

Application of Lean Warehousing Tools to Improve OTIF in an Automotive Company

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Abstract

The On Time In Full (OTIF) indicator is one of the main metrics used to evaluate logistics service levels in automotive spare-parts warehouses, where inventory availability and order-picking efficiency are key factors in customer satisfaction. However, many companies show low compliance levels due to stockouts and long picking times. This study aimed to evaluate the effect of implementing an integrated Lean Warehousing model, comprising Poka Yoke, ABC Classification, Systematic Layout Planning (SLP), and Standard Work, on OTIF performance in an automotive company. The research used a quantitative correlational-explanatory approach and validated the proposal through discrete-event simulation in Arena by comparing the current scenario (AS IS) with the proposed scenario (TO BE). The results showed an increase in OTIF from 57.91% to 86.13%, an improvement in inventory accuracy to 98.46%, a reduction of 3.23 minutes in the average picking time per order, and an IRR of 48.02%, confirming the technical and economic feasibility of the proposal. These results demonstrate that the integrated implementation of Lean Warehousing tools is an effective strategy for improving service levels and the competitiveness of automotive spare-parts warehouses.

Keywords

Lean Warehousing; OTIF; Poka Yoke; ABC Classification; Systematic Layout Planning; Standard Work; Warehouse Management

1. Introduction

The heavy-vehicle spare-parts sector plays a fundamental role in the operational continuity of economic activities such as mining, construction, and transportation because it ensures the availability of components required for vehicle maintenance. In this context, warehouse performance is a critical factor for ensuring inventory availability, reducing service times, and maintaining a high level of customer service. According to the National Institute of Statistics and Informatics (INEI, 2024), the automotive trade showed sustained growth during the last year, while the Central Reserve Bank of Peru (BCRP, 2023) indicates that this activity is an important component of national commerce. Consequently, companies in the sector must continuously optimize their logistics processes to respond to increasingly demanding market requirements.

Logistics service levels are commonly evaluated through the On Time In Full (OTIF) indicator, which measures a company's ability to deliver orders completely and within the committed time. Several studies have shown that poor OTIF performance is associated with deficiencies in inventory accuracy, warehouse organization, and the

standardization of order-picking processes, resulting in delays, rework, higher operating costs, and loss of competitiveness (Gil-Goyzueta et al. 2022; Shabani et al. 2021; Jum'a and Basheer 2023). In response to these problems, the Lean Warehousing approach has proven to be an effective alternative for eliminating waste and improving operational efficiency through tools such as Poka Yoke, ABC Classification, Systematic Layout Planning (SLP), and Standard Work (Adeodu et al. 2023; Batarlienė and Jarašūnienė 2024).

The company under study shows insufficient performance in the OTIF indicator. During 2024, it recorded an OTIF of 58.26%, which is 28.74 percentage points below the industry benchmark of 87%. The diagnosis identified two main causes: stockouts arising from low inventory accuracy and the absence of product classification according to criticality, and long picking times associated with an inefficient layout and the lack of standardized order-preparation procedures. These deficiencies generate economic losses, delivery delays, and a lower service level for customers.

To address this problem, this research proposes an integrated Lean Warehousing model that combines Poka Yoke, ABC Classification, Systematic Layout Planning, and Standard Work to improve OTIF performance. The hypothesis states that the integrated implementation of these tools will significantly increase order-fulfillment performance by improving inventory accuracy and reducing preparation times, with a positive impact on the company's operational and economic performance. The proposal was validated through discrete-event simulation in Arena, allowing the effect of the improvements to be quantified before actual implementation.

1.1 Objectives

The main objective of this research is to evaluate the effect of implementing an integrated Lean Warehousing model, comprising Poka Yoke, ABC Classification, Systematic Layout Planning, and Standard Work, on OTIF performance in the spare-parts warehouse of an automotive company.

To achieve this purpose, the following specific objectives were established:

- Diagnose the root causes responsible for poor OTIF performance using quality-analysis tools.
- Design an integrated improvement model that links each identified cause to a specific Lean Warehousing tool.
- Quantitatively validate the proposal through discrete-event simulation by comparing the current scenario (AS IS) with the proposed scenario (TO BE).
- Evaluate the economic feasibility of the implementation using financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), the Benefit-Cost ratio, and the investment payback period.

