A Lean Warehousing Approach to Improve OTIF in a Peruvian HVAC Distribution SME

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Abstract* – Heating, Ventilation, and Air Conditioning (HVAC) systems are essential for ensuring both the habitability of buildings and regulatory compliance within the construction industry in Peru. These parameters are crucial to guarantee the efficient removal of indoor pollutants and the proper intake of outdoor air, directly impacting the health, comfort, and safety of occupants. In this context, efficient management of HVAC equipment becomes critical. This paper presents a case study of a Peruvian SME in HVAC distribution, which faced operational challenges—including disorganized storage and low traceability—that contributed to a baseline OTIF performance of 86%. To address this, we developed a three-phase Lean Warehousing model. The model's impact was validated using Discrete-Event Process Simulation (Flexsim/Arena) to ensure analytical rigor and quantify results before physical intervention. Results confirm a significant increase in OTIF performance from 86% to 96%, achieving a 10% improvement consistent with global benchmarks. Additionally, the model achieved a 5.09-minute reduction in average picking time (from 18.67 to 13.58 minutes) and a 26% decrease in aisle obstruction. These findings validate a scalable, low-cost framework that provides a Benefit/Cost ratio of 4.43, offering a roadmap for other distribution SMEs in emerging markets.

Keywords—OTIF, Picking, 5S, Slotting, Standard Work

I. INTRODUCTION

The construction industry remains a key component of Peru's economic growth, contributing over 5% to national GDP and generating employment for more than 1.5 million people [1]. Its performance has a significant impact on the development of housing, infrastructure, and industrial projects across the country [1][2]. Within this sector, HVAC systems play a crucial role in ensuring building habitability and regulatory compliance [3].

However, the timely installation of HVAC systems is often a major source of risk for overall project timelines. Studies indicate that delays in HVAC installation can result in project schedule overruns of 10–20% and additional costs of up to 5–10% [3]. These setbacks can cascade into broader project setbacks, extending the entire schedule. Ensuring the reliable delivery of HVAC components is especially challenging due to their bulky nature, wide variety, and irregular demand patterns [4]. Common warehouse issues, such as poor layout design, unclassified inventory, and undocumented movements, can all contribute to delays and incomplete deliveries with inefficient picking processes that worsen cases of late order fulfillment. [2][4][5]

In this context, OTIF performance has emerged as a critical indicator of competitiveness and service quality within the HVAC supply chain [2]. The "In-Full" dimension reflects an order being delivered completely and correctly, while the "On-Time" dimension measures whether it arrives by the agreed-upon date. Inadequate OTIF performance often leads to extended project downtime, inefficient rescheduling of tasks, and diminished client satisfaction [3][6]. While OTIF rates above 95% are typically regarded as good practice benchmarks [7], many SMEs fall significantly below this threshold due to systemic warehousing issues

To adress these challenges, Lean Warehousing practices, including 5S, ABC classification, slotting, and standard work, have been shown to improve OTIF rates up to 30% [8]. Various studies also support the broader impact of Lean tools on inventory accuracy, picking speed, and order fulfillment reliability [9] [6]. However, many Peruvian SMEs in HVAC distribution still rely on informal or outdated warehousing practices, limiting their capacity to meet rising project demands [2].

This paper investigates the root causes of low OTIF performance in a Peruvian SME and proposes a structured Lean Warehousing model across three phases: Stabilize, Reorganize, and Define and Control. While the principles applied (Lean, 5S, Slotting) are transferable to SMEs across diverse distribution sectors, the key differential contribution lies in the analytical framework used for validation. We utilized FlexSim to construct a high-fidelity digital twin of the warehouse, which enabled the precise, quantitative measurement of improvements without physical capital expenditure. This simulation-based approach provides a crucial methodological advantage for SMEs, mitigating the financial risk of transformation. The validation confirmed the model's performance, achieving a 10% OTIF improvement (from 86% to 96%) that surpasses the sector benchmark and provides a compelling Benefit/Cost ratio of 4.43, thus establishing a replicable, evidence-based model for operational improvement in emerging markets.

