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Digital Transition on the Factory Floor: An Interoperable Application for Web Forms Management

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Summary: One of the main challenges in modern industrial environments is managing the large amount of physical documentation obtained during the production process, with companies increasingly seeking to adopt paperless alternatives. In the shop floor, each production line typically uses forms to check parameters conditions before and after production starts. The volume of paper documentation generated from these forms has created the need for a digital platform to streamline and digitize records, making the process more sustainable and efficient. This new interoperable web application provides various features for enhancing productivity, including form creation, customization, submission, and approval. Additionally, it automatically generates notifications and alerts to address specific situations, helping users react more quickly to production needs. By unifying all processes related to form management within a digital infrastructure, this solution modernizes the factory floor, reducing reliance on paper and incorporating innovative digital and industrial advancements.

Keywords: Digital transition, Industry 4.0, Industry 5.0, Document management system, Paperless factory, Manufacturing process control.

1. Introduction

The transition to the factories of the futures in the era of the fourth industrial revolution based on digital transformation is a significant topic at both academic and industrial levels [1-2]. As a term adopted globally over the past decade, Industry 4.0 is characterized by a paradigm shift in the production environment through the digitalization and integration of the entire value chain throughout the product lifecycle, leveraging key technological trends such as the Internet of Things (IoT) and Cyber-Physical Production Systems (CPPS) [3-4].

However, alongside all the advantages associated with this revolution and with unprecedent innovation and efficiency, new challenges have emerged in modern society, and the importance of social and ecological sustainability is taking on a leading role. This is how Industry 5.0 emerges to combine the technological tools and capabilities developed over the past decade with the need to place the worker at the center of the manufacturing/production process, aiming to promote a fundamental balance between the efficiency associated with Industry 4.0 and the sustainability related to Industry 5.0 [5].

One of the main challenges in modern industrial environments is managing the large amount of physical documentation produced during the production process, with companies increasingly seeking to adopt alternative policies and methodologies to this type of physical documentation [6]. In the industrial context of this study, each production line has an associated paper form where parameters related to the state/condition of production and equipment are recorded [7].

This study proposes a digital platform configured as an efficient interoperable web application where all procedures associated with the production line forms will be unified and centralized [8-9]. This platform is designed to streamline the creation, customization, submission, and approval of digital forms, and it incorporates features such as automatic notifications and alerts for specific situations. Despite the barriers that will need to be overcome, as this is a disruptive solution at the organizational level, the web application is a promising step in replacing the current paper-based approach, increasing production efficiency, facilitating the effective integration and collaboration of different stakeholders, and achieving the goals associated with digital transition and sustainable production [10-11].

The paper is structured as follows: Section 2 covers the technological context and academic work, Section 3 details the case study and the proposed solution, Section 4 discusses the impact on the factory and establishes a brief conclusion.

2. Background

The digital transformation promoted by Industry 4.0 technologies has highlighted the role of machines in the industry however, the need presented by Industry 5.0, to combine the efficiency and productivity of modern manufacturing with the principles of sustainability and human-centric production, promotes solutions capable of reconciling

the human-machine connection and the symbiotic relationship between them [12-13].

The adoption of these solutions implies significant changes, particularly in terms of Document Management System (DMS) and the use of technologies capable of promoting their digital transition [14]. Therefore, DMS are evolving into electronic DMS (eDMS), offering a digital solution capable of improving operational efficiency and the management of data, allowing companies to control the increasing amount of documentation produced, with benefits such as cost and time savings [15].

The ramp-up checklist, a term used in literature to define the type of forms filled out by the operators on the production lines, is a document commonly used at the beginning of shifts or during changes in the production flow [7, 16]. These checklists assist operators and maintenance teams in executing procedures related to equipment, processes, and the production system. While specific items may vary according to operational requirements, using an information system that integrates with asset management processes on the factory floor can improve maintenance strategies efficiency, reduce costs, enhance equipment reliability, and optimize overall asset use [16].

The existence of case studies related to the design, development, and implementation for information systems based on DMS constitutes a fundamental premise in assessing the feasibility of developing a solution capable of addressing the industrial process described in this study [17-18]. These approaches demonstrate the ability of different stakeholders in the system to perform actions, such as updates and modifications of documentation, simultaneously and automatically. Additionally, these eDMS can adapt to required demands and overcome intrinsic barriers to physical document management, such as inefficiencies associated with manual processes and record loss.