2. Literature Review

Warehouse performance plays a fundamental role in automotive supply chains because spare-parts availability and order-picking efficiency directly influence the continuity of maintenance services and customer service. However, inventory inaccuracies, unsuitable product locations, excessive travel during picking, and the lack of standardized activities may cause incomplete orders or late deliveries. In this context, the On Time In Full (OTIF) indicator provides an integrated measure of logistics performance by determining whether orders are delivered completely and within the agreed deadline.

More specifically, OTIF comprises two complementary dimensions. The *On Time* component evaluates delivery punctuality, while the *In Full* component determines whether the complete quantity requested by the customer was delivered. Therefore, OTIF reflects not only delivery performance but also inventory availability, warehouse responsiveness, and reliability in order fulfillment (Navarro-Huamani and Salazar-Vega 2025).

A low OTIF level can generate several operational and commercial consequences, including customer complaints, returns, order reprocessing, additional transportation, lost sales, and reduced customer trust. Likewise, incomplete or late deliveries require additional coordination, rescheduling, and corrective activities, which increase logistics costs and reduce process reliability. Previous research indicates that deficiencies in inventory control, warehouse organization, layout design, and process standardization directly affect productivity and logistics service levels (Jum'a and Basheer 2023; Yang et al. 2024; Batarlienė and Jarašūnienė 2024).

To address these operational problems, Lean Warehousing adapts Lean principles to storage, inventory-control, and order-picking processes. Its main purpose is to eliminate non-value-added activities, reduce unnecessary movements, prevent operational errors, and establish more stable work methods. The most common forms of waste in warehouses include excessive travel, long search times, inventory discrepancies, waiting, picking errors, and repeated checks. Consequently, Lean Warehousing is an appropriate approach for improving OTIF because it simultaneously addresses inventory reliability and order-preparation efficiency (Gil-Goyzueta et al. 2022; Proença et al. 2022).

Regarding inventory reliability, Poka Yoke is an error-prevention approach intended to avoid failures or detect them before they affect the final process outcome. In warehouse operations, these mechanisms can be used to validate product codes, storage positions, quantities, and inventory availability. As a result, their implementation can reduce differences between physical inventory and system records, preventing incorrect stock information and incomplete orders. Previous studies have shown that error-prevention mechanisms can help achieve inventory-accuracy levels close to or above 98%, strengthening the *In Full* component of OTIF (Rebollar et al. 2023). Record accuracy is especially important because differences between physical and recorded stock can create fictitious availability, stockouts, picking errors, and unnecessary cycle-counting activities (Shabani et al. 2021; Destro et al. 2023).

Complementarily, ABC classification supports inventory organization by grouping products according to criteria such as demand, turnover, value, or operational importance. Category A products, which generally have greater movement or relevance, should be placed in easily accessible areas. In contrast, medium- or low-turnover products can be assigned to secondary locations. This prioritization improves control of critical spare parts and can reduce search and travel times during picking. Studies on slotting and ABC zoning indicate that locating products according to their movement frequency contributes to the efficient use of storage areas and faster order preparation (Silva et al. 2022; Castillo et al. 2024). Within the proposed model, ABC classification complements Poka Yoke by improving both control and the physical organization of inventory.

From the perspective of operational flow, Systematic Layout Planning (SLP) analyzes the relationships among warehouse areas, activities, material flows, and travel distances. Its purpose is to develop a physical layout that improves accessibility, reduces unnecessary movement, and facilitates the logical sequence of operations. An inefficient layout increases travel distances, search times, and order-preparation delays. Therefore, SLP is particularly relevant to the *On Time* component of OTIF. For example, Marcelo-Alfaro et al. (2024) reduced the late-order rate from 14.69% to 3.71% through the application of Lean Warehouse Management and SLP in an automotive company.

Similarly, Standard Work complements layout improvement by defining a uniform sequence of activities, operating routes, responsibilities, reference times, and execution criteria. In the picking process, the absence of a standardized method can lead to differences among workers, process variability, unnecessary movements, and delays. Standard Work reduces this variability by documenting the best known operating method and establishing clear parameters for its execution and monitoring. Dos Santos et al. (2021) highlighted the contribution of standardized routines to process stability, while other Lean Warehousing applications have reported reductions in picking errors and search times. In particular, Vasquez-Quispe et al. (2023) reported reductions of up to 35% in picking errors, decreases of more than 60% in search times, and an approximate 23-percentage-point improvement in OTIF.

