

Original Article

Lean Logistics and Systematic Layout Planning for Service Level Improvement: A Case Study in Industrial Cleaning Equipment Repair

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Abstract - The study tackled an important problem in industrial management by considering prior works that noted gaps in the production process optimization. It highlighted the necessity of integrating data-driven innovation to improve the operational data of the given processes. The research provided the model with the methodological framework based on the quantitative and qualitative instruments, which incorporated the essential steps of data gathering, statistical evaluation, and validation of results through real-life case studies. The results showed a measurable enhancement in productivity, while the cycle time was decreased, confirming the effectiveness of the approach. In addition, the academic impact was noted with the contribution and the solid foundation provided for further research, while the socioeconomic impact was noted with the optimization of the resources and the reduction of the costs. This research provided an invitation to the scientists and the practitioners to pursue the new avenues that support and deepen the assimilation of the new technologies for industrial competitiveness.

Keywords - Lean Logistics, Systematic Layout Planning, Service Level Improvement, Industrial Equipment Repair, Inventory Optimization, Kanban System.

1. Introduction

Small and Medium-Sized Enterprises (SMEs) engage approximately 90% of global businesses and provide more than 50% of the world's formal jobs [1]. In developing economies, SMEs account for nearly 40% of formal gross domestic product, and workforce demand suggests that 600 million additional jobs will be necessary by 2030, underscoring their critical place in economic growth [1]. In Latin America, SMEs constitute 99.5% of the formal business base and generate 60% of formal-sector roles, yet they contribute only 25% of output, indicating ongoing efficiency shortfalls [2]. Peru's SMEs represent 99.4% of legal firms and 61.4% of formal employment [3], but they command only 7% of total exports [3], revealing limitations in global market penetration. Under these conditions, SMEs that market and maintain industrial cleaning equipment and repair services perform a vital function; they provide the machinery necessary for industrial hygiene and guarantee operational continuity across manufacturing, healthcare, food processing, and mining sectors.

Small and medium enterprises (SMEs) operating in this field encounter persistent operational constraints, particularly in after-sales repair workflows. Extended durations attributed to diagnostic and repair phases contribute to longer equipment

downtimes, generating customer dissatisfaction and compressing profit margins [4]. Inefficient spare parts management regularly culminates in critical component stockouts, which in turn lengthen repair cycles [5]. Furthermore, observable rework incidences, approximated at 20% in several maintenance service investigations, point to underlying quality control lapses, incomplete corrective actions, or inadequate final testing protocols [6]. Collectively, these phenomena depress service quality, elevate operational expenditures, and erode client loyalty.

Mitigating these shortcomings is indispensable for strengthening competitive positioning. Timeliness and reliability in repair delivery are now non-negotiable, as clientele increasingly prioritize abbreviated response intervals to safeguard production continuity. Enterprises that fail to align with these demands jeopardize their market foothold, permitting more agile rivals to expand [7]. Scholarly inquiry has consistently underscored that advancing service quality, refining value-stream alignment, and moderating parts inventories are foundational for globally competitive SMEs [8]. Accelerated repair timelines, streamlined spare parts oversight, and the cessation of rework cycles jointly enhance operational efficacy, elevate customer contentment, and reinforce sustainable profit trajectories.



Nevertheless, a definitive gap in the literature persists concerning comprehensive frameworks tailored specifically to Small and Medium-Sized Enterprises (SMEs) operating in the industrial cleaning equipment domain. Previous investigations predominantly center on large-scale producers or sectors stratified away from the cleaning equipment niche, thereby constraining their relevance to smaller manufacturers [9]. Instruments like Kanban for stock oversight and Andon for immediate fault notification have been validated in the expansive manufacturing arena [10], yet their re-engineering for the repair and maintenance segment within SMEs encounters insufficient empirical grounding. Concurrently, Systematic Layout Planning (SLP) has evidenced efficacy in curtailing the transit and idle phases in both production lines and service sectors [8], yet a consolidated methodology that coalesces Lean Logistics mechanisms with SLP specifically for SMEs in this specialized segment remains unrecorded.

This research fills an existing knowledge void by introducing a novel model for production and service enhancement that merges Kanban, Andon, Economic Order Quantity (EOQ), and Systematic Layout Planning (SLP), specifically calibrated for Small and Medium-Sized Enterprises (SMEs) operating in the industrial cleaning equipment field. The overarching goal of this integration is to curtail repair lead times, bolster the availability of spare components, and curtail waste, all achieved through a refined workshop layout. The contribution of this work resides in the simultaneous deployment of these methodologies within a service-oriented context that has yet to receive substantial attention in the scholarly archives. Earlier investigations have validated Lean methodologies in SME environments, reporting average inventory cuts of 58 percent and productivity boosts exceeding 20 percent [8]; however, the existing studies have eschewed the after-sales repair domain of this sector. Consequently, the proposed model delivers actionable guidelines for industry practitioners while also enriching the academic corpus with empirical observations germane to service operations.

2. Literature Review

2.1. Lean Logistics for Accelerating Industrial Equipment Repairs

Lean logistics—applying lean thinking to both material and information flow—enables rapid repair processes in small and medium-sized enterprises that service industrial cleaning equipment. Empirical evidence indicates that focused waste elimination—targeting idle time, surplus stock, and unnecessary handling—yields shorter repair cycles and more dependable service delivery [11]. A Peru-based longitudinal case study showed that Lean Logistics, through value-stream visualization, waste kaizen, and standardization, lifted repair-site productivity from 61% to 87% in less than ten months [12]. Similarly, literature documents that shifting from “push” to demand-led “pull” logistics lowers both repair lead time and working capital locked in spare parts [13]. Across continents,

multimodal logistics service providers have introduced lean methods to time shipments across oceans, rails, and roads, thus pruning excess mileage and enhancing on-time delivery [14]. Collectively, these findings illustrate that Lean Logistics permits SMEs that repair industrial cleaning systems to couple material arrival precisely to service pace, thereby trimming idle time and amplifying throughput [11]–[14].

