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Original Article

Design and Layout of Warehouses to Increase Productivity Using ABC and SLP Techniques in a Mining Company

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Abstract *- This research addresses the design and optimized distribution of a mining spare parts warehouse to increase productivity using the ABC and Systematic Layout Planning (SLP) techniques. The current problem of the company under study is centered on poor manual inventory management, characterized by disorganization, lack of a strategic classification of materials and inefficient routes, which negatively impacts response times and the accuracy of records, directly affecting productivity and profitability. To address these challenges, a design is proposed that integrates the ABC technique for prioritizing products according to their value and rotation, together with SLP, to optimize the layout of the areas and internal flows of the warehouse. The initial diagnosis revealed critical deficiencies, including an inventory accuracy of 88.19%, an OTIF delivery efficiency of 87.41% and an overall productivity of 76.83%. The study is based on existing literature, highlighting the positive impact of tools such as 5S, Lean Warehousing and ABC-SLP analysis in optimizing operational productivity. The design proposal includes a "U"-shaped layout to minimize travel times and optimize the location of high-turnover products, validated through simulations to assess its impact on key performance indicators. After implementation and reduced time and distance travelled factors, 94.97% for FILL RATE and 93.12% for OTIF were obtained, an improvement of 7.05% and 5.71%, respectively.*

Keywords *- ABC Analysis, Mining Industry Logistics, Productivity Optimization, Systematic Layout Planning (SLP), Warehouse Design.*

1. Introduction

Globally, warehouse management using traditional methods has often been the main reason for low picking productivity during order fulfilment, given that the lack of technological means to record accurate data on the quantity and location of items has led to significant time losses in the search for them by employees [1]. In the same context, the economy of the different companies providing warehousing services has been affected by poor warehouse management since most of them do not have an adequate work procedure regarding the systematic distribution and registration of their products that enter and leave daily, thus causing low operational productivity of employees responsible for order preparation of requested orders in the required time [2]. Indeed, [3] mentioned that poor warehouse management intervenes in non-compliance with a client's requirements due to the lack of establishment of the location and distribution of the products, which makes it difficult for the optimal productivity of the operators to prepare the necessary merchandise according to the request. Likewise, warehouse management in some companies does not use processes that provide important conditions to acquire the necessary information on how the warehouse is at the desired time, thus causing minimal performance in terms of the productivity of the collaborators regarding the management of the variety of products [4]. Consequently, international companies providing warehousing services have experienced user dissatisfaction, lower competitiveness and low profitability due to inadequate warehouse management about monitoring and control of products, elements, materials or stocks concerning their specific location, directly affecting operational processes, that is, the picking productivity of employees to carry out their assigned activities [5].

At a national level, various companies that are dedicated to marketing products have problems with their warehouses since a large part of these are used as deposits, being in poor condition, since the lack of awareness and insufficient knowledge of effective warehouse management has negatively influenced the low productivity of operators to have the orders requested by users on time, consecutively affecting the profits and profitability of companies for 90% of their invested capital [6]. Furthermore, productivity within Peruvian companies has been reduced by various factors within warehouses, such as disorganization, poor conditions, and poor management. This is why perfect order is sought and the main tools that allow correct storage management [7].

Although several studies have addressed effective methodologies and techniques to enhance warehouse productivity, including Lean tools, ABC analysis, and Systematic Layout Planning (SLP), there is still a notable research gap concerning the integrated application of these methods, specifically in spare parts warehouses within the mining sector. Notably, the lack of studies focused on mining spare parts warehouses limits understanding of the unique challenges in managing and distributing spare parts in this industry, where logistical efficiency is crucial due to high inventory turnover and significant economic impacts associated with response times.

In this context, a company within the mining sector dedicated to storing and distributing spare parts faces a critical issue related to low picking productivity. Specifically, problems such as low inventory record accuracy (88.19%), insufficient levels of On-Time In-Full deliveries (OTIF of 87.41%), and overall productivity of 76.83% were identified. These deficiencies primarily arise from the absence of strategic product classification, unclear operational procedures, and an inefficient physical layout, resulting in unnecessary delays and increased internal travel distances within the warehouse.

2. State of the Art

Several studies have proposed methodologies aimed at improving warehouse management to increase productivity. For instance, a study applied value stream mapping and the 5S method in warehouse management, achieving significant reductions in operating times: loading-unloading (31%), reception (30%), storage (22%), put away (32%), and picking (32%). The authors concluded that these methodologies substantially enhance warehouse productivity [8].

Similarly, another investigation improved the productivity of a logistics operator through Lean Manufacturing techniques, resulting in a 36.15% increase in total operating rate and a 73.4% reduction in truck dispatch times. This demonstrates the potential of Lean tools to reduce costs, eliminate waste, and improve productivity comprehensively [9].

In the context of spare parts warehouses, research conducted in Mexico focused on applying the 5S methodology in a sugar company's warehouse, addressing issues such as material mismanagement, disorder, poor cleaning, and excess, obsolete inventory. Post-implementation, the 5S methodology achieved 93% effectiveness, significantly reducing search times and errors related to material handling [10].

Additionally, another study developed a management model integrating Lean, Systematic Layout Planning (SLP), and Sales and Operations Planning (S&OP) tools to improve service levels in micro and small enterprises within the brewing industry. The implementation notably increased service levels from 84.34% to 96.65%, significantly decreasing inventory shortages [11].

In a related research conducted in Jordan, productivity improvements in manual picking systems were studied through computer simulation and WMS software, resulting in a productivity increase of 29%. This study highlighted the effectiveness of simulation-based approaches in optimizing warehouse operational costs and enhancing service satisfaction [12]. Further examples include a study in Venezuela, which used the PDCA cycle methodology to enhance spare part warehouse management for an automotive distributor. The approach eliminated major causes of incomplete orders and significantly reduced order preparation times [13].

In Colombia, researchers critically assessed logistics operations, applying the 5S methodology, ABC costing, and new warehouse layouts, achieving remarkable improvements in processing times and logistics costs, thus validating the effectiveness of these methodologies [14].

At the national level, a study aimed at improving warehouse productivity through ABC classification found a notable profitability increase, with a benefit-cost ratio of 1.27, thus confirming the effectiveness of structured warehouse management proposals [15]. Similarly, another national research demonstrated improvements of 13.31% in efficiency, 39.75% in productivity, and reductions in picking and packing times through targeted warehouse management practices [16].

Another significant study integrated Lean Warehousing tools within the commercial sector, such as 5S, Standardized Work, and Kaizen. This integration achieved remarkable improvements in service level (87% to 94%), cycle times (33% improvement), and tool search times (50% reduction), thus validating the relevance of Lean methodologies in diverse logistic contexts [17].

Moreover, a Lean Warehouse methodology applying Slotting, Standardized Work, and Poka Yoke techniques significantly enhanced key indicators such as OTIF by 28.94%, inventory record accuracy by 20.22%, and reduced product search times by 41.53%, demonstrating the broad applicability of these methods for mass consumption warehouses [18].

A further study focusing on warehouse management in an agricultural company in Lambayeque, employing 5S and ABC analysis methodologies, improved worker productivity from 72% to 92% and effectiveness by 30%, reinforcing the significant benefits of structured warehouse methodologies [19].

Lastly, research on facility layout optimization using the SLP methodology significantly reduced material handling costs by 44.7%, emphasizing the value of systematic planning in reducing operational inefficiencies and optimizing workflows [20].

All these studies collectively provide the theoretical foundation necessary to address the objectives and methodologies proposed in the present research, highlighting key dimensions and variables crucial for enhancing warehouse productivity.

