improvements over time (Hu et al., 2015).

The conceptual framework, designed to systematically analyze the implementation of Lean principles in community rice mills, incorporates the following components: Input Lean tools such as 5S, Kaizen, Value Stream Mapping (VSM), and Eliminating Waste, Redundant Steps (ECRS), alongside comprehensive employee training programs tailored to local capacities. The process involves a stepwise approach to Lean implementation, customized for small-scale agro-industrial contexts, including diagnostics, waste identification, process standardization, and continuous feedback mechanisms. The desired outputs include measurable improvements, such as waste reduction, increased productivity, elevated Overall Equipment Effectiveness (OEE), and long-term sustainability that encompasses environmental and economic resilience (Kumar et al., 2023). This model not only operationalizes Lean principles but also integrates considerations of sustainability and community impact, offering a holistic approach to rural industrial development that maintains academic rigor while ensuring practical applicability.

4. Materials and Methods

Research studies utilized the Mixed Methods Research methodology to acquire both comprehensive and detailed insights into the production process and waste minimization through lean principles at a rice mill. The investigation was conducted across three interconnected phases: Quantitative Research, Qualitative Research, and Participatory Action Research (PAR), which collectively facilitate the development of pragmatic operational innovations suitable for effective implementation.

Quantitative Research: The sample population comprises rice mill operators in Mueang district. Considering that there are a total of 125 rice mills—including small, medium, and large facilities—the researcher collected data from all rice mills within Mueang district, Kalasin province. The characteristics of small, medium, and large community rice mills are consistent across Thailand; therefore, these mills were selected as representative entities for this study. The data collection instrument utilized was a questionnaire with multiple-choice responses. The researcher personally explained each question to the respondents. The questionnaire was developed based on the Seven Wastes of Lean, derived from the concept of Lean Manufacturing. The instrument's validity was confirmed through Item-Total Correlation and Cronbach's Alpha, yielding reliability coefficients ranging from 0.98.

Qualitative research was conducted using in-depth interviews employing a semi-structured format. The researcher allocated one and a half hours at each site, personally conducting the interviews and utilizing audio recording devices. Ethical approval was obtained prior to data collection. Furthermore, non-participant observation was performed on a separate occasion outside the interviews, lasting three hours. Data collection involved five key informants representing mills of various sizes—small, medium, and large—selected through purposive sampling based on convenience to gather insightful perspectives. Quality assurance measures included Item-Objective Congruence (IOC) and triangulation techniques to ensure data validity. The results of the qualitative research were used to develop Pareto charts, fishbone diagrams, root cause analysis (Why-Why Analysis), and 5W+1H analysis to identify systemic root causes of the issues.

Participatory Action Research (PAR) encompasses the utilization of findings derived from both quantitative and qualitative analyses to formulate and evaluate waste reduction strategies within a rice mill operating at a single production facility. This methodology employs the ECRS (Eliminate, Combine, Rearrange, Simplify) principles to delineate four core processes in rice husk processing. The efficiency of production is assessed using the OEE (Overall Equipment Effectiveness) index, with comparative analyses conducted on data collected before and after the improvements. The PAR methodology comprises four phases: Plan, Action, Observation, and Reflection, as delineated by Kemmis & McTaggart (2013). In this participatory research, the researchers allocated a duration of two weeks to collecting diverse data from five rice mills, each operational during that period.

Data collection was conducted in accordance with research ethics, with informed consent obtained from participants. A review of the literature was performed to establish the conceptual framework, and data saturation principles were applied to determine the end of interviews. Quantitative data analysis employed descriptive statistics and references, including mean values and standard deviations, as well as correlation analysis. Meanwhile, qualitative data was analyses using content analysis methods and practical analysis of changes resulting from real experiment processes.

This study aims to develop innovations in the management of the rice milling process through an integrated research design that combines theoretical concepts with practical implementation. The objectives include enhancing efficiency, minimising waste, and improving the competitive capacity of the agricultural industry at the community level sustainably. It emphasizes applied scientific research in business and management within the regional context of Asia.

In this study, a diverse array of analytical tools was employed, including quantitative, qualitative, and participatory methods, to accurately identify the fundamental causes of issues within the rice polishing process. These methods proved effective and were specifically customized to suit the context of community rice mills in Thailand. All tools were grounded in the principles of Lean Manufacturing and adapted to the resource constraints of community mills. The research utilized the following tools:

1. Pareto Chart: To prioritize issues using the 80/20 principle, which suggests that most problems come from a small number of key causes, enabling targeted solutions.