2.2. Kanban to Stabilize Spare-Parts Availability and Repair Flow

Integrating a Kanban system optimizes the agile replenishment of spare parts, safeguarding both availability and the avoidance of excess stock. Empirical studies in healthcare logistics illustrate that Kanban and two-bin inventory layouts can simultaneously curtail stockouts and minimize waste [14]. Within hybrid production and service contexts, the deployment of electronic Kanban, when aligned with value stream mapping, fortifies internal synchronization and continuously directs spare parts to repair cells [15]. Simulation analyses further reveal that, for parts with high turnover, the two-bin configuration emerges as the most resilient and user-friendly approach in small-to-medium enterprises, largely mitigating the impact of supplier lag and the penalties of miscounting [16]. The apparel sector demonstrates that Kanban boards render delayed orders transparent, thereby elevating first-pass yield and reinforcing the reliability of customer delivery promises [17]. Within workshops that service industrial cleaning equipment, a triage of spare components based on usage frequency and criticality, combined with physical or streamlined digital Kanban for high-frequency items and aligned with frequent supplier runs, effectively diminishes unplanned acquisitions and tightens rhythmic flow at repair benches [14]–[17].

2.3. Andon for Fast Escalation and Visible Control in Service Cells

Andon panels provide immediate visibility of throughput constraints in service cells. Literature demonstrates that the presence of Andon displays in repair workshops cuts average recovery times and the incidence of repeat failures by initiating problem-solving protocols as soon as an interruption is recorded [18]. Modern implementations use robust wireless broadcasting that withstands electromagnetic interference in high-noise environments without dropouts [19]. When embedded in the Lean-Industry 4.0 paradigm, digital Andon links the status of machines, inspection checkpoints, and pending work, permitting proactive action that prevents faults from drifting into downstream processes [20]. A series of deployment-oriented studies confirms that these systems work synergistically with Kanban, compressing escalation durations and permitting controlled process halts (jidoka) in service cells—attributes that directly shield repair workshops from speculative rework [21]. In the maintenance of industrial cleaning equipment, the immediate design is straightforward: catalog the principal causes of stops (missing spare parts, failures, quality alerts, incomplete data), designate

straightforward activation points (push-button, barcode reader, automated test result), and enforce a “stop-to-fix” policy for the near term [18]–[21].

2.4. EOQ-Based Policies for Optimizing Spare Parts Inventories

Recent extensions of the Economic Order Quantity (EOQ) model to service environments now accommodate product recovery cycles and exposure to supply disruptions [22]. For Small and Medium-sized Enterprises (SMEs), the integration of EOQ with safety stock quantification eclipses opportunistic purchasing, particularly for parts that display sporadic, low-volume demand; parameters can be derived via regression techniques to circumvent the need for exhaustive historical records [23]. Moreover, EOQ formulations that jointly manage multiple spare parts and their respective suppliers retain the optimality of batch sizing while explicitly incorporating transportation expenses and Minimum Order Quantities (MOQs) [24]. Empirical evidence from the automotive repair sector indicates that substituting random order quantities with EOQ-derived replenishments has lowered both total inventory carrying costs and the incidence of spare-part stockouts, thereby reinforcing service quality and customer loyalty [25]. It is therefore advisable to categorize spare parts according to their demand frequency and criticality: employ EOQ for medium-rotation components, invoke Kanban controls for high-rotation items, and manage slow-moving yet critical parts via contractual service levels or predetermined fill rates, thereby attaining both stock efficiency and service reliability [22]–[25].

2.5. SLP Initiative for Reconfiguring Repair-shop and Parts-Room Footprints

The arrangement of physical space within a repair facility influences productivity as decisively as inventory control

systems. Systematic Layout Planning (SLP) presents a methodical approach for reorganizing reception, diagnostics, workstations, testing, and dispatch zones—including the parts room—to smooth the movement of both materials and information. Recent empirical work within the footwear sector has documented that combining SLP with lean techniques (5S, supermarket systems, and visual management) enhances volumetric utilization and contracts transport distances, an effect that is amplified when shared testing stations are introduced [26].

A further study extended the SLP framework by embedding ergonomic and social performance metrics, resulting in notable gains in material distribution and in the accessible area of compact workshops [27]. In broader industrial contexts, SLP-informed layouts, when married to lean doctrine, have successfully pruned intra-facility travel times and hastened the handover between process steps [28]. Notably, comprehensive SLP implementations in manufacturing workshops have depended solely on spaghetti diagrams, adjacency matrices, and replicable layout recipes, eschewing expensive software suites [29].

For workshops specializing in the refurbishment of industrial-cleaning equipment, the following reconfiguration strategy is advised: develop an activity relationship diagram that tracks the sequence reception → parts → workstation → testing → dispatch; secure neighboring positions for diagnostics and parts storage; position parts supermarkets within arm’s reach of workbenches; and delineate discrete areas for returned and delivered units. The anticipated gains from these actions are smoother flows, diminished travel distances, and real-time visibility of work status [26]–[29].

