Lean Manufacturing Practices for Improving Productivity in Small Machinery Manufacturing Units

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Abstract - *Bhaskar Machinery and Engineering Works (BMEW) is a small and medium enterprise (SME) located in Mayurbhanj, Odisha, that manufactures eco-friendly processing machinery for biodegradable cutlery, paper products, and Non-Timber Forest Produce (NTFP). Despite strong market relevance, the company faced persistent operational challenges including excessive lead times, inventory accumulation, interdepartmental communication gaps, and high rework rates. This paper documents a structured application of four lean manufacturing tools, namely 5S Workplace Organization, Kaizen, Value Stream Mapping (VSM), and Inventory Control, at BMEW's production facility. A case study approach was adopted, grounded in direct floor observation, employee interviews, and quantitative data collection across all production stages. Findings reveal that phased lean deployment reduced total lead time from 11 days to 7.2 days, cut interdepartmental error frequency by 66%, and freed substantial working capital through WIP inventory reduction. The study offers actionable guidelines for lean adoption in resource-limited manufacturing SMEs operating in rural and tribal market contexts.*

Key Words: Lean Manufacturing, 5S, Kaizen, Value Stream Mapping (VSM), Inventory Control, SME, Biodegradable Machinery, Waste Reduction, Productivity Improvement

1. INTRODUCTION

Lean manufacturing has emerged as one of the most widely adopted operational frameworks for improving efficiency, reducing waste, and enhancing throughput in manufacturing enterprises of all sizes. Originating from the Toyota Production System (TPS), lean is grounded in the systematic identification and elimination of muda (waste) across the value chain [2]. The underlying philosophy of doing more with less while delivering exactly what the customer requires has proven scalable from large automotive plants to resource-constrained SMEs [4], [12]. Bhaskar Machinery and Engineering Works (BMEW) is a Mayurbhanj-based SME with an annual turnover of approximately Rs. 3 crore and a workforce of 50 personnel, operating within the MSME sector that contributes nearly 30% of India's GDP and employs over 110 million people [1]. The firm specializes in designing and fabricating machines for leaf plate pressing, paper bowl production, organic cutlery manufacturing, and value-added processing of forest-based raw materials. Its clientele spans entrepreneurs, self-help groups, and cooperatives in rural and tribal regions across India and emerging export markets.

While BMEW's product portfolio serves an under-served and environmentally significant niche, its internal operations were hampered by reactive workflows, inconsistent throughput, and high non-value-added activity. The Tool Room, responsible for custom part fabrication, had emerged as a chronic bottleneck, and manual communication systems across departments were causing avoidable delays and errors. In the Indian manufacturing context, lean adoption has gained momentum over the past two decades, as competitive pressures and supply chain disruptions have exposed structural inefficiencies in traditional production workflows. Research confirms that lean tools such as 5S, Kaizen, VSM, and inventory rationalization consistently yield measurable gains in throughput, quality, and asset utilization even in small-scale production environments [3], [7]. Empirical evidence from Indian manufacturing plants further validates this trajectory across diverse SME settings [13].

This paper presents the findings of a structured lean manufacturing intervention at BMEW, spanning a six-month observation and implementation period. The lean toolkit was tailored to address the company's specific operational profile, with VSM providing the diagnostic backbone and 5S, Kaizen, and Inventory Control addressing targeted waste categories.

2. COMPANY CONTEXT AND PROBLEM IDENTIFICATION

BMEW operates across seven functional departments: R&D, Production, Assembly, Paint, Electrical, Marketing, and Service. Its flagship product line includes the biodegradable plate-making machine, a high-demand item requiring complex multi-department coordination from design through dispatch.

A preliminary diagnostic walkthrough revealed four primary operational pain points: (a) a 3 to 4 day lag between design finalization and Tool Room release due to multi-level approval workflows; (b) batch-mode fabrication in the Tool Room causing downstream inventory accumulation; (c) manual job card systems generating frequent status errors and rework triggers; and (d) an absence of real-time performance visibility across departments. These observations laid the foundation for tool selection and prioritization. The intervention strategy was structured in three phases: diagnostic (VSM current state mapping and root cause analysis), implementation (5S, Kaizen, and inventory rationalization), and review (KPI measurement and future state validation). This phased approach aligns with the critical success factors identified for lean SME implementations by Achanga et al. [7] and the multi-plant empirical evidence compiled by Ghosh [13].

