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Enhancing Warehouse Efficiency in Emerging Economies through Lean Warehousing and Systematic Layout Planning: A Construction Case Study

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Abstract

The construction sector had long faced structural inefficiencies, especially in warehouse management, where poor layouts and disorganization limited competitiveness despite previous efforts applying Lean practices. This study addressed the urgent challenge of reducing delays, damages, and reprocessing in a Peruvian distributor of construction materials. An integrated model was proposed by combining Systematic Layout Planning with Lean Warehousing tools such as Kanban, standardized work, and FEFO. The approach was validated through Arena simulation, which revealed measurable improvements. The order cycle time fell from 149 to 107 minutes, product damage decreased from 12.40% to 9.02%, and reprocessing dropped from 16.82% to 5.80%. Moreover, the Perfect Order Index rose from 64% to 81%, while annual economic losses were reduced by 27.6%. These outcomes showed that Lean and SLP integration strengthened efficiency and financial sustainability in distribution warehouses. The findings encouraged future research to explore digital integration and broader applications in emerging economies.

Keywords
Lean Warehousing, Systematic Layout Planning (SLP), Warehouse Efficiency, Construction Supply Chain, Emerging Economies.

1. Introduction
According to the Construction Economic Report (IEC), in 2022 formal companies accounted for 60% of material sales, while the remaining share was supplied by the informal sector, which tends to lower organizational costs and compete through reduced prices (Romero, 2017; Amaya et al., 2015). During that period, material prices rose by 8.9%, prompting suppliers to increase their prices by 2.5% and 10%. Consequently, formal companies are compelled to adopt planning strategies that safeguard both operational efficiency and profitability (Usco, 2014).

The rapid and highly competitive expansion of the construction industry demands a significant consumption of materials, which typically represents between 50% and 60% of a project's total cost (Kar & Neeraj, 2020). Challenges such as shortages, delays, losses, and damages directly affect project execution. Effective warehouse management mitigates these risks, enhancing cost efficiency, quality and workplace safety, delivery times, and customer satisfaction (Kusrini et al., 2018). Nevertheless, despite the availability of various approaches and indicators, a unified standard for assessing warehouse performance remains absent due to the heterogeneity of objectives and organizational structures.

This case study examines a medium-sized construction materials distributor in Peru, whose primary challenge is inefficient warehouse management. Disorganization in product categorization and an inadequate inventory layout hinder productivity, cause delivery delays, and compromise both material safety and condition, leading to an average Perfect Order Index of 65%.

The present research pioneers the application of SLP and Lean tools, specifically Kanban, work standardization, and the FEFO method to minimize reprocessing, optimize resource utilization by reducing damaged and compromised products, and improve material handling practices among workers while safeguarding operational continuity.

1.1 Objectives

The main objective of this study is to achieve improved warehouse management in a medium-sized construction materials distributor by ensuring optimal storage, handling, and safeguarding conditions for dispatch materials through the application of Systematic Layout Planning (SLP) and Lean Warehousing practices.

To accomplish this objective, the study relies on both theoretical literature analysis and an assessment of the current situation in the company's main warehouse. This includes the development of a problem tree to identify root causes, the application of Value Stream Mapping (VSM) to determine process value, and the use of a Pareto diagram to highlight the significance of the main causes of the problem (low POI).

Finally, the research seeks to propose targeted improvements through the implementation of Lean tools and to evaluate their effectiveness and feasibility using performance indicators and simulation software modeling, thereby identifying the potential impact of the proposed model.

2. Literature Review

This chapter provides the theoretical foundation that supports the development of the proposed model. It reviews key concepts and tools in warehouse management, emphasizing their relevance to construction supply chains in emerging economies. The analysis focuses on the Perfect Order Index (POI) as a central performance metric, the principles of Systematic Layout Planning (SLP), and Lean Warehousing practices such as Kanban, standardized work, and the FEFO method. By exploring previous studies and applications, the section establishes a comprehensive framework to contextualize the research and highlight the gap addressed by this study.

2.1 Perfect Order Index

It is a key logistics indicator that measures the full compliance of orders from a customer satisfaction-oriented perspective. It is composed of the sub-indicators: % of orders delivered on time, % delivered complete, % delivered without damage, and % delivered with accurate documentation (Alumbugo, Shakantu & Saidu, 2021).

Additionally, the POI facilitates the evaluation of supplier performance and strengthens the integration of material flows in the supply chain (Oey & Nofrimurti, 2018). Its benefits include higher inventory turnover, cost reduction, increased productivity, and improved customer service (Lukinskiy et al., 2022). In the construction sector, where material management is critical due to its volume and cost, the POI has been used to select the most efficient supplier, reaching a performance of up to 95.36% (Sholeh & Suwarto, 2020).

