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Original Article

Improving Operational Efficiency and Reducing Material Waste in a Precast Concrete SME: Insights from a Peruvian Case Study

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Abstract: *Precast concrete SMEs often suffered from operational inefficiencies, particularly due to non-standardized procedures, excessive material waste, and poorly designed layouts. Previous studies highlighted Lean Manufacturing as an effective methodology, yet its adaptation to resource-constrained SMEs remained underexplored. This research addressed those challenges by developing and implementing an integrated production model based on Lean Manufacturing, Kaizen, and Systematic Layout Planning. The model proposed key actions including work standardization, ergonomic redesign, supplier management, and layout optimization. Validation in a Peruvian SME revealed a 31.58% increase in value-added operations, an 80% reduction in rejected materials, and a 32.31% decrease in travel time. These results confirmed the model's effectiveness in reducing waste and improving productivity. Academically, the study contributed a replicable framework for lean implementation in SMEs. Socioeconomically, it strengthened the competitiveness and sustainability of small manufacturers in emerging economies. Future research should explore its scalability and digital integration to further enhance real-time process control and impact.*

Keywords: *Lean Manufacturing, Kaizen, Precast Concrete SME, Material Waste Reduction, Systematic Layout Planning, Work Standardization.*

I. INTRODUCTION

Precast concrete products, including poles and inspection boxes, play a major role globally in infrastructure development. In Latin America and specifically Peru, this sector is economically relevant due to the region's demand for modern infrastructure and construction services [1]. As reported by the Peruvian Chamber of Construction, there is rising urbanization attributed to an increased population that is creating a demand for modern infrastructure, and precast product manufacturing is growing to keep up with these needs [1]. Furthermore, this report also states that small and medium-sized enterprises (SMEs) face hardships in the industry due to increased expectations to fulfill demand and improve construction quality [2].

SMEs that specialize in producing precast concrete products tend to struggle with production inefficiencies. These issues make the businesses ineffectively compete due to the low operational effectiveness in the concrete product SMEs [3]. Qureshi et al. notes significant sources of contention as various factors associated with disorderly workstations, a lack of production process standardization, and excessive raw material wastage [4]. Inadequate work practices that are not regulated standardized also aggravate inefficiency, which subsequently reduces customer satisfaction alongside the product quality [5].

To ensure the sustenance and development of SMEs in the construction industry, these issues must be resolved. Improving processes not only enhances efficiency but also lowers costs and production time—critical factors for maintaining competitiveness in the global market [6]. As recent literature suggests, the adoption of Lean Manufacturing practices is one of the best ways to resolve these issues as it allows for waste in production processes to be identified and eliminated [7]. Even so, due to a few constraining factors, many SMEs have yet to implement these strategies, thus creating a deficit to be investigated [8].

Even with the increasing importance of Lean Manufacturing in the context of SMEs, the literature suggests that there is a striking lack of information. A multitude of research has been conducted regarding the application of Lean practices within large corporations, however, there is scant analysis on the application of such practices in the SME sector that produces precast concrete components [9]. This is the gap I intend to address with the proposed research by designing a production model based on Lean Manufacturing principles tailored to the specificities of the sector. I aim to incorporate tools such as work standardization and supplier management to fulfill these objectives [10].

The specific use of these tools in the context of SMEs operating in the precast concrete products industry—an area that has seen little action [11]—is where this contribution stands out. This effort will not only attempt to waste and improve efficiency but construct a theoretical framework that seeks to comprehend how these practices may be tailored to the region in Latin America, particularly Peru [12]. The contribution of this research will be important, as it will expand the range of academic knowledge and provide recommendations for the adoption of Lean practices in SMEs, which in turn could enhance the sustainability and competitiveness of the construction industry in the region [13].

As previously stated, the SME segment that manufactures precast concrete products is facing considerable challenges that require immediate intervention. The adoption of Lean Manufacturing strategies seems to be both plausible and requisite. An approach that directly caters to the characteristics of these small enterprises is, however, needed. This research intends to fill the knowledge gap by proposing an actionable framework and thus contribute to the enhancement of efficiency and competitiveness of SMEs in the precast products industry in Peru and Latam.

II. LITERATURE REVIEW

A. Lean Manufacturing and Continuous Improvement Methods in Precast SMEs

Applying methodologies like Lean Manufacturing, Kaizen, and Systematic Layout Planning has been beneficial for small and medium enterprises (SMEs) in precast concrete production concerning the logistical processes. For instance, the research done by Kusuma and Cahyana [14] states that the application of the SLP method enhanced production efficiency by 16% due to reduced travel distance and improved workflow. This also fits with the Lean Manufacturing principles that highlight elimination of waste and improvement of processes, as described by Amrina et al. [15].