2. The Fishbone Diagram (also known as the Ishikawa Diagram) facilitates the systematic categorization and analysis of the causes of problems across diverse domains.

3. Root Cause Analysis: The Why–Why Analysis is a continual process that entails posing detailed inquiries to determine the underlying cause of an issue, often utilized in conjunction with a fishbone diagram.

4. 5W1H analysis is used to gather perspectives and detailed information from stakeholders, enabling a thorough understanding of the issue and supporting the planning of corrective actions that cover all relevant aspects.

5. Overall Equipment Effectiveness: OEE. Utilized as an indicator of the outcomes of enhancements concerning availability, performance, and output quality prior to and following the implementation of Lean methodology.

These analytical tools have been incorporated into mixed methods research and participatory action research (PAR) to realize tangible outcomes that correspond with ground realities and can be sustainably expanded within the community.

5. Results

5.1. Quantitative Assessment of Waste Categories in Rice Mill Operations

The quantitative data collected from 125 rice mill operations through questionnaires on various losses—specifically, the seven types of waste—aims to establish conclusions regarding waste. It has been identified that the seven categories of losses include: 1. Loss attributable to overproduction; 2. Loss resulting from inventory storage; 3. Loss caused by transportation; 4. Loss due to movement; 5. Loss originating from the production process; 6. Loss attributable to waiting times; and 7. Loss caused by defective production. Overall, rice mill operators perceive that all seven categories of losses occur at a moderate level, with a mean score of 2.92, and the most significant loss being movement, which has a mean score of 3.34.

5.2. Qualitative Investigation of Waste and Improvement Opportunities in Community Rice Milling

Following the collection of quantitative data to ascertain the degree of loss, the process advanced to qualitative analysis. The researcher conducted comprehensive interviews with operators from five community rice mills, categorized into three sizes: large, medium, and small. The interviewees were responsible for overseeing the primary rice polishing processes; all possessed over ten years of professional experience. The topics addressed during the interviews included: 1) 7 Waste; 2) perspectives on issues within the rice polishing system—value-added activities (VA), non-value-added activities (NVA), non-value-added but necessary activities (NNVA), production volume, storage, machinery, work stations, waiting times, and waste within the system; 3) views on developing the rice polishing system utilizing Lean principles; and 4) suggestions for process improvements. The findings indicated that

5.2.1. Pareto Analysis of Key Loss Factors in Rice Processing Due to Overproduction

Rice processing: It is essential to reduce losses caused by overproduction, a phenomenon often driven by concerns about losing customers to competitors. This often results in an excess of rice production aimed at satisfying unverified demand, thereby leading to stockpiles of rice that cannot be sold within the appropriate timeframe. As a result, losses occur due to deterioration in quality. The researcher undertook an analysis to facilitate improvements, employing Pareto analysis to identify the principal deficiencies. The findings of this analysis, based on Pareto principles, are as follows:

1. Reduction of losses attributable to overproduction by fifty percent.

2. Reduction of losses attributable to inventory holding by thirty percent.

3. Reduction of losses attributable to defective production by twenty percent.

Upon the discovery that the issue of loss reduction due to overproduction, with fifty percent occurring at a significant proportion, was analyzed using the (Why-why analysis) technique, the causative factors identified within the process included excessive rice production beyond demand, machinery operating beyond capacity, improper machine settings during rice polishing, and an excessive intake of paddy rice, which resulted in defects within the production process.

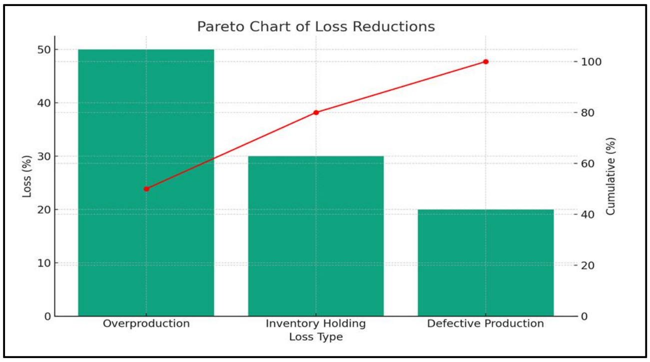

Figure 1: Pareto Chart of Loss Reductions

Table 1: Pareto Analysis of Loss Types and Their Cumulative Impact on Production Efficiency