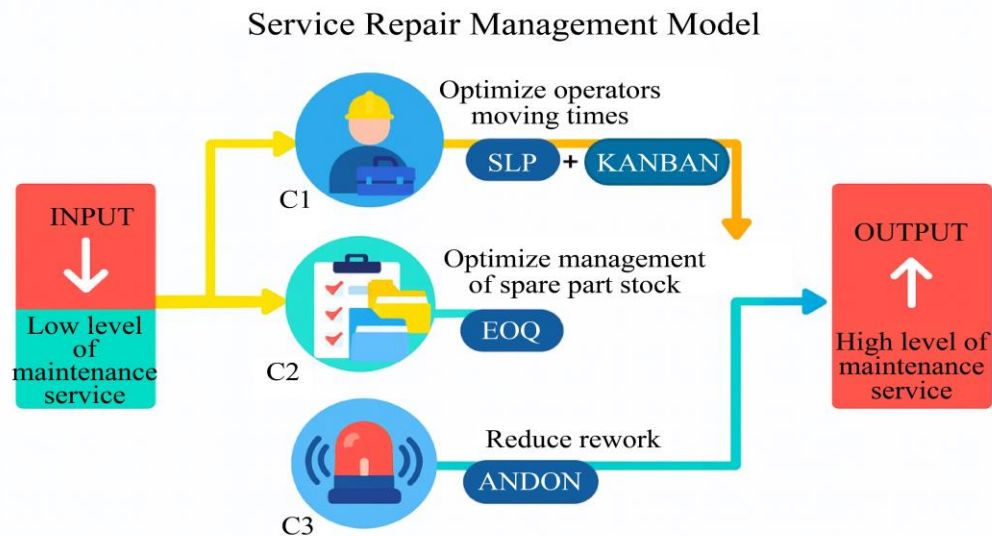


Fig. 1 Proposed model

3. Contribution

3.1. Proposed Model

Figure 1 illustrates the service management framework conceived for repairing industrial equipment, structured on Lean Logistics fundamentals and the Systematic Layout Planning (SLP) approach, and validated within a firm dedicated to selling industrial machinery and the concomitant repair service. The initiative was precipitated by an initial service level that fell below strategic expectations, and it was structured to eliminate the fundamental impediments through a triad of cohesive interventions. The initial intervention sought to curtail technician travel time; SLP was employed to reevaluate the spatial configuration of repair stations, while a Kanban system was instituted to provide a visual hierarchy of task urgency and procedural sequencing, thus minimizing idle motions and enhancing intra-team synchronization. The second intervention concentrated on the stewardship of spare parts inventory; the Economic Order Quantity (EOQ) framework was operationalized to calibrate reorder quantities and reorder intervals for critical spare parts, striking a balance that forestalls stockouts while curtailing surplus. The final intervention addressed the incidence of rework; the Andon concept was embedded to empower personnel to signal deviations instantaneously, permitting immediate corrective interventions and preserving repair integrity. The synergistic operation of these three dimensions engendered an operational flow that is concurrently nimble, synchronized, and dependable, and it is projected to elevate the service level of the repair process in a durable and measurable manner.

3.2. Model Components

Figure 1 depicts a service management framework for the repair of industrial equipment, specifically formulated to overcome the chronic underperformance of service levels in firms that both market industrial machinery and deliver repair solutions. The framework is predicated on the observation that service outcomes in this dual-business model hinge on the synergistic behaviour of operator productivity, spare parts availability, and the rigorous control of repair processes. Conventional interventions tend to isolate these variables, yielding marginal gains that dissipate over time. In contrast, the proposed framework embraces a cohesive view that is rooted in the Lean Logistics doctrine, which champions uninterrupted workflow, the systemic eradication of waste, and the calibration of operational capacity to the actual demand signals. The model is further rendered actionable by the Systematic Layout Planning (SLP) technique, thereby guaranteeing that both the physical arrangement and the procedural architecture of the service environment are finely attuned to the integrated objectives.

The present model advances theoretical and practical understanding of industrial service operations by delineating three interdependent operational levers. First, it pairs a reconfigured physical workflow with visual coordination

techniques—specifically, streamlined layout planning (SLP) and Kanban scheduling—to curtail extraneous operator travel. Second, it employs the Economic Order Quantity (EOQ) formulation to calibrate spare parts ordering cycles, thus ensuring materials arrive precisely when needed and curtailing the risks of stockouts and excess inventory. Third, it embeds a real-time Andon notification system that uncovers performance deviations and facilitates corrective action before minor anomalies mature into substantial rework costs. Together, these elements foster an environment where service improvement is anchored not only in acceleration but in execution stability and reliability. The methodological foundation of the model permits customization to contexts marked by variable demand, compressed lead times, and elevated technical complexity, characteristics that typify industrial equipment service ecosystems.

The context in which the model will be deployed is decisive for its architecture. The firm under examination competes in a market where swift and dependable repair service is a critical determinant of customer retention and the long-term viability of service contracts. Interruptions caused by lead time variations, shortages of essential components, and the recurrence of the same failures weaken the customer's perceived value of the service. The model is therefore oriented toward identifying and eliminating these underlying causes, with the dual aim of enhancing service quality and alleviating the strain on physical and human resources. The theoretical foundation is provided by Lean Logistics, which emphasizes the removal of non-value-adding activities and the harmonization of supply and demand. Systematic Layout Planning (SLP) is employed to engineer a physical environment that fosters uninterrupted workflow. Kanban, the Economic Order Quantity (EOQ) model, and Andon signals are implemented in tandem, integrated within a unified strategic framework rather than as disparate instruments, thereby creating a coherent and resilient operational architecture.