Furthermore, Kaizen has been effectively used in the precast concrete industry to reduce cycle time and operational costs, as shown by Quiroz-Flores et al. [16]. The utilization of these elements with continuous improvement through process analysis and waste identification ensures optimization level achieved a balance between quality and cost. The efficiency created from merging Lean Manufacturing with other sector-based approaches enables a responsive and adaptable structure that meets the ever-changing market demands [17].

A proper layout design of production areas is a fundamental element of these methodologies. Lean production principles also foster sustainable production as noted by Amrina et al. [15]. This helps SMEs enhance their competitiveness through reduced environmental harm and improved resource efficiency.

These methodologies are also related to advancing technology in digital manufacturing. Menendez [18] states that there is remarkable improvement in the quality or efficiency of prefabricated construction systems with digital manufacturing, which incorporates Lean Manufacturing principles and underlines the need for new technologies to be adopted for industrial processes.

B. Implementation of Work Standardization Toward Productive Efficiency

For the SMEs operating in the precast concrete segment of the construction industry, productivity is greatly impacted by work standardization. The creation of standard operating procedures aims to decrease production process variability, consequently enhancing product quality as noted by Zhang and Shi [19]. This allows companies to ensure all employees follow the same processes, thereby reducing variations and increasing consistency in the products received.

Zhang and Shi [19] specifically note how the imposition of standardization assists with the integration of Building Information Modeling (BIM) technology into the design processes of prefabricated structures. Standardization improves precision in engineering design and fosters a greater balance between the design finalization and production phases, thus refining the efficiency of overall construction processes.

Additionally, Liu et al. [20] highlight the advantages that standardizing work methods brings toward improving the cutting process of the reinforcement for precast components. Such studies allow companies to devise specific processes tailored towards developing continuous improvement systems, particularly those that minimize time and resource expenditure, which is vital in today's competitive environment.

Standardization reinforces process improvement measures, reinforcing sharper performance metrics alongside reduced operational expenditures. The construction sector is of particular concern due to its fluctuating working conditions, as it needs strict supervision of the production parameters.

C. Ergonomics in Work Design

In process improvement within SMEs, ergonomics is foundational because it considers the business environment and its relation to employee productivity and health. Khasanah et al. [21] have noted that ergonomically optimizing work facilities can greatly mitigate the risks of manual material handling, thus improving efficiency. Worker fatigue is a serious issue that diminishes product quality and increases safety risks in the workplace.

With respect to the production of precast concrete elements, ergonomic design enhances not only worker comfort but also operational efficiency. Hindratmo and Oktavia [22] provide evidence that ergonomic consideration in plant layout design enhances material handling cost savings.

From this standpoint, Campos-Sonco et al. [23], applying principles of warehouse management, integrated ergonomics into the design of the workspace, thereby greatly improving service delivery and employee satisfaction. The study describes the creation of a work environment that enhances productivity and emphasizes employee health as being central to the design.

Thus, the use of ergonomics in designing workplace architecture enables major advancements for precast operations in reducing occupational risks, improving production whilst caring for employee health and well-being.

D. Supplier Management and Supply Chain Relationships

In the precast concrete sector, supplier management captures the most attention from SMEs because the suppliers determine the quality of raw materials. Nicał's [24] research indicates that a comprehensive supplier management approach can bring optimization to the entire supply chain regarding timely access to requisite materials.

Different entrepreneurial strategies such as Vendor Managed Inventory (VMI) allow deeper integration of planners and suppliers, leading to lower inventory costs, which, in turn, improves production efficiencies, as observed by Quiroz-Flores et al. [16]. Similarly, the research outcomes of Quiroz-Flores et al. [16] underlined the potential of improved supplier management not only for enhancement of logistical processes but also as a stimulus for innovation in production processes.

Moreover, the literature underscores the need to establish and nurture strategic supplier relationships that transcend basic business interactions. Especially in the context of precast concrete, these relationships may include active joint innovation and participation in new product development. Azis's [25] research underscores that the establishment of common goals between companies and their suppliers leads to marked advances in the competitiveness of the industry and the quality of the final products.

Hence, managing suppliers well not only improves the efficiency of the supply chain but also serves as a driver for innovation and quality improvement for precast SMEs.

E. Systematic Layout Planning: A Key to Operational Efficiency

Last, but not least, Systematic Layout Planning (SLP) offers a solution for the layout planning and redesigning of facilities for precast concrete SMEs. This approach has benefits regarding the utilization of materials as well as the reduction of travel distances and production overall. According to Herwanto et al. [26], effective workplace planning will reduce costs and increase productivity.

In addition, the SLP model has been tested in a few other works, including that of Liu et al. [27], which focuses on the properly organized facility to enable free flow of work for all staff. This study strengthens the argument that a well-planned and designed layout will not only improve operational efficiency but also create a safer and more conducive workplace.

