

Original Article

Productivity-Focused Production Model: SLP, Standard Work, and 5S in a Metalworking SME for Heavy-Machinery Spares: A Case Study

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Abstract - Metalworking SMEs that produced heavy-duty spare parts often faced unstable flow, long internal travel, and rework; prior lean studies reported similar patterns in discrete manufacturing. This study addressed these challenges by integrating Systematic Layout Planning, Standard Work, and 5S in a four-month pilot. The contribution lay in a sequenced design that first redrew proximities, then codified the best-known method, and finally conditioned the workplace to sustain discipline. The model was implemented in a Peruvian SME and was assessed with before-and-after measurements. Productivity increased 35% (0.12→0.162 units per labor hour), defect rate fell to 3% (from 8%), and internal transfer time decreased 69% (28.1→8.8 minutes per unit). These effects suggested operational stability, safer supervision, and a low-capital path to competitiveness for small shops serving heavy industries. The findings invited replication with multi-site, longer-horizon designs and simulation-aided appraisal of layout alternatives. The study invited work that examined further the financial and environmental impacts.

Keywords - Lean Manufacturing, Systematic Layout Planning (SLP), Standardized Work, 5S Methodology, Metalworking SME.

1. Introduction

SMEs in the metalworking sector sustain capital-intensive supply chains by manufacturing critical spare parts and subassemblies for heavy-duty machinery. Globally, recent scholarship shows these firms face short, varied orders and therefore depend on robust internal capabilities and lean processes to remain competitive; SME-oriented Lean models have proved an effective, relatively low-cost route to improve productivity and process stability [1]. In Latin America—and in Peru in particular—case evidence indicates that resource-aware Lean deployments can raise service levels, cutting internal and external delays and improving on-time delivery [2]. Additional Peruvian studies report efficiency gains when Lean is integrated with maintenance and standardization in services and operations, reinforcing the approach's suitability for the local industrial fabric [3].

The recurrent operational pattern is familiar. Poor plant layout stretches routes, creates flow crossings, and inserts waits between processes, all of which inflate cycle time; redesigns guided by Systematic Layout Planning (SLP), supported by analytical models and discrete simulation, consistently reduce material handling and help balance discrete-manufacturing lines [4]. Classic and contemporary accounts document disciplined SLP decreasing distances, handling costs, and transfer times, yielding a more continuous

and supervisable flow [5], while coupling SLP with ergonomics and simulation facilitates selecting alternatives with lower handling costs and shorter transfers [6]. Variability in method and lack of standardization elevate rework and defect rates; consolidating Standard Work—anchored by the visibility and order provided by 5S—has been linked to verifiable defect reductions and cycle-time gains in labor-intensive SMEs [7]. In metalworking settings, combinations of 5S, standardization, and autonomous maintenance correlate with fewer nonconformities and steadier processes in similarly sized firms [8]. Disordered stations and weak visual discipline add losses from searching and setup, compromising safety and repeatability; 5S programs address these “invisible” wastes and establish the cultural base needed to sustain the standard [7], [8].

Addressing these gaps is not optional for producers of heavy-machinery spares, where due dates and dimensional precision are non-negotiable. Evidence indicates that acting on physical flow (SLP), method stability (Standard Work), and workstation conditioning (5S) yields improvements in lead time, productivity, and quality without disproportionate capital outlays [4]–[7]. In capital-constrained, mix-volatile environments, the trio works on structural causes: layout corrects the geometry of flow; standardization reduces human and technical variability; and 5S makes abnormality visible



while trimming search time. Even when complementary tools are present (e.g., autonomous or preventive maintenance), studies in metalworking attribute much of the performance gain to coherence among flow, method, and environment rather than to isolated projects [8], [9].

Despite progress, a clear research gap endures in metalworking SMEs dedicated to heavy-machinery spares: many published interventions adopt Lean tools partially (e.g., TPM+SLP or 5S with maintenance), whereas explicit integration of the SLP–Standard Work–5S triad as the backbone of process redesign in this subsector is less common [1-3], [9]. This study addresses that gap with an integrated production model: SLP to shorten transfers and remove crossings, Standard Work to fix the best-known method and curb defect rates, and 5S to stabilize the environment and enable visual control. Unlike proposals focused solely on equipment or housekeeping, our approach treats layout, method, and discipline as a coupled system. The working hypothesis is that the combination yields synergies beyond those of single-tool deployments: the redrawn flow clarifies routes and reduces waiting; standardization sustains optimal execution; and 5S consolidates habits that hold the gains over time. Hence, the contribution engages with prior findings—positive effects of each tool on its own—and extends them toward a holistic framework tailored to Latin American metalworking SMEs [10].

