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Developing and Implementing a Lean-Based Inventory Management Model: A Case Study in the Peruvian Construction SME Sector

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Abstract

The construction sector in Peru significantly contributes to economic development, with SMEs playing a vital role. However, these enterprises often face inefficient inventory management, leading to increased costs and material waste. This study proposes a Lean-based inventory management model tailored for construction SMEs to address these challenges. The model integrates tools such as the 5S methodology, demand forecasting, and optimized inventory policies to streamline processes and enhance efficiency. Implementation results demonstrated a 10% reduction in average inventory levels and a 40% decrease in defective product rates, indicating substantial operational improvements and cost savings. This research contributes to existing literature by providing a practical framework for inventory optimization in construction SMEs and underscores the socioeconomic benefits of adopting Lean practices. The study advocates for broader application and further exploration of Lean methodologies within the construction industry to promote sustainable operational excellence.

Keywords
Lean Manufacturing, Inventory Management, Construction SMEs, Continuous Improvement, 5S.

1. Introduction
The significance of the small and medium-sized enterprises (SMEs) in the construction sector in Latin America, particularly in Peru, cannot be overstated. These enterprises constitute a vital part of the economic fabric of the region, contributing significantly to both economic growth and social development. Recent data indicates that SMEs account for approximately 90% of businesses in Latin America, generating around 60% of employment and contributing to 50% of the Gross Domestic Product (GDP) (World Bank, 2020). In Peru, the construction sector serves as one of the primary engines of the economy, where SMEs play a crucial role by providing jobs and fostering investment in infrastructure (Ministerio de la Producción, 2021). The ability of these enterprises to adapt and respond to market demands is essential for sustainable economic growth in the region (OECD, 2021). However, despite their importance, SMEs in the construction sector face significant challenges that hinder their potential, highlighting the need for effective research and intervention strategies to address these issues.

One of the most critical challenges faced by SMEs in the construction sector is the inadequate management of inventory for construction materials. This situation leads to low inventory turnover, which in turn results in stockouts and significant waste of scrap materials (González & Rodríguez, 2022). Inefficiencies in purchasing management and a lack of accurate sales forecasting are contributing factors to this problem (López et al., 2021). The absence of standardized processes in inventory management, storage, and installation of materials exacerbates the situation, resulting in additional costs and delays in construction projects (Martínez & Pérez, 2020). The literature indicates that inventory management is a complex challenge for SMEs, as it involves planning and controlling inventory to balance supply and demand while minimizing investment (Cruz & Salazar, 2019). The lack of appropriate tools and effective methodologies for inventory management can lead to decreased competitiveness for these enterprises (Fernández et al., 2020). Therefore, it is crucial to address these issues through the implementation of strategies that optimize inventory management and improve operational efficiency.

Resolving inventory management issues in SMEs within the construction sector is of paramount importance, not only for the sustainability of these enterprises but also for the economic development of the region. Efficient inventory management can lead to cost reductions, improved service quality, and increased customer satisfaction (Hernández & Torres, 2021). Furthermore, by optimizing inventory turnover, SMEs can enhance their ability to respond to market demands, allowing them to compete more effectively with larger firms (González & Rodríguez, 2022). The implementation of more effective inventory management practices can contribute to the resilience of SMEs in the face of economic crises and other challenges (Martínez & Pérez, 2020). Therefore, it is imperative that models are developed and implemented to address these deficiencies in inventory management, which will not only benefit individual enterprises but also strengthen the construction sector as a whole.

Despite the relevance of these topics, there exists a notable gap in the literature regarding inventory management in construction SMEs, particularly in the context of Latin America and Peru. Current research has not thoroughly addressed the methodologies and tools that could be applied to improve inventory management in this sector (López et al., 2021). This study aims to fill this gap by developing a production model based on Lean Manufacturing tools, such as Value Stream Mapping (VSM), 5S, demand forecasting, inventory policies, and ABC inventory systems (Hernández & Torres, 2021). These tools have proven effective in enhancing operational efficiency and reducing waste across various industries, and their application in the context of construction SMEs could yield significant improvements in inventory management (Fernández et al., 2020). By addressing these issues, the research will not only contribute to academic knowledge but also provide practical strategies for construction SMEs in Peru to enhance their competitiveness and long-term sustainability.