2.2 SLP

Systematic Layout Planning (SLP), developed by Richard Muther, enables the optimization of space distribution through the analysis of qualitative and quantitative logistic relationships between functional areas within an organization (Hu & Chuang, 2022). This tool considers the sequence of processes and the proximity between areas to improve facility design, allowing the identification and evaluation of various activities, relationships, and alternatives involved in facility layout (Suhardi, Eldiana Juwita & Astuti, 2019).

Several studies highlight its direct impact on productivity and organizational performance. It is estimated that material flow can represent between 30% and 70% of total manufacturing costs (Lista et al., 2021), and SLP significantly contributes to reducing these costs by minimizing unproductive spaces, work-in-progress, and waste (Balcázar et al., 2020).

Moreover, its implementation allows for a reduction in transfer times by 30.4% and an improvement in facility distribution by 26.5% (Baca et al., 2021). It has also been demonstrated that SLP reduces unnecessary operator movements by decreasing the distance between areas, improving efficiency in operational spaces such as workshops (Gómez et al., 2021).

2.3 Lean Warehousing

2.3.1 Kanban

Kanban seeks high station utilization while maintaining low inventories, minimizing WIP through faster, un-delayed cycles (Namay et al., 2021). Literature reviews show Kanban reduces high-inventory problems by shortening delays and removing waste once bottlenecks are identified (Yilmaz et al., 2022). Visual control exposes bottlenecks and wastes, decreasing WIP and waiting (Gómez et al., 2021). In practice, Kanban boards that schedule production, material routing, and order flows improve quality, integrate inter-area communication, and cut delivery time by 69.47%, value-added time by 75.25%, setup time by 65.85%, and overall production cost (Montalvo et al., 2020). In commercial warehouses, Kanban cards help reduce out-of-stock to 0.30% by aligning reorder points and lot size, while improving online order fulfillment (Marques et al., 2022).

2.3.2 Standardized Work

Standardized work optimizes tasks and reduces resource consumption under stable work conditions to generate uniform results (Bringas et al., 2022), and adapts well to materials, machines, operators, and facilities as part of sound process planning (Punna & Nallusamy, 2018). Combined with other Lean tools, it yields efficiency gains and defect reductions; in a services microenterprise, standardizing packing and stacking increased satisfaction and defect-free shipments by 16.9% and 12.5%, respectively, raising service level by 9.8% (from 87.3% to 97.1%) (Villacrez et al., 2022).

2.3.3 FEFO (First-Expired, First-Out)

FEFO ensures that products closest to expiration leave first, unlike FIFO (which follows receipt order). As a perpetual inventory system, FEFO reduces waste for limited-shelf-life products but requires more effort to record and arrange items (Villacrez et al., 2022; Budiawan et al., 2019). Its goal is a warehouse plan that reduces nonconforming orders for perishables (Bonilla et al., 2019). Studies show FEFO can halve expiration-related waste compared with FIFO, cut rejection rates by 50%, and improve picking time and accuracy in perishable-product warehouses confirming FEFO as the best fit for limited shelf life products (Espinoza et al., 2020; Villacrez et al., 2022).

In summary, the literature reveals consistent evidence that combining layout planning and Lean practices generates measurable improvements in operational efficiency. However, there is limited research applying these tools to distribution warehouses in the construction sector, particularly within emerging economies. This gap highlights the need for a tailored methodological approach, which is developed in the following chapter.

3. Methods

This chapter outlines the methodological approach adopted to design and validate the proposed improvement model. It combines qualitative and quantitative techniques to diagnose inefficiencies, propose structured solutions, and evaluate their feasibility. The methods include the use of diagnostic tools such as Value Stream Mapping and Pareto analysis, the integration of Lean and SLP practices, and the application of simulation with Arena software. The chapter provides a systematic roadmap that ensures rigor and replicability in the research process.

3.1 Research approach

This study includes both qualitative and quantitative analysis, aiming to obtain a deeper understanding of a specific topic. It focuses on a small-scale distributor and retailer of construction materials such as bricks, cement, steel, and aggregates, with particular emphasis on the management of its main warehouse. Its scope is exploratory, as it addresses a problem that had not been previously investigated in the company.