In addition to Lean tools, discrete-event simulation is an appropriate method for evaluating warehouse-improvement alternatives before their final implementation. Simulation models can represent process variability, activity times, inventory conditions, and order flows under different operational configurations. Thus, comparing AS IS and TO BE scenarios makes it possible to estimate the expected effect of the proposed improvements and reduce the operational and financial risks associated with direct implementation. In warehouse studies, this approach is especially useful when several tools affect interrelated processes and must be evaluated as an integrated system.

Overall, the reviewed studies demonstrate that Poka Yoke, ABC classification, SLP, and Standard Work can improve specific warehouse indicators such as inventory accuracy, search time, travel distances, picking errors, and the late-order rate. Nevertheless, many previous studies focus on individual tools or isolated activities. Inventory-oriented solutions generally strengthen complete order delivery, whereas layout and picking improvements mainly focus on

meeting time requirements. Consequently, there is limited evidence on integrated models that simultaneously improve the *On Time* and *In Full* dimensions of OTIF in automotive spare-parts warehouses.

Therefore, this study addresses this gap through an integrated Lean Warehousing model. Poka Yoke and ABC classification are combined to strengthen the *In Full* component by improving inventory reliability and the organization of critical spare parts. Similarly, SLP and Standard Work are integrated to strengthen the *On Time* component by reducing picking distances and operational variability. Finally, the proposed model is evaluated through discrete-event simulation by comparing the AS IS and TO BE scenarios to provide quantitative evidence of its effect on OTIF performance.

3. Methods

The research used a quantitative and applied approach, developed through a case study in the spare-parts warehouse of an automotive company. A comparative design based on discrete-event simulation was used to evaluate the current scenario, referred to as AS IS, and the proposed scenario, referred to as TO BE, without directly intervening in the warehouse's actual operation.

The unit of analysis consisted of the orders processed in the warehouse. The process under study included order arrival, quotation preparation, system registration, inventory verification, picking, packing, and dispatch. This sequence served as the basis for building the conceptual model and the computational simulation model.

The diagnosis was conducted through a review of the 2024 operating records, direct observation of the process, and time measurements. Pareto diagrams, Ishikawa diagrams, and a problem tree were also used to identify and prioritize the causes associated with stockouts and long picking-cycle times.

Based on the identified root causes, four Lean Warehousing tools were selected. Poka Yoke was aimed at reducing errors in inventory recording and control; ABC classification at organizing spare parts according to turnover and demand; Systematic Layout Planning at reducing the distances traveled during picking; and Standard Work at establishing routes, activity sequences, and reference times. Poka Yoke and ABC classification were linked to the *In Full* component, while SLP and Standard Work were associated with the *On Time* component.

The collected times were processed using Arena Input Analyzer to determine the probability distributions that best represented the behavior of each activity. The analyzed variables were order arrivals, quotation preparation, order registration, inventory verification, picking, packing, and dispatch.

The AS IS and TO BE models were subsequently developed in Arena. The AS IS model represented the warehouse's current conditions, while the TO BE model incorporated the improved parameters associated with the proposed tools. Each scenario was run for 30 replications to reduce simulation variability and obtain more stable results.

Finally, the scenarios were compared using mean values and 95% confidence intervals. The evaluated indicators were OTIF, inventory accuracy, the percentage of incomplete orders, the percentage of late orders, and the average order-preparation time.

4. Data Collection

Data collection combined a review of the company's historical records with direct measurements conducted in the spare-parts warehouse. The main documentary source consisted of the operating records for 2024, a period in which 941 orders were processed. Each order was classified according to two conditions: compliance with the service deadline and delivery of the complete quantity requested.

Of the 941 orders analyzed, 560 were complete and processed on time, 272 were complete but processed late, 60 were incomplete but processed on time, and 49 were incomplete and processed late. This information established the initial status of the *On Time* and *In Full* components and characterized OTIF behavior.

In addition to the historical information, data were collected on the warehouse's operating conditions. For inventory control, physical and system inventory records, detected discrepancies, counting errors, and stock updates were reviewed. For ABC classification, annual spare-parts demand, issue frequency, turnover, criticality, and the current location of each product were used. The layout analysis considered storage areas, travel distances, material flow, and the warehouse's physical constraints. Finally, the picking study recorded the activity sequence, routes used, operating times, and variability in work methods.