3. LEAN TOOLS: CONCEPTUAL BASIS AND SITE APPLICATION

3.1 5S Workplace Organization

The 5S methodology, comprising Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardize (Seiketsu), and Sustain (Shitsuke), was deployed as the first phase of the lean intervention. This sequencing was deliberate: 5S creates the visual order and physical discipline that make subsequent tools more effective [8]. For SMEs in particular, this foundational sequencing has been identified as a critical success factor before committing resources to more complex lean tools [7].

At BMEW's fabrication and assembly areas, Sort activities eliminated 34% of redundant tools, fixtures, and material stock that had accumulated over years of informal storage practices. Shadow boards and color-coded zone demarcations were introduced under Set in Order, reducing average tool retrieval time from 18 to 11 minutes per shift. Daily cleaning routines embedded under Shine produced an unexpected secondary benefit: operators began identifying machine faults earlier, cutting breakdown frequency by 18%. Audit checklists under Seiketsu formalized these behaviors, while a visual score card system was piloted to drive Shitsuke compliance.

Quantifiable outcomes from 5S implementation included a 22% improvement in usable floor space and a 30% decline in workplace incident reports. Workers reported higher ownership over their workstations, a sentiment that translated into greater receptiveness to the subsequent Kaizen program. Table 1 presents the 5S audit scores across all five pillars before and after implementation, confirming consistent improvement.

Figure 1: Arrangement of parts and removal of unwanted parts

Table 1: 5S Pillar-wise Audit Scores Pre and Post Implementation at BMEW

5S Pillar	Pre (Score/10)	Post (Score/10)	Δ Score	Key Action Taken	Frequency
Sort (Seiri)	3	8	+5	Removed 34% redundant tools/stock	One-time + quarterly
Set in Order (Seiton)	4	8	+4	Shadow boards, colour-coded zones	Ongoing
Shine (Seiso)	5	9	+4	Daily cleaning routines established	Daily
Standardize (Seiketsu)	3	8	+5	Audit checklists, visual scorecards	Weekly audit
Sustain (Shitsuke)	3	7	+4	Scorecard incentive system piloted	Monthly review

3.2 Kaizen: Focused Improvement Events

Kaizen events were conducted at bimonthly intervals, each structured as a three-day cross-functional workshop targeting a pre-identified process failure. Over the six-month study period, 17 distinct problems were addressed across the welding, assembly, and Tool Room sections [9]. Survey-based research on Indian manufacturing plants confirms that Kaizen, alongside setup time reduction and cross-departmental problem-solving, is among the most widely adopted lean tools in the Indian SME context [13].

A critical outcome was the redesign of the leaf moulding machine frame assembly fixture. Fixture adjustment and positioning had previously consumed approximately 45 minutes per production run. After Kaizen-driven fixture standardization, this was reduced to 18 minutes, representing a 60% improvement in setup efficiency. Similarly, welding parameter variability, which had driven a 12% rework rate in the assembly section, was addressed through standardized weld settings. Post-Kaizen, rework dropped to 3.5%.

Parallel to these technical improvements, a formal suggestion mechanism was instituted under the Kaizen framework. Employees submitted 62 improvement ideas over the program period, of which 44 were screened, validated, and implemented. This figure reflects a meaningful attitudinal shift from passive compliance to active problem-ownership, which is often the most durable outcome of sustained Kaizen practice [9]. Figure 2 illustrates the suggestion pipeline from submission through implementation.