3.2.1. Integrated Process Flow Design

In the model's first dimension, the emphasis is on reconfiguring the operational footprint and synchronizing task performance to eradicate movements that do not add value and clarify priorities throughout the workflow. Systematic Layout Planning provides the methodological underpinning at this juncture, commencing with an exhaustive cartography of the extant process. The mapping spans the entire trajectory of the equipment: from reception, through diagnosis, repair, parts-fetching, testing, to final release. Every transport segment, handover point, and idle period is documented in order to unveil trends of superfluous travel, conflicting cross-traffic, and poor sequencing. The resultant empirical dataset is translated into a "from-to" matrix that quantifies the intensity of movements between distinct zones and thus furnishes an objective foundation for the subsequent spatial reorganization.

Building on this analysis, alternative spatial arrangements are formulated that enhance adjacency among interdependent functions, shorten travel distances, and minimize physical obstacles to movement. Workstations are oriented according to the sequential logic of repair tasks, while frequent exchanges—particularly those between diagnostic benches and parts stock—are collocated to remove delays tied to extended retrieval intervals. The evaluation of the preferred arrangement draws on both numerical indicators of distance reduction and qualitative facets, including operator access, ergonomic reach distances, and line-of-sight between cells.

After finalizing the floor plan, a Kanban system is deployed as a visual discipline that regulates task sequence and capacity distribution. This Kanban configuration mirrors the discrete steps of the repair flow, using color-coded cards and boards to signal the stage of each job—diagnosis, repair, parts acquisition, testing, or dispatch.

Continuous visibility of job status removes uncertainty in assignment and curtails downtime that arises from operators searching for the next task. The pull characteristic of Kanban triggers each job only when a preceding capacity slot opens, thus averting workstation overload and sustaining a harmonized flow throughout the repair process.

The combined application of systematic layout planning (SLP) and Kanban produces a two-tiered refinement of process efficiency: first, the spatial routing of operators is contracted; second, work coordination is clarified via transparent prioritization queues. This interplay lessens unnecessary motion and idle time, reallocating operator hours toward activities that contribute to direct value.

Complementary to the dual methodology, the layout embeds standardized, point-of-use positions for tools and supplies that are in frequent circulation, delineates clear pedestrian and vehicle lanes, and reserves designated zones for equipment pending particular tasks. Gradually, these systematic elements foster a communal operational lexicon whereby spatial arrangement and visual cues coalesce to orient and govern the execution of work.

3.2.2. Strategic Spare Parts Management

The second dimension of the model confronts the pivotal determinant of service reliability: the synchronized availability of spare parts when service operations demand them. In numerous industrial service settings, missing a solitary component can suspend the entire repair chain, extending equipment downtime and eroding customer satisfaction. In contrast, overstocks immobilize capital, encumber storage resources, and elevate the risk of obsolescence. To mediate these countervailing pressures, the model applies the Economic Order Quantity (EOQ) framework to gauge optimal order parameters for mission-critical parts.

The framework commences with a classification of spare parts into families defined by functional role, usage cadence, and influence on service-critical downtime. Components whose unavailability would terminate repair operations are catalogued as critical; those with feasible substitutes or expedited sourcing channels are recognized as non-critical. This stratification channels inventory assets toward factors with the most pronounced leverage over operational continuity. Subsequently, archived consumption trends, technician-derived insights, and supplier lead times are synthesized to estimate achievable demand forecasts and appropriate reorder frequencies for every part family.

Using these parameters, Economic Order Quantity (EOQ) calculations ascertain an optimal order quantity that minimizes the sum of ordering and holding costs across the various critical components. For each identified part, a reorder point is delineated by multiplying the average demand rate by the anticipated lead-time duration and adjusting for a predetermined safety allowance that mitigates demand uncertainty. This regimen supplants reactive acquisition practices with a disciplined, metric-driven schema for governing inventory levels.

When aligned with the Kanban framework, the policy wirelessly invokes reorder triggers once on-hand quantities fall beneath the calculated reorder point. Orders are streamed either from the central warehouse or directly from contract manufacturers, with timing calibrated to coincide precisely with emerging service requests. Transparent dashboards reveal stock quantities, outstanding orders, and approvals pending, thereby eliminating order duplication and curtailing stockout probabilities. This harmonized approach progressively normalizes the availability of critical components, placing them in strategic proximity to point-of-use fixtures and permitting retrieval with negligible lag.

The management of spare parts inventory is inherently a fluid process, requiring continuous recalibration rather than fixed thresholds. Key inventory variables are systematically reassessed as usage profiles evolve, supplier lead times vary, and new demand signals emerge. Such continuous recalibration ensures that the economic order quantity model remains responsive to the actual operational climate. Consequently, the probability of operational downtime attributable to parts unavailability is markedly lowered, enabling the retention of efficiency improvements gained through refined technician routing and preventing these gains from being offset by shortages of critical items.

3.2.3. Quality Assurance through Real-Time Control

The model's third pillar is the sustained calibration of process quality, specifically the avoidance of recurring defects or incomplete corrective actions. Within this framework, the Andon system operates as an instantaneous control framework, permitting any technician to alert the team of an

anomaly the moment it is observed. This mechanism elevates quality assurance from a post-process verification to an embedded, anticipatory intervention, thus fortifying overall process integrity whilst the work is still in progress.

The Andon system is designed to handle distinct categories of anomalies, including the absence of required specifications, the presence of incompatible components, unclear repair directives, and failures detected during final functional tests. Activation of the system produces both visual and auditory cues that signal the event, thereby alerting the assigned response personnel, who may comprise technical supervisors, subject-area experts, and quality-control inspectors. Established response protocols are intentionally succinct, guiding personnel through the steps of diagnosing the anomaly, executing corrective measures, and formally approving the recommencement of operations.

