Digital transformation as an approach to a warehouse 4.0

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Jesús Alberto Morales Rico [1]
Mauricio Alonso Pérez Ávila [2]
Lien Neil Tejeda López [3]
José Abel Carrasco Mora [4]

Abstract

Shipbuilding and ship repair projects require a complex variety of materials, including raw materials, supplies, consumables, equipment, and spare parts. These materials demand a robust process for effective materials management. Shipyards, especially those that combine shipbuilding and ship repair business units, face the challenge of variability in terms of the number of projects, which intensifies the demand and variety of items required. The materials management process includes sub-processes such as material requirements planning, receiving and shipping operations, inventory control, supplier-managed inventory, and the promotion of turnover. Consequently, the challenge for warehouse managers is to coordinate and streamline these activities to help maintain high levels of productivity in shipbuilding and ship repair projects. The purpose of this article is to analyze how disruptive technologies within the framework of Industry 4.0 can help warehouse managers address current and future challenges, particularly those arising from the diverse and dynamic nature of projects within an engineer-to-order system oriented toward project-based production. This includes exploring best practices, identifying opportunities for improvement, and formulating an implementation plan that incorporates both procedural and technological advancements.

Key words: Materials management, digital transformation, industry 4.0, disruptive technologies, shipyard 4.0.

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COTECMAR. Cartagena, Colombia. ROR: https://ror.org/01z04wv09
[1] Email: jamorales@cotecmar.com
[2] Email: mauperez@cotecmar.com
[3] Email: ltejeda@cotecmar.com
[4] Email: jcarrasco@cotecmar.com

Introduction

Industry 4.0, also known as the fourth industrial revolution, refers to an ecosystem that leverages the Internet of Things (IoT), new technologies, and cyber-physical systems to digitally transform factories [1]. As mentioned in the literature, the fourth industrial revolution [2] introduces disruptive technologies that fundamentally change how ecosystems operate and generate new business strategies. The adoption of digital technologies rapidly transforms organizations, driving them toward digital transformation [3].

Digital transformation is the process by which a company incorporates the technologies of the fourth industrial revolution across all its areas. This process fundamentally changes how the company operates, delivers value to its customers, and achieves its objectives more efficiently [4]. Additionally, the path to digital transformation requires alignment across all sectors of the organization, along with uniform leadership, as business units may have their own strategies for undergoing digital transformation [5].

Furthermore, digital transformation and innovative approaches significantly impact organizations [6]. If competitors quickly adopt new technologies, they can achieve a significant competitive advantage, positioning themselves more favorably in comparison to their rivals. In the case of warehouses, the industry is moving toward automation and digitization [7]. Intelligent warehouses can enhance productivity by reducing the number of decisions required and enabling strategic decision-making based on real-time warehouse data.

Technological tools play a crucial role in warehouse logistics. For example, IoT enables communication between physical and computerized objects through data collected by sensors [8]. Virtual reality devices can be used to visualize material names and locations in real time within physical spaces, while robots and drones can handle tasks such as inputs, outputs, inventory reviews, and counting. However, while these technologies have the potential to transform warehouse operations and logistics, their implementation requires thorough financial and technical studies.

At Cotecmar's warehouse, the procedures for material requirements planning, receiving and shipping operations, inventory control, supplier-managed inventory, and promotion of turnover fall under the broader materials management sub-process. Given this framework, warehouse managers face the challenge of coordinating and streamlining these activities to contribute to high productivity levels in shipbuilding and ship repair projects.

As mentioned in the literature, the incorporation of Industry 4.0 technologies will transform warehouse logistics by integrating automated computer systems that work collaboratively with humans, enhancing the effectiveness and efficiency of processes [9]. However, as noted in the research, organizations must follow a roadmap for digital transformation since it is not a change that can be implemented overnight [10].

Given this context, the objective of this article is to identify procedural improvements and determine the Industry 4.0 technologies applicable to the materials management sub-process of the Warehouse and Distribution Division at Cotecmar, located in Cartagena de Indias, Colombia.

The remainder of the article is organized as follows: Section #2 presents the methodological framework that was used in the course of the research; Section #3 describes the development of the research following each of the methodological phases; Section #4 details the conclusions and future work that may derive from the research; and Section #5 presents the acknowledgements. Section 2 presents the

methodological framework used during the research. Section 3 describes the research development process, following each of the established methodological phases. Section 4 outlines the conclusions and future work derived from the research. Section 5 provides acknowledgments.