2.1. Warehouse Management

Warehouse structuring should be aligned with clear objectives to optimize space utilization, facilitate easy inventory access, enhance customer service, maintain warehouse readiness, and reduce operational errors. Effective warehouse performance is closely linked to proper maintenance, protection, distribution, and overall management of merchandise [21].

Historically, warehouse management emerged during the electoral logistics of the United Kingdom in the 1940s, evolving gradually into an essential operational practice across various industries. Effective warehouse management is critical for organizations handling substantial quantities of raw materials and supplies, primarily due to its impact on cost reduction, service quality improvement, and enhanced economic performance [22].

2.1.1. Warehouse Processes

Storage represents the foundational element within a warehouse, serving as the designated area for product collection and retention. Determining the specific location for warehouse facilities involves evaluating factors such as available physical space, the duration of storage, and the specific characteristics of the products stored [23].

2.1.2. Warehouse Distribution

Effective warehouse planning involves structuring and adhering to defined production plans, frequently requiring adjustments due to technological advancements, new product development, facility expansion, resource optimization, and labor considerations. Warehouse distribution aims to maximize production quality, streamline labor organization, minimize product handling, ensure employee safety, enhance worker satisfaction, and consolidate production processes to reduce costs and improve productivity [24].

Types of Distribution

Effective merchandise receipt includes supervising and verifying the quantity and quality of resources, which are subsequently integrated into the manufacturing processes. Anticipating inventory requirements is crucial, and this process heavily relies on accurate forecasting methods to manage variability and predict demand trends [25].

Chaotic Warehouse

The chaotic warehouse system, predominantly utilized in e-commerce distribution centers, stores products in randomly assigned locations rather than fixed spaces. This method enables efficient item location and retrieval, supported by advanced tracking technologies such as barcodes and RFID systems. Despite its seemingly disorganized appearance, this approach optimizes space utilization and adapts effectively to inventory fluctuations, making it ideal for warehouses managing high turnover and diverse product ranges [26].

2.1.3. Inventory

Inventory management significantly influences purchasing decisions, aiming to fulfil customer requirements while reducing product-related costs, ordering expenses, and storage costs. Integrated with the broader supply chain, inventory management must align with organizational strategies focused on customer satisfaction [27].

Inventory encompasses the collection of items or products available within an organization for sale, production, or future transactions over a specified period. Typically, inventory includes raw materials, resources, and utilities essential for preparing and marketing finished products. Effective inventory management ensures a steady supply of essential materials to meet demand, thus enhancing overall operational efficiency [28].

Efficient inventory regulation addresses two primary objectives: maintaining adequate inventory levels for uninterrupted operations and minimizing total holding costs. Insufficient inventory can increase ordering costs, lead to lost sales opportunities, and negatively affect profitability, while excessive inventory ties up financial resources unnecessarily, increasing maintenance costs [29].

Organizations employ inventory management techniques to optimize resource utilization and reduce operational costs. Proper inventory control facilitates consistent availability and continuous customer service, enabling organizations to allocate surplus resources to more profitable activities [30].

ABC Classification

The ABC inventory system categorizes products based on their relative importance and contribution to overall profitability. This method leverages the Pareto Principle (80/20 rule), where 20% of items typically represent approximately 80% of warehouse activity and organizational income [31].

Category A products, being the most critical, require rigorous monitoring and higher resource allocation, typically representing around 20% of inventory items. Category B products, moderately important, constitute around 30%, while Category C products, the least critical, account for approximately 50% and require minimal control efforts [32].

ABC inventory classification provides detailed information, guiding organizations to reduce maintenance costs and optimize working capital deployment. Categorizing products facilitates frequent turnover, enabling faster recovery of invested capital [33].

Inventory turnover measures the frequency at which inventory is replaced within a given period, involving sales or utilization followed by replenishment. Distribution processes are integral to warehouse management and are responsible for the systematic arrangement, processing, and dispatch of products [34].

2.2. Productivity

Productivity refers to the relationship between total production obtained and the resources utilized to achieve this production. Specifically, it encompasses the relationship between inputs and outputs, considering effectiveness and efficiency as essential components. Productivity emphasizes the appropriate use of resources, creating value in the goods and services produced [35].

According to authors [36], productivity represents the relationship between the outcomes achieved and the time required to obtain them. As a comparative tool, productivity evaluates different economic systems by contrasting their outputs with the resources invested. Although closely related, efficiency differs from productivity; efficiency is concerned with producing high-quality goods in minimal time, while productivity involves product quality, resource use, and overall process quality.

Maximizing productivity includes improving processes and considering manufacturing as a social, heterogeneous, adaptive, and progressive mechanism. This concept highlights the critical balance and equity required among labor, capital, and the organizational environment, emphasizing that productivity measurement is fundamentally based on products manufactured and the resources necessary to develop the final product over a given period [37].

Authors [38] describe picking as a key logistical process encompassing order placement activities. These activities range from receiving and compiling orders to preparing materials for shipment. Picking is particularly significant, representing at least 60% of operational costs within a distribution center. In summary, ABC and Systematic Layout Planning (SLP) techniques are fundamental for enhancing warehouse management and operational productivity. The ABC technique allows the segmentation and prioritization of products based on their economic relevance and turnover frequency, leading to more efficient inventory control and optimized resource allocation. Meanwhile, SLP provides a structured approach to warehouse layout design, improving workflow, reducing travel time, and minimizing operational errors.

3. Contribution

The main novelty of this study lies in simultaneously and adaptively integrating the ABC technique and the Systematic Layout Planning (SLP) methodology specifically for managing mining spare parts warehouses. Although previous research has explored these techniques separately or within other industrial contexts, this work addresses an identified gap in the literature by validating the combined application of these tools in a sector with particular logistical challenges, such as mining.

3.1. Current Inventory Management Challenges

Currently, many companies manage warehouse inventory through manual processes. Operators record product entries and exits on physical control sheets, introducing a substantial risk of human error and complicating the real-time updating of inventory levels. These manual recordings are validated monthly using reports generated by systems such as SAP. However, reliance on manual processes frequently results in discrepancies between the physical inventory and the system records, adversely affecting replenishment and stock management decisions. Figures 1 and 2 illustrate the existing condition of the warehouse, characterized by considerable disorder and inadequate product classification. Such conditions hinder efficient product location and management, negatively impacting picking times.

Fig. 1 Current state of the warehouse

Fig. 2 Current state of the warehouse

An Ishikawa diagram (Figure 3) was developed to identify the root causes of warehouse-related issues, accompanied by a process flow chart detailing principal warehouse operations.

Subsequently, a Pareto analysis (Table 1, Figure 4) prioritized factors contributing significantly to disorder and poor classification, highlighting the necessity to address key issues such as inadequate sorting and routing systems.