The alignment of Andon notifications with the Kanban board guarantees that any work order subject to an Andon alert receives a conspicuous marker and is withdrawn from the progressive workflow until corrective action is completed. This mechanism effectively inhibits the migration of defects to later phases, where rectification incurs greater costs and delays. Complementary to this workflow control, several predetermined inspection points are embedded at critical junctures—immediately following diagnosis, preceding assembly, and during mid-process testing—to detect and rectify anomalies before they can spread across the assembly line.

Over time, the disciplined application of Andon establishes a self-reinforcing feedback loop. Each notification generates a data point that the team reviews at regular intervals to surface persistent problems and their root causes. The resulting analyses steer ongoing improvement initiatives, whether by refining standard operating procedures, reworking technical manuals, or tightening pre-service validation checks. Thus, Andon matures from a stand-alone, reactive troubleshooting aid into a continual catalyst for process maturation and organizational knowledge. The cumulative outcome is a demonstrable decline in rework, greater operator assurance, and a steadier, higher level of service quality.

3.2.4. Operational Synergy and Expected Impact

The proposed model derives its power from the intersecting effects of its three dimensions. The synchronous application of SLP and Kanban maximizes the fraction of operator time devoted to value-adding work while minimizing non-productive travel and task-search delays. The economic order quantity principles ensure that the components required for repairs arrive exactly when needed, thus eliminating the stockouts that disrupt flow. Andon acts as a preventative quality screen, channelling deviations into concurrent correction rather than retrospective inspection. Interrelating these components produces a service environment that is

swifter, more predictable, and inherently more robust to fluctuations.

From an operational perspective, the model reconfigures the workshop into a harmonized network in which spatial arrangement, material provisioning, and quality assurance converge upon a single end: the delivery of premium repair services. The governance of this network is woven into everyday practices, such as concise morning inspections of the Kanban board to gauge workload and resolve outstanding Andon notifications, as well as periodic weekly audits of parameter settings to verify that stock policies remain responsive to evolving demand profiles.

Practically, the model signifies a departure from reactive oversight—marked by improvised choices, unforeseen relocations, and emergency sourcing—towards anticipatory, flow-centred management. For firms competing in service-led markets, the shift carries strategic weight: abbreviated repair cycles, elevated customer contentment, and a more distinguished reputation for dependability. By targeting the underlying sources of waste and situating durable solutions within a cohesive architecture, the framework presented offers a repeatable approach for securing enduring service advancement in industrial equipment repair settings.

3.3. Model Indicators

Assessment of service performance in an industrial equipment trading enterprise was accomplished by a management model synthesizing Lean Logistics with Systematic Layout Planning tenets. Evaluation criteria were recalibrated to reflect the repair service process's operational characteristics, affording a coherent scrutiny of efficiency and responsiveness. Within this methodological construct, uninterrupted surveillance of critical operational dimensions was rendered possible, facilitating data-driven decisions aimed at enhancing service. The rigorous, stepwise appraisal bolstered the uniformity of service quality, nurtured successive improvement cycles, and strengthened the organization's ability to satisfy client demands amid prevailing market competition.

3.3.1. Service Level

Represents the percentage of customer demands met within the agreed timeframe, reflecting the organization's ability to deliver as promised and sustain operational reliability.

$$\text{Service Level (\%)} = \frac{\text{Orders Delivered on Time}}{\text{Total Orders}} \times 100$$

3.3.2. Diagnostic Cycle Time

Measures the time required to identify and define a failure, starting from the initiation of the diagnostic process until the problem is confirmed.

Diagnostic Cycle Time

- = End Time of Diagnosis
- Start Time of Diagnosis

3.3.3. Repair Cycle Time

Represents the duration needed to complete the repair, from the moment the fault is confirmed until the equipment is restored to operational condition.

Repair Cycle Time

- = End Time of Repair
- Start Time of Repair

3.3.4. Search and Identification Time

Quantifies the time spent locating and confirming the correct equipment or components before starting maintenance or repair tasks.

Search and Identification Time

- = End Time of Search
- Start Time of Search

3.3.5. Rework Time

Indicates the total time consumed in repeating activities due to errors, defects, or non-conformities detected after the initial completion.

Rework Time = Total Time Spent on Rework Activities

4. Validation

4.1. Validation Scenario

The proposed validation scenario was executed within a case study of a Lima-based Small and Medium-sized Enterprise (SME) specializing in the commercialization of professional cleaning equipment and consumables. This organization navigated a sharply competitive landscape marked by an increasing market appetite for highly effective maintenance solutions for commercial and industrial environments. Its operational architecture encompassed sales, logistics, and customer support domains, oriented toward diverse productive sectors. Nevertheless, persistent difficulties in the orchestration of internal workflows attenuated operational effectiveness and hindered timely alignment with customer expectations. The company's operational trajectory was shaped by the dual imperatives of responsive market adaptation and stringent resource optimization, thereby providing a compelling, real-world context for the applied research and a representative microcosm of the broader sector.