The manner with which SLP can be adjusted and adapted is advantageous toward SMEs whom, as mentioned, have limited working area. As per the study done by Saputra et al. [28], modifying the layout using SLP is very effective in reducing handling distances and allows the integration of new technologies or processes.

It is critical to note that SLP is part of an organization's improvement strategy system and not an independent process. Fadilah et al.'s study [29] underscores the strategic importance of layout reconfiguration as it can significantly enhance efficiency and product quality, thus reaffirming its fundamental contribution to operational planning in precast concrete SMEs.

III. CONTRIBUTION

A. Proposed Model

Figure 1 presents the proposed production model, developed for a small and medium-sized enterprise (SME) specialized in the manufacturing of precast concrete products. The main objective of this model was to reduce excessive raw material waste within the production process by integrating tools from Lean Manufacturing philosophy, Kaizen principles, and the Systematic Layout Planning methodology. The approach was grounded in standardizing work to minimize variability, applying ergonomic criteria to align operational conditions with human capabilities, improving supplier management to ensure timely material flow, and redesigning the facility layout to optimize space utilization. This integration was based on a comprehensive analysis of sector-specific background, a review of relevant literature, process assessments, and the company's historical data. The model enabled the design of a systemic and coordinated intervention aimed not only at minimizing material losses but also at fostering a culture of continuous improvement and enhancing the sustainability of the operational system.

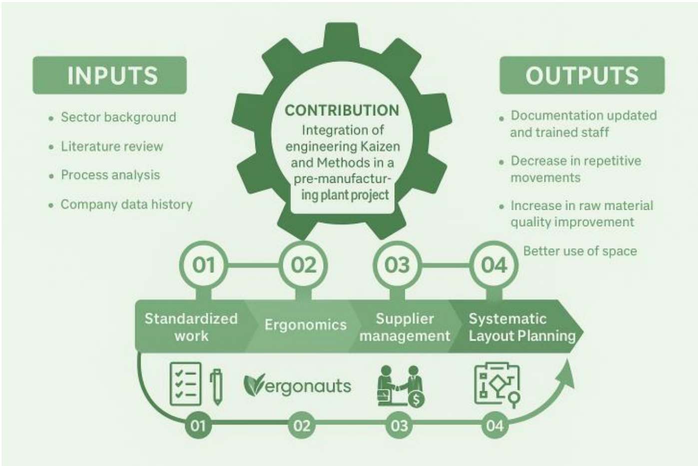

Figure 1 : Proposed Lean-Kaizen Production Model

B. Model Components

The proposed production model designed to eliminate a fundamental problem some small and medium-sized enterprises (SMEs) that manufacture precast concrete products face: material waste during production. This concern not only impacts the cost efficiency of the business, but its sustainability, and reliable operational functioning, as well. To address this issue, the model incorporates elements of Lean Manufacturing, Kaizen principles, and the Systematic Layout Planning (SLP) methodology done in an organized and contextual manner.

The model's differentiating value appears to be in defining multiple complementary approaches and articulating them through a logical intervention series. It is not generic or divorced from operational reality. Rather, it starts from a thorough diagnosis of existing production processes. It identifies structural waste root causes and provides specific suggestive tools to technologically evolve the production system. This model was developed for a precast concrete SME and considers the most common constraints of such SMEs, such as low available resources, high operational variability, and the requirement for continuous production.

The model is built on four interrelated technical components: Standardized work, ergonomics, supplier management, and layout optimization. These are based on internal company information, data, processes, and particular industry knowledge. In the following portions of this paper, I will describe each component explaining its rationale, implementation, and how it directly contributes to minimizing raw material waste.

a) Standardized Work: Foundation for System Stability

The first component of the model is standardized work, due to its capacity to eliminate operational variability and generate stable conditions for sustainable improvements. In the SME under study, several production activities lacked defined methods, with execution depending on individual worker criteria. This inconsistency increased the risk of errors, rework, and material loss. To address this, the model defined optimal procedures for key tasks, documented through visual instructions and validated with pilot tests.

Firstly, the procedure needed documenting in a step-by-step process with defined pictorial guides. Existing methods of critical operations like Concrete mixing, Mold preparation, Application of product are documented and validated in flowchart forms including standard times, equipment needed, and quality control checkpoints. Workers ensured attitudinal support through participatory approaches amid attempts to endorse acceptance of the standards to aid the overall solvability problem.