Through the integration of the digital checklist with workflow management tools, it is possible to provide the system with functionalities for task coordination related to completing these records. Situations where anomalies or deviations from the standards for proper production are detected can trigger notification and alert mechanism for the responsible teams, initiating procedures and actions to address the disruptive fields quickly [16]. This is also related with the system's ability to store previously reviewed and validated documentation, maintaining a record of the activities and changes made. This history can be accessed and reviewed at any time for auditing purposes or to conduct performance analysis based on historical data [16, 19].

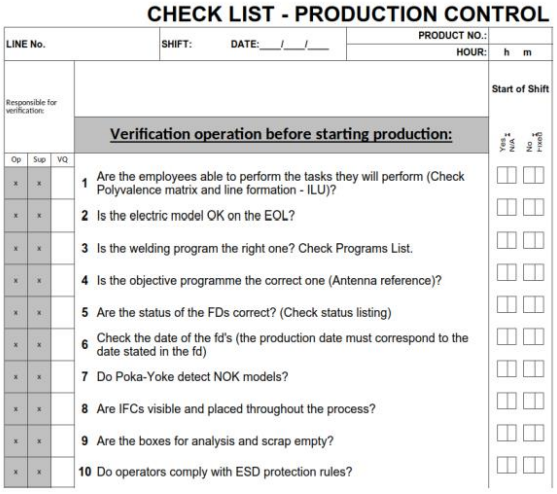
In summary, all studies and work conducted during the contemporary industrial revolutions, focusing on process digitalization and the transition to paperless factories, contribute to a solid scientific background, supporting the development of the solution that will be described in the next section.

3. Web Application Proposal

The solution described in this section considers a specific use case at Continental Advanced Antenna (CAA). CAA is part of the Continental group, operating at level 1 of the Automotive sector, primarily collaborating with the premium segment of automotive industry brands, with an annual production of approximately 15 million car antennas. The need for a document digitization solution emerged to streamline form creation and management on the production lines.

3.1. Industrial Use Case

At the factory floor level, there is a final stage of production where the Printed Circuit Boards (PCBs) are individualized, and the final assembly is performed. Typically, each type of antenna produced for a specific customer is associated with a dedicated assembly line. At CAA, the startup checklist, Fig. 1, is a document that must be mandatorily and carefully filled out at the beginning of each shift, with every reference change, and after extended maintenance/intervention in the process or quality issue. The purpose of this document is to verify compliance with the defined criteria for all production requirements.



CHECK LIST - PRODUCT CONTROL

LINE No.	SHIFT:	DATE:___/___/___	PRODUCT NO.:	
			HOUR:	h m

Responsible for verification:			Verification operation before starting production:	Start of Shift: Yes / No	Start of Shift: No / Fault
Op	Sup	VQ			
x	x		1 Are the employees able to perform the tasks they will perform (Check Polyvalence matrix and line formation - ILU)?		
x	x		2 Is the electric model OK on the EOL?		
x	x		3 Is the welding program the right one? Check Programs List.		
x	x		4 Is the objective programme the correct one (Antenna reference)?		
x	x		5 Are the status of the FDs correct? (Check status listing)		
x	x		6 Check the date of the fd's (the production date must correspond to the date stated in the fd)		
x	x		7 Do Poka-Yoke detect NOK models?		
x	x		8 Are IFCs visible and placed throughout the process?		
x	x		9 Are the boxes for analysis and scrap empty?		
x	x		10 Do operators comply with ESD protection rules?		

Fig. 1. Example of a Paper-based Ramp-up Checklist in CAA.

3.2. Paperless Solution

This checklist is filled out by the first operator on the production line, and despite having access to a computer, this record is manually kept on paper. The introduction of digital forms would make their completion more intuitive and less prone to errors. Regarding communication flow, the automatic notification of responsible teams, such as supervision and maintenance, and the creation of alerts would add value to the constant and effective monitoring of production line equipment and communication process

efficiency. Retaining a history of completed and validated forms could enable the formulation of analyses and conclusions about potential systematic issues in processes and/or equipment, facilitating more appropriate planning of the production process and preventive maintenance.

The envisioned solution is characterized by its cross-departmental use within the factory, contributing to the efficiency and integrity of operations and workflow. This improvement in data accuracy equips teams with the capability to make appropriate assessments and conclusions, instilling a sense of reassurance and confidence.

The main functions of this software would be digitizing forms, allowing their creation, customization, completion, validation, and management; generating notifications and alerts; retaining a computerized document history; managing traceability and access; and preserving data associated with backup and recovery plans.