Methodology

For the methodological development of this research, an adaptation of the methodology proposed by Frazelle [11], used for improving logistics processes in a warehouse, was applied. The methodology was divided into three phases (see Fig. 1).

Fig. 1 shows the following:

- Phase 1 - Research: In this phase, a literature review was conducted on digital transformation, Shipyard 4.0, and the current state of Shipyard 4.0 at Cotecmar. Additionally, specific literature on the 4.0 supply chain and logistics innovation techniques was reviewed. A state-of-the-art analysis of digital transformation projects in materials management was conducted using the business benchmarking tool to identify potential improvements within the materials management sub-process.

- Phase 2 - Innovate: During this phase, each procedure within the materials management sub-process was reviewed in detail. Initially, the way procedures are performed daily was compared to their theoretical descriptions. This phase also included an analysis of the technological capacity currently available to the sub-process and a detailed characterization, which formed the foundation for designing a digital transformation plan.

- Phase 3 - Implement: Based on the detailed characterization, this phase explored procedures that could be digitally improved and identified 4.0 technologies suitable for implementation. High-level designs and sketches were created, and meetings were held with Cotecmar's experts in 4.0 technologies to develop an improvement plan for the materials management sub-process.

Development of the research

This section outlines the research development process, following the phases described in Fig. 1.

Phase 1

The first phase focused on understanding digital transformation as a transversal change across an organization when digital technologies are adopted. Simultaneously, the concept of Shipyard 4.0 was explored as a framework in which all shipyard operations are supported by Industry 4.0 technologies.

At Cotecmar, the Shipyard 4.0 approach is discussed in prior research [12], which concluded that the transition toward Shipyard 4.0 is currently undefined. While the digital transformation process is supported by senior management, there is no strategy

Fig. 1. Methodological design used in this research.

detailing the "what," "how," and "when" for organizational transformation. Moreover, there is no designated leader responsible for the process.

Nonetheless, if Cotecmar wishes to maintain its status as a national leader, it must eventually embrace digital transformation to move toward Shipyard 4.0. This transition is considered essential for sustainable competitive development, as the implementation of Shipyard 4.0 [13] is not optional but necessary.

Benchmarking process. Business benchmarking can be defined as a tool in which internal processes are observed and compared with the way they are performed in other companies [14].

The purpose of this phase was to observe how information technologies are implemented in materials management at comparable organizations. Benchmarking exercises were conducted with companies in the region that have similar material management needs, including Argos.

In Argos' case, distribution is carried out using a home delivery system that delivers supplies and spare parts directly to production areas. Argos also promotes the use of QR codes integrated with high-level Microsoft Power BI interfaces, which provide warehouse inventory and financial information on purchases and sales.

Phase 2

To fulfill the second methodological phase, a detailed review was conducted of each procedure carried out in the materials management sub-process. The purpose was to detect procedural shortcomings and identify steps that could be improved, as well as those that could be digitally transformed.

To introduce improvements to a system, it is necessary to understand what is done, how it is done, when it is done, and other details that provide insight into its operation. Each procedure was reviewed individually and compared with the way it is performed daily by the personnel. This review revealed a series of documents that hinder the digital transformation process, as shown in Table 1.

