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Procedure to Ensure On-Time Delivery of Materials in Multifamily Housing Construction Projects Using Just-In-Time and Kitting In Small Construction

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Abstract - Construction companies are responsible for purchasing materials for the execution of construction projects, which consist of different stages; however, many times the materials do not arrive on time at the construction site. The material supply process is important within construction projects as it directly impacts the budget and schedule of the work. However, one of the most influential factors causing the delay in the delivery of material is the lack of a logistics plan for the supply of material in small companies. However, this leads to delays in the progress and delivery of the work. For this reason, this research focuses on ensuring the delivery time of construction materials in small construction companies for multi-family housing construction projects, specifically in the supply of materials through the use of the Just in Time and Kitting methodology, applying the use of an ERP. In this research, the following methodology is followed: (A) registration and analysis of information through expert judgment, (B) determination of the conventional material supply process in small construction companies, (C) development of the new supply process and (D) implementation of the new material supply process using the JIT and Kitting methodology. Finally, the result is a reduction in the delivery time of materials in the supply process, the metric being the average delivery time. In addition, a better management of the material supply process is obtained, in the logistics part. And the perception of the participants improved with the implementation of the new process. It is mainly concluded that the methodology used allows to ensure the delivery time of material, thus reducing the time in said process.

***Keywords*:** Material supply; delivery time; logistics; Just In Time; Kitting; Construction management

1. INTRODUCTION

The construction of multifamily housing faces significant logistical challenges in material delivery. According to research, more than 50% of deliveries are not made on time due to logistical issues and planning deficiencies [1]. Delays in delivery negatively impact the schedule and productivity of the projects, affecting multiple activities and generating significant cost overruns [2]. Additionally, data from Systec Construction estimates that between 60% and 70% of direct costs are related to materials and equipment, highlighting the importance of efficient management [3]. It is also reported that 26% of delays come from supplier delays, causing a domino effect that extends the duration of the projects and increases operational costs [4]. The lack of logistical infrastructure exacerbates this issue, increasing variability and delays [5].

Efficient management of material delivery times has been widely studied through various methodologies aimed at optimizing the supply chain. In this context, the Just-In-Time (JIT) system is implemented to synchronize material delivery with specific construction needs, reducing waiting times and storage [6]. Furthermore, Tetik's research demonstrates that the kitting technique, by organizing materials into pre-packaged kits for assembly, improves productivity and workflow stability in renovation projects [7]. On the other hand, digital technologies such as BIM (Building Information Modeling) and RFID (Radio Frequency Identification) have shown significant improvements in material flow. Applying them leads to a 16.1% improvement in construction time through real-time inventory management [8]. Similarly, [9] presents a Kanban system enabled with BIM that updates material demand in real-time, increasing efficiency and reducing delays. Additionally, simulation and mathematical optimization approaches have shown relevant results: [10] uses mixed-integer programming models to optimize deliveries and reduce logistics costs by up to 15%, while [11] employ multi-objective algorithms to improve delivery reliability and reduce transportation times in post-disaster contexts. This research aims to ensure timely material delivery, improve coordination between project stakeholders, and reduce operational costs through a Lean Supply Chain approach. A procedure based on Just-In-Time (JIT) and Kitting will be developed, adapted for small construction companies, aiming to reduce costs, minimize waste, and optimize efficiency and productivity in multifamily projects.

2. METHODOLOGY

To develop the proposed methodology, a quantitative and qualitative approach is adopted for a procedure that ensures timely material delivery in multifamily housing construction projects. This procedure is based on the Just-In-Time (JIT) and Kitting methodologies, specifically applied to small construction companies. To carry out this study, the research process methodology is developed, as in Fig. 1.