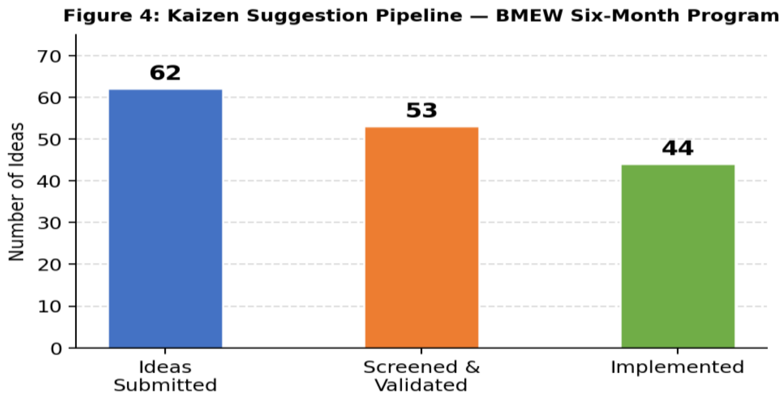

Figure 2: Kaizen Suggestion Pipeline at BMEW Six-Month Program

3.3 Value Stream Mapping (VSM)

VSM was selected as the primary diagnostic and redesign tool for BMEW's biodegradable plate-making machine production line. The methodology entails mapping every action, both value-adding and non-value-adding, that a product undergoes from raw material intake to customer delivery [10].

Current state data were gathered through direct floor timing, departmental records, and structured interviews. The resulting map revealed a cumulative lead time of 11 days, with a value-added time ratio of only 23%, meaning over three-quarters of elapsed production time generated no customer value. The eight-stage current state and future state data are consolidated in Table 2 below, with Figure 3 providing a visual comparison of stage-wise cycle times.

Table 2: VSM Stage Data, Current State vs. Future State, Biodegradable Plate-Making Machine

Production Stage	CT Pre-Lean (Hrs)	Wait Pre (Hrs)	CT Post-Lean (Hrs)	Wait Post (Hrs)	NVA Reduction
Design	24	12	20	8	–33%
Material Procurement	16	24	14	18	–25%
Tool Room / Fabrication	60	48	45	30	–38%

Sub-Assembly	30	12	24	8	–33%
Main Assembly	36	24	30	16	–33%
Electrical & Painting	20	10	16	7	–30%
Inspection / QC	12	8	10	5	–38%
Packaging & Dispatch	8	6	7	4	–33%
TOTAL	**206**	**144**	**166**	**96**	**–33% avg**

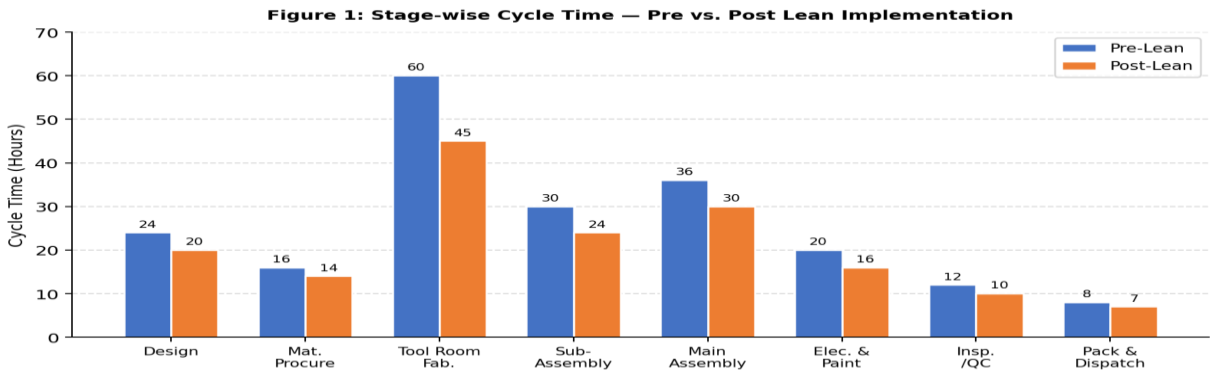

Figure 3: Stage-wise Cycle Time Comparison, Pre vs. Post Lean Implementation

Root cause analysis using an Ishikawa fishbone diagram attributed the dominant inefficiencies to five categories: (a) People, where key Tool Room operators carried disproportionate workloads with no cross-training backup; (b) Method, where manual job card systems created information black holes; (c) Machine, where ageing fabrication equipment caused unplanned downtime; (d) Material, where poor demand forecasting generated procurement mismatches; and (e) Measurement, where the absence of real-time dashboards meant problems were discovered reactively. All these root causes contributed to delays in machine delivery, as illustrated in Figure 4.