The access to the system would be subject to a login system through Windows authentication for all level of the corporate hierarchy: production operators, versatile operators, supervisors, coordinators and backoffice managers. Thus, it is possible to define different access levels and permissions based on the hierarchy and the functions assigned to each user. This authentication and permissions methodology enables the maintenance of records related to accesses and modifications, ensuring greater traceability and data security, with the generation of logs for situations such as accessing documentation history or changes in parameters and document structures.

In Fig. 2 we have a projection regarding the use of the software by production operators responsible for completing the start-up checklist.

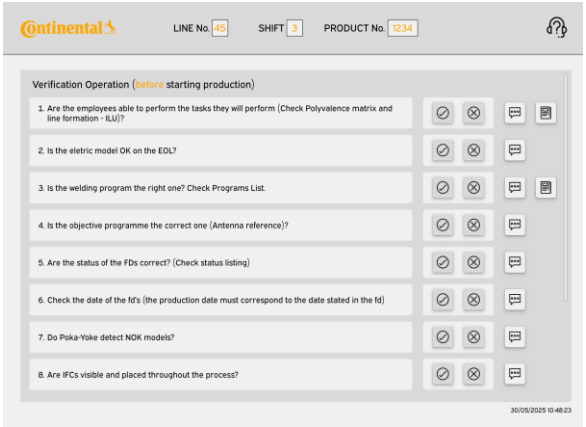


Fig. 2. Example of a Ramp-up Checklist Web Projection.

Through correct access to the software, this page is presented to the operators to complete the checklist digitally. This page displays the parameters that need to be verified before, during and after starting production. Each parameter has two verification components associated in order to record the status of the respective parameter. Each parameter also has an option if the operator wishes to write an observation, and if the operator needs to consult a document inherent to the verification of a parameter, this document can be consulted directly on the page.

In turn, Fig. 3 presents a screenshot of the software for some hierarchical superiors, who due to their work and functions need to have an active role in managing, supervising and maintaining the workflow. In the case presented, supervisors can maintain control over different validations and notifications through a single page, with a fixed vertical menu that allows intuitive navigation over different pages dedicated to specific functions.

Fig. 3. Example of a Supervision Dashboard

3.3 Restrictions

To meet the needs and expectations of users and comply with all applicable norms and regulations for software development and work conducted in this industrial context, it is necessary to evaluate constraints that may limit or potentially limit both the development and implementation of this system.

When it comes to the data produced and stored during the use of the system, robust and adequate authentication and authorization mechanisms are non-negotiable. These mechanisms ensure the privacy, security, and compliance of personal data according to applicable laws and regulations and protect sensitive and confidential information through security and encryption methodologies against unauthorized access and/or cyber-attacks.

Configuring controlled access based on hierarchical authorizations requires defining differentiated access levels, ensuring that authorized users only perform specific actions. This access control is complemented by the need to log and trace activities for auditing and monitoring purposes.

The system's importance and criticality for the proper functioning of the production process implies that its use must be efficient to avoid processing overloads, operate in parallel with other processes, and ensure the continuity of operations 24/7. This demands designing a simple system that minimizes risks and

failures that may arise not only from the software but also from the factory hardware.

Continuous system performance monitoring is a key aspect of system reliability. It should be conducted to identify and/or resolve potential problems that may arise, ensuring the system's continuous operation and minimizing the impact on the production process.

4. Conclusions

Implementing digitalization and electronic document management systems (eDMS) in an industrial environment represents a structural shift in how operational efficiency can be maximized by adopting systems capable of simplifying document processes.

The proposed solution will provide more intuitive document verification and completion, automate notification methodologies, and communicate critical events to the appropriate individuals and teams. Monitoring the production process in real-time will be possible in maintenance and supervision by analysing production conditions and necessary interventions, creating or customizing forms from existing templates, and consulting completion histories.

The web application's interoperability and interconnection of processes will enable the integration of systems and workflows, ensuring communicational efficiency. The digital records of information will promote better coordination and internal communication, with more proactive and responsive management of production processes. Regarding sustainability, the significant reduction in the amount of paper used will also be a notable benefit. Another advantage of adopting the application is the quality and accuracy of the data collected, reducing errors associated with the manual completion of paper forms.

All these advancements converge on the need to balance productive efficiency and sustainability in the context of Industry 5.0. Given the significant restructuring that the implementation of such a solution entails, it's crucial to plan adequately. This will ensure seamless integration with existing systems, processes, and workflows, enabling the transition to a new industrial paradigm. It will also ensure that all stakeholders benefit significantly, justifying all efforts and investments made.

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