Table 1. Pareto chart of causes

Detected Problems	Rating	Individual Percentage (%)	Cumulative Percentage (%)
Inadequate inventory control	10	17%	17%
Picking errors	10	17%	34%
Warehouse distribution	9	16%	50%
No product classification	8	14%	64%
Disorganized products	5	9%	72%
Purchase order errors	4	7%	79%
No procedure manuals	2	3%	83%
Poor utilization of SAP software	2	3%	86%
Lack of KPIs	2	3%	90%
Product obsolescence	2	3%	93%
Environmental conditions	2	3%	97%
Staff turnover	2	3%	100%

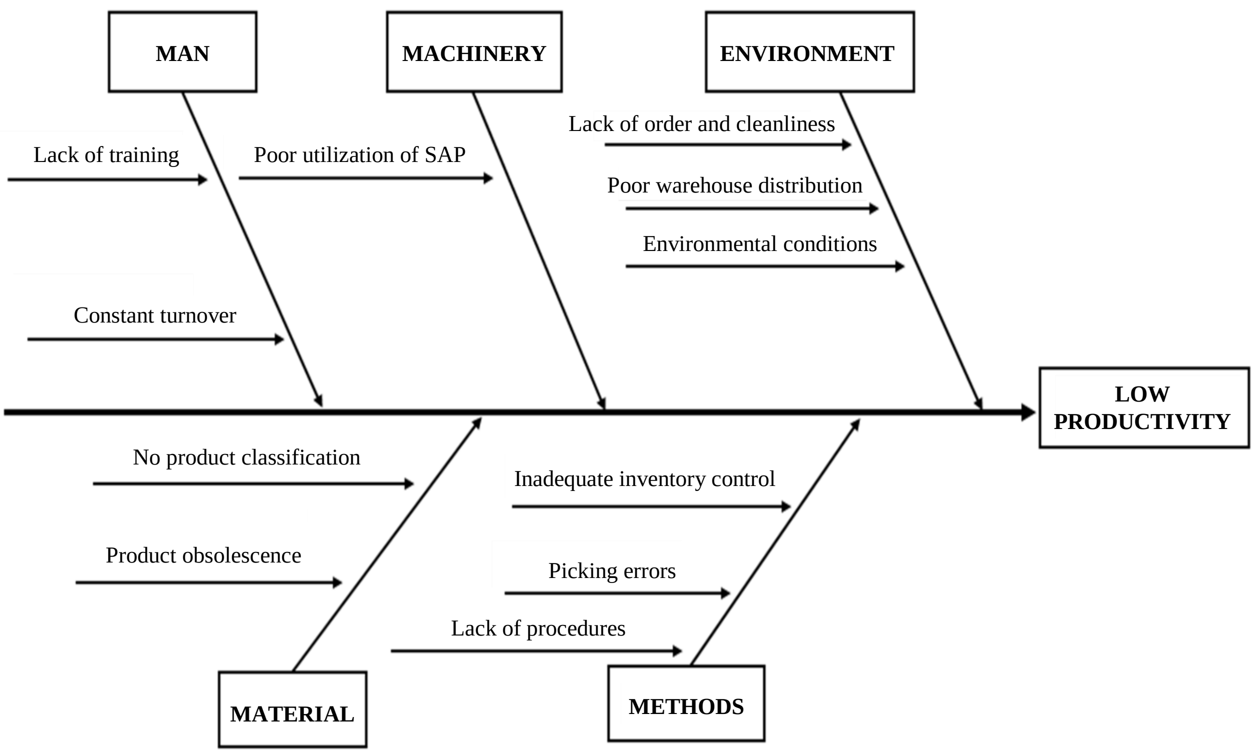

Fig. 3 Ishikawa diagram

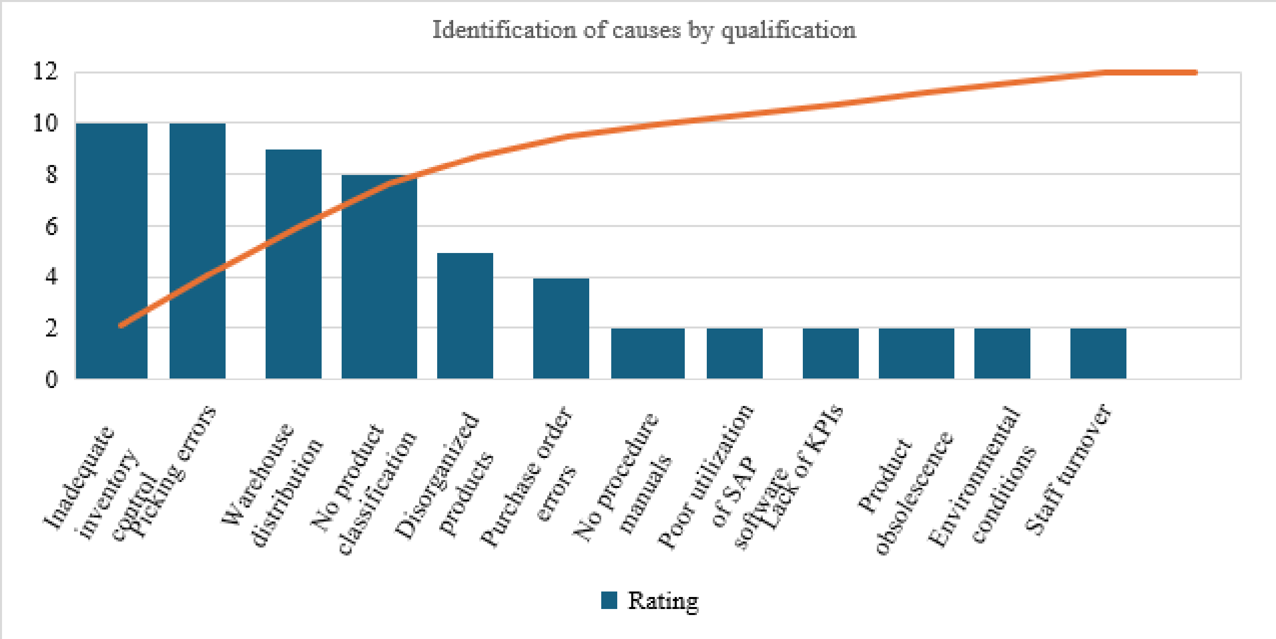

Fig. 4 Identification of causes by qualification

Table 2. Pareto chart of causes

Years (Accounting date)	Months (Accounting date)	TOTAL (PEN)
2023	Jan	527,764.38
2023	Feb	908,909.09
2023	Mar	1,014,957.79
2023	Abr	330,946.75
2023	May	518,684.99
2023	Jun	967,174.09
2023	Jul	641,849.73
2023	Aug	538,019.76
2023	Sep	2,253,519.32
2023	Oct	355,958.92
2023	Nov	968,166.91
2023	Dec	837,766.11
2024	Jan	695,308.33
2024	Feb	514,204.14
2024	Mar	278,346.83
2024	Abr	431,644.16
2024	May	462,433.66
2024	Jun	926,046.62
2024	Jul	775,041.65
2024	Aug	747,048.32
Total		14,693,791.54

This analysis identified that a few causes, such as lack of a sortation system and routes, generate most problems, suggesting that targeting these key factors would significantly improve warehouse management.

Currently, the warehouse's average operational metrics reflect a distance of 30 meters per picking operation, with a processing time of 1161 seconds, serving as a baseline for productivity improvements.

Historical purchase records (Table 2) show an average monthly order value of PEN 734,689.00.

Based on the previously analyzed data and its comparison with warehouse operations, several key findings have been identified, as presented in Table 3. These findings highlight critical areas for improvement in warehouse performance. Only 86.67% of scheduled deliveries are completed (Figure 5), leading to an undelivered value of PEN 24,489.63. This shortfall directly affects the company's cash flow (Figure 6).