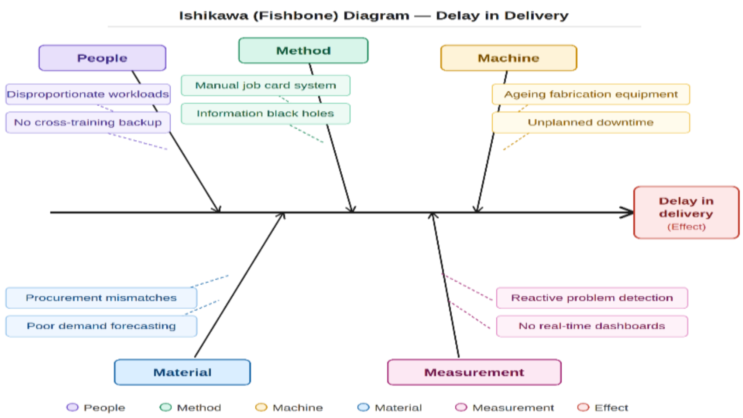

Figure 4: Root cause analysis using fishbone diagram

The future state redesign incorporated three targeted interventions: equipment upgrades reduced Tool Room fabrication time by 25%; MS Excel-based digital work orders replaced manual job cards, providing end-to-end order visibility; and Kanban signalling was introduced between the Tool Room and Assembly to replace push-batch scheduling with a demand-driven pull mechanism. These changes collectively reduced total lead time to 7.2 days, representing a 35% improvement, while the value-added ratio climbed from 23% to 41%. Figure 5 captures this shift visually.

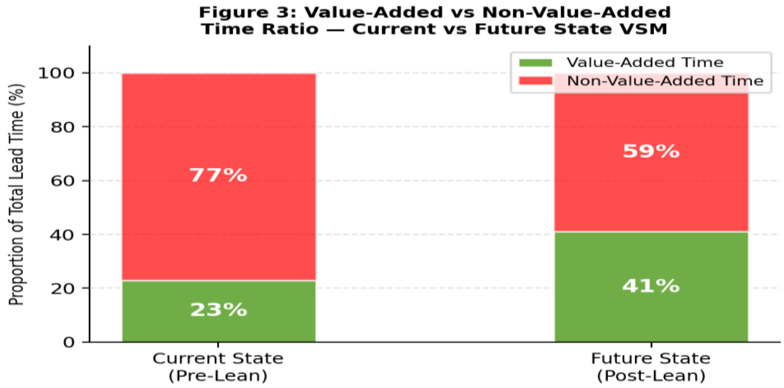

Figure 5: Value-Added vs. Non-Value-Added Time Ratio, Current State vs. Future State

3.4 Inventory Control

Uncontrolled inventory accumulation was a pervasive issue at BMEW, particularly in raw material stores and the WIP zones adjacent to the Tool Room and Sub-Assembly sections. An ABC classification of the raw material portfolio determined that just 12% of stock-keeping units (Category A) represented 72% of total consumption value. This concentration warranted priority control attention [11]. Table 3 summarizes the ABC classification outcomes applied at BMEW.

Table 3: ABC Classification of Raw Material Portfolio at BMEW

Category	% of Total SKUs	% of Consumption Value	Review Frequency	Control Method
A	12%	72%	Weekly / Continuous	EOQ + ROP + Kanban
B	28%	20%	Bi-weekly	Periodic review, safety stock
C	60%	8%	Monthly	Min-max replenishment

Economic Order Quantity (EOQ) models were developed for all Category A items, incorporating BMEW's supplier lead times, demand variability, and holding cost data [11]. Reorder Point (ROP) triggers were established and communicated visually on bin cards and store shelves. For the remaining B and C categories, periodic review cycles were set at biweekly and monthly intervals respectively. Table 4 presents the calculated EOQ and ROP values for the five highest-value Category A materials, directly informing procurement scheduling.