No.	Type of Loss	% Loss	Cumulative %
1	Overproduction	50%	50%
2	Inventory Holding	30%	80%
3	Defective Production	20%	100%

5.2.2. Root Cause Analysis of Inventory Storage Losses Using Fishbone Diagram

The inventory storage process must minimize losses ass ociated with storing inventory. Based on the Pareto Chart a nalysis presented in section 5.2.1., a reduction of thirty per cent in losses attributable to inventory storage has been ide ntified, which is regarded as a secondary issue. The researc her employed Fishbone diagram analysis to identify the fun damental causes of the problem, thereby facilitating the de velopment of appropriate solutions. To enhance the rice pol ishing process to reduce losses from inventory storage, an a nalysis of the root causes using the Fishbone diagram can b e delineated as follows.

1. People: Poor internal communication within the team and a lack of coordination between the purchasing and production departments.
2. Machines: Lack of information regarding the manufacturing capacity of the equipment; machines cannot respond immediately to changes in production volume.
3. Raw materials: Orders for unprocessed rice that do not meet actual requirements; missing accurate information about the quantity of rice needed at different times.
4. Methods: No efficient production planning system; lack of measures to monitor appropriate inventory levels of materials.
5. Environment: Working conditions that are not conducive to planning and coordination; lack of management support to improve processes.

5.2.3. Root Cause Analysis of Waste Generation Losses Using the 5W+1H Method

Reduction of losses attributable to waste generation. Based on the Pareto Chart analysis data presented in section 5.2.1., a reduction of 20 percent in losses caused by waste production was identified. To ascertain the root cause of this issue within the group, a comprehensive analysis was conducted utilizing the 5W+1H questioning method

Who is responsible for the rice polishing process? Production worker / Machine control operator

What is the problem? The production of rice husks that are more broken than usual

Where In which station was he born? Rice milling machine

When does it happen most frequently? Rice cultivation with high moisture content

Why did it happen? The humidity of the rice is inappropriate/ The machine has a problem.

How can it be reduced? Sun-drying/radiating rice to dry it, reducing moisture, and maintaining machinery properly.

5.2.4. Categorization of Process Improvement Steps Based on ECRS Principles

Based on the data collected from Sections 5.2.1.-5.2.3., it functions as an input factor within the collection process, which encompasses a series of complex procedures guided by the waste reduction principle (ECRS; Eliminate, Combine, Rearrange, Simplify). The researcher may categorize these procedures into groups according to the following principles.

Table 2: ECRS

Step	Current process	ECRS
1	Transporting paddy rice	Combine steps
	Quality inspection of paddy rice	to collapse
	Initial cleaning	Simplify
2	Cleaning of rice paddy husk	Combine steps
3	Threshing rice husks	-
4	Separation of rice husks	-
5	Sorting gravel stones	Combine steps
6	Separation of brown rice	-
7	First whitening treatment	Combine steps
8	Second whitening process	Combine steps
9	Third whitening process	Combine steps
10	Conditioning	Simplify
11	Exfoliation	Combine steps
12	Sorting the rice seedlings	-
13	Sorting rice stalks	-
14	Sorting rice stalks	Combine steps

5.3. Testing a new process developed from the Lean concept employing a practical research methodology

Based on the analysis step outlined in Sections 5.2.1. through 5.2.3., which was derived from a systematic synthesis, the researcher evaluated the effectiveness of the newly developed process by implementing it in a single community rice mill. Prior to conducting the efficiency assessment, the researcher gathered data on the existing system, encompassing all procedures, time requirements, rice quality, and encountered issues. Upon completion of data collection, the rice milling process was executed as designed, and a comparative summary of the results was produced.

Total Time: The traditional process requires 3 hours and 40 minutes (220 minutes). It entails numerous time-intensive procedures, such as repetitive cutting, manual gravel sorting, and conditioning. The improved process is completed in 2 hours and 50 minutes (170 minutes). It incorporates optimized procedures, including fewer cutting cycles and the utilization of more efficient machinery. Consequently, the new process reduces production time by 50 minutes, amounting to a time savings of approximately 22.73%.

Cost: The traditional process is characterized by a lengthier production timeline and an increased number of resource-intensive stages, which consequently result in higher process losses. The improved process yields a reduction in costs, approximately ranging from 10 to 15%, attributable to decreased production time and diminished process losses. As a result, the overall expenditure is decreased.