The company faced inefficiencies in its warehouse operations, specifically delays in order processing, product damage during handling, and disorganized inventory. The research adopts a mixed methodology:

1. **Descriptive Analysis** –to evaluate current performance indicators, map value streams, Ishikawa diagrams, pareto analysis and identify causes of inefficiency.
2. **Analytical Modeling** – to design an integrated improvement proposal combining Systematic Layout Planning (SLP) with Lean Warehousing tools (Kanban, Standardized Work, and FEFO).
3. **Simulation** – using Arena software to validate the impact of the proposed improvements under realistic operating conditions.

3.2 Proposed model

The proposed model was designed to address the structural inefficiencies identified in the warehouse operations of a construction materials distributor. The redesign was carried out using Systematic Layout Planning (SLP), which enabled the optimization of storage space, workflow organization, and material flow accuracy. This methodology provided a structured approach to reorganizing areas and reducing unnecessary travel distances, ensuring a logical arrangement that directly impacted efficiency and service reliability. In parallel, Lean Warehousing tools were integrated to enhance process control and operational discipline.

One of the key elements incorporated was the First Expired, First Out (FEFO) system, which prioritized the dispatch of materials approaching expiration through a digitalized record of shelf life. This practice minimized waste, safeguarded product quality, and ensured customer satisfaction. In addition, a Kanban system was introduced, supported by product cards and a visual management board, to streamline communication during inspections and facilitate real-time process monitoring. Standardized work was also a central component, emphasizing the training and supervision of personnel involved in picking, loading, and unloading activities. By reducing variability in task execution, this tool helped minimize errors and improve handling times.

The model was implemented through three sequential phases: analysis of the current situation, implementation of tools, and verification of results. The initial phase relied on diagnostic techniques such as Value Stream Mapping, Pareto analysis, Ishikawa diagrams, problem tree development, and KPI evaluation to identify inefficiencies. The second phase focused on implementing the proposed Lean and SLP solutions, while the third phase emphasized verification through indicator reevaluation, a monitoring and evaluation plan, and simulation with Arena software.

As illustrated in **Figure 1**, the model demonstrates its ability to transform critical operational challenges into measurable improvements. By aligning layout redesign with Lean practices, the approach ensured not only efficiency gains but also a systematic and replicable framework adaptable to similar contexts in distribution and supply chain management.

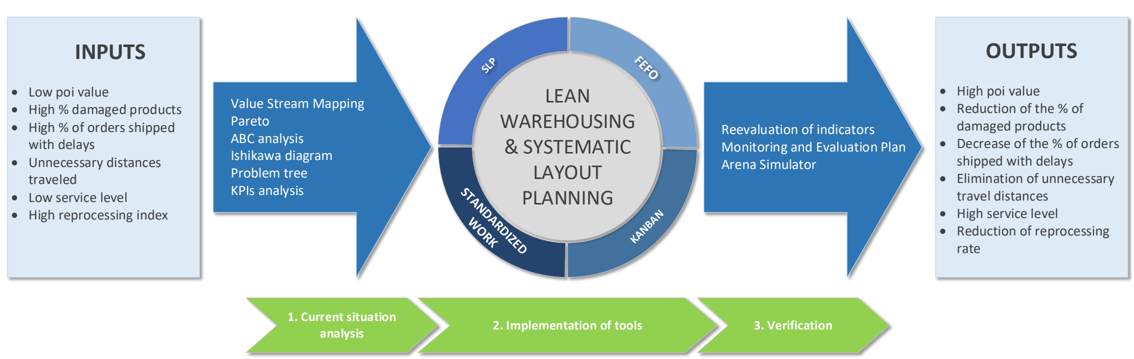

Figure 1. Proposed Model

3.3 Problem Analysis

The analysis of the problem aimed to identify the underlying factors limiting warehouse performance and to establish a measurable basis for evaluating improvement initiatives. In this context, the Perfect Order Index (POI) was selected as the primary performance indicator, since it integrates multiple dimensions of operational reliability into a single measure. This choice provided not only a comprehensive perspective of service quality but also a robust benchmark for comparing the company's results against international standards. By focusing on the POI, the study was able to capture deficiencies related to timeliness, completeness, accuracy, and product integrity, which collectively reflect the most critical aspects of customer satisfaction and cost efficiency.

3.2.1 Indicator Selection

The **Perfect Order Index (POI)** was chosen as the main performance indicator. It consolidates four critical sub-metrics:

- % of on-time deliveries
- % of complete orders
- % of undamaged products
- % of accurately documented orders

According to benchmarking by the American Productivity and Quality Center (APQC) in 2018, world-class companies achieve an average POI of 90%. This value was used as a reference point to evaluate Santa Patricia's warehouse performance.