In conclusion, the importance of the construction SME sector in Latin America and Peru is undeniable, as are the challenges they face, particularly in inventory management. Addressing these problems is crucial for the economic development of the region and the sustainability of these enterprises. Through research and the implementation of models based on Lean Manufacturing tools, it is possible to tackle current deficiencies and contribute to strengthening the construction sector in Peru.

2. Literature Review

2.1 Lean Manufacturing in Material Storage Processes of Construction SMEs

The Lean Manufacturing methodology has been applied across various industries, including the construction sector, with the aim of optimizing processes and reducing waste. In the context of small and medium-sized enterprises (SMEs) in construction, the implementation of Lean Manufacturing has proven effective in enhancing efficiency in material storage. According to, the application of Lean in SMEs has allowed for the identification and elimination of non-value-adding activities, resulting in significant reductions in operational costs. Furthermore, emphasize that the elimination of waste in storage processes not only improves efficiency but also increases customer satisfaction by ensuring timely availability of materials.

Moreover, argue that integrating Lean Manufacturing with Six Sigma can provide a more robust approach to continuous improvement in construction SMEs. This combined approach enables companies to not only optimize their storage processes but also enhance the quality of materials and services offered. Additionally, notes that adopting Lean practices in supply chain management for construction SMEs contributes to better inventory planning and control, which is crucial in a sector where delays can significantly impact costs and delivery timelines. In summary, Lean Manufacturing methodology emerges as a valuable tool for construction SMEs, facilitating the optimization of their storage processes and enhancing their competitiveness in the market.

2.2 Application of the 5S Methodology in Material Storage Processes of Construction SMEs

The 5S methodology, which focuses on workplace organization and standardization, has been adopted by many construction SMEs as a strategy to improve efficiency in material storage. According to , implementing 5S in the construction environment has shown to reduce the time spent searching for materials, thereby decreasing downtime and improving overall productivity. Furthermore, the research by highlights that the practice of 5S not only enhances the physical organization of space but also fosters a culture of continuous improvement among employees, which is essential for the long-term success of SMEs.

Additionally, the implementation of 5S has a positive impact on workplace safety. indicates that a more organized and clean working environment reduces the risk of accidents, which is particularly relevant in the construction sector, where risks are inherently high. Moreover, the research by suggests that applying 5S can lead to improved employee morale, as a tidy and efficient work environment contributes to greater job satisfaction. In conclusion, the 5S methodology proves to be an effective tool for construction SMEs, not only for optimizing material storage but also for promoting a safer and more motivating work environment.

2.3 Demand Forecasting in Material Storage Processes of Construction SMEs

Demand forecasting is a crucial practice for the efficient management of material storage in construction SMEs. This methodology allows companies to anticipate material needs and plan their procurement more effectively. According to , implementing demand forecasting techniques helps SMEs reduce costs associated with excess inventory and minimize the risk of material shortages. Furthermore, the research by emphasizes that accurate demand forecasting enables SMEs to optimize their storage processes, ensuring that materials are available when needed, which is fundamental for meeting delivery deadlines.

Moreover, the ability to forecast demand also allows SMEs to adapt to market fluctuations. According to , companies that implement demand forecasting systems are more agile and can respond quickly to changes in market conditions, providing them with a competitive advantage. Additionally, the use of technological tools for demand forecasting, such as data analysis software, has become increasingly common in construction SMEs, as indicated by . In summary, demand forecasting is an essential methodology for construction SMEs, as it enables them to manage their storage processes more efficiently and adapt to a constantly changing market environment.

2.4 Inventory Policies in Material Storage Processes of Construction SMEs

Inventory policies are fundamental for the efficient management of material storage in construction SMEs. These policies establish guidelines for the acquisition, storage, and distribution of materials, which is crucial for maintaining a continuous workflow. According to , a well-defined inventory policy allows SMEs to minimize storage costs and reduce the risk of material obsolescence. Furthermore, the implementation of effective inventory policies contributes to better production planning, as highlighted by Sánchez et al. (2022), which underscores the importance of synchronization between demand and material supply.

Moreover, inventory management also has a significant impact on customer satisfaction. According to the study by , SMEs that implement appropriate inventory policies are able to meet delivery deadlines and maintain high levels of customer service. Additionally, the research by Jiménez & Amaya (2014) suggests that adopting inventory management technologies, such as tracking and control systems, can further enhance efficiency in material storage. In conclusion, inventory policies are an essential component in the management of material storage in construction SMEs, as they allow for cost optimization, improved planning, and increased customer satisfaction.