2. Literature Review

2.1. Lean Manufacturing in Metalworking-Like SMEs

Evidence from small manufacturing settings shows that lean deployments deliver measurable gains in throughput, lead time, and quality when projects are scoped to the constraints typical of SMEs and sequenced to build capability over time [11]. Case-driven programs that prioritize “quick wins” (e.g., workplace flow, bottleneck relief) provide traction for deeper changes by visibly reducing waste and stabilizing processes [12]. Beyond isolated tools, frameworks tailored to very small firms highlight the need for a staged roadmap that aligns practices with resource limitations and workforce skills, a pattern repeatedly observed across multi-case analyses of small manufacturers [13]. This stream of work justifies coupling lean tools with pragmatic governance and skill development in SME contexts similar to metalworking spare-parts operations.

2.2. Facility Layout as a Lever (SLP and Allied Methods)

Facility layout emerges as a primary cost and time driver in discrete-part production; empirical studies using Systematic Layout Planning (SLP) report material-handling distance and travel-time reductions after re-zoning, adjacency corrections, and flow consolidation [14]. Recent layout redesigns in heavy fabrication and steel processing illustrate how combining SLP/CRAFT with flow metrics and iterative validation produces quantifiable savings in movement and congestion, while keeping investment modest—conditions aligned with

SME realities [15]. Complementary work integrates Design for Lean Six Sigma into strategic facility and space planning, showing how space utilization and capacity can be improved in regulated manufacturing sites through a structured DMADV logic that embeds lean flow principles from the outset [16]. Together, these findings support using SLP as the backbone of plant reconfiguration in spare-parts machining, where transport time and needless backtracking depress productivity.

2.3. Standardized Work to Stabilize Variability

Standardized Work (SW) is consistently associated with variability control, ergonomic balance, and defect reduction when methods are co-designed with operators and linked to takt and capacity sheets [17]. Case-based standardization programs in assembly-intensive environments document better repeatability and faster learning curves once work elements, sequencing, and in-process inventory are fixed and visually managed [18]. Earlier implementations also show that SW functions as a platform technology: once the baseline is documented and trained, subsequent improvements (e.g., line balancing or cell redesign) are easier to test and lock in, with documented reductions in walking, idle time, and rework [19]. For SME metal shops, these patterns argue for codifying best-known methods around set-ups, gauging, and inspection, then auditing their use to keep drift in check.

2.4. 5S as the Enabling Foundation and Change Spine

Empirical studies confirm that 5S delivers not only tidiness but throughput and safety gains by removing search time, clarifying status, and preventing mix-ups—effects amplified in fabrication and welding settings close to metalworking [20]. Methodological contributions also propose quantified indices to assess 5S maturity and target actions (e.g., via fuzzy logic and importance–performance analysis), which is useful when resources are thin and prioritization matters [21]. In practice, 5S and SW are mutually reinforcing, stable, labeled workplaces that reduce motion and mistakes, while SW sustains order and accelerates training; change-management evidence further indicates that structuring the transformation—clear sponsorship, staged wins, and staff engagement—raises the odds of durable adoption in operational settings [22]. These insights motivate treating 5S as the enabling layer for Standardized Work and as the visible backbone for day-to-day governance in a machining SME.

3. Contribution

3.1. Proposed Model

In Figure 1, the proposed production model was presented, structured around the Lean Manufacturing philosophy and designed with three main components supported by a transversal foundation of change management. The first component was Systematic Layout Planning (SLP), which aimed to optimize the arrangement of resources and the interaction between activities in order to promote a smoother

and more continuous material flow. The second component focused on Standard Work, emphasizing the identification of efficient working methods and the establishment of consistent operational practices to ensure repeatability and reliability in daily operations. The third component was represented by the 5S methodology, which fostered order, cleanliness, and discipline as essential conditions for process stability and long-term sustainability. Change management acted as a

cross-cutting element, enabling the proper adoption of these tools and supporting the organizational adaptation required to maintain results over time. The model was implemented in a small-to-medium metalworking enterprise dedicated to manufacturing spare parts for heavy-duty machinery, where the main objective was to strengthen competitiveness by reducing waste, standardizing processes, and creating a more efficient and reliable working environment.