This stage also resulted in the discovery and removal of activities that did not add value. After this step, best practices were captured and shared throughout the workforce in the form of standardized work sheets. This uniformity reduced both operational mistakes and established a baseline for ongoing refinement. Furthermore, it permitted early recognition of process variability, enabling prompt proactive measures which strengthened system dependability.

b) Applied Ergonomics: Aligning Human Performance with Work Conditions

The second component incorporates ergonomic principles to improve the interaction between workers and their physical work environment. In precast concrete manufacturing, tasks typically involve manual handling of heavy materials, awkward postures, and repetitive movements, which can lead to accidents, fatigue, and process inefficiencies. These factors contribute indirectly to material waste through drops, misalignments, or defective finishes.

To address these loss drivers, the model performed ergonomic evaluations of workstation interfaces designated as most impactful or high leverage workstations. These included postural screening checklists, motion studies, and ambient conditions assessments. Based on evaluation results, practical ergonomic solutions were provided through height-adjustable workstations, placement of mechanical aids, storage area reorganization, tool zoning, and enhanced ergonomics outstanding ergonomics.

Training on ergonomic techniques brought awareness concerning the workers' sitting, movement, and general safety practices. This helped reduce injuries and allowed more finely tuned or consistent work to be performed. As observed, ergonomics was not only a health concern but also an instrument for curtailing inaccuracies and the excessive use of materials due to tiredness or inefficiency.

c) Supplier Management: Organized External Logistics to Eliminate Internal Hurdles

The third component focuses on supplier management, as a critical interface between internal production and external material inputs. In the SME under study, some of the material losses originated not within the production line, but at the point of reception—due to delivery delays, incomplete orders, or poor-quality materials. These disruptions forced the team to improvise, often resulting in waste.

To counter this issue, the model proposed a communication-enhanced, standardized control strategy. Firstly, unambiguous communication protocols were set up with the suppliers regarding the technical requirements, schedule, and the quality standard. Also, the purchase orders together with the reception checklists included boxes which prescribed the mandatory criteria that had to be met for the inspections.

To control the compliance, qualitative attributes, and responsiveness of a supplier, a supplier performance evaluation system was also integrated. This system aided in fostering discussions aimed at continuous improvement and in the selection of more dependable supply alternatives where required.

A supplier's effective coordination improves the streamlined flow of materials, which directly lowers waste generated during the manufacturing processes. It also reduces the need for emergency materials storage, the risk of spoilage, and provides better predictability for processes. The alignment of supply and production greatly enhances the responsiveness and efficiency of the system.

d) Systematic Layout Planning: Redesigning the Physical Flow for Operational Efficiency

The final component involves the application of Systematic Layout Planning (SLP) to redesign the physical layout of the facility. In any manufacturing process, the spatial arrangement of workstations, storage, and equipment is a major determinant of productivity, especially when waste reduction is a core objective.

The layout redesign proceeded through four stages: activity analysis, relationship diagraming, space allocation, and layout proposal. The team started with the mapping of all internal material flows of the firm like aggregate transfer, mixing, molding, curing, and finally storage. After that, a relationship chart was developed aiming at ranking the adjacency to be given a prioritized proximity to high-interaction processes.

Next, along with the safety buffers, perimeter accesses, and ergonomic factors, the ideal spatial scope was described for each section. The layout design offered also aimed at minimizing superfluous movements, crossflows, and waiting spaces. Practical design feasibility was confirmed through the flow simulations and operative feedback collected during the testing phase.

The layout as such has increased visibility and safety while improving process flow, which led to diminished material handling inefficiencies. Supervision level and coordination of diverse operations also improved as a result. In adherence with Lean guidelines, the plant became smaller and less obfuscated in its structure, leading to more efficient and less obstructed workflows with effortless spatial resource allocation. This resulted in clear line obfuscation in the plant's structure.

Regarding the precast concrete products manufacturers, this model addresses the dire issue of material waste through a holistic lens it has engineered for SMEs. By systemically redefining workstation standards, ergonomics, supplier relations, and spatial layouts, the model aims to transform the firm on a macro scale. All proposed components bolster each other, thus creating a more robust, efficient, and predictable production system.

Beyond its technical contributions, the model supports a cultural shift toward continuous improvement, fostering operational discipline and active worker involvement. It is grounded in real production data and tailored to the constraints of small-scale enterprises, making it both practical and scalable.

The added value and technological updates encourage new adaptation for SMEs with similar industrial practices. The other SMEs within the industrial context are offered a methodological reference. This approach adds reduction of waste while increasing the competitiveness, reliability, and sustainability of the firm.

C. Model Indicators

The evaluation of the production model applied in a precast concrete SME focused on monitoring the performance of operations by adopting key criteria tailored to the reduction of raw material waste. The framework was built upon Lean Manufacturing principles, Systematic Layout Planning, and Kaizen philosophy to ensure a coherent and data-driven measurement approach. Specific metrics were defined to capture critical aspects of the production process and guide performance analysis. This structured monitoring allowed for the identification of improvement areas and supported decision-making, facilitating the continuous enhancement of operational efficiency within the company's manufacturing environment.