Rice Quality: The traditional process results in 10-12% broken rice, attributable to less thorough screening and sorting. Conversely, the improved process achieves a 7-8% broken rice rate, owing to enhanced screening techniques and more efficient handling procedures. This upgraded process produces higher-quality rice with a significant reduction in broken kernels and enhanced cleanliness, thereby commanding a higher market value for the final product.

Table 3: Comparative Summary of Traditional and Improved Rice Milling Processes

Aspect	Traditional Process	Improved Process	Improvement Summary
Total Time	3 hours 40 minutes (220 minutes). Includes repetitive cutting, manual gravel sorting, and conditioning.	2 hours 50 minutes (170 minutes). Optimized with fewer cutting cycles and more efficient machinery.	Time reduced by 50 minutes (~22.73% decrease).
Cost	Higher due to longer process time and resource-intensive stages.	Lower cost due to reduced time and process losses.	Cost reduced by approximately 10–15%.
Rice Quality	10–12% broken rice due to less thorough sorting.	7–8% broken rice due to improved screening and handling.	Higher quality with fewer broken kernels and better cleanliness.

5.4. Enhancement of Productivity through OEE: A Comparative Analysis of Conventional and Contemporary Rice Milling Processes

This study evaluates the duration of the primary milling process for paddy into rice and assesses production efficiency (OEE) within the manufacturing operation. The researcher employed Overall Equipment Effectiveness (OEE) as a metric for evaluating production performance, with the objective of improving efficiency and optimizing equipment utilization. This methodology incorporates three essential factors: Availability, Performance, and Quality. The process includes the following steps Step 1: Record actual operating time data, including cycle time, quantity of rice produced, waste amount, and reasons for stoppages. Step 2: Document the scheduled production time (Planned Production Time) from Monday to Saturday, between 08:00 and 18:00, while categorizing rice types and recording relevant data. Working hours are from 8:00 AM to 4:00 PM. Step 3: Log the actual number of products manufactured (Actual Production). And step 4: Record the quantity of products deemed acceptable. Step 5: Document the number of products that failed to meet quality standards (Defective Products).

Availability: The traditional rice processing procedure exhibits an actual operating duration of 360 minutes within a total planned timeframe of 480 minutes, yielding an Availability of 360/480=0.75 or 75%. Conversely, the new rice processing procedure has increased its actual operating duration to 420 minutes out of 480 minutes, resulting in an Availability of 420/480=0.875 or 87.5%. This comparison indicates that the new process demonstrates a machine availability that is 12.5% higher, thereby reflecting improved efficiency in time management.

Performance: Both processes possess an operational capacity capable of producing rice at a rate of 100 tonnes, contingent upon the machinery's capacity. The traditional process, in practice, can only yield 85 tonnes, corresponding to 85/100 = 0.85 or 85%. Conversely, the new process is capable of producing 95 tonnes, equivalent to 95/100 = 0.95 or 95%. This comparison indicates that the performance of the new process exceeds that of the traditional process by 10%, suggesting a reduction in losses attributable to speed or stoppages during production.

Quality: In the traditional process, the actual rice production amounts to 85 tonnes, of which 80 tonnes meet the requisite quality standards, corresponding to 80/85 = 0.9411 or 94.11%. In contrast, the new process yields an actual rice production of 95 tonnes, with a good yield of 92 tonnes, equivalent to 92/95 = 0.9684 or 96.84%. The comparison demonstrates that the quality of output from the new process exceeds that of the traditional process by 2.73%, thereby illustrating enhanced accuracy in the management of the production process.

Overall Equipment Effectiveness: OEE: The calculation of Overall Equipment Effectiveness (OEE) for the traditional process yields a value of OEE = 0.75 × 0.85 × 0.9411 = 0.5994, or 59.94%. Conversely, the OEE for the new process is calculated as OEE = 0.875×0.95×0.9684 = 0.8047, or 80.47%. The comparison indicates that the overall efficiency of the new process has increased by 20.53 percentage points, representing a substantial advancement within the industry.

The new rice polishing process exhibits superior Availability, Performance, and Quality metrics in comparison to the traditional process across all facets. An increase in OEE by over 20.53% highlights the potential to augment productivity, minimize losses, and strengthen the competitiveness of the rice mill. These modifications demonstrate that investments in the new production process can substantially improve operational efficiency and product quality.