3.2.2 Current Performance

In 2024, Santa Patricia reported the following averages across the four POI components:

- On-time deliveries: **83%**
- Complete orders: **95%**
- Accurate documentation: **97%**
- Undamaged products: **84%**

This resulted in an overall POI of **65%**, substantially below the industry benchmark. The primary gaps were observed in **delivery timeliness** and **product integrity because of the delays in the processes and the excessive number of damaged products** (Table 1).

Table 1. Logistics Performance Indicators of Santa Patricia SRL

2024	On-time deliveries	Complete Orders	Accurate documentation Orders	Undamaged Orders
January	86.00%	96%	95.0%	84%
February	83.00%	94%	96.0%	87%
March	84.00%	97%	96.0%	86%
April	85.00%	95%	94.0%	86%
May	79.00%	95%	94.0%	87%
June	84.00%	97%	98.0%	82%
July	80.00%	97%	97.0%	85%
August	81.00%	96%	99.0%	88%
September	82.00%	95%	97.0%	86%
October	85.00%	93%	98.0%	79%
November	87.00%	95%	97.0%	80%
December	85.00%	93%	99.0%	80%
Average	**83%**	**95%**	**97%**	**84%**

The financial impact of these inefficiencies in 2024 was approximately **1.34 million Peruvian soles**, representing 16% of annual revenues.

3.2.3 Value Stream Mapping

A Current State Value Stream Map (VSM) was developed (Figure 2) for key materials (cement, bricks, steel wires). The VSM highlighted long delays in unloading, picking, and inspection processes, largely caused by:

- Poorly structured warehouse layout
- Lack of standardization in inspection and handling
- Inefficient use of equipment and human resources