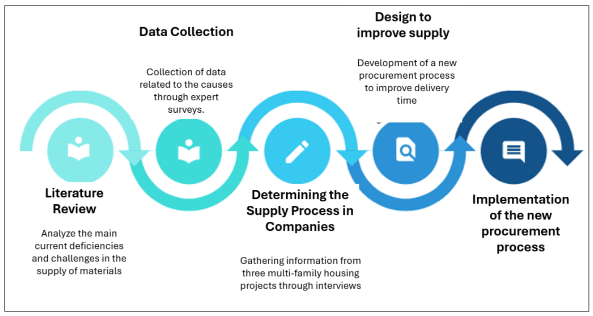


Fig: 1. Research Process Methodology

In the current state, material supply issues in construction projects are identified through the analysis of recent scientific articles and surveys of professionals (Table I), using a data collection technique that allowed for a better understanding of the situation and provided reliable data for analysis. The survey diagnosis reveals critical deficiencies, such as the absence of a logistics plan, communication problems between departments, failures in the coordination of acquisitions and deliveries, and the receipt of materials that do not meet technical specifications. Additionally, although supplier evaluation exists, there is a need to strengthen strategic planning, staff training, and data systematization. Table II presents the evaluated projects, where, through interviews, the supply process in the structure and finishing stages, the most requested materials, and supplier partnerships were identified. The analysis of three small construction companies shows a simple supply process, without a formal logistics department, where quotations and purchases are managed by the contractor, who assumes multiple roles without an organized information storage system. The process begins with the material request by the site manager, reviewed and approved by the administrator. Among the main identified issues are delays in delivery and lack of coordination with suppliers, causing project delays, cost overruns, and inefficient use of resources. In response, a solution is proposed based on the observed supply flow, integrating tools such as ERP software, the Just-In-Time (JIT) philosophy, the Kraljic matrix, and the Kitting methodology, aiming to optimize the planning, storage, and delivery of materials, thereby increasing the operational efficiency of small construction companies.

	Professionals surveyed by positions in the project	
Characteristics	Resident Engineer and Production Engineer	Logistics
Number of professionals interviewed	7	9
Average years of experience in the residential building industry	9	10

Table 1: Interviewed Professionals

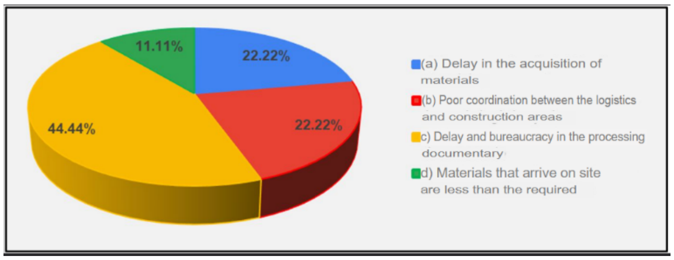
	Summary of Evaluated Projects		
Characteristics	Project 1	Project 2	Project 3
Company type	Small	Small	Small
ect type	Multifamily Housing		

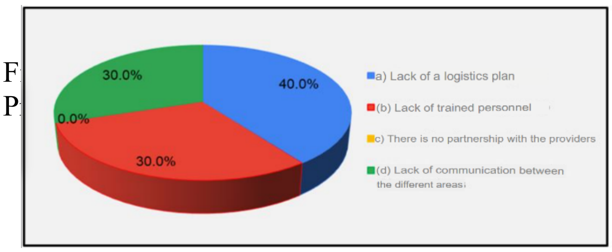
Table 2: Summary of Evaluated Projects

3. RESULTS

3.1. Recording and analysis of information

Interviews were conducted with construction site residents in residential projects to identify the main issues in material supply. The results show (Fig. 2) that the biggest problem is delays and bureaucracy in the documentation process (44.44%), followed by delays in material acquisition and poor coordination between logistics and construction, both at 22.22%. Additionally, 11.11% indicated that the materials received were fewer than requested. The main causes identified (Fig. 3) by the residents were the lack of a logistics plan (40%), lack of trained personnel, and poor communication and coordination between the involved areas.





In the second stage (Fig 4), logistics staff were interviewed, with results showing that the primary issue is the lack of coordination between logistics and construction departments (43.75%), followed by delays and bureaucracy in the documentation process (25%). Delays in material acquisition and discrepancies in delivered quantities were also mentioned (12.5%). Finally, 6.25% pointed out the lack of order planning as a contributing factor to logistics inefficiencies. They also suggested (Fig 5), that the main causes of the mentioned issues are the lack of communication between different areas, with 43.75%, and the lack of a logistics plan, with 37.50%. The surveys and analysis of the opinions of construction and logistics engineers reveal that the main deficiencies in material supply are delays and bureaucracy in the documentation process, as well as poor coordination between logistics and construction, caused by the lack of a structured logistics plan.