Value-added operations

This indicator reflects the proportion of operations that directly contribute to product value. A higher percentage implies greater efficiency and process effectiveness.

$$\text{Value-added operations (\%)} = \left(\frac{\text{Value-added time}}{\text{Total process time}}\right) \times 100 \tag{1}$$

a) *Operational activity time*

Represents the total duration taken to complete productive tasks within the process. Reducing this time indicates streamlined operations.

$$\text{Operational activity time} = \sum \text{Time for each activity (min)} \tag{2}$$

b) *Staff performance*

Measures the effectiveness and productivity of personnel in executing assigned tasks. Higher values reflect improved workforce utilization.

$$\text{Staff performance (\%)} = \left(\frac{\text{Actual output}}{\text{Expected output}}\right) \times 100 \tag{3}$$

c) *Unnecessary movements and efforts*

Indicates the percentage of non-value-adding motions within work processes. Lower values are desirable for minimizing waste.

$$\text{Unnecessary movements (\%)} = \left(\frac{\text{Time lost to unnecessary effort}}{\text{Total time}}\right) \times 100 \tag{4}$$

d) *Number of risk factors*

Represents the count of identified ergonomic or safety hazards in the workplace. A lower number reflects a safer and more stable environment.

$$\text{Risk factors} = \sum \text{Identified safety and ergonomic issues} \tag{5}$$

e) *Performance of potential suppliers*

Assesses how well suppliers meet predefined quality and delivery standards. Higher percentages indicate better supplier reliability.

$$\text{Supplier performance (\%)} = \left(\frac{\text{Compliant deliveries}}{\text{Total deliveries}}\right) \times 100 \tag{6}$$

f) *Rejected sample approval*

Quantifies the proportion of sample batches rejected due to quality non-conformance. Lower values indicate better incoming material quality.

$$\text{Rejected samples (\%)} = \left(\frac{\text{Rejected samples}}{\text{Total samples evaluated}}\right) \times 100 \tag{7}$$

g) *Travel time*

Captures the time required for materials or personnel to move across the layout. Reducing this time reflects better layout efficiency.

$$\text{Travel time (min)} = \sum \text{Walking or transport time per operation} \tag{8}$$

IV. VALIDATION

A. Validation Scenario

The validation scenario took place in a case study involving a small and medium-sized enterprise (SME) in the construction sector, located in Lima Metropolitan Area, Peru. This company specialized in the manufacturing of precast concrete products, particularly sewer inspection boxes for mass consumption. The organization operated in a production environment heavily reliant on manual labor and limited physical resources, which presented significant operational challenges. One of the main issues identified was the high level of raw material waste in the mixing area, which negatively affected both the efficiency and sustainability of the production process. This situation underscored the need to reassess traditional work methods and material management practices to minimize losses and optimize the use of available resources. In this context, the case study offered a suitable framework to evaluate improvement strategies grounded in modern industrial engineering approaches.

B. Initial Diagnosis

The diagnostic assessment conducted in the case study identified an excessive amount of waste in the mixing area as a critical issue for the operations of a small enterprise dedicated to manufacturing precast concrete products. In the last year, waste levels reached 10.5%, significantly exceeding the 5% benchmark considered world-class. This loss amounted to 214,373 kg of raw material, generating an economic impact of approximately S/. 48,155.58, which represented 5.51% of total costs. The main contributing factors were found to be inadequate work methods (38%), incorrect dosing of raw materials and inputs (26%), and poor space utilization and congestion (34%). Within these categories, notable findings included an incorrect task sequence (68%), non-standardized procedures (42%), untrained personnel (37%), and variation in raw material quality (60%). Additional issues involved insufficient ergonomic planning, lack of supplier certification, and an inadequate layout design. This analysis made it possible to directly link process inefficiencies to the structural components addressed by the proposed improvement model.

C. Validation Design

The proposed production management model, which integrates Lean tools, Systematic Layout Planning (SLP), and Kaizen principles, was validated through a four-month pilot implementation in a small concrete precast manufacturing company. This validation phase focused on reducing raw material waste by applying structured and continuous improvement techniques. The model was deployed across various stages of the production process, involving the reorganization of workspace layouts, the standardization of work methods, and the promotion of a culture of ongoing process refinement. The validation relied on data-driven monitoring, enabling a systematic evaluation of the model's operational and economic impact.

