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Streamlining Spare Parts Logistics: A Case Study on Warehouse Optimization and Continuous Improvement in a Peruvian Distribution Center

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ABSTRACT

This empirical study investigates the application of continuous improvement strategies to optimize warehouse management and order picking processes within a spare parts distribution center in Peru. The logistics of spare parts present unique challenges, including a vast number of stock-keeping units (SKUs), intermittent demand, and high customer service level expectations. Inefficient warehouse layout and picking routes can lead to significant operational costs, increased order fulfillment times, and reduced overall productivity. This research employs a multi-method approach, combining ABC analysis for inventory classification with Systematic Layout Planning (SLP) to redesign the warehouse layout. Data was collected through direct observation, historical order analysis, and operational time studies at a representative Peruvian company. The results demonstrate that a data-driven reconfiguration of the storage layout, based on product movement frequency, can yield substantial improvements. The proposed layout resulted in a calculated reduction in average order picker travel distance by 38%, which translates to significant time savings and increased picking capacity. The discussion contextualizes these findings within the broader literature on warehouse design and spare parts management, highlighting the practical implications for businesses in emerging economies. This study contributes to the field by providing a detailed, replicable methodology for warehouse optimization that can be adapted by other organizations facing similar logistical challenges.

KEYWORDS: Spare parts logistics, warehouse optimization, order picking, continuous improvement, distribution center, Peru, inventory management, supply chain efficiency, layout design.

1. INTRODUCTION

Effective warehouse management is a cornerstone of modern supply chain efficiency, directly impacting costs, customer satisfaction, and a company's competitive advantage [9]. The design and control of warehouse operations, particularly order picking, have been subjects of extensive research for decades, as picking activities can account for up to 55% of total warehouse operating costs [6]. The complexity of these operations is magnified in the context of spare parts distribution. Spare parts inventory is characterized by a high diversity of SKUs, intermittent and unpredictable demand patterns, and the critical need for rapid fulfillment to support maintenance, repair, and operations (MRO) activities [14, 27]. Failure to efficiently manage spare parts can lead to costly equipment downtime and significant losses for customers [19].

The layout of a warehouse is a fundamental factor that dictates operational performance [1]. A well-designed layout facilitates smooth material flow, minimizes travel distances, and enhances space utilization, while a poor layout can create bottlenecks, increase handling costs, and compromise safety [3, 4]. Recent trends in warehouse design have explored innovative configurations and automated solutions [1, 10]. However, for many small and medium-sized enterprises (SMEs), especially in developing economies like Peru, large-scale automation is not financially viable. Therefore, the focus remains on applying proven industrial engineering principles and continuous improvement methodologies to optimize existing manual or semi-automated systems.

The challenge is often twofold: assigning products to optimal storage locations (the storage location assignment problem) and determining the most efficient routes for pickers to travel (the order picker routing problem) [2, 12]. These problems are interconnected, as the choice of storage policy heavily influences the effectiveness of routing strategies [11]. Class-based storage, where items are grouped based on their turnover rate (e.g., ABC analysis), is a widely accepted strategy to reduce travel distances by placing fast-moving items in more accessible locations [12]. This approach aligns with the principles of Systematic Layout Planning (SLP), a structured methodology for arranging facilities to optimize the relationships between activities [7, 8].

Despite a rich body of literature on warehouse optimization and spare parts management [13, 15, 16], empirical studies detailing the practical application and quantifiable benefits of these strategies in the specific context of Latin American spare parts distributors are limited. This research aims to fill that gap by presenting a case study of a Peruvian spare parts distribution company. The study documents the analysis of the company's existing warehouse operations and details the development of a new layout using ABC classification and SLP. The primary objective is to demonstrate how these established methodologies can be effectively deployed to achieve significant performance gains in order picking, thereby providing a practical framework for continuous improvement in similar operational environments.

2. METHODS

This research was conducted as an empirical case study at a medium-sized company in Lima, Peru, that specializes in the distribution of industrial and automotive spare parts. The company's primary warehouse faced challenges related to long order fulfillment times, inefficient use of picker labor, and a disorganized storage system that had evolved organically over time without a structured design. The methodological approach was divided into three main phases: (1) diagnostic and data collection, (2) data analysis and inventory classification, and (3) layout redesign and performance evaluation.