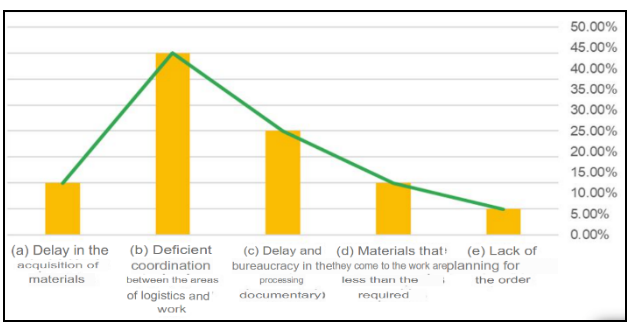


Fig. 4: Main Deficiencies in the Logistics Process for Logistics Department Engineers

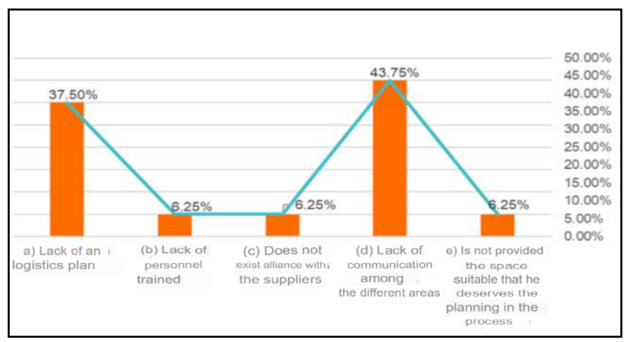


Fig. 5: Main Causes in the Logistics Process for Logistics Department Engineers

3.2. Delimitation of the Traditional Process

After creating the flowchart for these three companies, a detailed comparison of their supply processes was made. It was identified that these processes show significant similarities, mainly due to the simplicity inherent in smaller companies. These companies typically operate with a basic supply flow, involving a small number of stakeholders, and lack a dedicated logistics department.

The process begins on site, where the production area requests the materials through the production engineer. The production engineer submits the request to the resident engineer on site, who validates that the material is correct. Then, the request is sent for approval by the administrator, who signs and verifies the amounts to approve the budget. From there, the contractor is tasked with obtaining the materials, who is responsible for quoting and purchasing them. After purchasing the materials, coordination with the suppliers for delivery and reception at the site takes place. The supply flow in this company is simple; material quantities and balances are recorded in Excel.

The main deficiencies include the absence of a supply plan, as requests are generated based on the progress of the schedule and construction activities. Additionally, there is an integration issue among the supply chain actors, specifically between suppliers and contractors, which often causes delays in material delivery, impacting on the continuity of the planned work. The flowchart shown in Fig. 6 describes the traditional process. Based on the previous scheme, it was found that the average delivery time for corrugated steel in the structural phase of this company's project is three days on average (Fig 7).

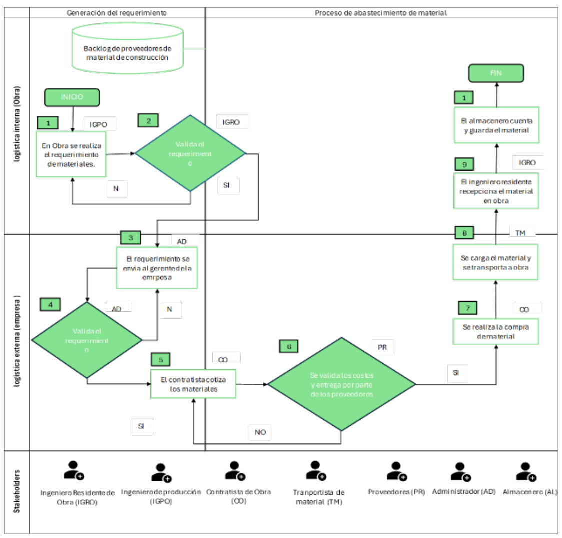


Fig. 6: Flowchart of the traditional supply process

APPLICATION DATE	SUPPLIER	QUANTITY	DELIVERY TIME	Average material entry time
16/07/2024	Aceros Arequipa	2.20 TON	2 days	3 days
23/07/2024	Aceros Arequipa	2.90 TON	3 days	
30/09/2024	Inkaferro	4.5 TON	3 days	
07/10/2024	Inkaferro	5.2 TON	4 days	

Fig. 7: Average material delivery time for Atlas company with traditional flowchart

3.3. Development of the new process

Based on the situation diagnosis, the construction companies interviewed face issues related to delays in material delivery. A solution is proposed to optimize supply chain management in small construction companies. Using the material supply flow of the interviewed companies as a basis, we adapted our proposal to an average flowchart to improve this process. The proposal integrates tools such as ERP software, the Just-In-Time (JIT) philosophy, the Kraljic matrix, and the Kitting methodology, with the goal of improving planning, storage, and delivery of materials.