a) Implementation of Improvement Tools in the Productive Process

To validate the production model, a set of improvement tools inspired by Lean Manufacturing, Systematic Layout Planning, and the Kaizen philosophy were executed in a small company that manufactured precast concrete components. The changes were made in stages and were tailored to the peculiarities and needs of the operation. This process attempted to mitigate the major raw material losses during the mixing operations, which had been identified as the most critical point of inefficiency, or in other words, the most significant waste. Each tool was applied toward a particular operational goal and was evaluated through the use of defined performance indicators. The initial phase of the project was four months duration, during which it was possible to conduct ongoing measurement of the determinate and the conditions for evaluating the strategies were defined in advance, so the evidence could be collected during and after the implementation of the strategies during which the effectiveness of each strategy could be evaluated.

b) Standardization of Work: Operational Stability and Process Consistency

The creation of standardized work was directed toward solving the inconsistencies in task performance and variability in procedure execution for some operations like mixing, mold setting, and casting. Prior to the intervention, all tasks were completed on the basis of informal rote experience without any structure or documented sequences. This created chaos due to variation in execution as well as irregularities in the handling of raw materials which resulted in instability and waste.

In an effort to overcome these deficiencies, a standardization process was designed which incorporated time studies, definition of value-adding versus non value-adding activities, and creation of standard operating procedures (SOPs). Operators were guided through the creation of visual work instructions and standardized checklists or task sheets for repeatable performance and to overcome chronic variability in result. The findings indicated that there was an increase in value added operations of 31.58%, from 57% to 75%. Furthermore, retrieval and operational activity time was lowered by 2.49 minutes per task, a 23.03% improvement.

The standardization improved staff performance from 42% to 77%, an increase of 83.33%. Greater clarity of roles and understanding of expectations contributed to reduction in task overlap and process interruptions, allowing for smoother production processes. Standardization of practices was essential in shaping a reliable production system within the framework of Lean Manufacturing principles.

Table 1 : Mixing time before and after implementing standardization of work

Operator	Mixing Time Before Implementation (minutes)	Mixing Time After Implementation (minutes)	Reduction (%)
Operator 1	11.87	8.97	24.43%
Operator 2	10.18	7.6	25.34%
Operator 3	10.39	8.38	19.35%
Average			**23.04%**

c) Ergonomics: Reducing Risks and Increasing Functional Comfort

The second intervention focused on addressing workspace ergonomic risks that had been linked to physical fatigue and inefficiency in the completion of tasks. The diagnosis phase uncovered numerous awkward postures, repetitive motions, and unnecessary movements while mixing and handling materials. These conditions were addressed through ergonomic assessments conducted via direct observation and mapping techniques. The mitigation analysis yielded ten ergonomic risk factors that required attention.

Based on the analysis, the modifications of the workstation resulted in a set of ergonomic improvements. Adjustments to work surfaces and tools were made to their sought appropriate heights and cubical materials to be organized to assume minimal reach distances. As a consequence, the employed ergonomic risk factors decreased from 10 to 6, reflecting a 40% reduction. Furthermore, unnecessary movements and efforts dropped from 28.5% to 22.8%, illustrating a 20% improvement.

The implemented ergonomic strategies in support of operators' physical well-being did indirectly influence productivity and quality maintain. Tasks were completed with reduced interruptions due to fatigue, discomfort, or ergonomically-provided rest breaks. Enhanced structural and dynamic postures facilitated workflows and minimized micro-stoppages. Ergonomics acted as additional supporting means to other strategies employed for continuous refinement of operational processes.

Table 2 presents the final REBA scores for five critical production activities, highlighting their respective action and risk levels. All tasks are classified as high or very high risk, indicating the urgent need for corrective actions to mitigate ergonomic hazards and ensure safer working conditions for operational personnel.

Table 2: Final scores for critical activities

Critical Activity	Final REBA Score	Action Level	Risk Level	Action Requerid
Move raw material to mixing area	8	3	High	Attention is required as soon as possible
Place raw material in selected area	8	3	High	Action must be taken as soon as possible
Mix	13	4	Very High	Immediate action must be taken
Place mixture in containers	10	3	High	Action must be taken as soon as possible
Carry containers to emptying area	11	3	High	Immediate action is required

d) Supplier Management: Ensuring Material Quality and Delivery Reliability

The strategic step aptly termed as supplier management aimed at fixing the quality volatility problem with raw materials, which had been flagged as a source of production waste. There were no formal supplier evaluation steps within the company. Approval processes were based on subjective and arbitrary informal standards. The result of this lack of order was erratic delivery schedules, non compliance in adherence to specifications, and an inordinate amount of rework during the mixing stage.

A supplier vetting matrix based on delivery reliability, adherence to quality standards, and incidence rate of violent nonconformity was established to solve these problems. During the four month pilot period, the compliance of all suppliers with the set criteria were evaluated and immediate corrective measures were put in place for suppliers who were below the set threshold. Sample rejection rates dramatically decreased from 25% to 5%, which indicate an 80% reduction in material failure rates. In addition to this, overall supplier claim performance also improved from 85% to 100%, indicating full compliance to the set criteria.