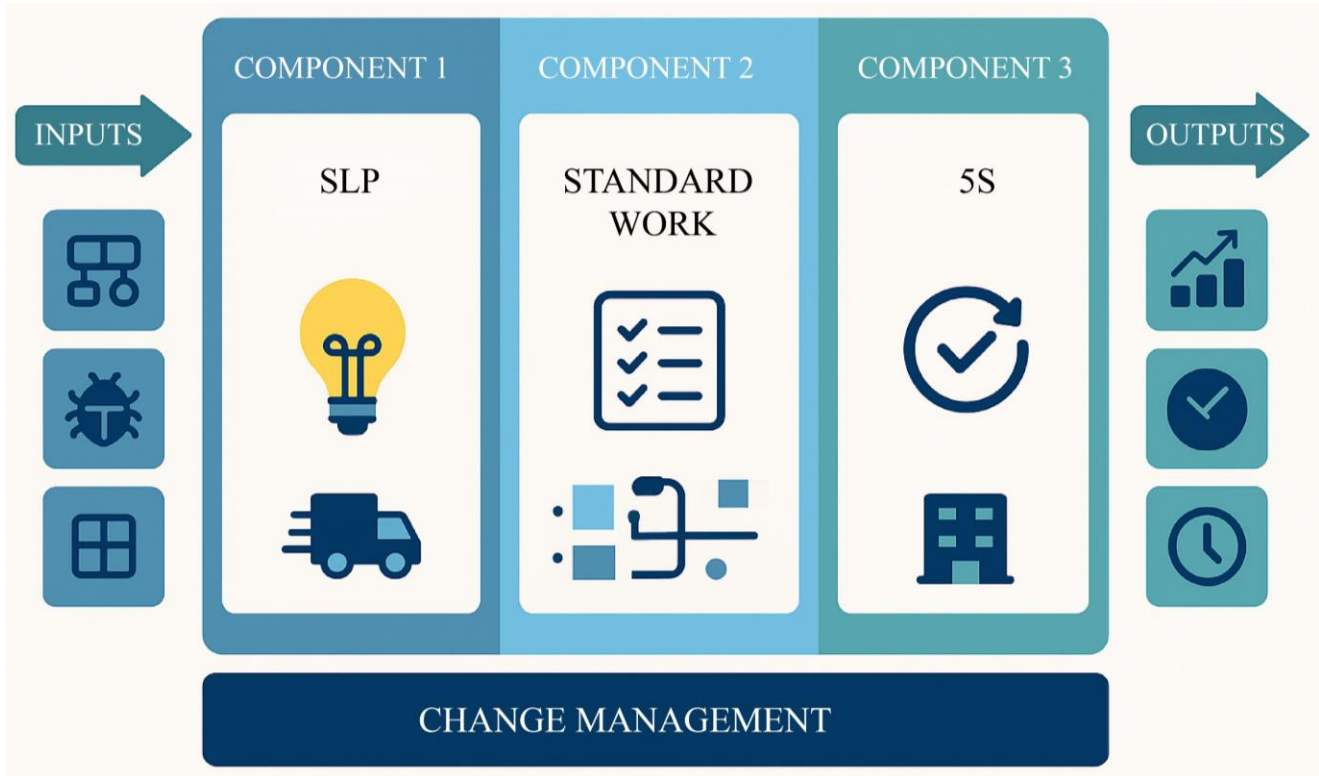


Fig. 1 Proposed model

3.2. Model Components

Figure 1 presents the proposed production model as a practical Lean Manufacturing architecture tailored to a metalworking SME that manufactures spare parts for heavy-duty machinery. The model integrates three operational components—Systematic Layout Planning (SLP), Standard Work, and 5S—supported by a transversal layer of Change Management that sustains adoption over time. Rather than treating tools in isolation, the design links spatial decisions, method definition, and workplace conditions so that material moves with minimal friction, tasks are performed consistently, and the shop floor remains readable at a glance.

3.2.1. Component 1 — Systematic Layout Planning: Designing the Path of Flow

SLP is the starting point because the plant layout constrains real efficiency. The company processes medium to heavy parts that are sensitive to handling and often require multiple machining and inspection steps; consequently, the distance traveled and the number of transfers matter. The

component begins by grouping parts into families based on routes, tolerances, and handling needs, then mapping current flows to reveal waiting zones, traffic crossings, and typical bottlenecks. A relationship chart guides proximity and separation: processes with frequent transfers move closer; noisy or chip-projecting operations gain controlled isolation; interim inspection is placed where it prevents defects from traveling. The preferred trajectories are linear or U-shaped, which shorten moves, reduce crane maneuvers, and improve line-of-sight supervision. SLP also defines aisle widths consistent with the transport equipment, positions safe staging points at the right height, and reserves space for tooling and fixtures used frequently. Implementation proceeds in modules—first the highest-rotation family, then adjacent families—so production continuity is preserved while learning from each move. Flexibility is built in with quick service connections and reserved reconfiguration zones, allowing the plant to absorb mix changes without losing the logic of flow.

3.2.2. Component 2 — Standard Work: Fixing the Best Known Way to Perform the Task

Once the path is clear, the model specifies how work is executed at each station. Standard Work functions as a shared language that captures the best-known method for safety, quality, and economy of motion. The sequence is documented from preparation to in-process checks and release, with unambiguous descriptions of prerequisites and acceptance criteria. Attention to ergonomics is explicit: tools within comfortable reach, proper working heights for heavy pieces, and transfer tables that bring the part to the plane of work. Visual job instructions display the sequence, tool layout, and key risks, allowing supervisors and peers to detect deviations without interrupting the operator.

Handoffs between processes include the minimum information needed by the next step—surface condition, orientation references, or measurement marks—so that batches are not delayed by avoidable questions. Training occurs on the job through demonstration, guided practice, and immediate feedback; competence is verified at the station and recorded to maintain a clear view of available skills. The standard is not a rigid rule; when a superior method proves beneficial under real conditions, it replaces the previous one, ensuring the documentation reflects the current best practice.