In Fig. 8, the process begins with the generation of the material request on-site by the engineer, who sends it to the resident for verification. Once validated, the request is forwarded to the logistics department for registration in the ERP system. Then, the materials are classified using the Kraljic matrix, and the purchase of critical materials is prioritized. If stock is insufficient, quotations and purchases are made from trusted suppliers. A minimum reserve of essential materials is created to apply Just-In-Time (JIT). Finally, deliveries are organized in kits, and delivery is managed by integrating JIT and Kitting, ensuring efficiency and punctuality. In Fig. 9, a detailed flowchart of how to use the Odoo ERP software is shown, which is involved with our main flowchart. It will help us develop steps 4, 8, and 12. In Fig. 10, a flowchart of the use of the Kraljic matrix is shown, which we will use in step 5 to select bottleneck materials, which are essential in the construction process, so their purchase should be expedited, and the JIT philosophy will be applied. This matrix will also help us identify materials to be grouped into Kits.

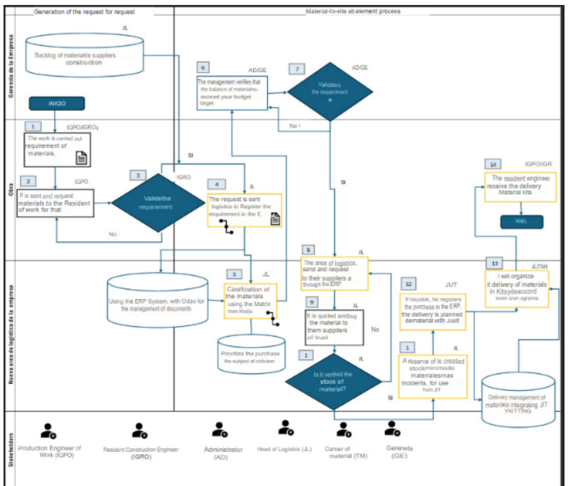


Fig. 8: Flowchart of the implementation proposal

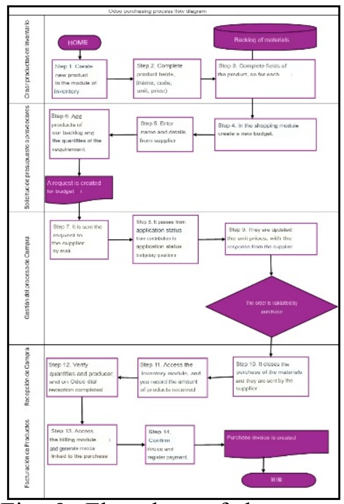


Fig. 9: Flowchart of the use of Odoo software

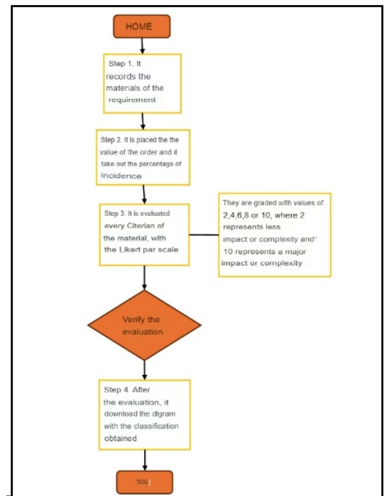


Fig. 10: Flowchart of the use of the Kraljic matrix to classify materials.

3.4. Implementation of the proposal.

We identified the area and key people who require training. Currently, the project is in the structural phase, and an analysis was conducted to determine the specific training needs. During the organizational mapping, we identified that the site supervisor, responsible for logistics and material supply, is one of the main individuals who requires training. Additionally, warehouse staff are included, as they play a crucial role in the efficient management and control of materials. The following outlines the implementation of the proposal for the supply of steel.