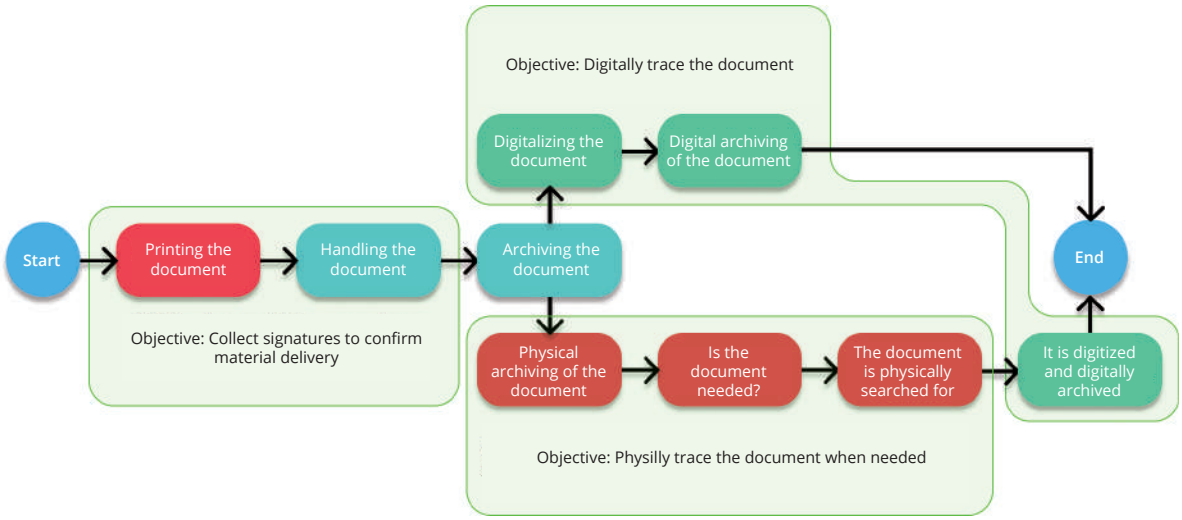
Based on Table 1, it was observed that the documents follow a specific pattern (see Fig. 2). Generally, once documents are created, they are printed for manual handling, such as adding signatures or filling in data. These documents are archived either physically or virtually. In the case of physical archiving, documents are digitized as needed.

Following this, the tools used to comply with the identified pattern were analyzed. It was

Table 1. Documents susceptible to be digitized.

Procedure	Documents	Frequency
P-GESLOG-003	Warehouse receipt and issue documents Referrals Endowment delivery document Packing list of materials Record of delivery of the materials.	Daily
P-GESLOG-004 P-GESLOG-005	Document for inventory taking	Media
P-GESLOG-015	Delivery of materials sold in inventory	Download

Fig. 2. Current pattern identified.



observed that desktop and laptop computers are primarily used, and most documents are generated using widely available tools like Word, Excel, and SAP ERP software. The technological tools currently available in the warehouse were also assessed:

- 10 computers, including 6 desktops and 4 laptops.
- 2 PDAs with barcode readers (currently not in use).
- 2 routers located in the main warehouse.
- 1 Samsung Galaxy A6 tablet with Stylus.
- 1 55-inch interactive whiteboard.

However, the Wi-Fi coverage is limited, with strong signals mainly in the Alpha Zone, weak signals in the Delta Zone, and no connectivity in the Bravo Zone. From a systems engineering perspective, some of the computers lack the performance required to handle the increasing number of transactions over the years. Furthermore, several devices experience technical issues that slow or freeze operations. Table 2 provides example data used to calculate the cost of lost productivity due to these issues.

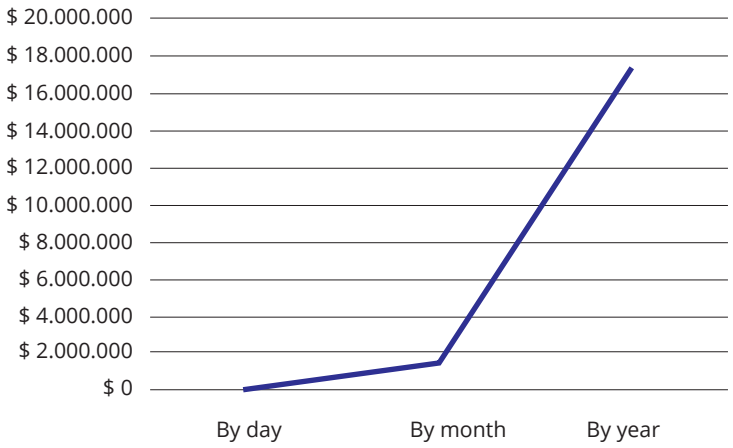
Using this data, it was estimated that working days per year total 246, with 20 working days per month. The losses amount to approximately 70,000 Colombian pesos per day. Fig. 3 illustrates the total cost of these losses per month and year.

As shown in Fig. 3, inadequate computer performance results in considerable annual resource losses, in addition to reduced staff productivity and potential customer service deficiencies. This issue is exacerbated by the

Table 2. Example data for calculating cost per lost hours.

# of Persons	% of hours affected	Hours computer failure	Pesos/Hour	Cost per lost hours
3	20%	1,6	55,000 COP	52,800 COP
4	10%	0,8	55,000 COP	17,600 COP

Fig. 3. Losses due to computer failures.



need for physical document handling, which introduces extra steps to the process.