3.2.3. Component 3 — 5S: Creating an Environment that Protects Flow and the Standard

This component shapes the physical and behavioral environment, making the standard easy to execute. The first move is to separate essentials from “just-in-case” items; accumulated fixtures and supports often hide problems and lengthen searches in metalworking shops. With the nonessential removed, the station is organized so every tool has a fixed, unmistakable home; shadow boards and labeled containers allow absence to be visible immediately. Organization mirrors the Standard Work: if a gauge is used early, it lives within immediate reach; if a fixture appears at the end, its location avoids interfering with earlier steps.

Cleaning is treated as inspection: bright surfaces reveal leaks, chips signal cutting issues, and clear guides expose abnormal wear. Short open- and close-of-shift routines protect production rather than compete with it, and simple visuals explain what must be cleaned and why. Storage, labeling, and replenishment rules keep coherence across areas so that a visitor understands the logic within minutes. The discipline grows through daily habits and light audits that recognize progress and correct drift without turning 5S into a punitive ritual. The approach extends to support functions: the tool crib operates with traceable issue/return, maintenance keeps spare parts and consumables visible and organized, and logistics sets staging zones that do not invade production paths. The result is a shop that “speaks”: empty locations indicate pending material, red tags surface obsolescence, and misaligned markers flag movement in clamps or stops.

3.2.4. Cross-Cutting Component — Change Management: Enabling and Sustaining Adoption

Change Management runs underneath the three components, aligning behavior with technical decisions. The message is concrete and close to the shop floor: fewer unnecessary moves, fewer searches, fewer reworks; clearer flow, safer conditions, and learning shared in the open. Implementation follows short, visible iterations with modest scopes—reposition a set of machines, standardize a critical operation, consolidate 5S in one cell—each with on-floor verification. Pilots provide credible results and feed adjustments to the next iteration. Training favors practice at the workstation, and local leaders—formal and informal—act as reference points during the transition. Coordination across functions is intentional: if SLP creates a cell that needs frequent replenishment, logistics adapts its routes; if Standard Work requires specific tools at arm’s length, the tool crib ensures availability; if 5S sets locations and signals, maintenance respects and reinforces them during interventions. Resistance is addressed with empathy and evidence: concerns are heard, tested in the process, and resolved without blame. Over time, agreements turn into habits, and the improved way of working becomes the default rather than a special project.

3.2.5. System Integration and Expected Behavior on the Shop Floor

Although described separately, the components operate as one system. SLP clarifies the path and reduces geometric friction; Standard Work transforms experience into a consistent sequence; 5S keeps the stage clean, ordered, and revealing; Change Management preserves alignment and nurtures learning. In a metalworking SME that manufactures heavy-duty spare parts, this integration shortens travel for bulky pieces, stabilizes setups, and reduces informal coordination that previously slowed production. The operation becomes more predictable not by imposing rigidity, but by removing sources of variation that add no value. When issues appear, the team inspects the flow, the method, and the environment with a single lens; if a part stops, it checks whether the path is clear, the standard is followed, and the station helps rather than hinders. The approach favors observation at the source, small practical fixes, and rapid conversion of proven improvements into the new standard. In this way, the plant grows more resilient, and the daily routine reflects what the model seeks from the outset: a readable flow, a shared method, and a workplace that invites doing things right the first time.

3.3. Model Indicators

To track the model’s contribution, the team used a lean-aligned evaluation scheme spanning flow design (SLP), method execution (Standard Work), and workplace conditions (5S). Tailored to heavy-duty spare-parts fabrication, the scheme combined periodic shop-floor reviews with documented comparisons over successive iterations. This

arrangement grounded managerial decisions in observable practice, allowed like-for-like judgments across phases, and provided the governance required to sustain continuous improvement and productivity growth—without binding the discussion to tool-specific metrics here.

Productivity (Units/LH)

Quantifies output per labor hour, capturing how effectively the workforce converts time into finished parts. The figure shows that higher values signal capacity released by Lean–SLP without additional staffing.

$$\text{Productivity} = \frac{U}{LH}$$

Defective Products (%)

Expresses the share of units failing inspection relative to total production. It summarizes quality losses that drive rework or scrap; a lower percentage reflects steadier execution and better process capability.

$$\text{Defect Rate (\%)} = \frac{U_d}{U_t} \times 100$$

Transfer Time (Min/unit)

Represents the average minutes a unit spends moving between areas. It reveals layout and logistics waste; lower values indicate shorter routes, fewer handoffs, and a cleaner flow.

$$\text{Transfer Time per Unit} = \frac{\sum_{i=1}^M t_{\text{transfer}}^{(i)}}{U}$$

Cycle Time (Min/unit)

Measures the average elapsed minutes from first operation to completion for one unit, including processing, waiting, setups, and internal moves—an immediate lens on flow performance and delivery responsiveness.