Step 1 – Installation of Odoo software on the site engineer's, logistics, and warehouse staff computers: The first step involved entering the technical office and the site warehouse. Next, we shared the Odoo software with the site engineer to monitor orders from their computer. Afterward, we checked that the software was functioning correctly.

Step 2 – Generation of material requests and their registration in the ERP: Based on the progress of the construction and the need for materials, new material requests are generated to ensure the continued progress of the project. The site engineer creates and verifies these requests. After creating the material request, the engineer proceeds to load the material information into the Odoo ERP database (Fig. 11) to then proceed with material quotation.

Step 3 – Classification of materials using the Kraljic matrix: In this step, the site engineer classified the most demanded materials in the structural phase, applying the criteria from the matrix and an Excel template (Fig. 12). It was identified that rebar is a strategic material, while prefabricated beams and ready-mixed concrete are bottlenecks and should be prioritized for purchase.

Step 4 – Approval of the request by management and material quotation via the ERP: The site engineer sends the request to a company representative for approval due to the high cost of the steel purchase. Afterward, the material is quoted in the ERP, generating quotation requests (Fig. 13) that are sent by email.

Step 5 – Material purchase from suppliers: After quoting the material, the site engineer proceeds with the purchase according to the request, generating purchase orders (Fig. 14). Shipping conditions are defined, specifying whether the cost of shipping is included in the price.

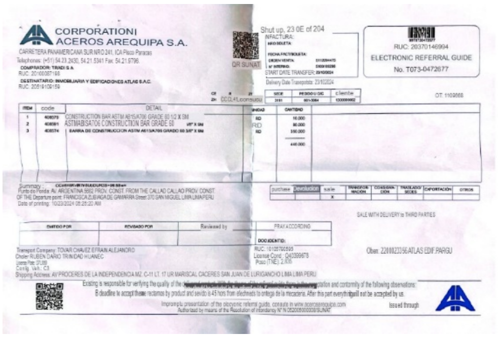


Fig. 11: Registration of material requests in the Odoo ERP system.

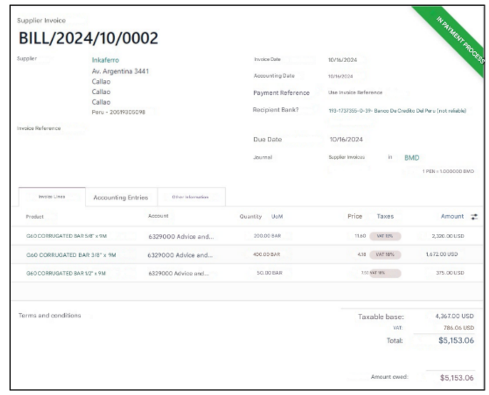


Fig. 12: Classification of the most critical materials using the Kraljic matrix.

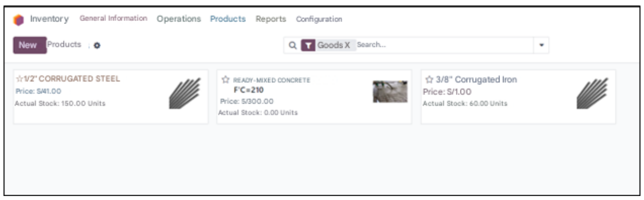


Fig. 13: Generation of quotation.

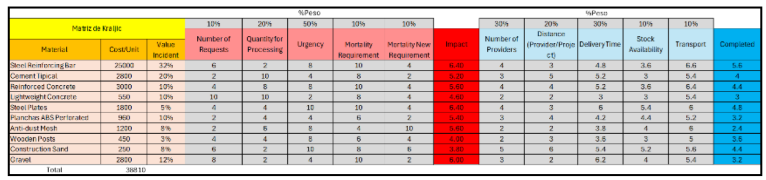


Fig. 14: Generation of purchase orders.