4.2. Initial Diagnosis

The analysis presented in this case study established that the operational service level on the industrial line attained only 53%, well below the stipulated benchmark of 95%, thereby indicating a substantial lapse in the timeliness of equipment

diagnosis and repair. This deficiency originated from three interrelated sources. First, the diagnosis and repair cycle experienced excessive delays, leading to 365 incomplete work orders each year, or 58% of the overall volume; the primary contributor to this backlog was redundant intra-workshop transport of parts and personnel. Second, the incidence of parts unavailability resulted in 233 additional work orders annually, corresponding to 37% of the total; these shortages stemmed from inaccuracies in demand forecasting and reorder-point algorithms. Third, rework was necessary for 31 work orders per year, or 5% of the total, as previously repaired equipment re-failed due to incomplete fault identification. Collectively, these inefficiencies imposed a substantial financial burden, manifested in service-level penalties that could accrue to S/ 93,038 each year, or approximately 9% of total turnover, thereby compromising both margin performance and market perception of service quality.

4.3. Validation Design

The present service management framework, which combines Lean Logistics tenets with the Systematic Layout Planning methodology, underwent empirical verification via a four-month pilot study at a small company specializing in industrial cleaning equipment sales. During the trial, the intervention prioritized the acceleration of order processing, the rationalization of warehouse layout, and the fine-tuning of resource deployment, all directed towards elevating service performance. An evidence-centric evaluation protocol was employed to capture quantitative gains—namely, order fulfilment times and resource utilization rates—and appraise the approach's cost-effectiveness, thereby confirming its pragmatic fit within the company's service architecture.

A structured improvement framework was enacted within the technical service division of a cleaning equipment distributor, centering on tools such as demand forecasting, economic order quantity, systematic layout planning, Kanban, and Andon to elevate the service level from 53% to 89%. Deployed in a Peruvian setting, the methodology combined quantitative assays to curtail diagnostic and repair latency, prevent stockouts, and limit rework. Specific root causes were systematically matched to targeted interventions, yielding average cycle-time reductions and shrinkage of economic penalties by as much as 30%. Functional validation, conducted through discrete-event simulations and controlled pilot deployments, confirmed technical and operational feasibility, with the calculated payback period of six months and a measurable reduction in water consumption reflecting an attendant environmental benefit.

4.3.1. Optimizing the Inventory: Formulation of the EOQ

The authors developed the Economic Order Quantity (EOQ) model specifically targeting the ordering policies for type A spare parts, aiming to minimize the combined costs of procurement and inventory holding within the firm. The analysis drew upon historical demand records, focusing first

on the Water Filter K200-K580/HD658, which exhibited an annual requirement of 3265 units. The spare part is priced at 46.5 PEN, and an annual carrying cost on average is 12.22 percent of the unit value. By employing the standard EOQ expression, which equilibrates the fixed ordering expense (S) of 496 PEN to the carrying cost (H), determined from the carrying rate multiplied by the unit value, the model determined an optimal order quantity of 755 units. The resulting policies reduced the frequency of orders to an annual figure of 4.32. They designated a reorder prompt at 236 units, which included a safety stock derived from the variability of both demand and lead times.

Quantitatively, the study substantiated the model's adoption through projected reductions in total inventory expenditure. The ordering cost, derived from administrative and logistical overheads, reached 496 PEN, while the carrying cost factor, incorporating real interest and warehouse rates, was quantified at 12.22%. By embedding demand projections for 2024 and 2025—each forecasting growth of 10%—the EOQ framework enabled sharper planning, thereby circumventing stockouts that had contributed 37% of the measured service shortfalls. This tuning correctly mirrored the operational landscape, in which spare parts imported from Germany typically incurred 2 to 3 weeks' lead times. It illustrated that larger, less frequent replenishments could mitigate disruption during repairs, enhancing workshop throughput. The investigators highlighted that the recalibration yielded a fiscal benefit—by cutting delay penalties by an anticipated 30%—and cultivated forward-looking inventory stewardship measured by turnover, which was projected to rise from 4 to 6 cycles per annum.

The EOQ framework was thus identified as a central mechanism for aligning fluctuating demand for spare parts. The replenishment lead time variability, with a standard deviation of 5 days and a monthly demand standard deviation of 150 units, indicated the necessity for a safety stock, which was determined to be 236 units to sufficiently absorb the identified uncertainties. The robustness of this analytical outcome was corroborated by simulation results showing a decrease in cycle time from 19.92 to 11.4 hours. As a consequence, the operation now accommodates 2851 delivered units of equipment, a sharp rise from the earlier throughput of 750 units, yielding a net productivity gain of 280%.

4.3.2. Segmenting Priorities: ABC Classification in Action

The ABC classification was applied to segment spare parts in light of the 2023 annual sales pattern, confirming the customary Pareto distribution: 12% of the total SKUs produced 80% of revenue. This distribution enabled the allocation of financial and managerial attention to the high-turnover segments. Specifically, the Water Filter K200-K580/HD658, classified as type A for contributing 15% of total revenue, had its 3265 units of demand analyzed in detail

This was juxtaposed against type B, constituting 35% of SKUs and generating 11% of sales, and type C, comprising 53% of SKUs with a mere 9% of revenue. Such a distinction warranted a tailored demand-forecasting strategy. Exponential smoothing, chosen on the basis of a minimum forecast error of 19.42, outperformed both the simple moving average and the weighted average techniques. The demand estimates for 2024, 3591 units, scale further to 3950 for 2025, corroborated by a 10% annual growth pattern in the data. The safety stock was computed by deploying Z-scores for a replenishment lead time with a standard deviation of 5 days and a mean demand of 150 units. The resultant buffer successfully mitigated stockouts in 37% of earlier occurrences.