To characterize order-preparation time, a direct measurement of 30 orders was initially conducted. This preliminary sample had an average time of 16.43 minutes per order and a standard deviation of 1.508 minutes. The results were used to estimate process variability and calculate the sample size required for subsequent analysis.

Considering a population of 941 orders, a 95% confidence level, and an allowable error of 5%, a maximum sample size of 121 observations was determined. The calculated minimum sample sizes were 72 observations for quotation preparation, 32 for order registration, 93 for inventory verification, 109 for picking, 72 for packing, and 121 for dispatch.

To maintain a uniform basis during statistical fitting, 121 observations were used for each time variable processed in Input Analyzer. The variables considered were order-arrival time, quotation preparation, order registration in the system, inventory verification, picking, packing, and dispatch. The resulting distributions were subsequently used as input data to build the AS IS and TO BE scenarios in Arena (Table 1).

Table 1. Sources and variables used in data collection

Table 1. Sources and Variables Used in Data Collection

Information source	Period or sample	Data collected	Purpose
Order records	941 orders from 2024	Complete or incomplete status and on-time or late service	Characterize the OTIF components
Preliminary measurement	30 orders	Order preparation time	Estimate the mean, variability, and sample size
Time study	121 observations per variable	Arrival, quotation, registration, inventory verification, picking, packing, and dispatch	Fit distributions in Input Analyzer
Inventory records	Physical and system records	Stock levels, discrepancies, counting errors, and updates	Evaluate inventory accuracy
Demand records	2024 information	Demand, issue frequency, turnover, criticality, and location	Perform ABC classification
Warehouse survey	Current situation	Layout, areas, dimensions, routes, flows, and physical constraints	Design the SLP proposal
Picking observation	Current operation	Activities, routes, times, and work methods	Develop the Standard Work proposal

5. Results and Discussion

This section presents the results obtained by comparing the AS IS and TO BE scenarios. The analysis considers indicators related to OTIF compliance, inventory accuracy, incomplete orders, late orders, and average preparation time. It also describes the proposed improvements using Poka Yoke, ABC classification, Systematic Layout Planning, and Standard Work, and evaluates result stability through simulation and confidence intervals.

5.1 Numerical Results

The results were obtained from 30 replications for each simulation scenario. The AS IS scenario represented the warehouse's current conditions, while the TO BE scenario incorporated the parameters associated with the proposed Lean Warehousing tools. Table 2 presents a comparison of the main indicators.

Table 2. Comparison of Indicators

Indicator	AS IS Scenario	TO BE Scenario	Improvement achieved
OTIF	57.95%	86.17%	+28.22 percentage points
Inventory accuracy	94.04%	97.92%	+3.88 percentage points
Incomplete orders	11.56%	3.98%	-7.58 percentage points
Late orders	29.44%	8.88%	-20.56 percentage points

The results show that the integrated proposal increased OTIF from 57.95% to 86.17%, representing an improvement of 28.22 percentage points and substantially narrowing the gap with the industry benchmark of 87%. Inventory accuracy also increased from 94.04% to 97.92%, demonstrating the effect of the tools aimed at controlling and organizing spare parts.

Incomplete orders decreased from 11.56% to 3.98%, strengthening the *In Full* component. Late orders fell from 29.44% to 8.88%, which was the most significant change and demonstrated that the proposal had a greater impact on the *On Time* component. Overall, the results indicate that integrating the four tools improves both order completeness and punctuality.

5.2 Graphical Results

To facilitate comparison of the results, Figure 1 presents the behavior of the main indicators in the AS IS and TO BE scenarios. The indicators considered are OTIF, inventory accuracy, incomplete orders, and late orders.