Table 3. Historical data

HISTORICAL DATA	QUANTITY
AVERAGE VALUED SUPPLY / MONTH	PEN 734,689.00
ORDERS / MONTH	120
AVERAGE VALUE PER PURCHASE ORDER (PO)	PEN 6,122.41
ORDERS DELIVERED / WEEK	20
ORDERS NOT DELIVERED / WEEK	3
VALUE OF DELIVERED ORDERS / WEEK	PEN 159,182.62
VALUE OF NON-DELIVERED ORDERS / WEEK	PEN 24,489.63

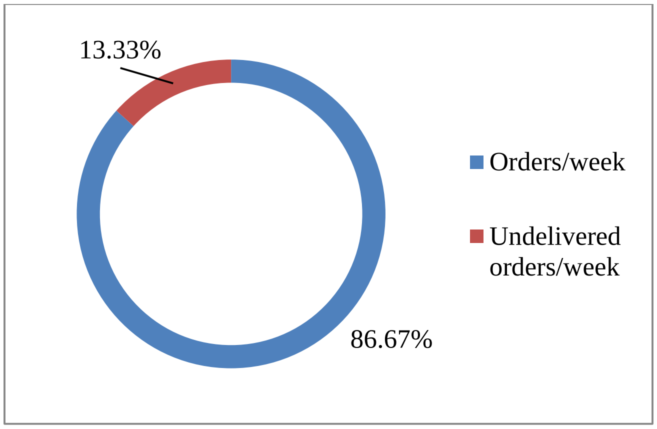

Fig. 5 Current fill rate

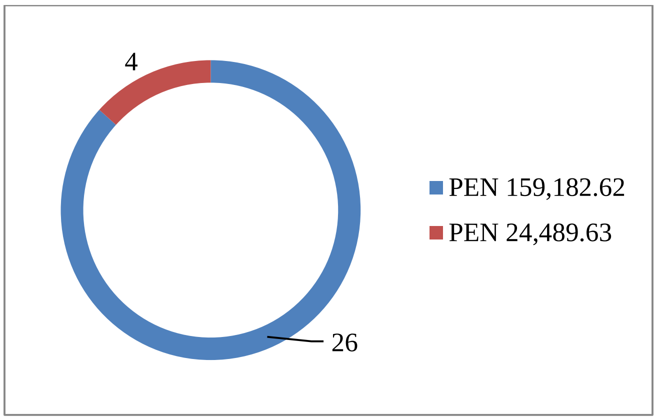

Fig. 6 Valued fill rate

The most recent warehouse inventory review determined that out of a total of 381 recorded items, 336 matched the actual physical quantities found in their designated locations. This corresponds to an Inventory Record Accuracy (IRA) of 88.19%, highlighting the need to strengthen control and recording procedures to minimize discrepancies and improve data reliability within the system.

The calculation was performed using the formula presented in Equation (1), where ERI is the Accuracy of the Inventory Record.

$$\text{ERI} = \frac{\text{Correct Physical Quantity}}{\text{Recorded Quantity}} * 100 \quad (1)$$

$$(\text{ERI}) = \frac{336}{381}\, X\, 100 = 88.19\%$$

A flow chart was developed to provide a clear and concise visualization of the steps followed by warehouse operators. Through analysing this activity flow, several areas for improvement were identified, including bottlenecks and redundancies that hinder operational efficiency. This diagnostic assessment underscores optimising internal routing to enhance overall productivity.

As illustrated in the flow chart (Figure 7), each staff member travels an average of 31.85 meters to locate inventory items, representing a considerable loss of time and efficiency in warehouse operations. Additionally, the average time spent per search is 16.59 minutes per person. These findings reveal an inefficient warehouse layout and suboptimal product placement, negatively impacting productivity and spare parts management response times.

On the other hand, calculations regarding the fulfilment of requested orders were carried out for 20 weeks. The effectiveness rate was determined by comparing the number of dispatched orders to the total number of orders requested. The weekly results of this analysis are presented in the following table, which outlines the effectiveness values by week.

Table 4. Effectiveness calculation

Month	Week	Orders Requested	Orders NOT Dispatched	Effectiveness
Jun-24	1	13	1	92.31%
Jun-24	2	12	2	83.33%
Jun-24	3	34	6	82.35%
Jun-24	4	41	5	87.80%
Jul-24	5	31	2	93.55%
Jul-24	6	27	4	85.19%
Jul-24	7	16	3	81.25%
Jul-24	8	28	3	89.29%
Aug-24	9	24	2	91.67%
Aug-24	10	21	1	95.24%
Aug-24	11	16	2	87.50%
Aug-24	12	31	5	83.87%
Sep-24	13	23	2	91.30%
Sep-24	14	8	1	87.50%
Sep-24	15	11	2	81.82%
Sep-24	16	26	3	88.46%
Oct-24	17	21	2	90.48%
Oct-24	18	17	2	88.24%
Oct-24	19	33	4	87.88%
Oct-24	20	28	3	89.29%