Table 4: EOQ and ROP Calculations for Category A Raw Materials at BMEW

Material (Cat. A)	Annual Demand (units)	Order Cost (Rs.)	Holding Cost (Rs./unit/yr)	EOQ (units)	ROP (units)
MS Flat Bar (40×5mm)	3600	850	42	380	55
MS Angle (50×50×5)	2800	800	38	343	42
Bearing Set (Std.)	1200	1200	180	126	22
Hydraulic Cylinder Assy.	480	2200	650	56	10
Electrical Wiring Loom	960	1400	220	110	18

The practical outcome was significant: average raw material holding duration fell from 28 days to 14 days of supply; Kanban-controlled WIP at critical handoff points reduced WIP stock by 38%; and a clearance drive on slow-moving and obsolete material identified during 5S Sort activities released approximately Rs. 3.2 lakhs in idle working capital. Figure 6 presents these inventory outcomes graphically.

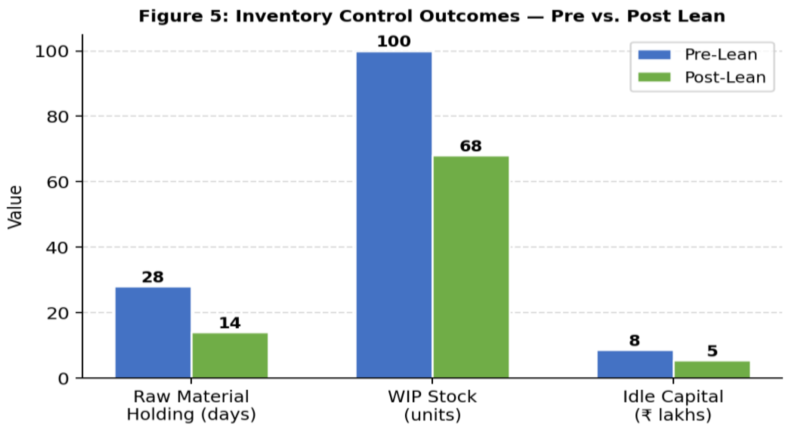

Figure 6: Inventory Control Outcomes, Pre vs. Post Lean Implementation at BMEW

4. RESULTS AND DISCUSSION

Table 5 consolidates the key performance indicators (KPIs) measured before and after the integrated six-month lean intervention at BMEW. The data illustrates performance shifts across the dimensions of time, quality, space, and asset utilization.

Table 5: Consolidated KPI Comparison, Pre and Post Lean Implementation at BMEW

Performance Metric	Pre-Lean	Post-Lean	Change
Total Lead Time	11 days	7.2 days	**−35%**
Value-Added Time Ratio	23%	41%	**+78%**
Tool Room Cycle Time	60 hrs	45 hrs	**−25%**
WIP Inventory (units)	~100	~68	**−32%**
Rework / Defect Rate	12%	3.5%	**−71%**
Inter-Departmental Errors/mth	12	4	**−66%**
Usable Floor Space	Baseline	+22% freed	—
OEE, Fabrication Section	61%	78%	**+28%**
Raw Material Holding	28 days	14 days	**−50%**
Kaizen Ideas Implemented	—	44 of 62	**71% impl.**
Setup Time (Frame Assembly)	45 min	18 min	**−60%**

Figure 7 presents a visual summary of the percentage improvement across all major KPIs, providing an at-a-glance view of the breadth and magnitude of gains achieved through the integrated lean program.