To design a relevant solution for transforming the current pattern of the sub-process (see Fig. 2), it is necessary to understand why each step is performed and the underlying reasons for the procedure.

As seen in Fig. 4, for the material issuance procedure, it is necessary to collect the signature of the recipient to ensure a record of material delivery. These documents are then physically archived for future reference, if needed.

The problem lies in the need to print and store these documents physically. This requires additional space in the warehouse for shelves to archive the documents. Furthermore, if documents are no longer needed, they may remain on the shelves indefinitely, occupying valuable space and creating inefficiencies when searching for specific records.

To address these issues, an improvement is proposed that relies on a new digital pattern (see Fig. 5) and includes technological upgrades for the warehouse computers.

Fig. 4. Background reasons for the activities.

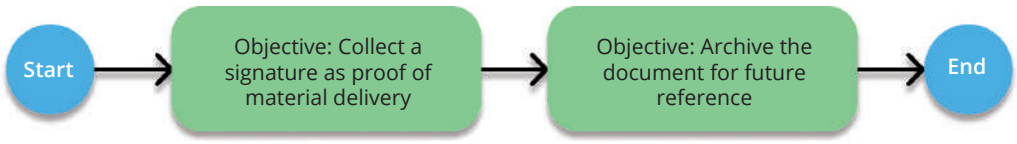
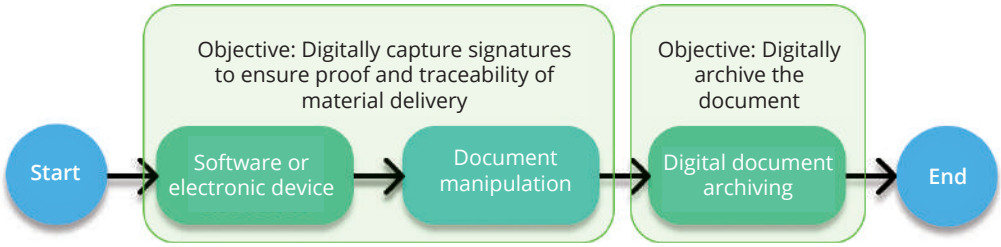


Fig. 5. Proposed pattern.



As shown in Fig. 5, implementing a new pattern that allows documents to be handled digitally through software or electronic devices significantly reduces the number of procedural steps. This improvement enhances productivity and efficiency in document management and retrieval. Additionally, digitally archived documents facilitate the use of artificial intelligence software to analyze stored data and predict material or supply orders.

Phase 3

To complete the third phase of the methodology, high-level designs or mockups were developed to illustrate potential implementations of 4.0 technologies in the materials management sub-process. The focus of this phase is to achieve early victories—small, easy-to-implement changes that bring immediate improvements to the procedures.

Based on the research conducted during the first phase, several potential applications and solutions for materials management were identified. These include: Using radio-frequency identification (RFID) for material identification and tracking; Implementing IoT systems, such as telemetry to monitor tank levels, detect leaks, and track historical data; Using sensors to measure temperatures in special-condition storage rooms; Employing autonomous robots and intelligent machinery for material entry, exit, organization, inventory tracking, and even warehouse cleaning. Utilizing augmented or virtual reality systems to improve material search and inventory processes.

However, due to the high initial implementation costs of these technologies (e.g., robotics, drones, autonomous vehicles, IoT), their cost-benefit ratio is not favorable in the early stages of the research. Therefore, the following technologies, listed in Table 3, are proposed for initial implementation.

The technologies in Table 3 were selected because they are the most practical and relevant to the daily activities performed in the materials management sub-process.

One critical proposal is implementing a system for electronic and/or digital signatures, which is essential for tracking material deliveries. This activity, performed daily in the warehouse, has a significant impact on the digital transformation process. A new system design is presented in Fig. 6.

As shown in Fig. 6, the nature of the activity remains unchanged, even with the proposed modifications. This reflects the essence of digital transformation: achieving objectives more effectively and efficiently with the support of digital technologies.

Table 3. Possible 4.0 technologies currently applicable.