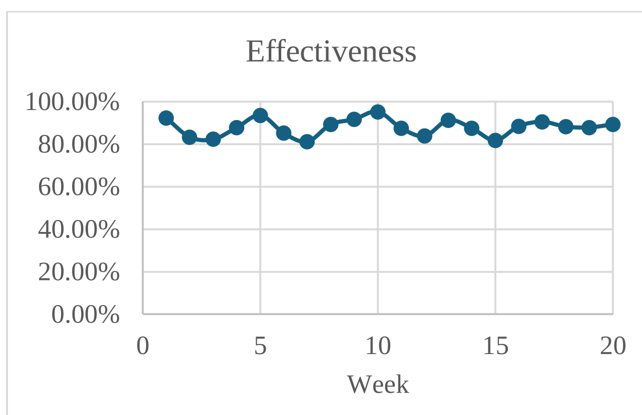

Fig. 8 Effectiveness chart

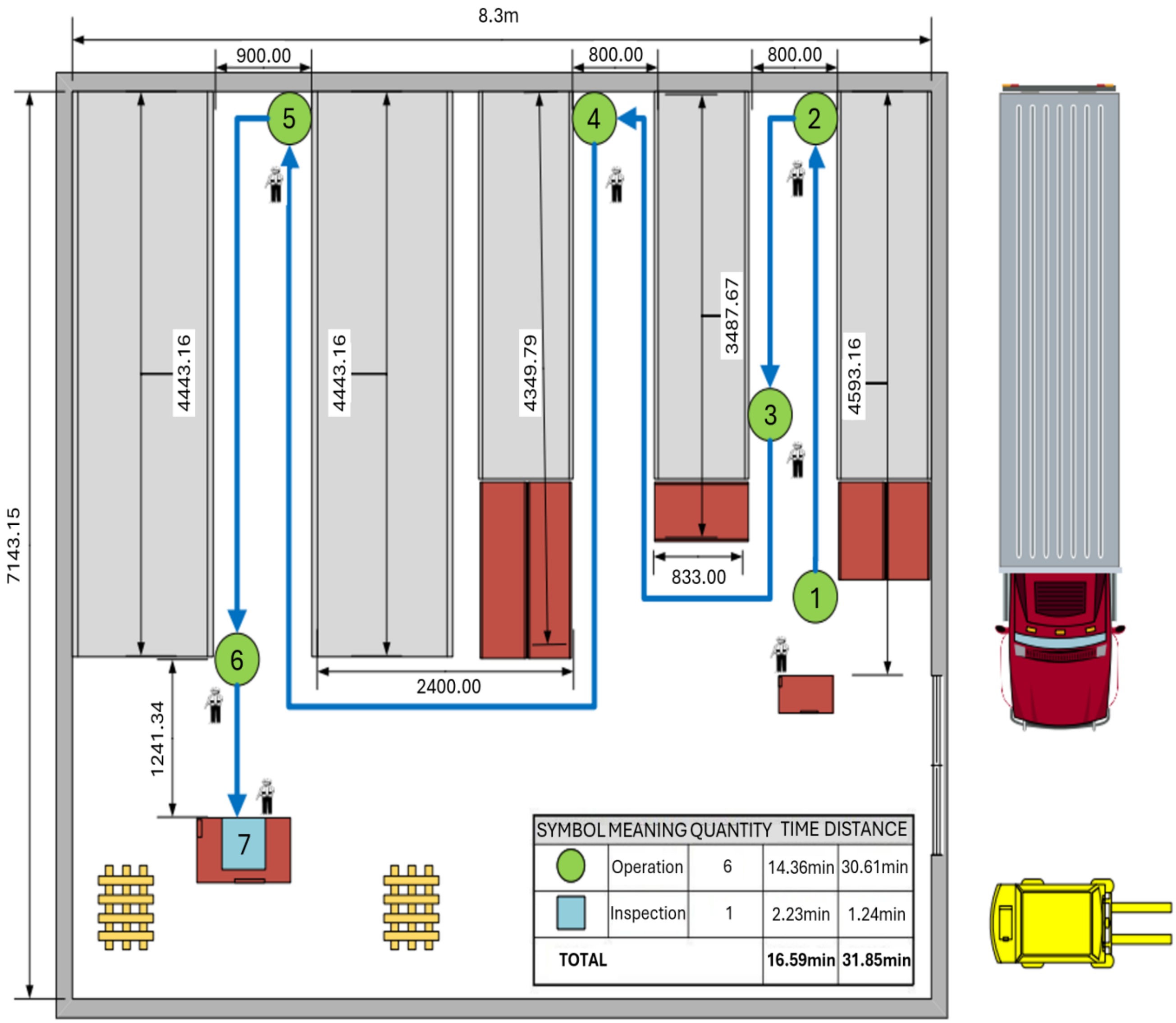

Fig. 7 Current route diagram

An average efficiency of 87.92% was obtained based on the key concepts and methodology used for its calculation (Table 4) (Figure 7).

The efficiency calculation in this study considered two key factors: on-time deliveries and complete order fulfilment. These components were assessed using the OTIF (On-Time In-Full) indicator, which is calculated by multiplying the "On-Time" rate by the "In-Full" rate (Table 5). This metric provides a comprehensive service performance measure by capturing the punctuality and completeness of order deliveries.

The average efficiency recorded over the 20 weeks was 87.41% (Table 5). This initial indicator serves as a baseline for guiding the development and implementation of improvement proposals.

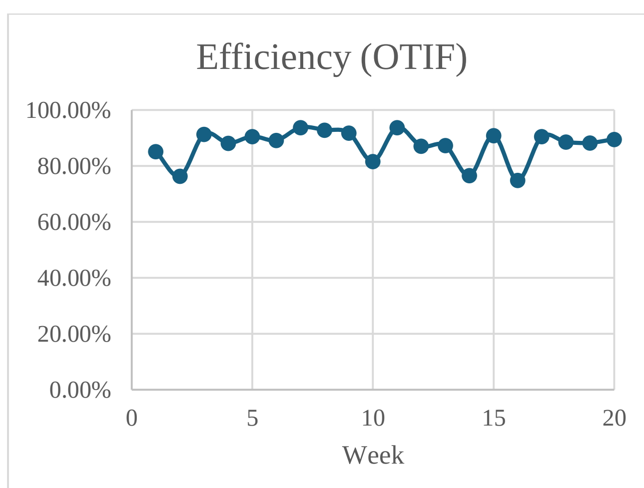

Fig. 9 Efficiency (OTIF)

Table 5. Efficiency (OTIF)

Month	Week	Late Delivered Orders	Incomplete Delivered Orders	ON-TIME	IN FULL	Efficiency (OTIF)
Jun-24	1	1	1	92%	92%	85.21%
Jun-24	2	2	1	83%	92%	76.39%
Jun-24	3	2	1	94%	97%	91.35%
Jun-24	4	3	2	93%	95%	88.16%
Jul-24	5	1	2	97%	94%	90.53%
Jul-24	6	1	2	96%	93%	89.16%
Jul-24	7	0	1	100%	94%	93.75%
Jul-24	8	0	2	100%	93%	92.86%
Aug-24	9	1	1	96%	96%	91.84%
Aug-24	10	3	1	86%	95%	81.63%
Aug-24	11	0	1	100%	94%	93.75%
Aug-24	12	4	0	87%	100%	87.10%
Sep-24	13	2	1	91%	96%	87.33%
Sep-24	14	1	1	88%	88%	76.56%
Sep-24	15	1	0	91%	100%	90.91%
Sep-24	16	3	4	88%	85%	74.85%
Oct-24	17	0	2	100%	90%	90.48%
Oct-24	18	1	1	94%	94%	88.58%
Oct-24	19	2	2	94%	94%	88.25%
Oct-24	20	2	1	93%	96%	89.54%

Table 6. Productivity calculation

Month	Week	Effectiveness (FILL RATE)	Efficiency (OTIF)	PRODUCTIVITY
Jun-24	1	92.31%	85.21%	78.65%
Jun-24	2	83.33%	76.39%	63.66%
Jun-24	3	82.35%	91.35%	75.23%
Jun-24	4	87.80%	88.16%	77.41%
Jul-24	5	93.55%	90.53%	84.69%
Jul-24	6	85.19%	89.16%	75.95%
Jul-24	7	81.25%	93.75%	76.17%
Jul-24	8	89.29%	92.86%	82.91%
Aug-24	9	91.67%	91.84%	84.19%
Aug-24	10	95.24%	81.63%	77.75%
Aug-24	11	87.50%	93.75%	82.03%
Aug-24	12	83.87%	87.10%	73.05%
Sep-24	13	91.30%	87.33%	79.74%
Sep-24	14	87.50%	76.56%	66.99%
Sep-24	15	81.82%	90.91%	74.38%
Sep-24	16	88.46%	74.85%	66.22%
Oct-24	17	90.48%	90.48%	81.86%
Oct-24	18	88.24%	88.58%	78.16%
Oct-24	19	87.88%	88.25%	77.55%
Oct-24	20	89.29%	89.54%	79.95%

Productivity was determined by calculating the product of efficiency and effectiveness. According to the methodology referenced in [39], this approach involves multiplying both factors to obtain the overall productivity value.

An average productivity of 76.83% was obtained (Table 6), indicating the presence of significant deficiencies in warehouse processes that require attention and corrective measures.

Fig. 10 Productivity chart

During the evaluation period, an average productivity of 76.83% was achieved, reflecting a moderately efficient performance of the available resources and the established operational objectives.

3.2. Proposed Model

The main contribution of this research lies in developing an optimized warehouse layout design through the integration of ABC classification and Systematic Layout Planning (SLP) techniques specifically tailored to the management of mining spare parts. This study validates the effectiveness of these tools within a specialized logistics context. It presents a practical and quantifiable approach that can be replicated by companies facing similar challenges in warehouse management.

Figure 11 illustrates the proposed solution model. This model integrates product classification based on economic relevance (ABC) with a strategic spatial and internal flow design (SLP), reducing operating times, improving inventory record accuracy, and enhancing operational efficiency and effectiveness. This comprehensive approach addresses common issues such as disorganization, unbalanced resource allocation, and lack of process standardization, offering an effective and sustainable solution.

Moreover, the research emphasizes the importance of incorporating quantitative analysis tools and simulation techniques to assess the real-world impact of improvement initiatives. The results—such as increased average productivity and reduced travel times—positively influence operational performance and financial outcomes, establishing a valuable benchmark for the mining sector and other industries with comparable logistics dynamics.

In summary, this study advances best practices in warehouse management and reinforces the applicability of proven methodologies within specific contexts, thereby broadening their relevance and adaptability across complex business environments.

