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A DMS to Support Industrial Process Decision-Making: a contribution under Industry 4.0

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Abstract

This paper presents the development of an Information System (IS) an automotive manufacturing.The system was developed to reduce waste and increase productivity, through better decision-making. The used methodology to implement it was the Business Process Management (BPM). A DMS (Document Management System) for decision making support was built, reducing the action time and providing faster maintenance of all needed data. As a result, the users time decision making and the administrator maintenance was reduced by a total of 26 minutes, corresponding to a 1.61 € reduction per unit built, which means an efficiency of 41%.
The present work fits in the company's strategy for Industry 4.0 and a more sustainable environment, being a positive driver of Industry 4.0 implementation and transformation.

Keywords: Industry 4.0; Information System; Document Management System; Decision Support System and Business Process Management.

1. Introduction

The fourth Industrial revolution (Industry 4.0) is the digital transformation of manufacturing, which incorporates the association between the Industrial Technology (IT) and Operational Technology (OT), Big Data (BD) analysis and organization, coordination between Sensors plus Actuators with Robotics, leading to the Artificial Intelligence (AI). Since the fourth industrial revolution, the industrial level is in constant change. Therefore, concerning the innovation drivers that can be worked to achieve the industry 4.0 level, one of them is the digitalization drive. The integration by digitalization and optimization of various systems and processes in the factory are needed to promote the gradual

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monitoring of this global change. Companies that want to achieve digitalization needs to support all the processes in Information Systems (IS) or technologies with the integration of the equipment and machines controlling, planning and management. Concerning the company where this work was developed, a world-class manufacturing in the automotive industry, that produces specific models to order only have the capacity for a sustainable improvement concerning the available budget. With the excessive use of physical documentation, as one of the negative points present in the factory, several projects can be done to combat this way to proceed, by optimizing different flows inherent to its use, reducing overall physical documentation and associated costs. [1].

The present project consists of optimizing decision-making from some process already established and reduce the overall physical documentation spread around the different sectors in the factory. The analysis, conception and implementation of an Integrated Documental Management (IDM) through the different areas of the factory and the support of decision making were the main goals of this project. Based on the analysis of the found the situation and using the resources available by the company, it was possible to develop and implement several solutions able to improve the process performance.

The paper's structure is divided into seven sections: the first corresponds to this Introduction; Section 2 corresponds to a literature review concerning industry 4.0, IS and IDM systems the issues developed in this paper; Section 3 refers to the methodology used in this work; Section 4, theoretical context of the problem under study, describes the work developed according to the adopted methodology; Section 5 presents the case study and, finally, Section 6 contains the discussion of the general results and; Section 7, the conclusions of this work.

2. Literature review

The concept of Industry 4.0 requires a long-time period of development and analysis of industrial revisions, covering the following four aspects, considered as the future manufacturing visions [2]:

Factory: As one of the main components of Industry 4.0, the future factory is going to involve a new integration of all manufacturing resources, like sensors, actuators, machines, robots, conveyors, among others. They will exchange information automatically, transforming the factory into conscious and intelligent enough to predict and maintain the machines, to control the production process, and to manage the factory system. In addition, many manufacturing processes, such as product design, production planning, production engineering and services, are going to be simulated as modular, which means these processes are not only commanded by a decentralized system but also controlled interdependently. All these interactions will lead to the Smart Factory [3], increasing the number of maintenance objects. Additionally, their technical complexity is rising and unplanned breakdown results in high costs [4,5].

Business: A complete communication network will exist between various companies, factories, supplier, logistics, resources, customers, during this new revolution. The real-time configuration will be optimized, depending on the demands and status of associated sections in the network, which makes the maximum profit for all cooperatives with the limited sharing resources. The future business network is influenced by each cooperating section, which could achieve a self-organizing status and transmit the real-time responses to the customers and stakeholders [6].

Products: With Industry 4.0, a new type of products generated in manufacturing will be achieved. These products are embedded with sensors, identifiable components (RFID technology), and processors which carry information and knowledge to convey functional guidance to the customers and transmits the users' feedback to the manufacturing system. With these elements, many functions could be added to the products, for instance, measuring the state of products or users, carrying this information, tracking the products, and analyzing the results depending on the information. In addition, a full production information log can be embedded with product assisting product developer in optimizing their design, function and maintenance [7].

Customers: Customers will also have a lot of advantages under Industry 4.0, by including a new purchasing method. It allows customers to order whatever products needed. In addition, customers could change their order and ideas at any time during production even at the last minute with no charge. On the other hand, the benefit from the smart products enables the customer not only to know the production information of the product but also to receive the advice of utilization depending on their own behaviours [8].