$$\text{Cycle Time per Unit} = \frac{T_{\text{elapsed}}}{U}$$

4. Validation

4.1. Validation Scenario

The medium-sized metalworking SME under analysis is based in Lima, Peru, and specializes in producing spare parts for internal heavy-duty equipment. Medium-sized production batches that are customized for each remit are produced in response to changing mining and construction sector specifications. In addition to internal maintenance and a stewarded tool crib, the physical layout incorporates cutting, machining, surface treatment, and dimensional inspection. Persistent space and working-capital ceilings limit operational choices and skew tactical daily priorities, despite the existence of a vast institutional reservoir of tacit knowledge. Transactional data filtering reveals the classic symptoms:

random in-process accumulation that obscures queue clarification, sporadic tooling or material stockouts, erratic fixture and tool set procedures, and excessive semi-finished stock transport. When taken as a whole, these factors increase the anticipated throughput speed and the projected delivery forecast bands, frequently resulting in cascade re-planning and unanticipated overtime. Severity zone diagnostics point to a bifocal production plank consisting of a widely disrupted material loop, a history of irregularly codified practice, and an aisle-deprived workplace devoid of routine 5S discipline.

4.2. Initial Diagnosis

The case study's diagnosis found a 15.38% productivity gap: 0.13 units per labor hour compared to the sector benchmark of 0.15. That shortfall had a real cost: PEN 65,500, which is about 11% of the company's annual revenue (PEN 573,250). There were two main reasons for the loss: 35.29% of it was due to faulty output, and 64.71% of it was due to time spent moving work between areas. Three common problems on the shop floor were non-standardized methods on the conventional lathe (35.29%), unnecessary routing and backtracking (41.18%), and messy work areas (23.53%). In steel-bushing manufacture, they all lower effective capacity, lengthen cycle times, and move performance away from the expected level.

4.3. Validation Design

The Lean–SLP production model was tested in stages at a small metalworking company that makes heavy-duty spare parts over the course of four months. The team first established a baseline by doing walk-throughs and time-motion logs. Then, they changed the flow with SLP, improved the method with Standard Work, and stabilized the stations with 5S. We used paired time studies, mapped travel distances, first-pass yield counts, and capacity checks, along with daily notes from the shop floor, to figure out what impact they had. A simple cost analysis compared the cost of moving and setting up new equipment with the cost of releasing labor hours. This showed that the company was credible and that it made sense from a business point of view for a company with limited resources.

4.3.1. Introduction to the Design and Implementation

The implementation was carried out in a metalworking SME that manufactured spare parts for heavy-duty machinery. A component-based design grounded in Lean principles guided the work and was stitched together by a transversal change-management approach. The architecture combined a physical redistribution of the shop floor through Systematic Layout Planning (SLP), the stabilization of task execution through Standard Work, and the conditioning of the workplace through 5S. Each decision was anchored in the diagnostic baseline and translated into verifiable targets: productivity at 0.12 units/LH with a target of 0.15, a defect rate of 8% with a target below 3%, transfer time of 28.1 min/unit with a target of 18.5 min/unit, and a cycle time of 492 min/unit with a target

of 418 min/unit. The rollout proceeded in stages and was evaluated with a before-and-after scheme to preserve traceability from problem to intervention while protecting delivery commitments.

4.3.2. Cross-Cutting Component: Change Management for Adoption

Change management served as continuous scaffolding for the technical work. The team framed a clear purpose narrative, identified on-floor champions, and used short feedback huddles to surface concerns and recalibrate the plan. Operator participation was treated as the center of gravity rather than a procedural checkbox. Training took place at the workstation and included mixed demonstration, guided practice, and immediate feedback; competence was verified in execution, and multi-skilling was documented. This component acted as an organizational shock absorber: it sustained 5S discipline, strengthened adherence to Standard Work, and accelerated stabilization of the new spatial flow. Brief daily routines—five to ten minutes—helped review commitments, remove obstacles, and maintain a direct line between supervisors and operators. In practice, these rituals reduced hesitation during changeovers, aligned expectations across shifts, and gave the rollout a predictably human cadence.

4.3.3. Physical Redistribution with Systematic Layout Planning: from Dispersed Layout to Compact Flow

Plant architecture was the subject of the first technical front. The key processes—conventional lathe, CNC lathe, machining centers, inspection, and cleaning—were dispersed and connected by routes with crossings and backtracking, according to a relational analysis of areas. This increased the transfer time to 28.1 minutes per unit. Two layout options were created and contrasted based on weighted criteria: flexibility for a changing product mix, visibility for supervision, ease of material flow, continuity of process sequence, and safe transit. In addition to bringing together operations with frequent handoffs, the selected layout favored linear or U-shaped trajectories, isolated noisy processes without disrupting sequence, and placed interim inspection where deviations could be detected early.