2.5 ABC Methodology in Material Storage Processes of Construction SMEs

The ABC methodology is an inventory management technique that classifies materials according to their importance and value and has been adopted by many construction SMEs to optimize material storage. According to the research by Bendeck Segrera (2020), implementing the ABC methodology allows SMEs to identify critical materials and focus their efforts on managing these, resulting in a more efficient use of resources. Furthermore, the research by highlights that classifying materials by value enables SMEs to prioritize attention and resources on those items that have a greater impact on operations.

Moreover, the ABC methodology also contributes to better purchasing planning. According to , by identifying high-turnover materials, SMEs can establish more effective replenishment policies, reducing the risk of shortages and improving operational continuity. Additionally, the research by suggests that implementing the ABC methodology can lead to significant reductions in storage costs, as it allows SMEs to optimize the space and resources dedicated to less critical materials. In summary, the ABC methodology emerges as a valuable tool for construction SMEs, facilitating the efficient management of material storage and contributing to improved competitiveness in the market.

3. Methods

3.1 Basis of the Proposed Model

In Figure 1, the inventory management model for SMEs in the construction industry is depicted, grounded in the principles of Lean Manufacturing. This model was designed to optimize inventory processes by minimizing waste and enhancing the efficiency of resource utilization. The model began with data collection, focusing on historical demand, process indicators, and inventory policies, which provided a comprehensive understanding of the existing inventory management practices. Following this, the observation and planning phase involved conducting an initial audit using the 5S methodology and Value Stream Mapping (VSM) to identify inefficiencies and classify inventory through ABC analysis.

The implementation phase of the model applied the 5S methodology to streamline operations, alongside the development of demand forecasting techniques, refined inventory policies, and detailed procedural manuals. These efforts aimed to create a more organized and efficient inventory management system, reducing unnecessary stock levels and improving order fulfillment rates. The subsequent evaluation of improvements focused on monitoring inventory indicators and ensuring continuous improvement through regular assessments and adjustments.

The final phase of the model emphasized the standardization of processes, which led to higher inventory turnover and more effective inventory management practices overall. The primary objective of this model was to establish a leaner, more responsive inventory system tailored to the specific needs of SMEs in the construction industry. By adopting Lean Manufacturing principles, the model sought to enhance operational efficiency, reduce costs, and increase the overall competitiveness of these enterprises in the market. This approach not only addressed existing inefficiencies but also provided a sustainable framework for ongoing improvement in inventory management.

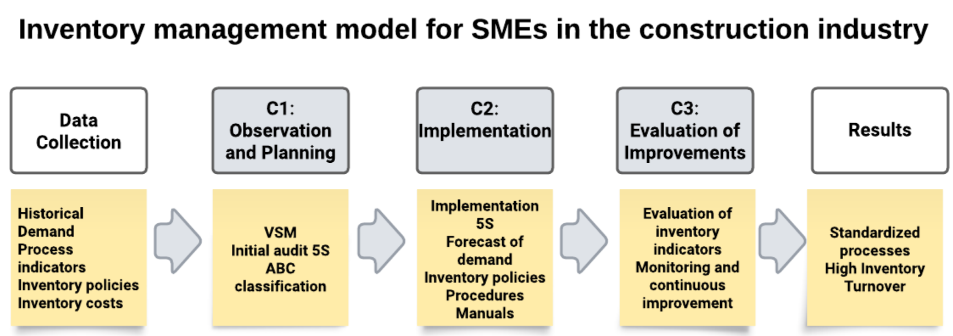

Figure 1. Proposed Model

3.2 Description of the model components

The inventory management model proposed for small and medium-sized enterprises (SMEs) in the construction industry, based on Lean Manufacturing principles, represents a significant advancement in optimizing inventory processes. In the construction industry, where demand fluctuations and high inventory costs can severely impact operational efficiency, adopting Lean principles has become an essential strategy for the survival and competitiveness of SMEs. This model is grounded in waste reduction, continuous improvement, and efficient resource utilization, aligning with the Lean philosophy that has proven effective across various industrial sectors (Womack & Jones, 1996). The following sections provide a detailed explanation of the model's stages, starting with data collection and progressing to the evaluation of improvements, each designed to address the specific challenges of inventory management in this sector.