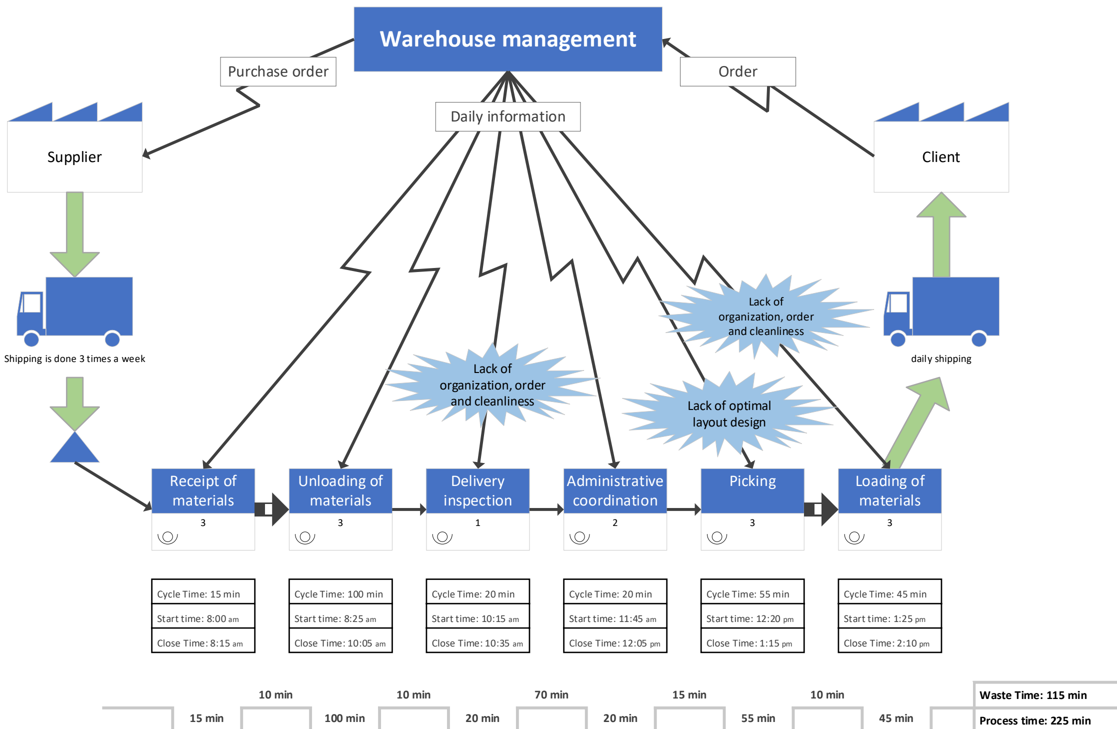

Figure 2. Value Stream Mapping for cement, bricks and steel

3.2.4 Root Cause Analysis

The diagnosis conducted in the case study showed that the low Perfect Order Index (POI) was the central operational issue, with an average of 60% over the last twelve months and 90% of customers experiencing delays in order fulfillment. This technical gap was reflected in financial losses from damaged goods totaling \$163,437.28. As synthesized in Figure 3, two immediate causes dominated: delays within processes accounted for 54% of incidents, while damaged or compromised products explained the remaining 46%. The analysis further traced several root drivers. Poor warehouse layout organization contributed 24% by forcing unnecessary travel and misplacement. Operator-related handling problems were prominent, with improper maneuvers responsible for 29% and additional errors in material handling adding 14%. Inspection weaknesses triggered 16% of rework, amplifying lead-time variability. External and temporal factors also mattered: 11% of issues arose from suppliers delivering damaged or compromised items, and 6% stemmed from the natural decline in product integrity during storage. Together, these proportions portrayed an operation constrained by spatial design, human factors, and quality assurance gaps, which jointly undermined service reliability and eroded financial performance.

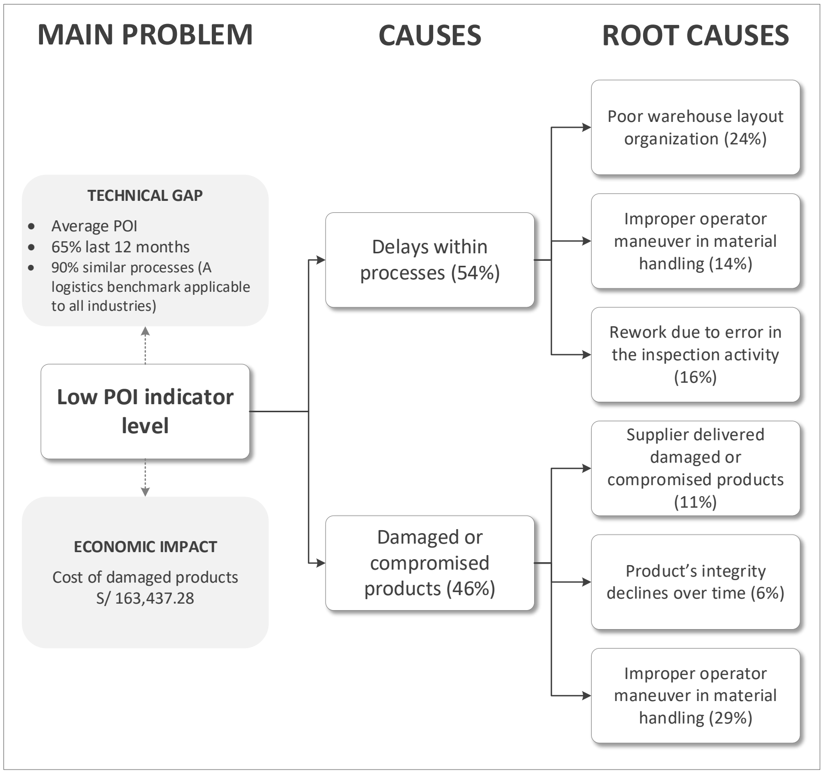

Figure 3. Problem Tree

The analysis confirmed that improving layout design and implementing Lean tools were the most relevant opportunities to close the performance gap.

3.4 Key Indicators

The following KPIs were defined for post-implementation evaluation (Table 2):

- **Perfect Order Index (POI)**: target 95%
- **Order Cycle Time**: target ≤115 minutes
- **Reprocessing Index**: target ≤5%
- **Product Damage Index**: target ≤7%
- **Supplier Service Level**: target 98%
- **Inventory Age**: target ≤9%

Table 2. KPI dashboard

KPIs	Current	Target	Variation
POI	65%	95%	30%
Order Cycle Time	149 min	115 min	20%
Product Damage Index	12.40%	7%	6.15%
Reprocessing Index	16.82%	<5%	11.82%
Supplier Service Level	95%	98%	3%
Inventory age	16.21%	9%	7.21%

The methodological framework provided a structured process to diagnose inefficiencies and design an integrated solution based on Lean and SLP tools. Having established this foundation, the next step involved collecting the empirical data required to validate the model. The following chapter describes the data collection process in detail.

4. Data Collection

This chapter presents the procedures followed to gather the information required for the analysis and validation of the model. Data were collected through direct observation, structured interviews, and the examination of historical records in the company. The scope of the study covers the entire material flow, from reception to dispatch, ensuring a holistic understanding of warehouse dynamics. These inputs served as the basis for both the diagnostic evaluation and the construction of the simulation scenarios.