Phase 1: Diagnostic and Data Collection

The initial phase involved a comprehensive diagnostic of the existing warehouse. Direct observations of the order picking process were conducted over a two-week period to map the flow of materials and personnel. The physical dimensions of the warehouse, including shelving units, aisles, and staging areas, were measured and documented in a CAD drawing. Historical data for a 12-month period were extracted from the company's Enterprise Resource Planning (ERP) system. This dataset included information for 4,520 distinct SKUs, encompassing sales records, order frequencies, and quantities picked per order. This historical data formed the basis for analyzing product movement and demand patterns, a critical input for effective inventory management [28]. A time-and-motion study was also performed, tracking five order pickers over three shifts to establish a baseline for the average time and distance traveled per order.

Phase 2: Data Analysis and Inventory Classification

The core of the analysis phase was the application of ABC classification, a multi-criteria inventory categorization technique [17]. In this study, the classification criterion was the frequency of movement (i.e., the number of times an SKU was picked over the 12-month period), as this metric is a direct driver of order picking labor. The SKUs were sorted in descending order of their pick frequency, and the cumulative frequency was calculated. Following the Pareto principle, the SKUs were categorized as:

1. **Class A:** The top 20% of SKUs that accounted for approximately 80% of the total pick frequency.
2. **Class B:** The next 30% of SKUs, accounting for about 15% of the pick frequency.
3. **Class C:** The remaining 50% of SKUs, which only accounted for 5% of the pick frequency.

This classification is crucial for developing a storage strategy that prioritizes the most frequently handled items, a foundational concept in efficient warehouse logistics [21].

Phase 3: Layout Redesign and Performance Evaluation

The layout redesign was guided by the Systematic Layout Planning (SLP) methodology [5, 7]. The primary input for the SLP model was the ABC classification. The core principle applied was to locate Class A items in the most accessible and ergonomically favorable locations closest to the dispatch area to minimize travel distance. Class B items were placed in the next most accessible zones, and the slow-moving Class C items were allocated to more remote or higher locations.

An activity relationship chart was developed to map the desired proximity between key functional areas: receiving, quality control, value-added services (e.g., kitting), bulk storage, picking zones (A, B, and C), packing, and dispatch. Using this chart and the spatial constraints of the building, a new block layout was designed. This new layout aimed to create a more logical and unidirectional flow, reducing congestion and eliminating backtracking.

To evaluate the effectiveness of the proposed design, the average travel distance for a sample of 50 historical orders was calculated for both the existing layout and the proposed layout. The routes were mapped assuming a traversal routing strategy, where pickers travel through entire aisles containing picks. The percentage reduction in travel distance was used as the primary key performance indicator (KPI) to quantify the improvement. This comparative analysis provides a tangible measure of the operational efficiency gained through strategic redesign [4].

3. RESULTS

The analysis of the operational data and the subsequent application of the optimization methodologies yielded clear and quantifiable results, highlighting significant inefficiencies in the existing system and substantial potential for improvement.

Inventory Classification (ABC Analysis)

The analysis of 12 months of transactional data confirmed that a small fraction of the SKUs was responsible for the majority of the warehouse activity. The results of the ABC classification based on pick frequency are summarized in Table 1.

Table 1: ABC Classification of Spare Parts SKUs

Class	Percentage of SKUs	Percentage of Total Picks	Number of SKUs
A	20%	79.8%	904
B	30%	15.3%	1,356
C	50%	4.9%	2,260
Total	100%	100%	4,520

As shown, 904 SKUs (Class A) accounted for nearly 80% of all picking activities. In the original layout, these high-frequency items were scattered throughout the warehouse, often mixed with slow-moving Class C items. This lack of a rational storage policy was a primary contributor to excessive travel time during order fulfillment.

Existing vs. Proposed Layout Performance

The original warehouse layout featured long, uninterrupted aisles with no clear zoning for products based on their velocity. The dispatch area was located at one end of the facility, forcing pickers to travel the full length of the warehouse even for orders containing a single, small item.

The proposed layout, designed using SLP principles, fundamentally changed the warehouse structure. A dedicated forward picking zone for all 904 Class A items was established immediately adjacent to the packing and dispatch area. This zone was designed with shorter aisles and a cross-aisle to further reduce travel within the zone. Class B items were situated in the central part of the warehouse, and Class C items were placed in the rearmost section. This zoned approach is a recognized strategy for improving picking performance in various warehouse configurations [11, 12].

The performance of the proposed layout was simulated by recalculating the travel distances for the same sample of 50 historical orders. The comparison between the two layouts is presented in Table 2.