II. LITERATURE REVIEW

A. 5S: Physical Organization to Reduce Errors

The 5S methodology—Sort, Set in Order, Shine, Standardize, and Sustain—is widely recognized as a practical tool for promoting systematic working habits and maintaining a well-ordered, clean work environment. [10][11]. By applying these principles, organizations can remove unnecessary items, arrange equipment and materials efficiently, and establish routines that maintain these improvements over time [12]. In HVAC distribution, where warehouses must handle bulky, irregularly shaped components such as fans and ducts, well organized spaces are critical to avoid blockages and wasted movements [13]. Evidence from previous studies suggests that 5S practices can increase usable warehouse space up to 25% and decrease travel and picking durations by approximately 20%. [12][13]. However, some studies emphasize that smaller companies may struggle to keep the benefits of 5S long term, due to barriers such as insufficient leadership support, low training investment, and weak resource allocation [11][14]. These findings suggest that while 5S offers clear benefits for optimizing warehouse space, maintaining its impact depends on consistent employee engagement and reinforcement.

B. ABC Analysis and Slotting: Demand-Based Location Optimization

ABC classification remains one of the most widely used methods for structuring inventory according to demand frequency and sales contribution, helping distribution centers focus their resources on high-priority items [6]. While traditional ABC analysis is common, more recent studies emphasize multi-criteria approaches that combine sales volume, turnover, and prioritization to allocate storage locations more strategically [6][15]. Fontana and Nepomuceno [16] demonstrated that using a multi-criteria ABC system reduced picking travel distances by about 12%, directly addressing inefficiencies caused by excess movement.

Slotting builds on ABC classification by arranging items based on picking frequency, size, and weight, thereby minimizing search time and unnecessary travel [17]. This practice is especially beneficial in operations that handle bulky or irregular items, like ventilation equipment components. Empirical studies focused on SME distribution warehouses have found that well planned slotting can reduce picking and internal transport times by approximately 20–23% [2][18]. However, these improvements rely on maintaining updated demand data and training employees to adapt to layout changes as needed.

C. Standard Work: Minimization of Errors and Variability

Implementing standard work routines plays a vital role in ensuring consistent operations, maintaining process control, and securing traceability across warehouse activities. In the context of HVAC distribution, where items may be temporarily loaned for customer demonstrations or excluded due to quality issues, the lack of formal registration often results in inventory mismatches and incomplete deliveries [2]. Implementing formal standard work policies can address these challenges by requiring systematic documentation of every stock movement and status update [2][19]. Industry benchmarks indicate that implementing structured standard work practices can reduce inventory discrepancies by approximately 35% and improve OTIF performance up to 45% [20].

However, research also highlights that rigid application without room for operational flexibility can limit the tool's effectiveness, especially in high-mix, low-volume environments like HVAC supply chains [19][21]. Without ongoing audits and workforce training, standardized procedures often drift away from actual practice, undermining long term benefits. Therefore, successful standard work must balance clear process guidelines with enough adaptability to respond to demand variability, reinforced through continuous training and periodic reviews [19].

D. Lean Warehousing in the HVAC sector

Lean Warehousing refers to the application of Lean Manufacturing principles to storage and distribution activities, aiming to eliminate waste and increase overall operational efficiency [20]. This approach is especially relevant for industries such as HVAC, where high product variety and irregular demand patterns create persistent challenges related to space utilization, stock accuracy, and timely order fulfillment [2][22]. Lean Warehousing interventions led to a 23% increase in OTIF performance, a comparable reduction in picking and packing times, a 30% improvement in warehouse space utilization, and an average lead time reduction of approximately 18%. [23] These results highlight the potential for Lean strategies to enhance service reliability and increase operational efficiency.

However, the literature also shows that the successful adoption of Lean Warehousing practices is not guaranteed across all operational environments. Factors such as unpredictable order volumes, complex SKU profiles, and insufficient digital integration can limit the effectiveness of Lean tools in distribution centers [24]. Small and medium-sized enterprises may struggle to maintain the behavioral and cultural changes needed to sustain Lean improvements if they lack consistent employee training or dedicated resources for continuous improvement [24]. These challenges emphasize that Lean Warehousing should not be viewed as a one-time intervention but rather as an ongoing organizational commitment.

III. METHODOLOGY

A. Fundamentals

Recent studies demonstrate that combining multiple Lean tools within structured frameworks can effectively address operational inefficiencies in small and medium-sized distribution centers. A Lean Warehousing model for a Peruvian SME who integrated 5S, slotting, and standard work through a mapped process, resulting in measurable improvements in OTIF delivery and inventory traceability. Salloum, Kazancoglu and Sezen [19] showed that applying Lean practices such as 5S, standardized workflows, and visual management together improved space utilization and reduced picking times by more than 15% in SME warehouses. Similarly, Serna-Ampuero et al. [8] found that integrating 5S, ABC classification, and standard work reduced the rate of returns and inventory discrepancies, enhancing overall stock accuracy. These results confirm the advantage of implementing Lean tools in a coordinated, phased approach rather than in isolation.