4.1 Scope of the System

To collect the necessary information, seven visits were conducted at the warehouse to gather quantitative data on activities related to warehouse management. This included inventory records, loading and unloading times, the volume of dispatched products, incident reports, and facility layout plans. The system under study begins with the reception of materials from suppliers and concludes with the dispatch of products to customers. All activities were analyzed to identify inefficiencies and provide quantitative inputs for the simulation. Furthermore, data collection was carried out through direct observation, review of historical records, and field visits, complemented by interviews with management and warehouse supervisors. These interviews provided additional insights into procedures, process times, and performance indicators (Figure 4).

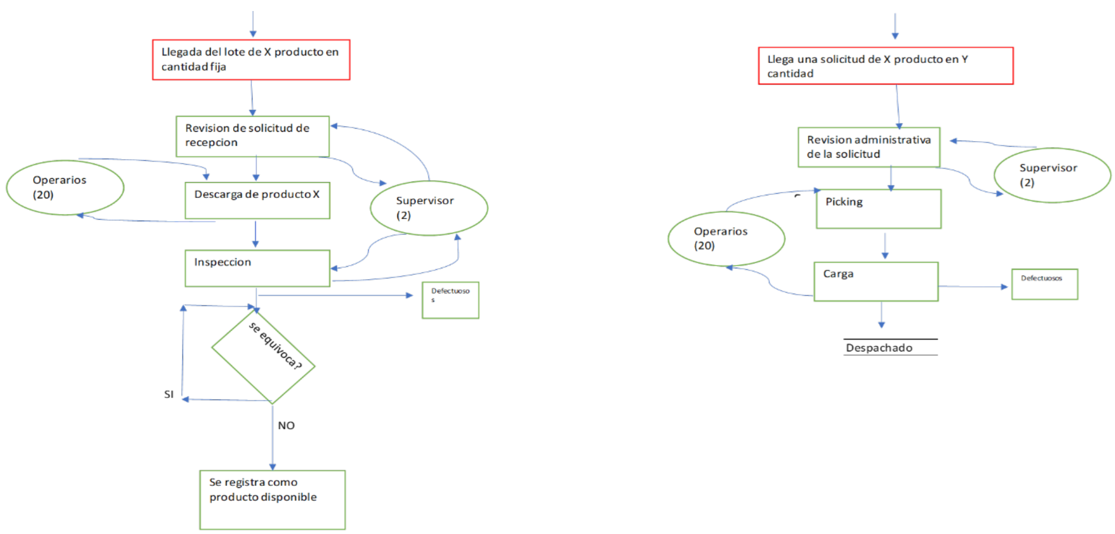

Figure 4. Current system

4.5 Simulation Setup

To validate the feasibility and expected impact of the proposed improvements, the Arena Simulation software was employed to replicate the dynamics of warehouse operations. The simulation was designed to contrast two alternative scenarios:

Current System (As-Is): A baseline model representing the warehouse's existing operating conditions, capturing current inefficiencies and bottlenecks.

Proposed System (To-Be): A redesigned model integrating the Systematic Layout Planning (SLP) approach with Lean Warehousing tools, specifically Kanban boards and cards, standardized work procedures, and FEFO inventory management.

The models were carefully constructed to ensure that the general structure and process logic remained consistent between both scenarios. The distinction lay in the controlled variables, which were adjusted in the TO-BE configuration to reflect the expected impact of the improvement initiatives.

Figure 5 presents the first simulation model, which represents the inbound flow of materials and includes product reception, unloading, and inspection activities. Meanwhile, **Figure 6** illustrates the second simulation model, which focuses on the outbound flow of goods, covering administrative coordination, order picking, and loading processes. Together, these figures provide a comprehensive visualization of the warehouse's end-to-end material flow, allowing for robust experimentation and evaluation.