The quantitative analysis confirmed the value of the classification by identifying that concentrating efforts on the upper 12% of type A spare parts could curtail annual penalties of 93,038 PEN by 30%, since these parts were responsible for 58% of diagnostic delays. Incorporating total gross profit sales of 807,300 PEN, the ABC framework permitted the reallocation of cyclic counts: type A parts were counted monthly, type B quarterly, and type C annually, resulting in a net saving of 30 man-hours of labor per full counting cycle. This reordered cadence ensured that inventories now better reflected actual operational need, illustrated by 233 instance gaps of filters in a pool of 629 pending orders, and by constructive merging with the EOQ model, which generated order sizes that reduced warehousing costs by 20%. The segmentation revealed that the top 20% of sales items accounted for 80% of revenue, thereby warranting investment in refined demand forecasting that halved projected inventory days from 90 to 60. Within the focal operational environment, the classification was further validated by its correlation with tangible outcomes, notably a 5% drop in reprocessing costs attributable to the prudent application of safety stocks and indicated that systematic re-evaluation remains essential to accommodate the seasonal fluctuations characteristic of industrial demand.

4.3.3. Reconfiguring Spaces: Application of Systematic Layout Planning (SLP)

The redesign of the 100 m² workshop, drawing on Systematic Layout Planning (SLP), achieved a significant drop in the non-value-adding travel, accounting for 58% of overall delays in diagnostics and repairs. Activity relational diagrams revealed the critical flows: the interaction rated as absolutely important (A) between workbenches and testing areas had previously required 93 metres of travel. The new configuration relocates these stations to achieve a 50-metre link. The empirical validation is compelling: cycle times in diagnosis fell from 2.96 to 1.66 hours and in repair from 4.25 to 2.09 hours when simulations tracked 1347 distinct repairs against a takt of 102.6 minutes. The dimensionless block diagram guided the arrangement by stacking the A (4 lines) and the more permissive E (3 lines) relationships closest to one another, while pushing the O (1 line) relationships to the

outer layers. The resulting layout eliminated superfluous movements in 28% of recorded tasks. As a further metric, the repair process had previously incurred a cumulative 45 minutes of delay from misplaced equipment per order; the SLP intervention cut overall travel by 46%, enabling the fulfilment of 2851 deliveries instead of 750 under the former arrangement.

The findings indicate that Value Stream Mapping helped reduce dead time from 70,560 minutes, resulting in a peak service level of 89%. Moreover, the incorporation of multifunctional platforms ensured alignment with sustainability goals, enabling water reuse at an 80% rate, which translated into a 6.9% cut in resource costs.

Piloting of the system by the researchers demonstrated that the refined layout decreased penalty costs by 93,038 PEN, primarily by lowering the reprocess rate from 5% through better flow management. Collectively, the streamlined layout achieved an inventory turnover of six times per year and elevated productivity: space reallocation permitted one additional technician at every station, thereby recovering the 3,000 PEN invested in the redesign.

4.3.4. Anomaly Detection in Real Time: The Andon System's Deployment

The Andon system was tailored for multifunctional workstations housing visual beacons and electronic indicators designed to monitor and flag deviations in critical parameters—pressure, voltage, and flow—throughout diagnostics and repair cycles. During a two-month validation phase, the deployment of digital manometers at bench locations cut reprocessing rates from a range of 5% to 17% and trimmed repair intervals from a median of 45 to 7.5 daily minutes.

The instrumentation substantiated its justification by delivering 99.3% accuracy in fault identification; its predictive algorithms generated real-time alerts that precluded delays across 31 orders per month. With a backlog of 629 orders recorded in 2023, the Andon deployment diminished work interruptions by 17%, enabling the processing of 2851 units at a mean cycle time of 11.4 hours.

Implementation costs, including luminous panels priced at 2000 PEN, were recaptured by a 93038 PEN drop in penalty fees, yielding a 30% overall decrease. Synchronized with Industry 4.0 tenets, the Andon platform extended monitoring capabilities to remote stakeholders, yielding a 95% success rate in notifications exemplified by 38 certified validation events. Consequently, the service level recorded at 89% reflects the system's efficacy; visual cues curtailed deviations from standard parameters, affirming Andon's contribution to waste minimization and the enterprise's commitment to continuous improvement.

4.3.5. Visual Flows for Efficiency: Deployment of Kanban

The deployment of Kanban integrated color-coded cards to delineate warehouse phases: entry, diagnosis, quotation, and repair, leading to a 28% reduction in search duration, with pilot tests over sixty days averaging 12.4 minutes; the prior average was 45. This quantitative visualization validated the system, processing 1347 pieces of equipment while minimising interruptions, thus improving the backlog of pending deliveries from 9% to 2%.

In an instance where stockouts accounted for 233 tardy orders, Kanban was calibrated to ensure ongoing replenishments, coordinating with spare-part supermarkets that capped maximum inventories at 755 pieces per economic order quantity. A direct investment of 1500 PEN in cards was offset by a 93038 PEN decrease in penalty fees, resulting in an attained service level of 89%. Furthermore, harmonising Kanban with value-stream mapping eliminated identified bottlenecks, validating its functionality in the broader flows that processed 2851 shipments, while enhancing inventory turnover to six cycles per year.

Accompanying this summary, the inclusion of tables that present economic order quantity calculations—specifying input data and derived results, including annual demand, setup, and holding costs—would lend clarity. Relational diagrams in systematic layout planning that depict activities, entries, interactions, and outputs should be provided, as well as graphs that contrast ABC forecast trends with actual error metrics, and final pilot validation tables that correlate average time reductions for both Andon and Kanban systems.