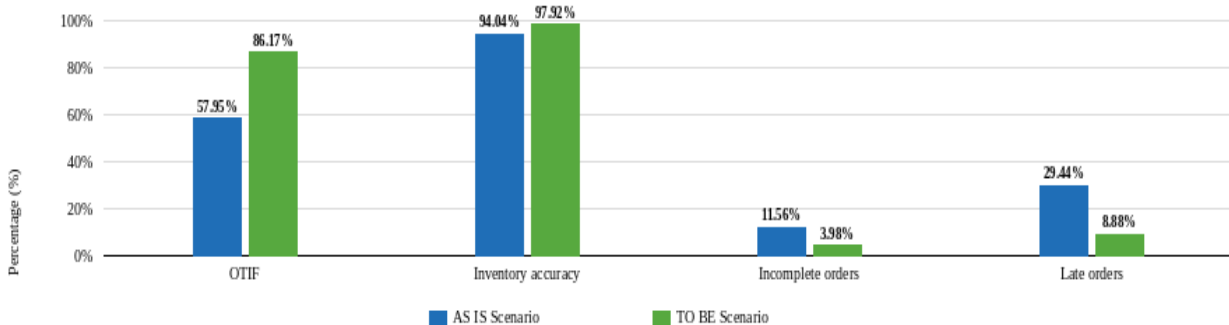


Figure 1. Comparison of Indicators in the AS IS and TO BE Models

An increase in OTIF and inventory accuracy is observed, together with a reduction in incomplete and late orders. The greatest improvement is the decrease in orders processed after the established deadline.

To evaluate the stability of the simulation results, Figure 2 presents the 95% confidence intervals for the OTIF indicator in the AS IS and TO BE scenarios.

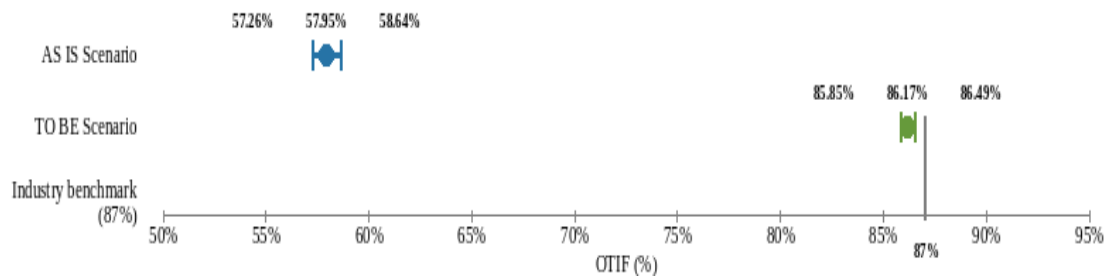


Figure 2. Comparison of OTIF Confidence Intervals

The confidence intervals of the two scenarios do not overlap, demonstrating a consistent difference between their results. In addition, the TO BE scenario reaches an average of 86.17%, which is close to the industry benchmark of 87%.

5.3 Proposed Improvements

The proposal integrates four Lean Warehousing tools directly related to the identified root causes: Poka Yoke, ABC classification, Systematic Layout Planning, and Standard Work. The first two strengthen the *In Full* component, while the last two improve the *On Time* component (Table 3).

Table 3. Relationship between Identified Causes and Proposed Improvements

Identified cause	Tool	Improvement developed	Related result
Differences between physical inventory and system inventory	Poka Yoke	Digital system and QR codes to validate products, stock, and locations	Higher inventory accuracy
Lack of spare-parts classification	ABC Classification	Organization by demand, turnover, and issue frequency	Reduction in incomplete orders
Excessive travel during picking	SLP (Systematic Layout Planning)	Layout redesign and reduced travel distances	Shorter preparation time
Absence of a defined route	Standard Work	Standard sequence, route, and times for picking	Reduction in late orders

Poka Yoke was developed through a digital system that makes it possible to register spare parts, check stock levels, and validate their locations. As a complement, ABC classification organized products according to the demand and turnover recorded during 2024, prioritizing high-movement items in easily accessible areas. These improvements increased inventory accuracy from 94.04% to 97.92% and reduced incomplete orders from 11.56% to 3.98% (Figure 3).