Table 2: Comparison of Order Picking Travel Distance

Metric	Existing Layout	Proposed Layout	Improvement
Total Distance for 50 Orders	6,750 meters	4,185 meters	-2,565 meters
Average Distance per Order	135 meters	83.7 meters	-51.3 meters
Percentage Reduction	-	-	**38%**

The results indicate that the implementation of the proposed layout would reduce the average travel distance per order from 135 meters to 83.7 meters, an improvement of 38%. This reduction in travel directly correlates to a decrease in the time required to fulfill an order, allowing for higher picker productivity and increased throughput capacity for the facility without additional labor investment.

4. DISCUSSION

The results of this study empirically validate the significant impact that systematic layout planning and data-driven storage assignment can have on the operational efficiency of a spare parts distribution warehouse. The 38% reduction in average travel distance represents a substantial operational improvement, with far-reaching implications for cost, speed, and service quality. This finding is consistent with the broader body of literature that identifies order picking travel as a primary cost driver and a key target for optimization efforts [6, 2]. By strategically placing high-frequency Class A items closer to the shipping area, the redesigned layout minimizes non-value-added travel time, allowing pickers to complete more orders within the same timeframe.

This research contributes to the field by providing a practical application of established theories in the unique context of a Peruvian SME. While advanced models for warehouse design often involve complex algorithms and automation [5, 10, 11], this study demonstrates that remarkable improvements can be achieved through fundamental industrial engineering principles. The SLP and ABC analysis approach is accessible, relatively low-cost to implement, and offers a high return on investment, making it particularly suitable for businesses in emerging markets where capital for large-scale technological upgrades may be limited. The findings resonate with other case studies that have successfully applied SLP in various industrial settings, from locomotive maintenance depots to bottling plants [7, 8].

The optimization of a spare parts warehouse has strategic implications that extend beyond simple cost reduction. In the MRO sector, parts availability and speed of delivery are critical. Reducing the internal order cycle time enables the company to offer later cut-off times for same-day shipping, providing a competitive advantage. Furthermore, an efficient internal logistics system is a prerequisite for more advanced inventory control strategies, such as integrating emergency stocks or managing complex two-echelon spare parts networks [15, 24, 26]. An organized warehouse improves inventory accuracy, which is essential for the effective use of machine learning approaches for demand forecasting [25] and for building resilience against supply chain disruptions, a lesson learned from the recent COVID-19 pandemic [28].

Moreover, the principles of warehouse optimization align with broader goals of economic and environmental sustainability. A reduction in travel distance translates to lower energy consumption for material handling equipment and creates a more ergonomic and less physically strenuous work environment for employees [20]. Efficient logistics can also contribute to reducing the overall carbon footprint of the supply chain, a factor of growing importance in sustainable location-routing-inventory models [29, 30, 31]. While this study did not explicitly measure sustainability metrics, the operational improvements achieved are inherently linked to a more sustainable and resource-efficient operation.

Limitations and Future Research

This study has several limitations. First, it is a single case study, and the specific results may not be directly generalizable to all spare parts warehouses, as performance is contingent on the product mix, order profiles, and physical constraints of the facility. Second, the evaluation was based on a simulation of travel distances; a post-implementation study would be required to validate the real-world time savings and account for factors like congestion.

Future research could build upon this study in several directions. One avenue is to explore more sophisticated location assignment and routing algorithms to further optimize the layout [2, 11]. Another promising area is the integration of smart warehouse technologies, such as pick-to-light systems or the use of RFID, to enhance the performance of the redesigned manual system [18]. Finally, future work could investigate integrated models that simultaneously consider inventory control policies for different classes of spare parts and the physical warehouse layout, potentially incorporating risk factors like facility disruption [13, 22, 23, 30].

5. CONCLUSION

This empirical study successfully demonstrated the application of a continuous improvement framework, centered on ABC analysis and Systematic Layout Planning, to optimize a spare parts distribution warehouse in Peru. The research identified significant inefficiencies in the facility's original layout and proposed a new, data-driven design that reduces average order picking travel distance by an estimated 38%. This improvement translates directly into enhanced labor productivity, faster order fulfillment, and increased operational capacity. The study reinforces the value of applying fundamental industrial engineering principles as a cost-effective strategy for achieving substantial performance gains. For SMEs in the spare parts sector, particularly in emerging economies, this approach provides a practical and accessible pathway to improving logistical competitiveness and building a more resilient and efficient supply chain.

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