Besides all these planned visions of manufacturing, many researchers and companies have been working on Industry 4.0 in many fields around these concepts, being the production line demonstration and smart products, the two typical examples shown of the Industry 4.0 development.

Industry 4.0 concept cannot be successfully implemented unless the manufacturers accept it, and they will not embrace it unless all the benefits and challenges of that being identified [9]. It will create better productivity and higher efficiency. Over five years, more than 80% of European companies will digitalize their value chain to increase the efficiency by up to 18%. By 2020, European industrial companies will invest more than 100 billion Euros annually on Industry 4.0 [10].

Economically can be influenced by the advent of the new paradigm and the emerging technological developments. The digitization consists of the convergence between physical and virtual worlds and will have a widespread impact in every economic sector [11]. This will be the main driver for innovation, which will play a critical role in productivity and competitiveness.

Concerning digitalization drive, it is needed to integrate the processes support and management into the IS. It is understood that a system is an organized and dynamic process with input functions, which are processed in order to organize, structure and disseminate raw data into information, see Fig. 1.

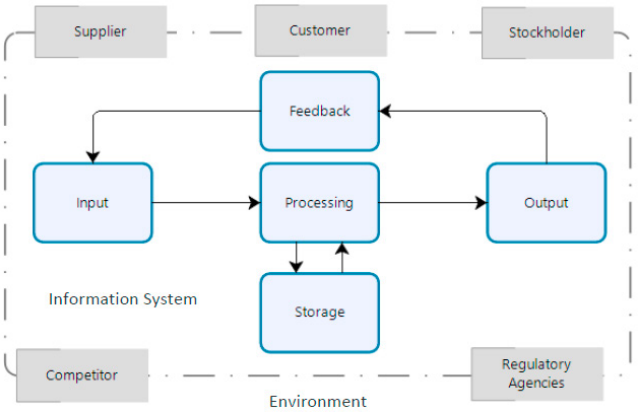

Fig. 1 – Information System Structure Process [12]

The input captures and collects raw data from within the organization or from the external environment. After this, it is processed, which involves converting the raw data into meaningful information. The process stage can involve calculations, comparisons, taking alternative actions and storing data. Finished the processing phase, an information output is received, normally in the form of documents and/or reports. The feedback process verifies, analyses and evaluates the IS outputs, being able to connect, if necessary, the input functions [12,13].

The IS development workflow, seen in Figure 2, show the five different stages of analysis and data compilation structure and cooperative methodology.

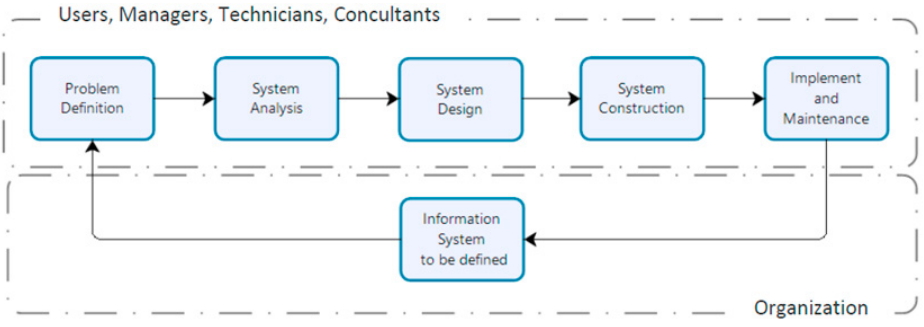

Fig. 2 – Information System Development Workflow [14]

The main goals adjacent to the implementation of an IS normally are the ones described [15]: All information technology supports and assists the Organization's strategies and objectives; Ensure greater control; Expand security and productive processes; Minimize associated risks such as loss of information; Broaden overall performance; Improve resource applications; Reduce costs associated with processes; Support in decision making.

The IS development which provides the management of the entire document information lifecycle is called Document Management System (DMS), which is one of the fields associated with the new trend of digitization. More than that, DMS allows the analysis of unstructured information flows and the creation of routines and working methods in the organizations, improving their performance. It is noticeable, due to all changes occurring with the Industry 4.0, that the market for DMS is evolving, both on the supply and demand side [16]. The main goal of DMS is to achieve different types of systems which will optimize the operator's self-decision, increasing productivity and subsequently decreasing cost.