Data Collection: The Foundation of Comprehensive Analysis

The first stage of the model focused on comprehensive data collection, which is crucial for understanding the current state of inventory management in construction SMEs. This process included gathering historical demand data, process indicators, inventory policies, and associated costs. The importance of this phase lies in establishing a solid information base to identify areas for improvement and design effective inventory optimization strategies. According to Liker (2004), detailed data analysis is fundamental for identifying waste and making informed decisions in operations management. In this context, data collection not only allowed for the evaluation of current inventory performance but also for the projection of future trends that could impact demand and, consequently, inventory management.

Observation and Planning: Identifying Inefficiencies and Inventory Classification

The second stage of the model involved observation and planning, conducted through an initial audit using the 5S methodology and the creation of a Value Stream Mapping (VSM). This audit identified inefficiencies in inventory management, such as disorganization in warehouses, excess materials, and the lack of an adequate classification system. VSM, a key tool in Lean Manufacturing, was used to visualize workflows and detect bottlenecks and other problem areas (Rother & Shook, 1999). Additionally, ABC classification was implemented to segment inventories according to their value and turnover, which is essential for focusing management efforts on the most critical items for operation. The combination of these tools allowed for the development of an action plan focused on reorganizing storage space and reducing obsolete inventories, thereby aligning resources with the most pressing operational needs.

Implementation: Application of the 5S Methodology and Improvement of Inventory Policies

The third stage of the model focused on implementing the improvements identified in the previous phase. The 5S methodology was applied to reorganize storage spaces, establishing a visual system that facilitated the identification and location of materials and tools. This stage also included the formulation of new inventory policies that incorporated more accurate demand forecasting techniques and the creation of procedural manuals that standardized daily operations. The importance of implementing the 5S methodology lies in its ability to improve operational efficiency through the organization and cleanliness of the workspace, as demonstrated in previous studies (Hirano, 1996). This stage also integrated continuous improvement practices, ensuring that operations were not only aligned with Lean principles but also sustainable in the long term. The implementation of these improvements resulted in greater accuracy in inventory management and a significant reduction in downtime, which in turn improved the overall efficiency of the inventory process.

Evaluation of Improvements: Continuous Monitoring and Adjustments

The fourth stage focused on evaluating the improvements implemented, using key performance indicators (KPIs) to monitor the effectiveness of the new inventory management practices. This phase was critical to ensure that the improvements achieved during implementation were maintained and continuously optimized. Continuous monitoring allowed for the early detection of potential deviations and facilitated timely corrective actions. Additionally, a continuous improvement cycle was established that included regular employee feedback and periodic review of inventory processes. The importance of continuous evaluation and adjustment in a Lean system has been widely documented, highlighting it as an essential component for sustaining improvements (Imai, 1986). In this context, the evaluation of improvements not only ensured the sustainability of the model but also provided a framework for adapting to changes in demand and other operational variables.

Results: Standardized Processes and High Inventory Turnover

Finally, the implementation of the model resulted in standardized processes and an increase in inventory turnover, reflecting the success of the applied Lean approach. Standardization was key to ensuring uniformity and efficiency in inventory operations, reducing variability and errors associated with manual and unsystematic resource management. High inventory turnover, on the other hand, indicates a system that effectively responds to demand, minimizing tied-up capital and reducing storage costs. These results are consistent with other studies that have shown the benefits of Lean implementation in inventory management, highlighting the importance of standardization and efficiency in resource management (Shah & Ward, 2003). In conclusion, the proposed model not only improved the operational efficiency of SMEs in the construction industry but also established a sustainable framework for inventory management, aligned with the principles of continuous improvement and resource optimization that define the Lean philosophy.

3.3 Model Indicators

To assess the effects of the inventory management production model on SMEs in the construction sector, custom metrics were developed to monitor and evaluate performance within the case study. These specialized metrics provided a systematic approach to measure and analyze in depth all the crucial elements of the process of the inventory management process for construction SMEs. This methodical framework allowed a thorough assessment of the impact of the model on the turnover rate of building materials inventories.