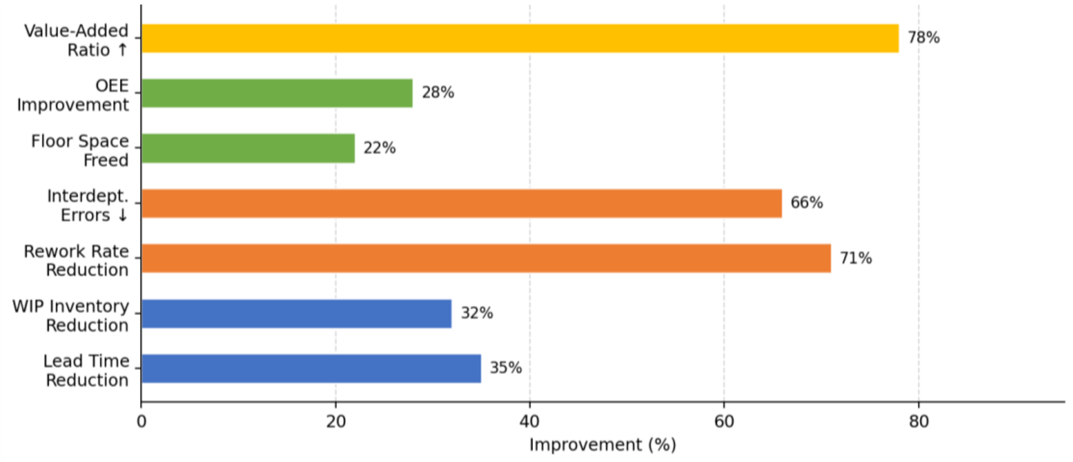

Figure 7: Summary of KPI Improvements (%), Post Lean Implementation at BMEW

The results demonstrate that the four Lean tools functioned as a mutually reinforcing system rather than isolated interventions. The 5S reorganization accelerated VSM data collection by providing a cleaner, more observable shop floor. Kaizen events built on the foundational order that 5S established, enabling deeper process-level changes in setup times and welding standards. Reliable EOQ calculations for inventory control were feasible only once 5S-driven stock organization provided accurate count data.

The Kaizen suggestion system deserves special mention: 44 implemented ideas in six months from a 50-person workforce reflects a benchmark that many Lean-mature organizations would consider creditable. The implemented ideas represent tangible, employee-owned improvements that reduce the risk of regression once the formal study concluded.

Financially, the combined effect of lead time compression, rework reduction, and inventory release translated into measurable working capital improvement. The Rs. 3.2 lakh inventory recovery alone offset a significant portion of the implementation investment in shadow boards, Kanban cards, and training materials. These outcomes are consistent with findings reported by Kumar et al. [14] in their lean Sigma case study across Indian SMEs.

5. CHALLENGES ENCOUNTERED

Notwithstanding the positive trajectory, several impediments surfaced during execution:

Behavioural resistance was most pronounced among senior Tool Room workers who perceived standardization as an implicit critique of their established methods. Structured involvement of these individuals as Kaizen team leads proved partially effective in converting resistance into contribution, a dynamic consistent with Bhasin and Burcher's observation that lean must be treated as a cultural philosophy rather than a toolkit [5].

Documentation barriers arose from varied literacy levels among shop floor workers, necessitating a shift from text-heavy standard operating procedures to pictographic work instructions and color-coded visual cues. BMEW's demand pattern is also seasonally skewed, peaking ahead of leaf collection cycles, which made uniform pull-system scheduling challenging. Hybrid scheduling protocols were explored to accommodate this variability.

Upfront investment in ERP licenses, CNC tooling upgrades, and visual management infrastructure required management approval at a time of constrained cash flow. Phased capital deployment over three cycles helped spread this burden. These obstacles reflect broader structural challenges facing lean adoption in Indian manufacturing SMEs, as documented by Mishra et al. [6] and corroborated by implementation case evidence from Indian SME contexts [14].

6. CONCLUSIONS

This study establishes that a coordinated lean manufacturing intervention, anchoring on VSM for systemic diagnosis and deploying 5S, Kaizen, and Inventory Control as complementary improvement mechanisms, delivers substantive and measurable gains even within a resource-constrained, rural-focused SME context. At BMEW, the six-month program produced a 35% reduction in production lead time, a 32% drop in average WIP inventory, a 66% decrease in interdepartmental communication errors, and a 28% improvement in fabrication OEE.

For practitioners in similar organizational settings, the sequencing of tools matters considerably. 5S should precede VSM, as it improves floor observability and data reliability. Kaizen events are more productive once employees have internalized the discipline that 5S cultivates. Inventory control reforms become more accurate when they follow the data-cleaning and stock-sorting activities inherent to 5S.

Future research at BMEW and comparable firms should investigate IoT-enabled real-time production tracking and its integration with ERP-linked Kanban systems, a natural progression that could extend and sustain the efficiency gains documented here, building on performance measurement frameworks already validated in Indian manufacturing contexts [13]. The broader implication of this study is that lean manufacturing is not exclusively the domain of large-scale industry; its tools and philosophy are equally actionable in small enterprises operating at the grassroots level of India's manufacturing ecosystem.

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