Initially, DMS was associated with the process of paper dematerialization, which is one of the biggest problems in all industry. This excess amount of paper produced leads to a tremendous decentralized cost and the need for non-add value tasks such as the introduction of the same data into different IS. However, today the concept has evolved, and it is much more than just capturing, scanning, archiving and later querying documents [17]. Once a DMS workflow is implemented the following advantages will come right away [16]: Documents and associated process dematerialization; Management of the company's file in a centralized way; Standardization of documents, processes and procedures; Standardization of work processes; Speed in the availability, access and treatment of documents; Control of information flows (documents and processes); Gains in administrative efficiency and consequently reduced operational costs; Reduction of the need for physical space for files and cost with photocopies; Ability to measure resource efficiency.

The IS can be divided into the horizontal integration through value networks refers to the integration of several IT systems, processes, resources and information flows within an organization and between other organizations. In the other side, the vertical integration and networked manufacturing systems concerns through the departments and hierarchical levels of an organization, from Product Development to Manufacturing, Logistics and Sales.
The aim of these two types of integration is to deliver an end-to-end solution across the entire value chain whose purpose is facilitating product customization and reducing operational costs using Cyber-Physical Systems (CPS) to digitally integrate the whole value chain [18].

3. Methodology

In order to simplify processes involved in completing business objectives, it was used a Business Process Management (BPM) methodology. This is becoming the principal framework that describes all the continuous improvement approaches to process management. Total Quality Management, Workflow Management, Lean Methodology and Six Sigma are now viewed as narrow areas of the larger BPM [14,19].

Optimizing the performance and efficiency of organizations through process management is the main objective of this methodology. It allows to reduce costs, operate expenses and cycle time of processes, increasing the operational efficiency of companies and making them more competitive, see Table 1.

Table 1 – BPM workflow implementation [14]

BPM workflow	Description
Initial needs analysis	Identify the process to be mapped, in addition to the duration, cost and your goal.
Documentation, design and analysis of the current process	Document draw and analyse the existing process to improve the conditions of execution and operation.
New process design and structure model	Model the newly developed process to provide a better structure analysis and identification.
New process implementation	After modelling and simulating, the new process is implemented through validations that ensure its execution.
Process Management	The implemented process continues to be controlled and monitored to seek further improvements, initiating new analysis for a continuous lifecycle.

Business processes orientation to IS implies the convergence of organizational business and software models. This

provides a framework that allows the model design of technological implementation and organizational interdependence architecture. To this supported method, the scientific research calls it Business Process Model and Notation (BPMN) [20].

The use of models ensures the complete and correct definition of functionalities, the satisfaction of customer needs, robustness, security and other types of requirements before implementation in code. This leads to a reduction of costs that may arise from future changes and that are difficult to carry out in unstructured architectures [13].

Unified Modelling Language (UML) is a standard modelling language applied in software engineering. It is used to specify, visualize, modify, construct and document the artefacts during the development phase of object-oriented software so that the project meets all requirements [20].

In the context of this project, UML was used to define conceptual data models during the functional analysis phase of content and processes. The conceptual model data allows to get a clear idea of the entities of the production system and the entities of the document management system, as well as the relations between them.

4. The theoretical context of the problem under study

The growth of the demand for information, the increase in the amount of data generated by industrial organizations and the greatest need for availability and control of this information for quicker decision-making lead the company to need more than an interconnected set of IS [1], [12]. As organizations begin to document their processes, it becomes an administrative task to keep track of them. As processes changes, improvement is crucial to know which processes are the most recent. It is also important to manage the process so it can be easily updated.

The requirement to manage the process documentation has been one of the driving forces behind the creation of the DMS. This system follows a sequence of processes, beginning with the dematerialization. Where electronic documents, which are a photograph of the paper documents in use, are produced. After this initial approach, the normalization of all types of documents in the company must be standardized. Indexing electronic documents is the next step, being this process equivalent to the physical file indexing.

The DMS workflow must be simple and capable of registering the various states by which a document flows, providing its immediate location. Associated to this, there is a cost reduction, since physical documents are eliminated and the time decision making increased substantially [17]. It must be said that all IS supports decision making, even if indirectly. The Decision Support Systems (DSS), a computer-based system, may help the decision making by using models and data to solve identified problems and automating a variety of tasks. These systems can aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge and aiding the process of structuring decisions [21]. Then, the solutions of documental management are critical to the organizations in order to allow not only an increase in levels of efficiency and effectiveness of the processes, but also the management of information with the necessary speed required nowadays. The DMS implementation solution brings transparency, predictability of costs and better performance in the daily management of activities. This led to a significant increase in productivity and new opportunities for processes workflow optimizations [14]. The digitalization processes are intrinsically related to the DMS implementation. This brings a more sustainable environment to the company's strategy, being an essential pillar of the Industry 4.0 transition [22].