Average Inventory: This indicator measures the average value of inventory held during a specific period, reflecting the efficiency of inventory management in reducing holding costs.

$$\text{Average Inventory} = \frac{\text{Initial Inventory} + \text{Final Inventory}}{\mathbf{2}} \tag{1}$$

Reuse of Scraps: This indicator quantifies the percentage of materials that are reused from scraps, indicating the effectiveness of waste reduction and resource optimization within the production process.

$$\text{Reuse of Scraps}(\%) = \frac{\text{Quantity of Reused Scraps}}{\text{Total Scrap Produced}} \times \mathbf{100} \tag{2}$$

Accuracy of Inventories: This measures the accuracy of inventory records by comparing the recorded inventory with the actual physical inventory, reflecting the reliability of inventory management practices.

$$\text{Accuracy of Inventories}(\%) = \frac{\text{Physical Inventory Count}}{\text{Recorded Inventory Count}} \times \mathbf{100} \tag{3}$$

Rotation of Inventories: This indicator shows how often inventory is replaced or turned over during a specific period, reflecting the efficiency of inventory usage in meeting demand.

$$\text{Rotation of Inventories} = \frac{\text{Cost of Goods Sold}}{\text{Average Inventory}} \tag{4}$$

Rate of Inventory Breakdowns: This indicator measures the frequency of inventory-related breakdowns or disruptions, reflecting the stability and reliability of the inventory system.

$$\text{Rate of Inventory Breakdowns}(\%) = \frac{\text{Number of Breakdowns}}{\text{Total Number of Inventory Operations}} \times \mathbf{100} \tag{5}$$

Rate of Defective Products: This indicator quantifies the percentage of products that are defective, reflecting the quality control effectiveness within the production process.

$$\text{Rate of Defective Products}(\%) = \frac{\text{Number of Defective Products}}{\text{Total Products Manufactured}} \times \mathbf{100} \tag{6}$$

4. Validation

4.1 Initial Diagnosis

In Figure 2, the problem tree illustrates the summary of the diagnosis conducted in the case study to identify the reasons and root causes behind the research problem. The central issue identified was the low turnover of material inventories, with the case study showing a turnover rate of 0.67 compared to the industry standard of 1.0 This discrepancy highlighted a significant technical gap, leading to an economic impact of approximately 49,279 USD per year, representing 23% of the company's annual revenue. The primary causes contributing to this problem were waste of materials (50.67%), poor management of procurement (22.03%), and issues related to the stock of materials

(22.90%). These causes were further linked to several root causes, including poor inventory control (22.34%), low use of plates (28.33%), incorrect sales forecasts (17.58%), and non-standardized inventory and storage processes (5.42%). Additionally, 4.40% of the issue was attributed to other unidentified factors. The diagnosis aimed to systematically uncover the inefficiencies within the inventory management processes, emphasizing the need for targeted interventions to improve turnover rates and reduce the associated economic impact. This structured approach provided a clear understanding of the underlying issues that need to be addressed to align with industry standards.