This intervention also alleviated process variability, since better coordination with suppliers ensured a uniform quality of materials. The enhanced quality of the supply chain contributed directly to the reduction of deviations associated with the concrete mixture and the standardization of the operations.

Effective supplier control not only guaranteed the provision of good quality raw materials but also improved the stability of the production system in general, harmonizing external conditions with internal improvements and processes.

Figure 2 illustrates a visual model of the supplier management process using brown tones and representative icons to enhance clarity. The cycle spans from product knowledge to control and updating, ensuring strategic decisions are made through analysis, continuous evaluation, and performance improvement within the supplier selection and monitoring framework.

Figure 2 : Supplier management process

e) Systematic Layout Planning: Optimizing Flow and Reducing Travel Time

The last intervention was the application of Systematic Layout Planning (SLP) to restructure the workstation and to enhance the efficiency of material flow. The previous layout had been prepared without regard to the proximity or functional relationships, contributing to excessive internal transport and congestion within the facility. A different approach using SLP methodology to enhance the sequence of operations and collaborative activity transport distances was proposed.

Additionally, the boundaries of the input and output points were changed, the sequence alignment of workstations was adjusted to be more sequential, and the storage areas were merged. These changes helped reduce average travel time from 32.5 to 22 minutes, achieving a reduction of 32.31%. Moreover, the new layout aided visual management of the workplace and order, better coordination reduced cycle time.

In this case, the company streamlined production line responsiveness by reducing transport times and simplifying routes. These layout changes also supported earlier ergonomic and standardization enhancements, fostering a more cohesive and efficient integration of the workplace systems. This is why Systematic Layout Planning offered a spatial framework that enabled the overarching objectives of the Lean-Kaizen model in this case study.

Figure 3 illustrates the proposed optimized layout developed through the application of Systematic Layout Planning (SLP). This redesigned arrangement reduces unnecessary travel paths, minimizes backtracking, and improves the flow of materials and personnel across functional areas, enhancing spatial efficiency and supporting a more streamlined and productive manufacturing process.

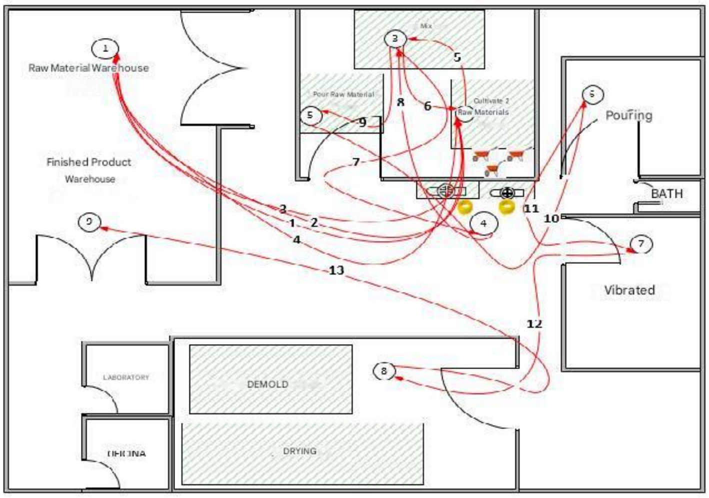

Figure 3 : Proposed optimized Layout

D. Results

Table 3 presents the performance of key indicators following the validation of the proposed production management model, which integrates Lean tools, Kaizen principles, and Systematic Layout Planning in a small concrete prefabrication company. The results demonstrated significant improvements in both operational and organizational variables, aligned with the objective of reducing raw material waste. Notably, value-added operations increased by 31.58%, while staff performance improved by 83.33%, indicating a more efficient use of time and human resources. Furthermore, reductions were achieved in operational activity time and internal travel time, decreasing by 23.03% and 32.31%, respectively. Additional improvements included a marked reduction in risk factors and rejected sample rates, reinforcing the model's positive impact on both process quality and operational control. These findings confirm that the implemented model contributed effectively to enhancing productivity and minimizing inefficiencies within the production system.