Table 4: Enhancement of Productivity through OEE: A Comparative Analysis of Conventional and Contemporary Rice Milling Processes

Factor	Traditional Process	New Process	Calculation	Difference (%)
Availability	360 min / 480 min = 0.75 (75%)	420min /480min = 0.875 (87.5%)	0.75 vs 0.875	+12.5
Performance	85 tonnes / 100 tonnes = 0.85 (85%)	95 tonnes / 100 tonnes = 0.95 (95%)	0.85 vs 0.95	+10.0
Quality	80 tonnes / 85 tonnes = 0.9411 (94.11%)	92 tonnes / 95 tonnes = 0.9684 (96.84%)	0.9411 vs 0.9684	+2.73
Overall Equipment Effectiveness (OEE)	0.75 × 0.85 × 0.9411 = 0.5994 (59.94%)	0.875 × 0.95 × 0.9684 = 0.8047 (80.47%)	0.5994 vs 0.8047	+20.53

6. Discussion

This study aims to enhance the efficiency of community rice mill operations, which are a fundamental economic structure playing a significant role in the food system and community security in rural areas. It utilises the Lean Manufacturing framework as a strategic tool to reduce waste, foster contribution in the production process, and develop continuous improvement approaches through local knowledge integration. The results from evaluating the processes before and after improvements following the Lean approach indicate that participatory waste reduction involving the community not only has measurable effects in terms of reducing time and improving product quality but also leads to the development of (socio-technical resilience), which is a core aspect of community-level rice mills.

1. Structural waste constitutes an inherent phenomenon within community systems. Based on data collected from 125 community rice mills, the most prominent form of waste identified was Unnecessary Movement ($\bar{x}$ = 3.34). This predominance primarily arises from informal management structures that lack oversight of raw material flow, the absence of standardized equipment layouts, and inadequate design of the mill's spatial configuration to support the process sequence. From a systems perspective, this unnecessary movement can be analyzed as a consequence of the community's path dependency, which consolidates traditional work behaviors without scrutinizing the production process (Pierson, 2000). Although there is no intention to generate waste, the local social structure, which values familiarity over innovation, necessitates more than purely technical solutions for process improvement; it requires socio-cultural strategies to foster acceptance.

2. Embrace Community Context: Transitioning from Industrial Principles to Mechanisms for Community Development. The implementation of Lean within the community necessitates a shift from a top-down industrial perspective towards a bottom-up, participatory improvement approach, also known as Participatory Lean. This aligns with Liker's (2004) framework, which posits that Lean is not solely a tool for process enhancement but also a means of cultivating an organizational culture grounded in shared learning and development. In this project, the researchers employed a community-based process to collaboratively analyze Value Stream Mapping (VSM) with community members. They also utilized the ECRS approach through Kaizen Team workshops involving rice millers, cooperative managers, and paddy rice farmers who submit their produce to the system. Facilitating all stakeholders in identifying system vulnerabilities not only mitigates resistance to change but also fosters a sense of ownership among participants, a critically important factor in community systems. The reduction of production time from 220 minutes to 170 minutes and the decrease in broken rice percentage from 10–12% to 7–8% are not merely technical achievements but also social outcomes arising from interactions between indigenous knowledge—local tacit knowledge—and modern production techniques. This demonstrates the potential for developing community mills that are technologically integrated while maintaining cultural harmony. These findings are consistent with the research conducted by Tran, Dao, and Nguyen (2023), which indicates that applying Lean, integrated with stakeholder participation in Vietnamese rice cooperatives, significantly enhances Overall Equipment Effectiveness (OEE) and reduces process waste.

3. OEE and Internal Capability Building: The increase in the OEE value from 59.94% to 80.47% is noteworthy, particularly in systems that do not utilize automation or Internet of Things (IoT) enhancements. This indicates that efficiency improvements are not necessarily contingent upon technological advancements but can stem from designing shared learning within the organization. This approach is consistent with the findings of Muchiri and Pintelon (2008), who observed that small and medium-sized enterprises (SMEs) must rely on a behavioral shift among personnel within the system, in conjunction with technical development, to enhance OEE. Furthermore, the concept of internal collaboration within the production process is supported by the work of Rifatullah et al. (2022), which emphasizes that internal organizational competence, especially horizontal collaboration among teams, is a critical factor in ensuring supply system efficiency, even in business environments that do not utilize advanced technology, such as community rice mills. Within community-based management, the sustainability of OEE values is linked to establishing internal learning mechanisms, such as monthly meetings to monitor results from implementing 5S or displaying weekly OEE figures on boards in the mill. These practices establish a feedback loop that fosters continuous improvement beyond the scope of a specific project.