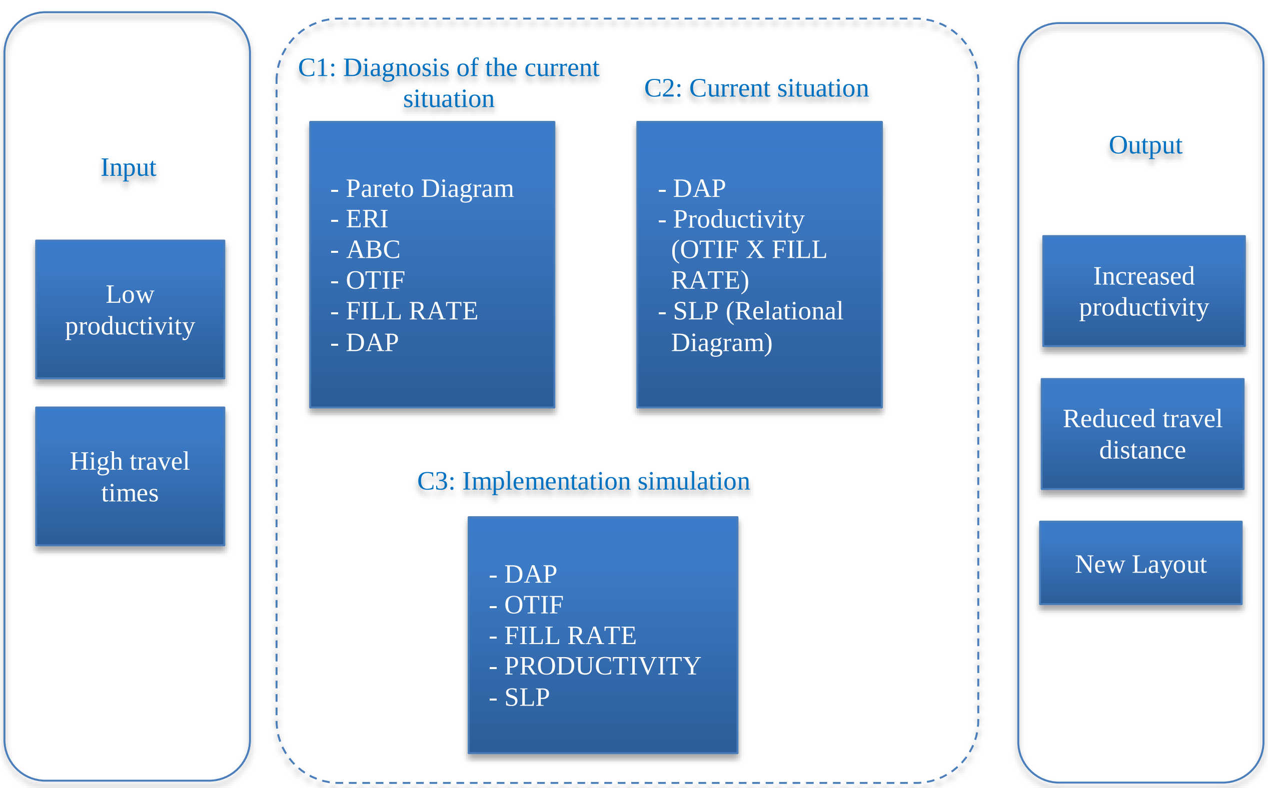

Fig. 11 Proposed solution model

Table 7. ABC Classification of Materials

Material Description	UM	Frequency Orders / Month	Utilization Percentage	Accumulated Percentage	Classification
CAT PISTON CODE 186-9177	UN	560	18.83%	18.83%	A
CONNECTOR 16 - 16FJX / FERRULE R12 - 16	UN	480	16.14%	34.97%	A
HDPE PIPE 2 1/2"	UN	285	9.58%	44.55%	A
EARPLUG WITH CASE	UN	240	8.07%	52.62%	A
14" NEOPRENE GLOVES	PAIR	178	5.99%	58.61%	A
HEXAGONAL BOLT 1/2"X10" (BLACK) NC FULL THREAD	UN	170	5.72%	64.32%	A
ENGINE AIR FILTER CAT 269-7041	UN	143	4.81%	69.13%	A
CLAMP CAT CODE 186-9428	UN	124	4.17%	73.30%	A
2" WATER HOSE X 1 METER	UN	120	4.03%	77.34%	A
7502 HALF-FACE SILICONE RESPIRATOR 02 WAYS 3M	UN	118	3.97%	81.30%	A
2" WHITE REFLECTIVE TAPE - DIAMOND (ROLL X 45 M)	UN	116	3.90%	85.21%	B
CHEVRON DELO GOLD ULTRA X 15W40 OIL (X 5 GAL)	UN	78	2.62%	87.83%	B
STEEL TOE SHOE SIZE 40	PAIR	68	2.29%	90.11%	B
LIME GREEN PADDED COVERALL SIZE M	UN	64	2.15%	92.27%	B
CLUTCH KIT (HINO)	UN	42	1.41%	93.68%	B
UPPER PISTON RING CAT CODE 344-5153	UN	32	1.08%	94.75%	B
ALUMINIZED RAYON JACKET SIZE M	UN	27	0.91%	95.66%	B
TIRE 12.00-20 20PR SUPER TIMBER KING PLUS GOODYEAR	UN	25	0.84%	96.50%	B
CONICAL DRILL BIT 38MM - CODE 50145	UN	25	0.84%	97.34%	B
HALOGEN-FREE CABLE N2XOH 3-1X95 MM2 0.6/1KV. ELCOPE CODE 10446D52G20037A	UN	23	0.77%	98.12%	B
FULLER GEARBOX TRACK KIT	UN	20	0.67%	98.79%	B
ALTERNATOR 020501005 CODE 020301003	UN	14	0.47%	99.26%	B
CEMENT TYPE 1 (42.5 KG)	UN	7	0.24%	99.50%	C
HYDRAULIC HAMMER HYDRONOCK MODEL FR3000	UN	4	0.13%	99.63%	C
ERGONOMIC CHAIR	UN	4	0.13%	99.76%	C
GAS DETECTOR DRAGUER X-am 5600	UN	3	0.10%	99.87%	C
CYLINDER HEAD FOR CATERPILLAR C32 ENGINE	UN	2	0.07%	99.93%	C
GENERATOR C9 CAT 300KW SERIES LX905204 / ENGINE SERIES: S9X07252 / MANUF. 2023	UN	2	0.07%	100.00%	C

The proposed solution model was developed based on the performance indicators established in this research, with productivity indicators to be simulated using the Arena simulation software. The ABC classification method is applied to prioritize products with the highest turnover and value within the warehouse. Items categorized as "A" are strategically positioned in easily accessible locations, reducing time and travel distance during operations. According to the data, the warehouse processes an average monthly frequency of 2,974 items in customer orders (Table 7).

Upon completion of the assessment matrix, a Relationship Diagram will be developed to visualize the interactions and required proximities among the various areas within the warehouse.

This diagram is constructed based on the frequency and relevance of inter-area relationships, as detailed in Table 8. The insights gained from this analysis will form the foundation for the subsequent step: the development of the Space Diagram.

In the Space Diagram, specific zones within the warehouse will be designated and arranged according to the proximity guidelines established in the Relationship Diagram. This organization aims to optimize material flow and enhance accessibility to high-turnover products, improving overall warehouse efficiency.

This matrix includes the values corresponding to the demand for the highest-turnover products. Additionally, the established routes for retrieving each product are represented, providing a comprehensive view of operational flows within the warehouse.