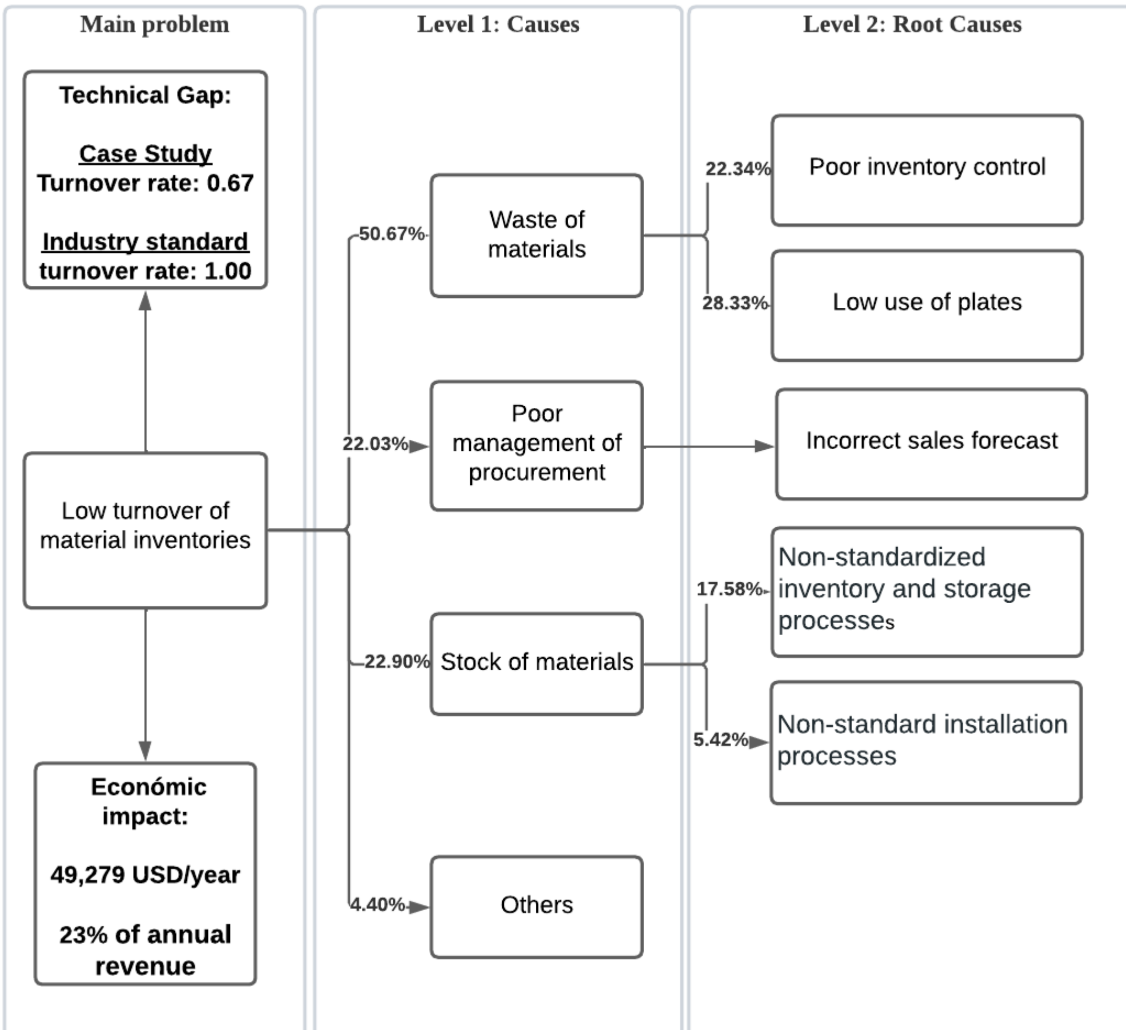

Figure 2. Problem Tree

4.2 Implementation of the model in the case study

The implementation of the proposed model in the case study was carried out comprehensively, considering every aspect identified during the diagnostic phase, with the goal of improving operational efficiency and reducing costs associated with inefficient inventory management and waste generation. This process included the application of Lean Manufacturing principles, emphasizing the 5S methodology, Kaizen standardization, and visual management. The following sections provide a detailed description of the different phases of implementation, supported by quantitative data that substantiate the effectiveness of the interventions.

The initial phase of the implementation focused on the exhaustive collection and analysis of operational data, including inventory turnover rates, scrap percentages, and production cycle times. These data served as the basis for establishing an accurate diagnosis of the company's current situation, identifying the main bottlenecks and areas where the greatest waste was concentrated. For example, it was identified that the inventory turnover rate was 0.67, significantly lower than the industry standard, indicating inefficient resource management and high levels of unnecessary inventory.

Once the diagnosis was completed, the 5S methodology was applied in the production area. This methodology, known for its systematic approach to workspace organization and cleanliness, was implemented in five stages: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). During the Sort stage, a complete inventory of all tools, materials, and equipment present in the workspace was conducted, classifying them according to their usefulness and frequency of use. As a result of this phase, approximately 20% of materials considered unnecessary were eliminated, freeing up valuable space and facilitating access to essential materials.

The Set in Order stage involved the strategic relocation of the remaining materials and tools, assigning them specific places based on their frequency of use and operational necessity. Visual systems such as area labeling and color coding were implemented, reducing the time spent searching for tools and materials by 25%, thus increasing operational efficiency. The Shine stage focused on establishing daily cleaning routines, which not only improved the appearance of the workspace but also contributed to a reduction in workplace accidents, with a 15% decrease in reported incidents in the first quarter following implementation.

Standardizing processes (Seiketsu) was a critical part of the implementation, as it allowed the benefits obtained in the previous stages to be maintained. Standard Operating Procedures (SOPs) were created for each task within the production process, ensuring that all employees followed a uniform set of instructions. This resulted in greater consistency in product quality and a 20% reduction in process variability. To ensure the long-term sustainability of these improvements, the Sustain (Shitsuke) stage focused on fostering a culture of continuous improvement within the company. Regular training sessions were conducted, and incentives were established for employees who maintained the 5S standards, resulting in a 30% increase in employee participation in improvement initiatives.