4. Systemic Proposals for Sustainable Development. Although the results of this research demonstrate satisfactory efficiency, the most significant lesson is to emphasize that Lean must undergo contextualisation at the community cultural level in order to attain long-term success. Consequently, the systemic suggestions are: 1) Designing a Lean-community model that emphasizes process adaptation alongside cultivating a culture of inquiry, critical thinking, and continuous adjustment; 2) Support from the government should not be limited to machinery or funding but should also invest in facilitation processes and capacity building within the community rice mill; and 3) Establishing a social audit system that enables the community to evaluate its improvements independently, thereby reducing reliance on external experts.

The aforementioned findings further substantiate the assertion by Seetharaman et al. (2015) that the implementation of Total Quality Management (TQM) should emphasize process development in conjunction with organizational growth. Particularly in small-scale organizations characterized by informal structures, Roh and Lee’s (2013) research indicates that Lean Inventory will yield efficiency outcomes only when the concept is authentically integrated with the organizational culture and participatory processes. Similarly, the work of Park, Heo, and Choi (2016) demonstrates that collaboration between the agricultural and business sectors at the community level—specifically through cooperative efforts in distribution systems—can generate mutually beneficial value if managed strategically and founded on mutual trust, analogous to the management of a network of local rice mill producer farmers. Kim and Park’s (2015) study further suggests that eco-certification contributes to enhancing the capacity of agricultural organizations by increasing product added value and credibility. This underscores a significant trend for community rice mills to establish a foundation for environmental sustainability. In conclusion, this study illustrates the potential for integrating Lean Manufacturing within local community contexts via participatory methodologies. Such integration can transform community rice mills into learning organizations that are resilient, sustainable, and capable of prospering within a grassroots economic framework.

Policy recommendations and suggestions for future research based on the findings of this study should include the government's consideration of promoting the development of community rice mills through structural support policies, such as providing research grants to design production processes suitable for each local context. It is also advisable to organize training sessions to transfer knowledge on management efficiency and to develop criteria for assessing qualitative performance at the community level. Furthermore, efforts should be made to foster collaboration between academic institutions, local agencies, and farmer groups to establish sustainable mill management models in the long term. For future research, the scope should be expanded to include community rice mills in other regions of the country or neighboring countries, such as the Philippines, India, and Vietnam, to compare differences in efficiency and technology application under varying socio-economic conditions. Additionally, in-depth components such as life cycle costs and environmental impacts should be studied to build a more comprehensive systemic knowledge base.

7. Conclusion

This research examines the efficiency of rice polishing processes in community rice mills, comparing traditional systems with newly developed systems. The primary evaluation criterion employed is Overall Equipment Effectiveness (OEE). The adoption of strategies aimed at improving system efficiency—such as reconfiguring production layouts, reducing downtime caused by machinery failures, implementing quality control at each stage, and incorporating optimized logistics and distribution planning—has led to substantial improvements in OEE metrics. Significantly, these advancements have been observed not only in equipment utilization rates and the quality of final products but also in the reduction of transportation delays and distribution inefficiencies (Saengsathien & Namchimplee, 2022). The findings suggest that community rice mills are capable of attaining significant enhancements in operational efficiency and logistics performance without requiring substantial capital investments, provided that process design and distribution systems are customized to local conditions. Furthermore, the implementation of green logistics practices and the reinforcement of trade-oriented distribution channels can extend these advantages beyond production, fostering grassroots economic development, reducing losses within the agricultural sector, and promoting sustainability within local and regional supply chains. By integrating Lean manufacturing principles with strategic improvements in logistics and trade, community rice mills in Kalasin can bolster their position as competitive entities within both domestic and international rice markets.

8. Limitations

Although the study offers valuable insights into the application of Lean Manufacturing in community-based rice mills, several limitations must be acknowledged. Firstly, the case study was confined to a limited number of local rice mills, which may influence the generalizability of the findings. Secondly, the analysis was carried out over a six-month period, potentially not capturing the long-term sustainability impacts comprehensively. Thirdly, while the research concentrated on operational efficiency, it did not extensively evaluate the financial return on investment (ROI) or socio-cultural factors that could affect adoption. Future research should aim to include larger samples across different regions, employ longitudinal analysis, and incorporate economic and social variables to yield a more comprehensive understanding of Lean implementation within rural agro-industrial systems.

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