Table 3: Indicators After Model Implementation

Indicator	Unit	As-Is	To-Be	Results	Variation (%)
Value-added operations	%	57%	70%	75%	31.58%
Operational activity time	Minute	10.81	9.5	8.32	-23.03%
Staff performance	%	42%	85%	77%	83.33%
Unnecessary movements and efforts	%	26.40%	20%	21.80%	-17.42%
Number of risk factors	times	12	8	6	-50.00%
Performance of potential suppliers	%	85%	95%	100%	17.65%
Rejected sample approval	%	25%	10%	5%	-80.00%
Travel time	Minute	32.5	25	22	-32.31%

V. DISCUSSION

The outcomes derived from implementing the suggested Lean-Kaizen model exhibit marked enhancement in operational efficiency along with reduction in waste, both of which have been the focus of previous research particularly concerning SMEs manufacturing precast concrete products. The 31.58 percent increase in value-added operations coupled with 32.31 percent decrease in transport time agree with the findings by Kusuma and Cahyana where it was shown that the application of the Systematic Layout Planning (SLP) method enhances production efficiency through improved material flow [15]. Likewise, the work standardization strategies applied in this study are aligned with the conclusions drawn by Zhang and Shi about standardization not only augmenting product quality but also improving technological synergies and controlling the processes [19]. Furthermore, the enhanced relationships with suppliers and their improved 80 percent rejection rate of inputs corresponds to Nicał's remarks that assert active suppliers' relations greatly strengthen the supply chain while preventing loss through non-conforming quality defects [24]. In general, the results of this study reinforce the previously existing literature with more empirical results on the integration of Lean tools into resource-constrained SMEs.

This research contains several self-imposed constraints. Because model validation was performed in a single company within the Lima Metropolitan Area, the results may not be applicable to other construction SMEs of different sizes, types, or regions. Furthermore, the model's impact cannot be fully evaluated due to the short validation period of four months and the lack of long-term assessment. Although aspects like the seasonality of demand or changes in the cost of raw materials could affect the model, the author chose not to incorporate these external shifting variables during the study. The author's conclusions lack statistical significance due to not employing advanced tools, which greatly diminishes the rigor of the results.

Findings of this research provide a few actionable strategies for auxiliary businesses within the precast concrete products industry. First, the combination of standard operating procedures with ergonomics facilitates the attainment of equilibrium and improvement of safety in work conditions, which increases output levels, reduces workplace hazards, and enhances employee health. Second, the model's supplier management criteria foster more effective and strategic business partnerships, as the suppliers of raw materials guaranteed their quality and were not subject to changes that would necessitate additional labor to correct. Third, and finally, redesigning the layout according to the SLP method minimizes not only the time required for transport but also efforts that do not add value while helping to achieve order and control of processes—allowing for the easier execution of ongoing enhancements. All these actions together allow SMEs to better manage their available resources and shift towards more environmentally friendly and competitively advantageous systems of production. Subsequent investigations ought to broaden the scope of the model's implementation on other companies in the industry, domestically and internationally, to check the model's flexibility in other production contexts. It would also be beneficial to include virtual elements like 3D models, or even IoT sensors for automated data collection, which would allow for monitoring performance in real time and, therefore, rapid responsive action. A different promising avenue pertains to a quantitative analysis of the costs and benefits of the implementation of the model, with particular focus on its operational as well as financial metrics. Furthermore, exploring the model's influence on organizational culture could be examined as the organization shifts towards a continuous improvement philosophy that demands greater employee participation and adaptations in management frameworks. Finally, the integration of ecological or "lean-green" perspectives could refine the model by addressing the integration of environmental concern, which is increasingly relevant given the rising consciousness about the industrial ecological footprint.

VI. CONCLUSION

The research shows that implementing Lean Manufacturing techniques such as Kaizen and Systematic Layout Planning into the operational model of SMEs precast concrete production plants greatly enhances process productivity, decreases raw material waste, and optimizes cost factors. The reorganization of work standards including ergonomic adjustments, supplier negotiation management, and layout reshaping achieved significant results such as increasing value-added operations by 31.58%, reducing activity time by 23.03%, and decreasing rejected materials by 80%. These results validate the model's capability to solve the most important problems of productivity and sustainability inefficiencies in the focus industry.

This research is particularly valuable in addressing an urgent need from Latin American SMEs to improve their infrastructure competitiveness. In conditions with limited resources and high variability in operations, the model provides an effective and easy-to-copy answer designed with modern principles of industrial engineering in mind. The study focuses on specific structural waste factors and inefficiency to advance knowledge in practical manufacturing contexts. The addition to the body of knowledge is the context-specific application of Lean approaches in SMEs; most research to date focuses on large-scale industries. Also, the incorporation of ergonomic considerations and the control of the suppliers' performance adds more depth to the model's multifunctional character. Thus, this research fulfills both the academic gap in the literature and practical needs for other companies with similar operational problems, making it easier to implement the findings.

It has been noted that the results not only confirm the applicability of Lean-based strategies in smaller enterprises but leave the door open to further optimization. Subsequent research may consider investigating the model's adaptability, its economic benefits over an extended time frame, or its integration with digital systems for real-time tracking. By taking this approach, the model could position itself as an enabling foundation aimed at advancing industry-wide continuous improvement, waste reduction, and sustainable growth in the entire precast concrete industry.

VII. REFERENCES

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