Technology	Implementation possibilities
Artificial Intelligence	• Collect information about incoming and outgoing materials and create a predictive model to aid decision making when generating purchase orders. • Design a predictive model to generate a bill of materials according to a specific type of project (construction, repair or maintenance).
Automation	• Creation of automations that gather information from documents or spreadsheets. • Creation of flows that allow the generation of data crosses from different spreadsheets.
QR Codes, Bar Codes	• Streamline the way in which activities such as inventory taking are carried out and allow for quick identification of materials.
System for taking electronic and/or digital signatures	• Digitize the way in which document signatures are taken, allowing them to be done through an electronic device, streamlining the flow of the procedure in order to serve customers.

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Fig. 6. New pattern using electronic/digital signature.

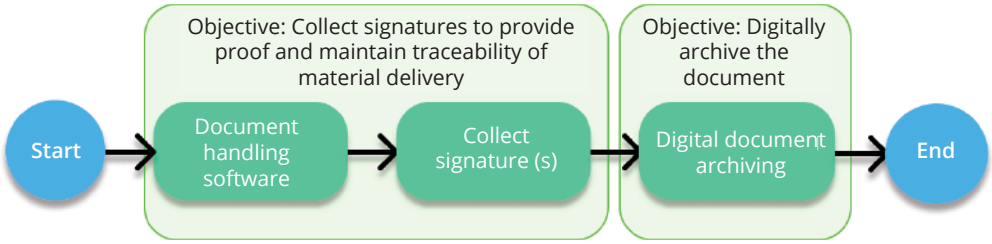
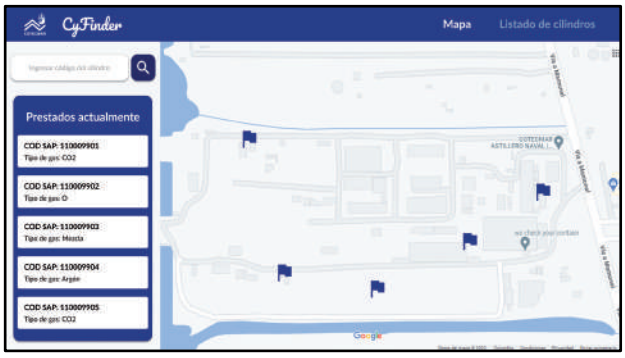
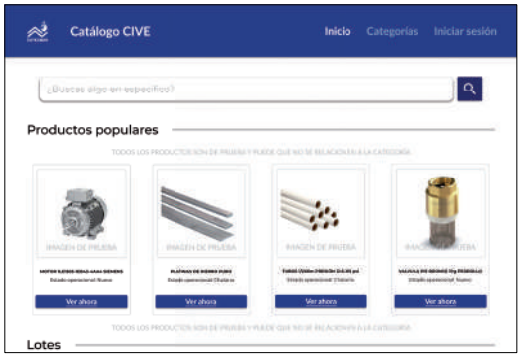


Fig. 7. Mockups created during the research.





Additionally, mockups were created to define and refine ideas for subprocess improvements. Two specific designs are shown in Fig. 7.

These mockups illustrate potential warehouse improvements, including an application for the geographic location of cylinders and a materials catalog. The intention is to continue developing web-based applications to enhance the materials management sub-process.

For automation, Cotecmar has access to the Microsoft application package, which includes Power Automate for process automation and Power BI for database visualization. These tools can be used at no additional cost and would significantly aid in monitoring costs and material movements over specific periods.

Conclusions and future work

This study identified key procedures with the potential for implementing 4.0 technologies to support the initiation of digital transformation in the materials management sub-process.

The methodology provided a clear vision of the scope of the proposed improvements. Initially, research was conducted on digital transformation, Shipyard 4.0, and the technological solutions used by companies like Argos to address material distribution challenges. This was followed by an analysis of each procedure, comparing theoretical descriptions with actual daily practices. Finally, in collaboration with warehouse personnel, technologies applicable to the digital transformation process were identified.

The digital transformation process is intended to begin in the Warehousing and Distribution Division of Cotecmar's Administrative and Financial Department, located in Cartagena, Colombia.

Future work will focus on enriching the implementation phase by pursuing early victories through procedural and technological

solutions. Additionally, efforts will be made to develop and introduce improvements to the SAP ERP system used by the corporation.

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About this article

The authors of COTECMAR who participated in the article declare that they were not involved in the review, evaluation, selection and publication phases of this article.

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