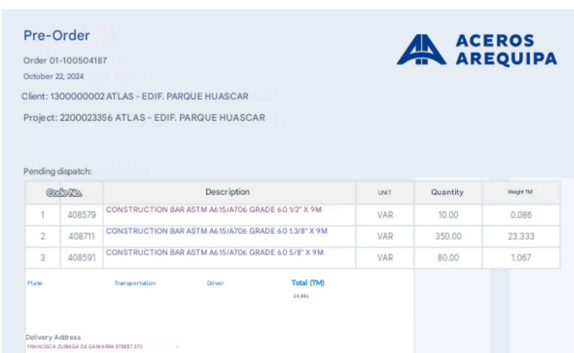


Fig. 15: Request for delivery guide from the supplier

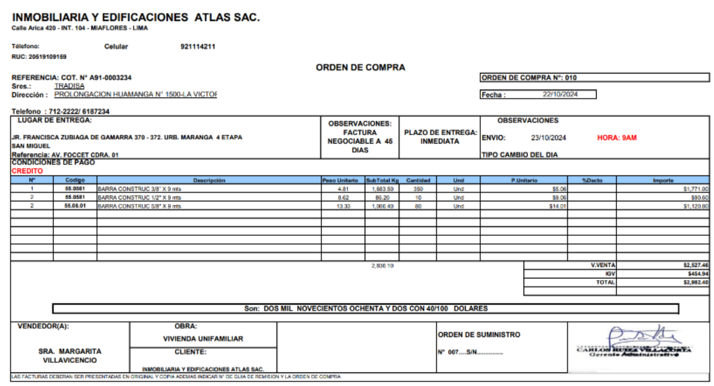


Fig. 16: Material delivery and invoicing registration in the ERP

. **Step 6** – Reception of materials at the site and new stock registration in the ERP: The site engineer receives the material delivery and verifies that it is complete according to the quantity requested in the purchase order. The delivery note is requested from the supplier (Fig. 15), and the material is stored in the designated location on the layout. Then, the new material stock is registered in the ERP, and the invoices are stored (Fig. 16).

Step 7 – Material storage and grouping into kits: Once the staff stores the materials in the project warehouse, we proceed to group them. The materials are organized into kits, following the quantities specified in the schedule, according to the assigned activity.

4. ANALYSIS AND INTERPRETATION

According to the factors defined in Part 3, it was found that the main problems are delays and bureaucracy in the documentation process, along with poor coordination between the logistics and construction areas, caused by the lack of a logistics plan for material supply to the construction site. In the traditional supply process, we identified the problem of the absence of a logistics plan, which is reflected in the average delivery time of 3 days because the project engineer must register the material requirements on one platform, manage quotations on another, and complete the purchase on a third, in addition to waiting for the company's administrative approval. This fragmented process increases management time and is also affected by suppliers' response times. In contrast, the proposed solution reduces the average delivery time to just one day, representing a 66% reduction compared to the traditional system. This improvement is due to the implementation of the ERP, which centralizes all the project engineer's tasks in one platform: requirement registration, quotations, purchasing, administrative approval, and invoicing. This enables more efficient control and tracking of purchases. Furthermore, the Just-In-Time (JIT) approach ensures that deliveries are scheduled according to the immediate needs of the project.

5. VALIDATION

After the implementation of the proposed methodology and the simulation of the steel material supply process during the structural phase, its effectiveness was validated by comparing key performance indicators before and after applying the improvements. The goal of implementing JIT and Kitting was to ensure timely delivery of materials. Two supply phases were compared: the traditional approach and the improved process, showing a reduction in delivery days while maintaining the supplier compliance rate. Delivery time was reduced from an average of three days to one, achieving a two-day reduction in the process. Additionally, staff satisfaction was measured through Likert-type surveys, resulting in an overall acceptance of the implemented tools, with satisfaction increasing from "Satisfied" to "Completely Satisfied", Fig 17. The results support that the use of the ERP, JIT philosophy, and Kitting batches improved the efficiency and reliability of material delivery, optimizing the supply process.

Fig. 17: Comparison of satisfaction before and after.

6. CONCLUSION

The implementation of the new supply process through a guide to ensure material delivery time, using the JIT and Kitting methodology, has proven to be effective. This research achieved a reduction in the average material delivery time to the site by approximately two days, from the three days typically required in the traditional process to just one day with the new process. This improvement was made possible by centralizing information in one area, optimizing the traditional material supply process. Furthermore, regarding the perception of the participating staff, surveys indicated a shift in satisfaction levels from "Satisfied" to "Completely Satisfied" concerning the material supply process. The proposal improved the experience of internal customers (site supervisor, warehouse staff), generating a positive impact that reinforces the importance of a well-structured and managed supply system.

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