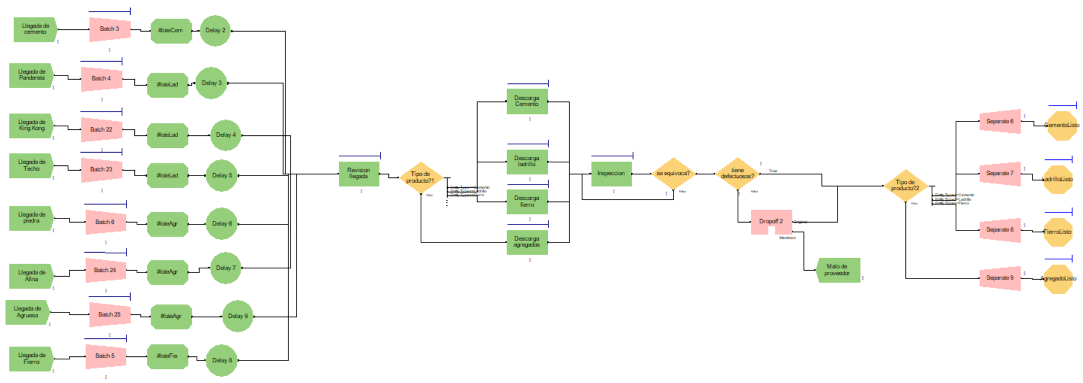

Figure 5. Simulation model of the inbound material flow

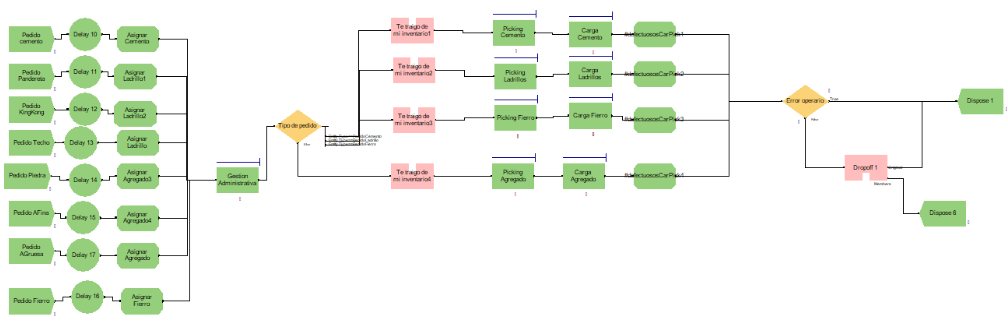

Figure 6. Simulation model of the outbound material flow

To ensure the statistical reliability of the results, the number of replications required for each scenario was determined through pilot testing. An initial experiment with 30 replications established variability patterns, after which the optimal number was calculated to be 117 replications. This ensured a half-width of 3.5 at a 95% confidence level, thus guaranteeing the credibility and robustness of the comparisons.

In addition to replication, data reliability was a key consideration. The simulation models were parameterized using empirical data obtained from warehouse observations, structured interviews, and historical performance records. This alignment with actual operating conditions enhanced the external validity of the study, bridging the gap between simulation outcomes and practical application.

By consolidating these methodological steps, the simulation setup provided a controlled experimental environment where both baseline inefficiencies and the potential benefits of the proposed model could be quantified. The structured comparison allowed for a rigorous validation of the improvements in terms of cycle time, product integrity, reprocessing rates, and overall service quality.

This robust design ensures that the insights obtained from the simulation are both statistically sound and practically relevant, laying the groundwork for the subsequent analysis presented in the next chapter.

5. Results and Discussion

This chapter reports the outcomes obtained from the implementation and validation of the proposed model. The results of the simulation are analyzed to assess improvements in operational performance, including cycle time, product damage, reprocessing, and POI levels. A discussion follows, comparing these findings with prior studies and highlighting both the practical implications and the limitations of the research. This section provides the analytical core of the article, demonstrating the relevance and contribution of the study to the field of industrial engineering.

5.1 Simulation Outcomes

The Arena simulation was executed with **117 replications** under both current and proposed scenarios. Results demonstrated significant performance improvements in critical warehouse indicators after applying the integrated model (SLP + Lean tools) **(Table 3)**.

Table 3. Model results

Indicator	Current	Target	Improvement
Total order cycle (cement)	149 min	120 min	107 min
Index of defective products by handling	12.40%	7%	9.02%
Reprocessing Index	16.82%	5%	5.80%

The order cycle time surpassed the improvement target, dropping to 107 minutes. Product damages were reduced by 27%, though the 7% target was not fully achieved due to residual operator errors. Reprocessing decreased substantially, nearing the 5% benchmark.

5.2 Impact on POI Components

The improved model enhanced the two weakest POI components: on-time deliveries and undamaged products (Table 4).

Table 4. Results of improvement in POI components

Components	Current	Improvement
Orders on time	83.00%	96.04%
Orders without defect	84.00%	91.68%

This translated into an increase in the overall **POI** from **64% to 81%**, a 26.5% improvement.

5.3 Economic Impact

The financial analysis revealed substantial cost savings. Losses from product damages, primarily caused by operator mishandling, were reduced by 27.6% annually (Table 5).

Table 5. Economic impact of the improvement proposal

Economic losses	Current situation	Improvement	Difference
Total cost of defectives	$ 958,559.40	$ 697,274.66	27.26%

The model therefore contributes not only to operational efficiency but also to financial sustainability.