In order to avoid lengthy stoppages, implementation proceeded in brief waves. A specialized provider moved heavy equipment, aligned machines, repositioned racks, and marked the floor; internal staff cleared areas and moved light handling items. Staging zones were positioned away from major routes, transfer points were set at the appropriate height, and aisle widths were matched to transport equipment. The redistribution established clear validation goals, including securing short, readable routes that reduced lifting manoeuvres and simplified supervision, and reducing transfer time from 28.1 to 18.5 minutes/unit as an initial threshold. Crossings decreased, access to panels remained unobstructed, and the distinction between material and human flows became apparent as the route became more straightforward. In

addition to cutting down on distance, the new geometry made the flow readable immediately, enabling later elements to act on a more subdued background.

4.3.4. Standard Work: Fixing the Best-Known Way to Operate

Inside each station, the execution was stabilized by the second front. To distinguish value-adding actions from searches, redundant moves, and overlapping checks, the critical product's process was meticulously mapped out, and its sequence was improved. To eliminate ambiguity, clear visual aids were displayed at the workstation, and detailed instructions were written with preconditions, control points, and acceptance criteria. A cycle of demonstration, practice, and verification was used in the training, and checklists were used to record both proficiency and common mistakes. Surface condition, orientation reference, and key tolerances were the minimum information set used to order handoffs between stations so that batches did not pause for unnecessary questions.

Reducing the defect rate from 8% to less than 3% and recovering preparation minutes by removing searches and rearranging tools were two specific goals that came with standardization and were in line with earlier symptoms. By differentiating between machine and operator contributions, the measurement protocol highlighted micro-interruptions and directed improvement efforts toward the appropriate levers. The standard was regarded as a living baseline, and training materials were updated whenever a better approach continuously outperformed the existing one in real-world scenarios. This strategy transformed improvement from an intermittent campaign into regular housekeeping.

Cycle time (min/unit) before intervention (492), the target (418), and the achieved result (408) are contrasted in Figure 2. A more stable, readable production flow is consistent with the reduction above the target, which implies shorter waits and transfers as well as fewer micro-interruptions.

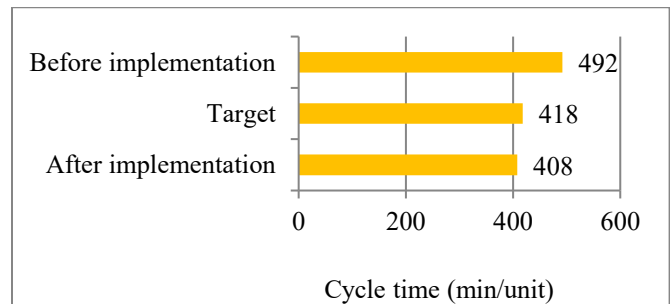


Fig. 2 Cycle Time: Baseline, Target, and Post-Implementation

4.3.5. 5S: The Workplace as the Foundation for Method and Flow

The third front conditioned the environment. The initial 5S assessment showed an average compliance of 35% with marked variability across stations. The target was set above

80% sustained compliance, focusing first on areas that constrained the flow. “Just-in-case” items that consumed space and hid problems were removed; fixed homes were defined for tools and gauges; aisles and storage limits were demarcated; and short opening and closing routines reframed cleaning as inspection. Physical order mirrored the standard: if a tool was needed in the second step, it lived within one easy reach; if a gauge appeared at the end, it sat off the path of earlier actions. This coherence trimmed micro-interruptions, reduced searching, and made abnormalities stand out early.

Cycle-time reduction served as the integrator for this component, with a target of 418 min/unit from a baseline of 492 min/unit. The audit format was intentionally brief so that cell leaders could apply it without ceremony, creating transparent comparisons among areas and shifts. Over time, the environment started to “speak”: empty locations signaled pending material, colored tags exposed obsolescence, and misaligned markers flagged clamp movement—visual cues that supported disciplined, low-effort control.

Figure 3 shows a radar chart of the 5S audit before and after implementation. Baseline (“As-Is”) scores were low and uneven; post-implementation (“Results”) increased across Seiri, Seiton, Seiso, Seiketsu, and Shitsuke, approaching the “To-Be” target and indicating strengthened operational discipline, workplace order, and standardization.

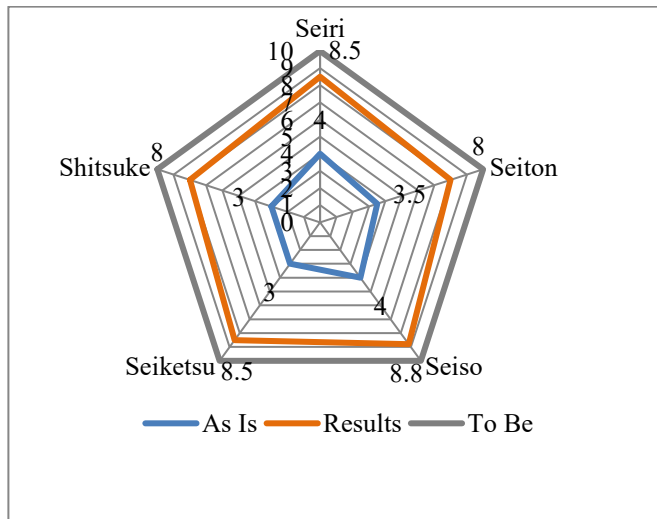


Fig. 3 5S Audit before and after implementation

4.3.6. Causal Integration: From the Problem to the Solution Architecture

The design sequence responded directly to the diagnostic causes. Lack of method standardization at the conventional lathe was dealt with through Standard Work and on-the-job training; unnecessary routes were addressed with SLP; and disordered areas were treated with 5S. This traceability prevented dilution of effort and allowed each component to carry a small set of targets consistent with its purpose: transfer