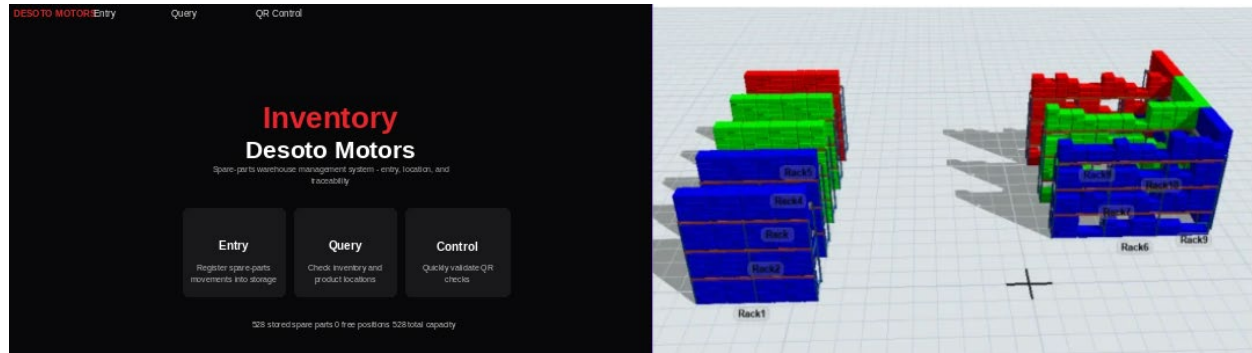


Figure 3. Poka Yoke System and Spare-Parts Organization through ABC Classification

SLP made it possible to redesign the warehouse layout by considering flows, travel paths, and physical constraints. Standard Work subsequently established a standard route and sequence for order preparation. As a result, the average picking time decreased from 16.43 to 13.20 minutes per order, and late orders were reduced from 29.44% to 8.88% (Figure 4).

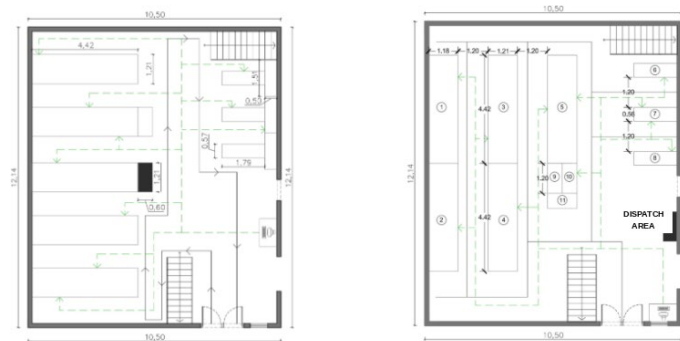


Figure 4. Layout Redesign and Standardization of the Picking Process

Overall, the proposed tools improve inventory control, spare-parts locations, internal travel, and the way picking is performed. In this way, the proposal simultaneously addresses the *In Full* and *On Time* components, contributing to the increase in OTIF.

5.4 Validation

The proposal was validated through a discrete-event simulation model developed in Arena. First, the AS IS scenario was represented using the times and parameters observed in the warehouse. The TO BE scenario was then built by incorporating the improvements associated with Poka Yoke, ABC classification, SLP, and Standard Work. Both scenarios were run for 30 replications.

The stability of the results was evaluated using 95% confidence intervals. The OTIF of the AS IS scenario had an average of 57.95%, with an approximate interval from 57.26% to 58.64%, while the TO BE scenario reached 86.17%, with an interval from 85.85% to 86.49%. The absence of overlap between the two intervals demonstrates a consistent improvement after implementing the proposal.

The other indicators also showed favorable behavior: inventory accuracy increased, while incomplete and late orders decreased. Therefore, the simulation results support the effectiveness of the proposed tools in improving OTIF compliance.

6. Conclusion

This study demonstrates that implementing an integrated Lean Warehousing model comprising Poka Yoke, ABC Classification, Systematic Layout Planning (SLP), and Standard Work significantly improves the On Time In Full (OTIF) indicator in the spare-parts warehouse of an automotive company. The combined application of these tools increased inventory accuracy, reduced order-preparation times, and raised OTIF to a value close to the industry benchmark. The economic evaluation also confirmed that the proposal is technically and financially feasible, demonstrating that operational improvements also generate economic benefits for the organization. The main contribution of this research is the integration of several Lean Warehousing tools into a single OTIF-oriented improvement model, showing that their combined application produces better results than implementing each tool separately. In addition, validation through discrete-event simulation in Arena made it possible to quantify the proposal's impact before implementation, providing a replicable methodology for automotive companies and other warehouses with similar characteristics. As future work, the model should be validated under actual operating conditions, and the simulation should be complemented with tools such as Arena Output Analyzer to strengthen the statistical analysis of the results. Future research could also incorporate other continuous-improvement methodologies and evaluate the model's performance in different industrial sectors, thereby expanding the evidence on the application of Lean Warehousing to improve logistics service levels.

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