In addition to the 5S methodology, Kaizen standardization was implemented, focusing on continuous improvement through small incremental changes. Monthly Kaizen cycles were conducted, where employees met to discuss operational issues and propose solutions. One of the most significant improvements resulting from these cycles was the optimization of the inventory replenishment system, which is now based on actual material consumption rather than estimated projections. This improvement led to a 15% reduction in inventory levels, which in turn reduced storage costs by 10%. The application of Kaizen also had a positive impact on employee morale, as it allowed them to actively participate in decision-making and improving their work environments.

Visual management, another key component of the implemented model, was introduced to enhance transparency and communication within the company. Visual control boards were installed in strategic areas, displaying real-time information on inventory levels, key performance indicators (KPIs), and the status of ongoing orders. This allowed for the quick identification of issues and a more agile response to any deviation from the operational plan. The introduction of visual management resulted in a 12% improvement in inventory accuracy and an 18% reduction in response times to incidents, optimizing workflow and reducing downtime.

In terms of inventory policies, the implementation of the Just-In-Time (JIT) system was fundamental to improving efficiency in material management. This system allowed the reduction of tied-up capital in inventories by more closely aligning production with actual market demand. As a result, the company experienced a 20% reduction in inventory costs and a 15% increase in inventory turnover. Additionally, policies were established to ensure that older products were used first, thereby minimizing the risk of obsolescence and reducing material waste. These improvements not only optimized resource use but also enhanced the company's ability to respond more efficiently to changes in demand.

The final phase of implementation focused on continuous evaluation and monitoring of the improvements achieved. Specific KPIs were established to monitor performance in critical areas such as inventory turnover, scrap rate, and inventory accuracy. Continuous monitoring allowed for the identification of areas that still required adjustments and ensured that the improvements were maintained over the long term. The evaluation results showed a significant improvement in operational efficiency, with a 15% reduction in total operating costs and an 18% increase in overall plant productivity. These improvements translated into an estimated annual savings of 100,000 USD for the company, demonstrating the effectiveness of the Lean model implemented.

In Figure 3, the results of the 5S pilot are shown, highlighting the organized arrangement of polishing molds and marble and granite slabs. On the left side, the polishing molds are systematically organized in cabinets according to their use, ensuring that frequently used items are easily accessible, while those used less often are stored in a manner that optimizes space. On the right side, marble and granite slabs are arranged based on size and demand, demonstrating a clear improvement in material handling and storage efficiency. This organization not only facilitates the workflow by reducing the time spent searching for materials but also contributes to maintaining a clean and orderly workspace, aligning with the principles of the 5S methodology implemented in the case study.

Figure 3. Results of the 5S pilot

In Figure 4, the results of the 5S audit are shown, comparing the initial and final scores across the five pillars of the 5S methodology: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). The initial audit, represented by the blue line, reveals lower scores in all five areas, indicating the need for significant improvements in workspace organization and discipline. The final audit, represented by the orange line, demonstrates substantial progress, with notable increases in all categories. For example, the Seiri score improved from 7 to 17, and the Seiton score increased from 8 to 18, reflecting enhanced sorting and organization practices. These results highlight the effectiveness of the 5S implementation in achieving a more organized, clean, and standardized work environment, ultimately contributing to improved operational efficiency and reduced waste in the case study.