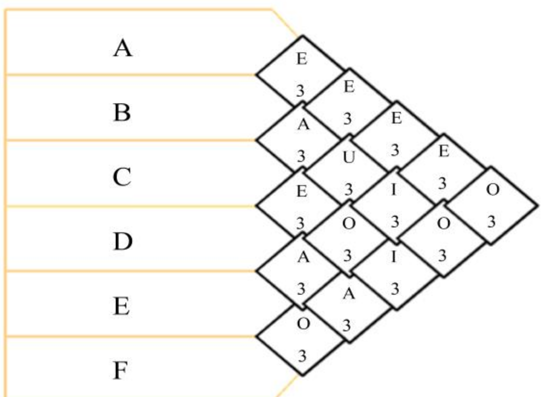

Fig. 12 Relational diagram

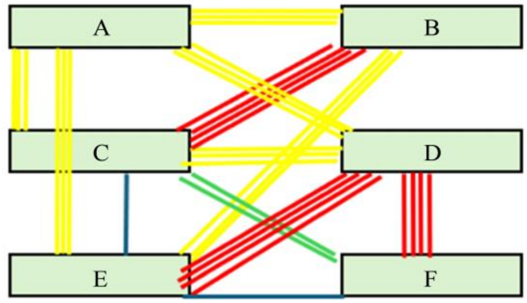

Fig. 13 Relational Space Diagram

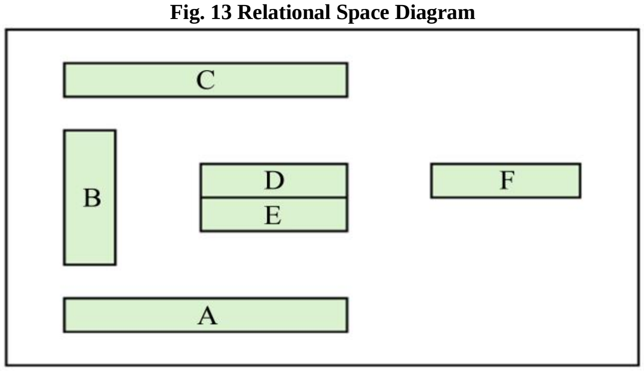

Fig. 14 Proposed layout

Table 9 presents a classification of activities based on the value contributions associated with the sales of each product, enabling a more strategic allocation of resources and prioritization of warehouse tasks.

The Relationship Diagram illustrates the significance of the connections between activities, establishing a hierarchy of priorities (Figures 12 and 13).

The spaces are connected using lines that reflect their predetermined levels of importance. Ultimately, a new U-shaped layout is proposed to enhance the overall flow of warehouse operations and improve efficiency.

Table 8. Valuation matrix

Product	Description	Average Monthly Demand	Route	Segments	Total Segments
1	CAT PISTON CODE 186-9177	560	A-B-C-D-E-D	5	2800
2	CONNECTOR 16 - 16FJX / FERRULE R12 - 16	480	B-C-A-D-F	4	1920
3	HDPE PIPE 2 1/2"	285	B-C-D-F-E-A	5	1425
4	EARPLUG WITH CASE	240	D-E-B-E-A-D	5	1200
5	14" NEOPRENE GLOVES	178	A-C-F-A-C-E	5	890
6	HEXAGONAL BOLT 1/2"X10" (BLACK)	170	C-D-F-C	3	510
7	ENGINE AIR FILTER CAT 269-7041	143	A-B-F-D-A-E	5	715
8	CLAMP CAT CODE 186-9428	124	D-E-A-B-F	4	496
9	2" WATER HOSE X 1 METER	120	A-C-F-A-D	4	480

Table 9. Positional rating

ACTIVITY	SALES	% Accumulated	CLASSIFICATION
D-F	1558	0.14	A
D-E	1484	0.14	A
B-C	1325	0.12	A
C-D	1015	0.09	E
A-D	983	0.09	E
A-C	956	0.09	E
A-B	827	0.08	E
A-E	792	0.07	E
B-E	480	0.04	I
C-F	468	0.04	I
A-F	298	0.03	O
E-F	285	0.03	O
B-F	267	0.02	O
C-E	178	0.02	O
A-A	0	0.00	U
B-A	0	0.00	U
B-B	0	0.00	U
B-D	0	0.00	U
C-A	0	0.00	U
C-B	0	0.00	U
C-C	0	0.00	U
D-A	0	0.00	U
D-B	0	0.00	U
D-C	0	0.00	U
D-D	0	0.00	U
E-A	0	0.00	U
E-B	0	0.00	U
E-C	0	0.00	U
E-D	0	0.00	U
E-E	0	0.00	U
F-A	0	0.00	U
F-B	0	0.00	U
F-C	0	0.00	U
F-D	0	0.00	U
F-E	0	0.00	U
F-F	0	0.00	U

The new Process Analysis Diagram (PAD) demonstrates a substantial improvement in operational efficiency, showing a reduced travel distance of 13.7 meters and a total execution time of 630 seconds. These metrics underscore the effectiveness of the proposed redesign in minimizing both travel and idle times during warehouse operations. Furthermore, the newly proposed layout in the route diagram reveals a significant enhancement in the efficiency of internal processes. The average time required to complete the route has been reduced to 10.51 minutes, while the total distance travelled now measures 13.6 meters (Figure 15). These improvements represent a notable optimization compared to the previous layout and directly contribute to increased productivity and reduced costs associated with unnecessary movement within the warehouse.

3.3. Indicators

The indicators are shown in Table 10.

Definition of terms:

- Effectiveness: The capacity to achieve desired objectives or outcomes, regardless of the resources utilized.
- Efficiency: The ability to accomplish objectives while minimizing the use of resources, time, and costs.
- Productivity: The ratio between the outputs generated and the resources employed to produce them.
- Route Diagram: A visual representation that outlines the movement of personnel, materials, or information within a process or physical space.
- ABC Classification: Method for prioritizing inventories according to their value or frequency of use.
- Warehouse Layout: The physical arrangement of operational areas, equipment, and inventory within a warehouse, aimed at optimizing workflow and space utilization.
- On-Time In-Full (OTIF): A key performance indicator measuring the Percentage of customer orders delivered on time and in the correct quantity.
- Fill Rate: A metric indicating the proportion of customer demand met through immediate stock availability within the agreed timeframe.
- Inventory Record Accuracy (ERI): A measure that compares recorded inventory data with the actual physical stock, reflecting the precision of inventory management.
- Relationship Diagram: A graphical tool that depicts the interactions and required proximities between different areas or processes, often used in layout planning and process optimization.

Table 10. Matrix of indicators

Objective	Indicator / Formula	Initial Evaluation	Target
Increase effectiveness	$Effectiveness = \frac{Delivered\ Orders}{Requested\ Orders} * 100$	87.92%	95%
Increase efficiency	$On\ time\ In\ full = \frac{One\ Time\ \% * \ In\ Full\ \%}{Delivered\ Orders} * 100$	87.41%	93.12%
Increase productivity	$Productivity = Efficiency * \ Effectiveness$	76.83%	88.46%