However, while these integrated models demonstrate clear operational benefits, they have mostly focused on general retail or manufacturing environments. They do not fully reflect the unique challenges faced by HVAC distribution companies, where high product diversity, irregular demand, and the frequent loaning of equipment without formal traceability create persistent gaps in inventory control and delivery reliability. The Stabilize–Reorganize–Define & Control model proposed in this paper builds on the strengths of prior models but extends their scope by incorporating targeted solutions for these unique operational conditions, ensuring that improvements can be sustained through clear policies, staff training, and regular audits.

B. Conceptual Model

The proposed model is based on the Lean Warehousing approach. It focuses on eliminating waste, optimizing storage space, and improving the OTIF performance. The strategy is structured in three interconnected stages: (1) Stabilize Processes, (2) Reorganize, and (3) Define and Control, each integrating specific Lean tools—5S, Multicriteria ABC & Slotting, and Standard Work—as illustrated in the following figure.

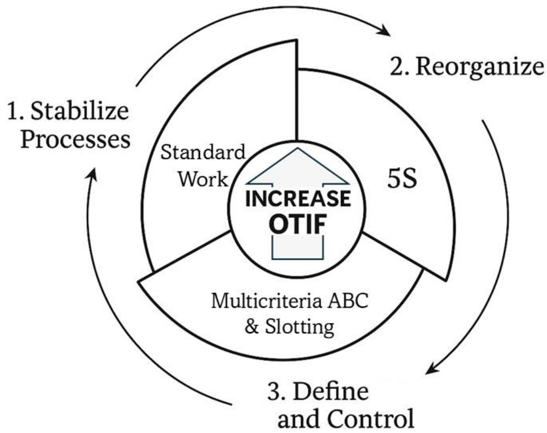

Fig. 1. Lean Warehousing Model

The proposal directly addresses the identified root causes of low OTIF: obstructed storage space, lack of classification by rotation, and inventory inaccuracies due to unregistered damaged or loaned products

. Each tool applied is justified with literature evidence and directly linked to operational KPIs.

C. Implementation Stages

The proposed model is structured into three sequential stages: Stabilize Processes, Reorganize, and Define and Control. Each stage is designed to address persistent operational inefficiencies common in HVAC distribution while incorporating practical measures for sustainability. All activities will be carried out within the warehouse

1) Stage 1: Stabilize processes

This initial stage, focused on Process Control, involves implementing Standard Work to establish operational discipline and reduce process variation, a core principle derived from Lean Six Sigma methodology. The objective was to formalize procedures for reception, dispatch, handling, and registration of materials, with a specific emphasis on improving traceability.

To achieve this, two critical control mechanisms were implemented:

1. Formalized Inspection and Nonconformity Management: Upon product arrival, a formal inspection process is carried out to detect damage or nonconformities. Any item that fails inspection is immediately recorded in a nonconformity log, and its status is updated in the warehouse management system. This ensures visibility over items sent back to the factory for repair, preventing them from being mistakenly considered available stock.
2. Digital Loan Formalization: To eliminate inventory inaccuracies, all product loans are formalized through a digitally signed agreement between the company and the client. These documents, which include return conditions and are pre-authorized by the general manager, are registered in the warehouse system, allowing real-time monitoring of borrowed inventory.

The impact of these control mechanisms was rigorously quantified using Arena Process Simulation, which demonstrated that formalizing loan agreements successfully reduced the probability of untracked loans from 55% to 35%. This stabilization of processes directly contributed to a 6% improvement in the In-Full Delivery metric, establishing a stable and reliable operational baseline.

2) Stage 2: Reorganize

The second stage enhances the physical layout and daily discipline of the warehouse using the 5S methodology. Beyond basic housekeeping, this step systematically removes excess materials, reassigns underutilized areas, and defines clear functional zones for processes such as returns, order staging, and equipment testing. Visual markings, directional signage, and rack labeling help guide material flows and operator movement, reducing unnecessary search and transit time. To ensure these improvements do not deteriorate over time, a structured cleaning and inspection routine is implemented, with clearly assigned responsibilities and quarterly 5S audits. This deliberate focus on maintaining organized and accessible work areas directly supports shorter picking paths, reduces safety hazards, and prevents the re-accumulation of waste that would undermine efficiency gains.