time for SLP, defects, and preparation times for the standard, 5S compliance, and environmental cycle time. Interactions were intentional: the compact layout revealed true bottlenecks; the standard pinned down the best known method; 5S delivered readability and fewer frictions; and change management preserved habits and alignment. Taken together, these moves formed a socio-technical system in which the physical, procedural, and behavioral layers reinforced one another.

4.3.7. Operational and Rollout Considerations

Execution demanded careful choreography with production and purchasing. Equipment moves and floor marking were scheduled in low-load windows; consumable replenishment was synchronized with the restart of relocated stations; and the availability of critical tools was confirmed before each switch. Internal teams prepared spaces and relocated light items, while a specialized provider handled the transfer and leveling of machines and secured anchors. Utilities—power, air, and extraction—were checked ahead of time, and quick-connects were installed to simplify later adjustments. This coordination minimized downtime and allowed the plant to resume pace without shocks. On the human side, short, frequent communications kept the “why” and the “how” visible, eased anxieties about new paths and postures, and ensured that lessons from one wave informed the next.

4.3.8. Coherence Between Tools and Metrics

The measurement architecture was designed to reflect causality and avoid overlap. Transfer time (min/unit) captured SLP’s direct effect on distance and handoffs. Defect rate (%) and operation times reflected method stability after standardization. 5S compliance (%) served as a mirror of order and discipline, and cycle time (min/unit) integrated the joint effect of method and environment. Productivity (units/LH) acted as the synthesis indicator. For each metric, sources, units, and sampling rules were defined: on-floor readings, double-observer checks, trend control, and removal of outliers tied to special causes. The intention was pragmatic—signals robust enough to support decisions without bureaucratizing control and keeping measurement close to real work.

4.3.9. Validation Design and Measurement Protocol

Validation followed a before-and-after design anchored in a clearly documented baseline. The plan advanced in waves: first, SLP reorganized flow for the highest-rotation family; next, Standard Work stabilized the critical operation and its interfaces; finally, 5S consolidated discipline at the stations with the heaviest traffic. Each wave defined a tight scope and a verification plan: traced routes and transfer time for SLP; sequence conformance and time variability for the standard; and 5S compliance and visible order for the environment. Daily walkthroughs were paired with weekly time-motion studies, recording distance traveled, first-pass counts, duration of minor changeovers, and micro-stoppage reports. Economic

plausibility was reviewed by contrasting released labor-hours with relocation and setup costs, and “no-investment” choices were documented whenever a method or order adjustment yielded benefits comparable to a purchase. The protocol separated method from outcomes: here, the manuscript defined goals, samples, and rules; numerical results were left to the Results chapter.

4.3.10. Technical and Organizational Lessons

Several lessons emerged that are useful to similar SMEs. Starting with spatial flow simplified everything that followed; once distances were constrained and routes were clear, sources of variation in the method became visible and tractable. Standardization gained traction when instructions were paired with visual aids and training occurred at the station; competence was demonstrated in execution, which shortened assimilation time and reduced dependency on a few experts. 5S proved meaningful when it was linked to flow continuity and safety, and when compliance was tracked with a brief,

transparent instrument. Finally, change management made the difference between a one-off push and a sustained practice: short huddles, quick removal of impediments, and visible leadership presence helped the organization turn better methods into everyday habits.

4.4. Results

In Table 1, the validation results tell a consistent story. Productivity rose from 0.12 to 0.162 units/LH—about 35%—comfortably clearing the 0.15 target. Defects fell from 8% to 3% ($\approx 63\%$ relative gain). Transfer time collapsed from 28.1 to 8.8 min/unit (-69%), beating the 18.5 benchmark by a wide margin. Cycle time also tightened, moving from 492 to 408 min/unit (-17%) and improving on the 418 expectations. Read together, these shifts indicate that the SLP–Standard Work–5S bundle removed avoidable travel, clarified task execution, and released capacity, leaving a steadier, faster flow.