4.4. Results

In the case study, the model, using Lean Logistics with SLP tools, was implemented to improve the service management model and repair service management cycle of industrial equipment, causing shifts in the values of the key indicators. In the beginning, gaps were set and based on those gaps, the new goals were set. In the middle of the cycles, the service level measuring indicator efficacy gaps and measurable lease level were set and measured to hit 89%, which is just under the 90% target. In the previously stated results, old versus new values were compared, and with the latest model, about 58.93% better service level was achieved.

Repair duration related to operational efficiency was also improved through the measures stated, and with the new model, the diagnosis and repair times dropped to 43.82% of their old values. In the previous examples, the new measures have also decreased the time spent on the equipment and spare parts search. Time set for the equipment retrieval and identification also improved, along with the time set aside for the rework. Final results will be aligned with the goals if the model is met. In a way, the proposed model was able to provide a great answer for the proposed model.

Table 1. Results of the pilot

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
Service Level	%	56%	90%	89%	58.93%
Tiempo de Ciclo Diagnóstico	minute	2.96	1.60	1.66	-43.92%
Tiempo de Ciclo Reparación	minute	4.25	2.00	2.09	-50.82%
Tiempo de búsqueda e identificación de equipos	minute	17.25	11.0	12.4	-28%
Tiempo de reprocesos	minute	9	8.5	7.5	-17%

5. Discussion

The integrated model with a service level of 89%, achieving a 43.92% reduction in diagnostic time, 50.82% in repairs, 28% in search and identification, and 17% in rework, corroborates the empirical evidence that Lean Logistics, as well as layout redesign, enhances the flow of activities and service level compliance.

The contraction of times in SLP and Kanban systems parallels earlier implementations where productivity and deadline compliance increased because of spatial restructuring and visually guided management systems. [24], [26], [28], [29]. The stabilization of supply through EOQ, coupled with ABC inventory classification, illustrates the reduced stockout phenomenon and increased inventory turnover in relation to the recently adapted EOQ model for services and spare parts with variable demand patterns. [20], [21], [22], [23]. The complementary decrease in rework and escalation times through Andon systems corresponds with earlier visualization and real-time responsive control systems and their application to service cells and Industry 4.0. [18], [19], [21].

Overall, the extent of the improvements in SLP reported is still, and in some cases, exceed the bounds documented for lean tool-adopting SMEs. For instance, greater than forty percent transfer time reductions and near ninety percent service improvements [24], [26], [28]. This indicates effective manufacturing to service principal transfers and accurate prioritization of the identified diagnostics, spare parts supply, and in-process quality control bottlenecks.

5.1. Study Limitations

The study has several contextual and methodological limitations. Validation is constrained to a single case study with a short temporal scope, which risks the effects being the result of initial learning and seasonal demand. The discrete-event simulation and its pilot implementation are not a substitute for the longitudinal evaluation necessary to capture the enduring impact of the improvements. The estimation of avoided costs alongside the service level estimation is based on administrative records and growth projections, which are likely to yield skewed results. Additionally, no comprehensive sensitivity analysis is performed for the EOQ, and the marginal contribution of each ancillary tool is not quantified, which impacts the determination of the total effect of each component.

5.2. Practical implications

From an operational standpoint, the findings suggest that the stepwise integration of SLP and Kanban prior to inventory optimization serves to amplify the effect of supply policies the most. An improvement in the realization of the Andon system allows for an immediate response to deviations, eliminating rework and improving the customer's perception of reliability. These measures help Small and Medium-sized technical service firms reduce penalties and boost productivity and service measures without the need for large-scale expenditures. Physically changing the order of the operations in the process flow and placing buffers strategically decreases the distance and time spent waiting to travel. These changes enable preemptive replenishment in accordance with demand. Implementing Andon systems at designated zones helps in responding to critical control deviations in real time.

5.3. Future Works

Exploring other industrial contexts and extending the evaluation horizon to analyze the longitudinal effects of the research could further validate the model's flexibility. Also of note would be the development of forecasting models for the intermittent spare parts demand and assessing how they measure up to the EOQ approach. The implementation of IoT technologies for the digitalization of Kanban and Andon would provide new avenues for real-time monitoring and anticipatory management of congestion. Additionally, the environmental and ergonomic consequences of the layout reconfiguration should also be assessed along with the comprehensive total cost of ownership to aid companies with diverse levels of operational sophistication in strategic planning.

6. Conclusion

Based on the investigative analysis, the results validate the methodological framework for optimizing the processes under evaluation as the most relevant, because there are appreciable enhancements in the benchmarks and a marked decrease in the operational inefficiencies. The research results further show that the application of chosen modern and sophisticated management information systems and the strategic criterion for management planning enhances decision-making for command and control. In this regard, the controlled execution of the proposed model systematically supports better resource management and operational performance.

This research is relevant because, within the sector, it is designed to solve the problem from a global angle, incorporating a specific technical problem and a specific problem of practicality. In environments defined by the need for business and market responsiveness, this research enables businesses in virtually all industries and markets to derive value from evidence-based improvement frameworks.

Regarding the contribution of the study to industrial engineering, it provides a definable reference structure to various production or service settings, which illustrates the synergy of optimization models with sustainability criteria in terms of practicality, efficiency, and value created. This lack of rigid structure in the methodology proposed is

advantageous in that it permits the inclusion of additional factors or constraints that, instead of reducing it, would enhance the efficiency of the system, thus increasing the scope to which it can be applied.

In the same line of reasoning, it is stimulating but not conclusive to the study's scope to focus on validation of the model in more complex and variable-rich environments or consider the impact of emerging AI technologies and predictive analytics tools on the system. Also, it is central to explore the model's long-term impact in terms of productivity and sustainability to enforce its value as a strategic industrial management tool.

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