3) Stage 3: Define and Control

This last stage introduces a Multicriteria ABC Analysis and Slotting Optimization Strategy to optimize item placement. Instead of relying solely on sales volume, this ABC classification uses a normalized index that combines two variables: sales volume and inventory turnover. The normalization formula is defined as:

$$\mathrm{X}n_{ij} = \frac{X_{ij} - min_{ij}}{max_{ij} - min_{i}j}$$

Where $\mathrm{X}n_{ij}$ is the normalized value and X_{ij} is the original value of either sales or inventory turnover. This process standardizes both variables, making them directly comparable. These normalized values are then weighted—typically equally, though weights can be adjusted based on strategic priorities—and aggregated to form a final score:

$$\mathrm{Score} = 0.5 * \mathrm{X}n_{i} + 0.5 * \mathrm{X}n_{j}$$

This final index enables precise identification of high-priority SKUs that are both in high demand and represent significat revenue. These items are assigned to high-access locations within the warehouse.

Slotting is then engineered, analyzing not only demand indicators but also physical characteristics such as dimensions, weight, and picking frequency. Items are grouped and positioned to reduce walking distance and facilitate ergonomic handling. Special attention is given to balancing loads across racks, minimizing vertical reach or lifting requirements for heavy equipment.

The effectiveness of the optimized layout was not merely assumed but was rigorously modeled and verified using Flexsim Discrete Event Simulation. This advanced process simulation provided a highly precise, quantitative measurement of the improved flow and resource utilization. The simulation proved that the optimized slotting change reduced the operator's average walking distance by 28.9%, thereby providing quantitative evidence of the model's analytical rigor and confirming the overall 5.09-minute reduction in average picking time.

By combining standardized workflows, disciplined spatial organization, and data-driven inventory management with explicit controls for traceability, auditing, and training, this model responds directly to persistent challenges in HVAC distribution. Its phased structure—moving from stabilization to physical reorganization and finally to prioritized control—provides SMEs with a clear roadmap to improve On-Time In-Full delivery, space utilization, and inventory accuracy, while building the operational resilience needed to maintain these improvements in the face of irregular demand and complex order flows.

D. Model Indicators

On Time Delivery: This indicator measures the percentage of orders delivered on time and without errors.

$$OTD\ (\%) = \frac{On\ time\ orders}{Total\ orders}$$

In Full Delivery: This indicator measures the percentage of orders delivered.

$$IFD\ (\%) = \frac{Complete\ orders}{Total\ orders}$$

Picking & Packing Time: This indicator measurres time required to locate, retrieve and prepare items for an order.

Obstruction Level: This indicator measure the access restrictions in operational zones.

$$OL\ (\%) = \frac{Obstructed\ area}{Total\ area\ available}$$

Inventory Accuracy. This indicator measures alignment between system and physical inventory.

$$IA\ (\%) = \frac{Inventory\ discrepancies}{System\ Inventory}$$

Damaged Products at Dispatch. This indicator measures damaged products in order to prevent incomplete deliveries.

$$Damaged\ PD\ (\%) = \frac{Damaged\ Products}{Incomplete\ Orders}$$

Borrowed Products Identified at Dispatch. This indicator measures traceability of borrowed items with no registration.

$$BP = \frac{Borrowed\ Products}{Total\ Discrepancies}$$

IV. RESULTS

To validate the proposed Lean Warehousing model, three distinct strategies were implemented. First, a pilot test of the 5S methodology was carried out in the dispatch zone, targeting space obstruction. This intervention resulted in a 26% reduction in aisle obstruction and a notable decrease of 5.09 minutes in average picking time. These improvements were due to workspace tidiness, which was reflected on faster visual identification of SKUs, reduced time spent rerouting around cluttered paths, and less operator fatigue due to improved ergonomics.

To assess the effectiveness of multicriteria ABC classification and slotting, a digital warehouse model was built in FlexSim. After reorganizing product locations based on turnover rate and physical characteristics, operator routes became significantly shorter. The warehouse manager's average walking distance was reduced by 28.9%, while the warehouse assistant's route decreased by 25.2%. Additionally, the proportion of time spent navigating the warehouse with and without load was reduced by approximately 3%. These results indicate more efficient route execution, minimized unnecessary movement, and enhanced agility in the picking process, contributing directly to increased productivity and reduced physical workload.