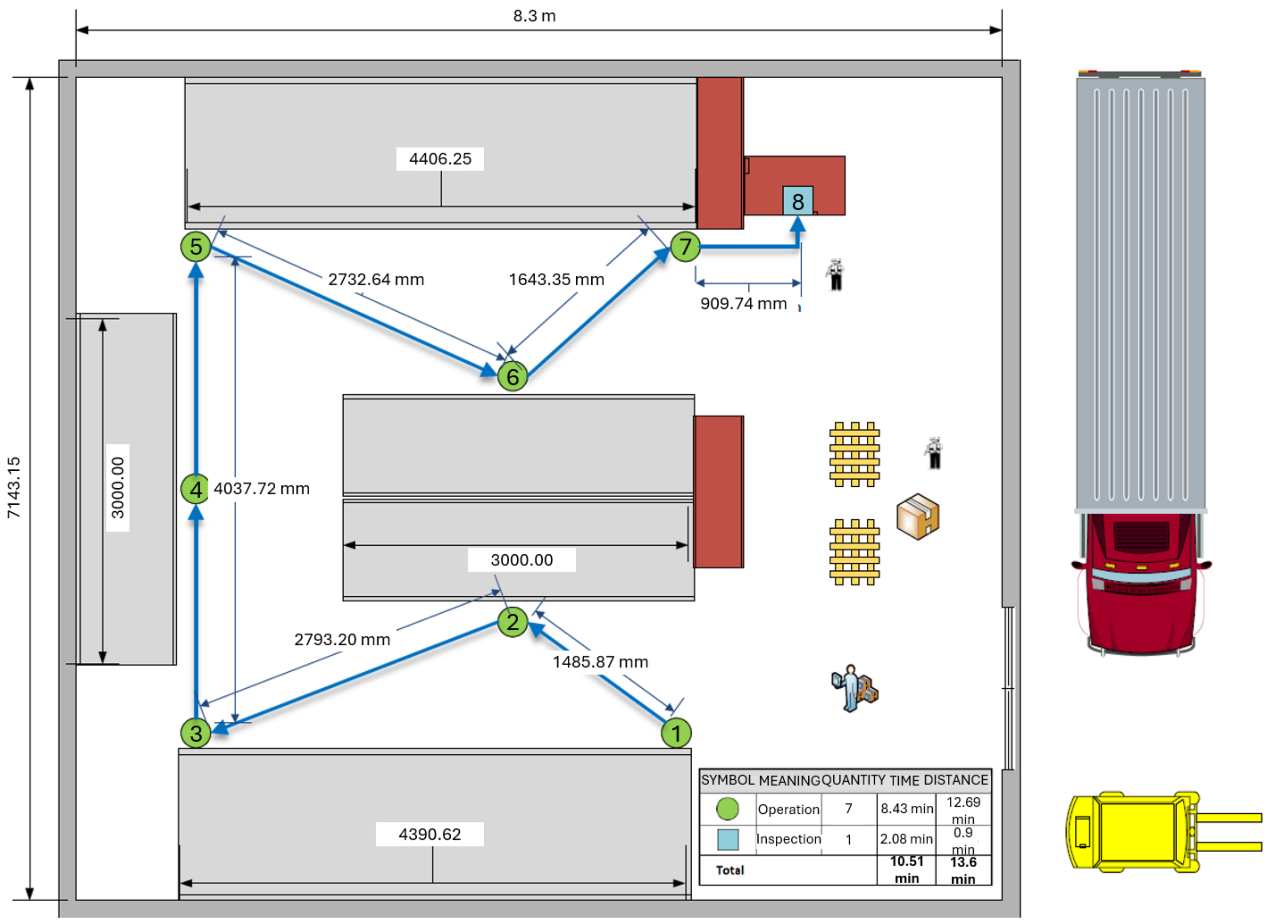

Fig. 15 New route diagram

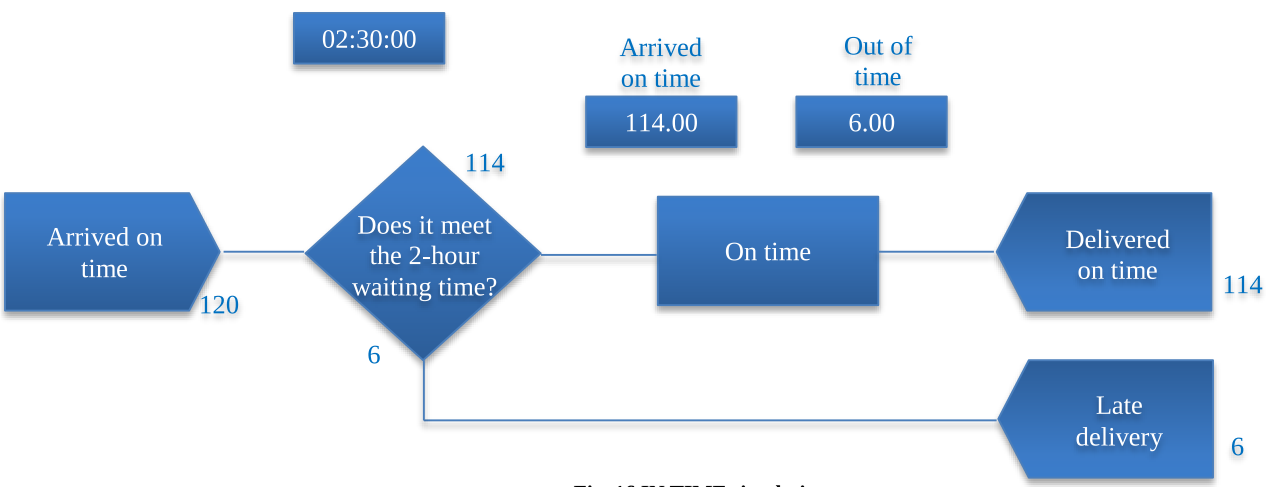

Fig. 16 IN TIME simulation

3.4. ARENA Simulation

A simulation was conducted using Arena Simulation software to analyze and optimize warehouse operations, focusing on evaluating the fill rate and the key variables associated with the OTIF (On-Time In-Full) indicator. The simulation model replicated current logistics system conditions, enabling the assessment of the potential impact of the proposed improvements. The results provided a quantitative foundation for identifying bottlenecks, refining operational processes, and enhancing service levels by ensuring customer orders' timely and complete fulfilment.

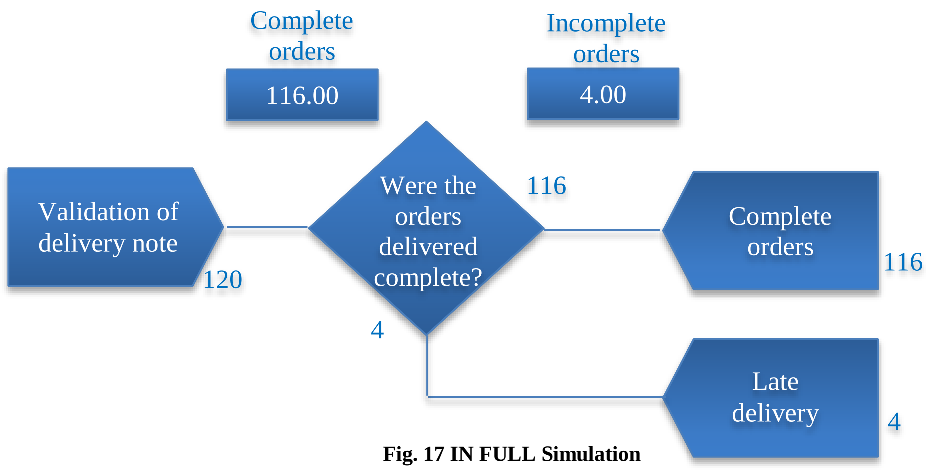

Fig. 17 IN FULL Simulation

4. Conclusion

Utilizing the appropriate analytical tools provides the necessary visibility to identify which techniques are required to enhance warehouse operations. In this study, the application of the Route Diagram, Ishikawa Diagram, Pareto Diagram, and Process Analysis Diagram (PAD) proved essential.

Initially, the FILL RATE and On-Time In-Full (OTIF) indicators were recorded at 87.92% and 87.41%, respectively-values that revealed opportunities for improvement in dispatch accuracy and delivery quality. Following implementing strategies to reduce travel time and distance, these indicators increased to 94.97% for FILL RATE and 93.12% for OTIF, reflecting improvements of 7.05% and 5.71%, respectively.

It is critical to highlight the role of simulation using Arena software in validating the redesigned layout and updated operational flows. The simulation confirmed notable enhancements in efficiency and effectiveness, ultimately leading to increased productivity from 76.83% to 88.46%.

The newly proposed layout, developed by integrating Systematic Layout Planning (SLP) and ABC classification techniques, facilitates a more efficient operational flow about time, travel distance, and product organization. Furthermore, its implementation does not require a significant financial investment, as it primarily involves a physical reconfiguration of the existing space-making it a highly viable and cost-effective solution.

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