5.4 Scenario Analysis

To examine long-term effects, three additional simulation scenarios were developed to project results over subsequent months of continuous implementation. Each scenario represented the following period (a month) since the implementation of the Improvement Proposal (Table 6).

Table 6. Results comparison table

Indicator	Current	Improvement	Scenario 1	Scenario 2	Scenario 3	Media
Total order cycle (min)	149.83	107	87	76	79	80.62
Index of defective products by handling	12.40%	9.02%	6.52%	4.57%	4.07%	5.05%
Reprocessing index	16.82%	5.80%	2.03%	1.62%	1.7%	1.80%

Results indicate stabilization after the third scenario, suggesting that the proposed model achieves sustainable improvements over time.

5.5 Discussion

The findings of this study confirmed that the integration of Systematic Layout Planning (SLP) with Lean tools generated substantial improvements in warehouse performance indicators. The reduction in order cycle time from 149 to 107 minutes and the decrease in reprocessing from 16.82% to 5.80% aligned with the results of Montalvo et al. (2022), who demonstrated that the joint use of SLP and Kanban significantly reduced delivery times in textile microenterprises. Similarly, the improvement of the Perfect Order Index (POI) from 64% to 81% is consistent with Alumbugu et al. (2021), who argued that this indicator directly reflects customer satisfaction and can be significantly enhanced through structured management. The decrease in product damages through standardized work and visual control also supports the findings of Gómez et al. (2020), who revealed that Lean-based process redesign reduces handling defects. Additionally, the results correspond with Lista et al. (2019), who emphasized that layout optimization through SLP can generate up to 30% improvement in material flow costs. Finally, the economic savings of 27.6% obtained in this study are in line with Balcázar et al. (2021), who highlighted that reducing unproductive spaces and losses from deterioration directly strengthens financial sustainability.

Although the results demonstrated significant improvements, this study has limitations that must be acknowledged. Validation relied on simulation under controlled conditions, which means that real variability in demand and human behavior was not fully represented. Furthermore, the analysis focused on a single case study in a construction materials distribution company, limiting the generalizability of the findings to other industries or contexts.

The findings have strong practical implications for small and medium-sized enterprises in emerging economies. Evidence suggests that integrating Lean tools with SLP not only optimizes operational times and reduces losses but also enhances economic sustainability by lowering costs associated with reprocessing and damaged products. These results indicate that companies in the construction sector may adopt similar methodologies to improve competitiveness, even in contexts characterized by resource constraints and high market pressure.

Future studies could expand the scope of this research by incorporating digital tools such as warehouse management systems (WMS) and IoT-based technologies, which could further improve process traceability and reduce operational variability. Longitudinal studies that examine the long-term effects of the implementation would also provide more robust evidence regarding the sustainability of the outcomes. Another relevant direction would be to assess the applicability of the proposed model in other supply chain sectors, such as light manufacturing or agribusiness, where operating conditions differ, but efficiency gains could be equally significant.

6. Conclusion

The study confirmed that integrating Systematic Layout Planning with Lean Warehousing tools generated significant and measurable improvements in warehouse performance within a construction materials distributor. The order cycle time decreased from 149 to 107 minutes, product damages were reduced from 12.40% to 9.02%, and reprocessing declined from 16.82% to 5.80%. Furthermore, the Perfect Order Index increased from 64% to 81%, while annual economic losses decreased by 27.6%. These quantitative results provided clear evidence of the model's effectiveness in enhancing operational reliability and financial sustainability.

The importance of this research lies in its capacity to address persistent inefficiencies in warehouse management, a critical issue in supply chains operating under resource constraints and demand volatility. By focusing on practical tools adaptable to real contexts, the study demonstrated how systematic approaches could transform operations and provide resilience for companies in emerging economies where construction plays a central role in development.

From an academic perspective, the study contributes by extending Lean applications beyond manufacturing and showing their adaptability to distribution processes. The integration of Kanban, FEFO, and standardized work within a redesigned layout proved to generate measurable improvements, reinforcing the argument that Lean principles, when combined with structured layout planning, can yield tangible and replicable benefits. This framework enriches the literature by highlighting how operational models can be adapted across diverse supply chain contexts.

In conclusion, the evidence confirmed that the proposed model not only reduced inefficiencies but also improved financial results, offering companies a structured path toward competitiveness and sustainability. Future studies may expand its application to different industries, incorporate digital technologies for process traceability, and assess long-term impacts through longitudinal research. These directions would strengthen the understanding of integrated approaches and their role in building resilient supply chains.

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