TABLE I. KEY PERFORMANCE INDICATORS PICKING

Indicator	Operator	As Is	To Be
Travel Distance	Warehouse Manager	674.29 m	479.94 m
	Warehouse worker	710.02 m	531.48 m
State Bar – Travel empty & Travel loaded	Warehouse Manager	10.64%	7.67%
	Warehouse worker	11.19%	8.45%

In parallel, an Arena model was developed to simulate the impact of standard work procedures on inventory traceability and product condition control. By incorporating formal protocols at the receiving stage, including visual inspections and systematic registration of nonconforming items, the simulation showed a reduction in undetected damages from 12% to 5%. In addition, the formal registration of borrowed equipment lowered untracked loans at dispatch from 55% to 35%. These improvements translated into a 6-percentage-point increase in the In-Full Delivery (IFD) metric, as fewer defective or unaccounted-for items reached the final stage of order fulfillment.

Overall, the validation process revealed significant improvements in key performance indicators, as summarized in Table II.

TABLE II. KEY PERFORMANCE INDICATORS IMPROVEMENT

Challenges	Indicators	Values		Improvement
		As-Is	To-Be	
Obstruction in aisles	OB	61%	34%	26%
Long picking items	Average Picking time	18.67 minutes	13.58 minutes	5.09 minutes
Detection of damaged products at dispatch	Damaged PD	12%	5%	7%
Borrowed products not identified	BP	55%	35%	20%
Inaccurate inventory records	IA	91%	98%	7%
Delays in delivering complete orders on time	OTD	94%	99%	5%
Incomplete fulfillment of delivery items	IFD	91%	97%	6%
Orders not delivered on time and in full	OTIF	86%	96%	10%

In addition to the operational results, an economic evaluation was conducted. With an implementation cost of approximately $926, the project achieved a Net Present Value (NPV) of $3,180, indicating that it generated more than three times the initial investment within one year. The Benefit/Cost ratio reached 4.43, meaning that for every dollar invested, $4.43 were returned in value. A sensitivity analysis showed that the B/C ratio remained greater than 1 in over two-thirds of simulated scenarios, confirming the project's resilience even under conservative assumptions.

Altogether, these results confirm that the model improvement, OTIF from 86% to 96%, stems from the coordinated use of all Lean tools as an integrated model, not from isolated interventions.

V. DISCUSSION

Recent literature confirms the effectiveness of Lean tools in improving warehouse performance in SMEs, often leading to better order fulfillment [2][8]. However, a methodological gap persists while studies show operational gains from slotting and other Lean applications [5], they typically rely on physical implementation alone, failing to test their proposals in simulated or controlled environments before deployment.