Table 1. Results of the pilot

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
Productivity	Units/LH	0.12	0.15	0.162	35%
Defective products	%	8%	3%	3%	-63%
Transfer time	Min/unit	28.1	18.5	8.8	-69%
Cycle time	Min/unit	492	418	408	-17%

5. Discussion

The numbers in the case—productivity going from 0.162 units/LH (about 35% above baseline) to 0.162 units/LH, defective output going from 8% to 3%, transfer time going from 28.1 to 8.8 min/unit (-69%), and cycle time going from 492 to 408 min/unit (-17%)—are very close to what the literature says will happen when plant-flow redesign, method stabilization, and workplace discipline are all used together. The sharp contraction of transfer time is in line with Systematic Layout Planning studies that cut handling distance and travel time after correcting adjacencies and consolidating routes [4-6]. The drop in defects is consistent with evidence that Standardized Work reduces process variation once task sequence, checkpoints, and training are formalized at the station [7], and with metalworking cases where SW is paired with TPM/5S to curb nonconformities [8].

Cycle-time relief and the rise in labor productivity mirror the role of 5S as an enabler that removes search and makes abnormalities visible, smoothing flow and sustaining execution [10]. Finally, the joint pattern—less geometric friction (SLP), codified execution (SW), and a readable environment (5S)—is similar to broader syntheses in metals and engineering that link simultaneous changes in flow, method, and visual control to measurable performance gains [10]. The staged “quick-win” logic used here is similar to improvement programs that keep momentum going during SME deployments [12].

5.1. Study Limitations

The study's limitations pertain to its scope and design. The evidence is derived from a single SME and a four-month pilot, which limits external validity and precludes the observation of seasonality; the before-and-after design lacks a control group, thereby failing to fully isolate learning or demand effects. Metrics are operational and adequate for feasibility (e.g., productivity, transfer time, cycle time, defects); however, they do not encompass disaggregated financial indicators such as cell-level ROI, cost-to-serve, or cost of poor quality. Time-and-motion measurements depend on repeated readings and sampling rules, but they can still be affected by observer bias, and some error is always possible. Generalization to other metalworking SMEs is contingent upon product mix, spatial limitations, and workforce maturity; therefore, effect sizes should be extrapolated judiciously.

5.2. Practical Implications

The findings point to a practical strategy for metalworking SMEs with limited resources. Prior to committing to moves, validate alternatives by first using SLP to redraw proximities in order to shorten routes and reveal the actual bottleneck [4], [5]. Then, in order to suppress avoidable variation and make new takt targets credible, lock the most well-known approach with Standardized Work linked to on-the-job training [7], [8]. Lastly, 5S should be employed as the operational framework that maintains routine gains and keeps stations readable. By combining the technical rollout with

light-touch change management techniques, such as visible sponsorship, short feedback loops, and a clear purpose, the likelihood that new routines will become the norm rather than a project artifact is increased [12]. Design-for-flow techniques offer an organized method of incorporating capacity and material-handling considerations into facility and space decisions from the beginning, when space or regulatory constraints are mandatory [16].

5.3. Future Works

Multi-site, longer-horizon studies that include comparison groups and monitor the persistence of gains after the pilot should be part of future research to expand the body of evidence. Prior to reconfiguration, discrete-event simulation would aid in valuing alternate layouts and waiting dynamics under various mixes and volumes; instrumenting machines and travel paths (such as RTLS and telemetry) would more clearly divide waiting, processing, and preparation. While design-for-flow techniques could be tested to incorporate layout logic into early facility and space decisions, integrating SMED and TPM with SLP-SW-5S would broaden the scope toward changeover reduction and equipment stability [16]. Finally, research on the sustainability of 5S and Standardized Work with regular audits and behavioral reinforcement—as well as how operator turnover impacts the durability of results—would provide practical advice for SMEs looking for stability over the long run.

6. Conclusion

In a metalworking SME that produces heavy-duty spare parts, this study shows that incorporating Systematic Layout Planning, Standard Work, and 5S results in quantifiable

operational gains: productivity increases from 0.12 to 0.162 units/LH ($\approx 35\%$), the defect rate decreases from 8% to 3%, transfer time contracts from 28.1 to 8.8 min/unit (-69%), and cycle time decreases from 492 to 408 min/unit (-17%). The evidence suggests that the bundle releases capacity without the need for additional staffing and facilitates flow supervision through three complementary mechanisms: shortened routes, codified method, and readable workplace. These enhancements highlight the intervention's practical significance in a resource-constrained setting by stabilizing lead times, lowering firefighting, and creating headroom to absorb order mix variability. Additionally, the research is important because it offers a low-capital way to regain competitiveness while adhering to the safety regulations and dimensional accuracy typical of heavy-machinery components.

The study's methodological contributions include a concise, sequential design that links each tool to a particular outcome and a lean-aligned indicator scheme; empirically, it uses before-and-after measurement to document magnitudes and targets within a four-month pilot; and practically, it describes a choreography that reduces downtime and speeds up shop floor learning. While multi-site and longer-horizon evaluation is necessary for broader confirmation, final observations indicate strong results within scope. In addition to financial and sustainability assessments, future work can use instrumented time-motion and RTLS to separate preparation, processing, and waiting; integrate SMED and TPM to reduce changeovers and strengthen equipment stability; and use discrete-event simulation to compare layout alternatives prior to moving equipment.

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