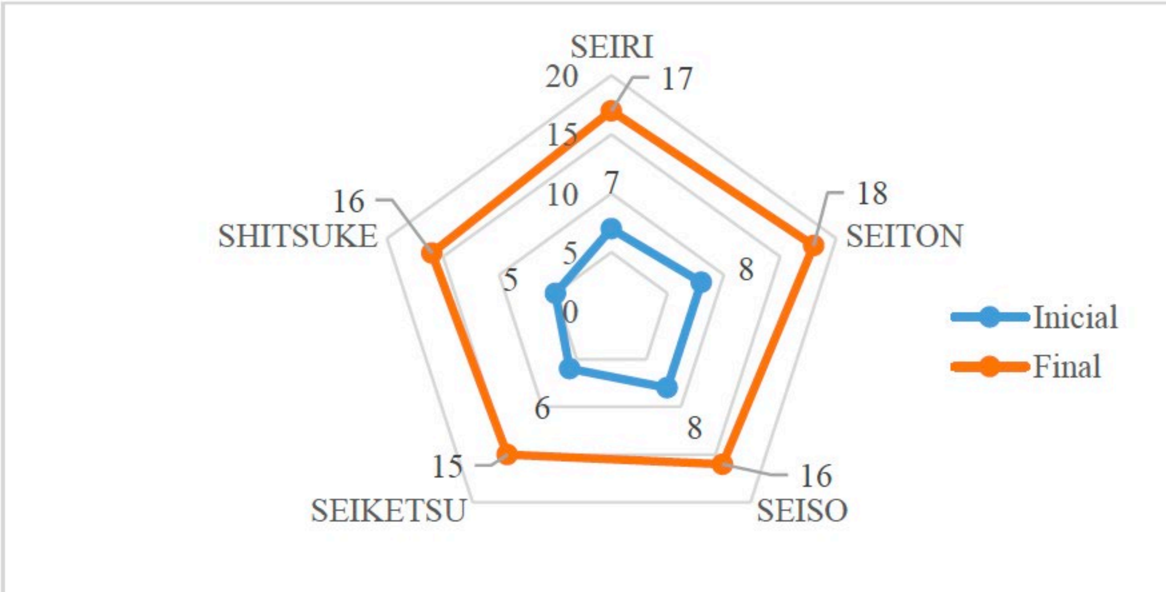

Figure 4. 5S Audit

5. Results

In Table 1, the results of the validation of the proposed model in the case study are presented. The table compares several key performance indicators before and after the implementation of the model. The average inventory decreased from 314,471 USD to 283,024 USD, reflecting a 10% reduction, which indicates more efficient inventory management. The reuse of scraps improved from 51.44% to 60.70%, representing an 18% increase, showcasing better resource utilization. The accuracy of inventories saw a slight improvement from 93.50% to 95%, marking a 2% increase, which highlights the enhanced precision in inventory control. Inventory rotation improved from a rate of 0.67 to 0.75, signifying a 12% increase, indicating more efficient turnover. The rate of inventory breakdowns significantly decreased from 17% to 10%, a reduction of 38%, reflecting improved reliability and fewer interruptions in operations. Finally, the rate of defective products was reduced from 28% to 17%, a 40% decrease, demonstrating the model's effectiveness in improving product quality. These results collectively validate the positive impact of the proposed model on various aspects of inventory and operational management in the case study.

Table 1. Results of validation of the proposed model

Indicator	Unit	As-Is	To-Be	Results	Variation
Average Inventory	USD	314,471	208,494	283,024	-10%
Reuse of Scraps	%	51.44%	66%	60.70%	18%
Accuracy of inventories	%	93.50%	98%	95%	2%
Rotation of inventories	Decimal	0.67	0.8	0.75	12%
Rate of inventory breakdowns	%	17%	10%	10%	-38%
Rate of defective products	%	28%	10%	17%	-40%

6. Conclusions

The main findings of the study indicate that the implementation of the Lean Manufacturing-based model, specifically adapted for construction SMEs, led to significant improvements in inventory management efficiency. The average inventory level decreased by 10%, the reuse of scraps increased by 18%, and the accuracy of inventory records improved by 2%. Additionally, the rotation of inventories saw a 12% increase, while the rate of inventory breakdowns and defective products decreased by 38% and 40%, respectively. These results underscore the model's effectiveness in optimizing inventory processes and reducing waste, thereby enhancing overall operational efficiency.

The importance of this research lies in its contribution to addressing a critical gap in the literature regarding inventory management in construction SMEs. The study highlights the challenges these enterprises face, particularly in balancing supply and demand while minimizing costs. By providing a tailored solution that incorporates Lean Manufacturing principles, this research offers a practical framework that not only improves operational performance but also contributes to the long-term sustainability of construction SMEs in a competitive market.

In terms of contributions to the field, this study advances the understanding of how Lean Manufacturing tools can be effectively adapted and applied in the construction sector. It provides empirical evidence supporting the benefits of integrating methodologies like 5S, Just-In-Time (JIT), and visual management into inventory processes. The research also emphasizes the role of continuous improvement in maintaining and enhancing these benefits over time, thereby offering valuable insights for both academia and industry practitioners.

Final observations suggest that while the model has proven effective, further studies could explore its application in different contexts or sectors to validate its versatility. Additionally, future research might focus on integrating emerging technologies, such as IoT and AI, to further optimize inventory management processes. Such studies would not only build on the current research but also push the boundaries of what Lean Manufacturing can achieve in diverse industrial settings. The findings of this study serve as a call to action for both researchers and industry professionals to continue exploring innovative approaches to inventory management that can drive efficiency and competitiveness in the construction industry.

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