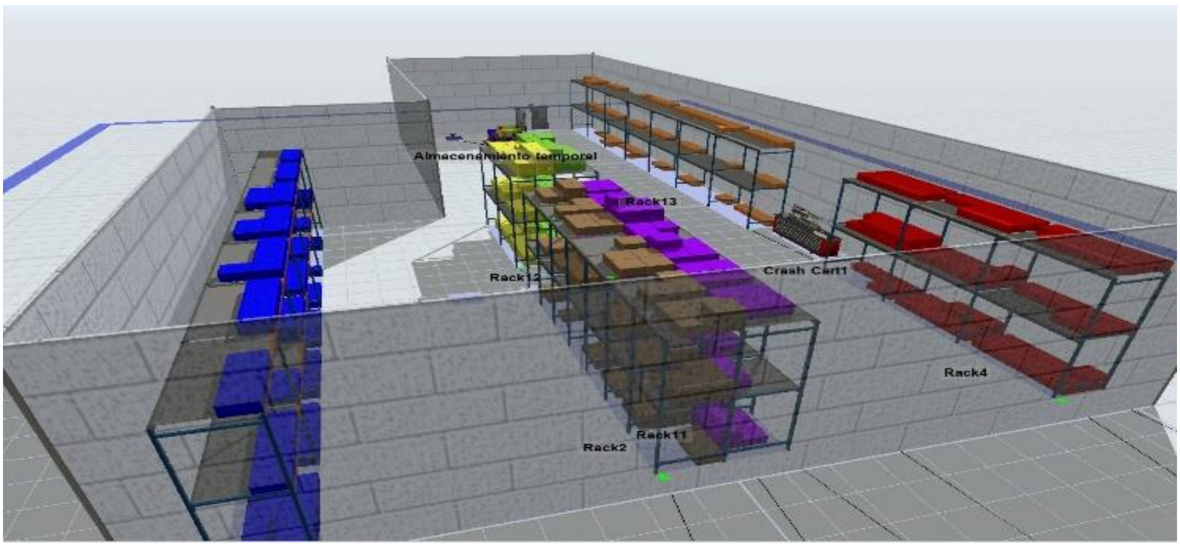

Fig. 2. Warehouse Layout in FlexSim

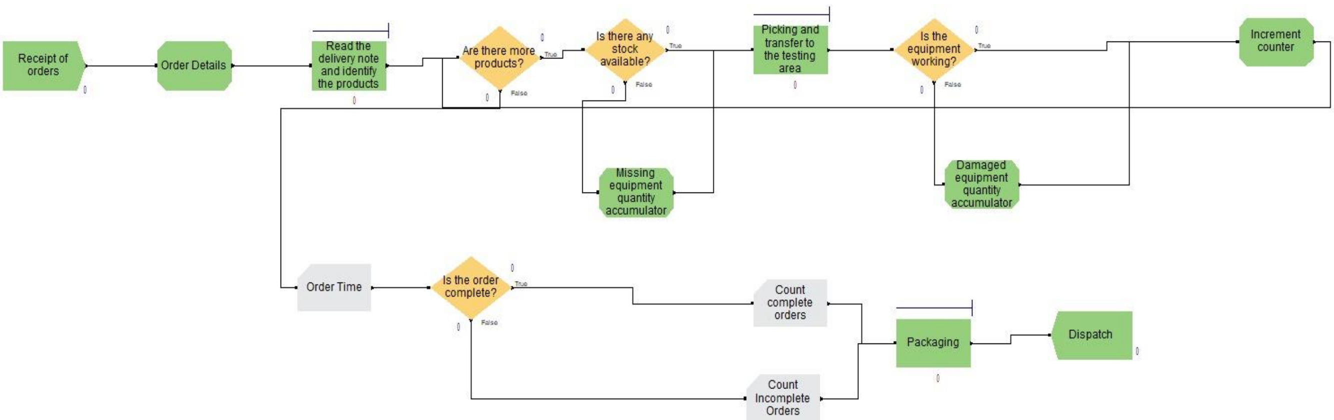

Fig. 3. Process Model in Arena

This study fundamentally extends the methodological rigor of prior Lean warehousing research by introducing a digital twin of the warehouse using FlexSim and Arena Discrete-Event Process Simulation. This approach is the cornerstone of our analytical rigor, allowing the physical environment, equipment constraints, and operator behavior to be simulated under both current and improved layouts. This digital validation bridges the critical gap between conceptual design and implementation, enabling the model to anticipate bottlenecks, precisely quantify travel distance reductions, and validate the effectiveness of multicriteria slotting before any physical commitment. The use of simulation effectively reduces the risks of deploying layout changes without performance guarantees—an aspect rarely addressed in the existing literature [4] [19].

The operational gains resulting from this process are competitive with or exceed outcomes reported in the global literature, confirming the model's contribution beyond the specific context. The resulting reductions align with benchmarks reported by Valdivia et al. [9] and Duque Jaramillo et al. [4] yet were achieved through predictive modeling rather than post-hoc observation.

Overall, this study contributes significantly by establishing a scalable and evidence-based paradigm for SME transformation. The model's success is not contingent on the specific HVAC context but on its modular framework (Stabilize, Reorganize, Define and Control) and its reliance on digital validation using low-cost simulation. This methodological structure offers a highly replicable structure for any SME seeking to improve fulfillment reliability in volatile or high-mix distribution environments.

VI. CONCLUSION

This study examined the operational causes behind low OTIF performance in a Peruvian SME within the HVAC distribution sector. The proposed solution was a Lean Warehousing model designed to enable timely and complete deliveries, tailored to the limitations and variability typical of SMEs in this industry.

The model was structured using Lean tools supported by prior literature, and its effectiveness was tested through simulation before implementation. FlexSim enabled the evaluation of layout and slotting improvements under realistic operating conditions, while Arena modeled the effects of standardized procedures on fulfillment outcomes. This dual-simulation approach provided a controlled environment to anticipate the impact of each intervention without disrupting daily operations.

Following implementation, OTIF improved from 86% to 96%. This increase confirms that the model effectively addressed the delivery issues initially identified. The study therefore meets its core objective: to demonstrate that Lean Warehousing, when deployed as an integrated and validated system, can significantly improve delivery performance in resource-constrained SMEs.

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