5. Case Study

The initial phase of the project led to the search and debate for the most appropriate solutions. After the definition of the initial solution, the design implementation of the new system was built, being able to manage the flow of information more efficiently. Following this phase, the developed system was ready to be implemented. In Figure 3, it can be seen the system development process interactions applied. The sequence below is related to the system development process:

1) Identification and selection of documents capable of being integrated into the program to be developed;
   a. Application of the lean methodology to these documents and associated tasks;
   b. Transform obsolete documents into simplified and current templates;
2) Delete all information that does not add value;
3) Identification of the actions and tasks associated with the process, which are liable to be automated;
4) Software definition and proper programming language;

5) Definition of the structure and content of the database that supports the system;
6) Definition of the computer support where the database will be stored;
7) Survey of requirements for the program to be developed (Functional and Non-functional);
8) Definition of what information will be required to be introduced by the user to generate the desired output;
9) Definition of the control and security actions that the program should contain;
10) Identification of which parameters are common to all and which ones should be flexible;
11) Elaboration of formulas and functions that ensure intelligent software;
12) Elaboration of a simple and intuitive interface.

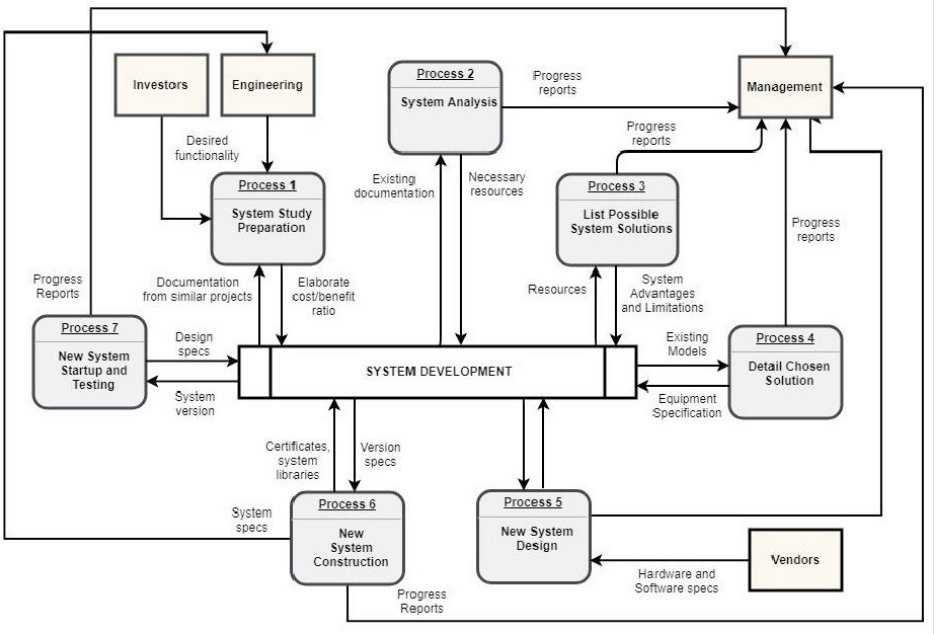

Fig. 3 - System development processes' interactions

Functional requirements describe what the system was expected to do. It was related to the functionality the system should perform or which information should keep. They covered the description of information inputs and outputs that resulted from the interaction between users and systems. On the other hand, Non-functional requirements were related to qualitative system properties, describing attributes and overall qualities that the system should provide to functional requirements, such as performance measures or security considerations. Below are described the Functional and Non-Functional requirements from the first and second project, respectively.

Functional Requirements

- Elimination of information that does not generate value;
- Reorganization of the data parameters;
- Automatic application of formulas and functions that make the program smarter and the output generated more appropriated;
- User-friendly layout, providing easier and faster maintenance;
- Data and User Traceability, providing better control of the system;

Non-Functional Requirements

- Program code access requires administration and user password input;
- Only the system developer is allowed to edit the system code and design;
- The administrator has access to historical data traceability;
- Common language and knowledge, therefore available to all stakeholders;
- User-friendly interface that is intuitively used;

- Excel database support for the developed system.

Program Requirements

- To whom is the information system made? This DMS was developed specifically for the Engineering department team, directly related to the logistical changes made in the LC70 assembly components used.

What is needed to develop the intended system? It was debated along with the engineering team all the system functionality, as well as the actions used in the process. A lack of flexibility in monitoring and maintaining all data were registered. Completed the survey of the necessary requirements for optimization, it was noticed that a program should be built for the database support.

- How is the work developed? The initial process is done on a simple Excel sheet, where 120.000 data field are monitored through associated filters. Therefore, it was necessary to create a program supported by the existing database, to allow the user a greater, better and easier monitoring and maintenance of the whole system. The created program was developed in such a way that one main UserForm (UF) provides all needed work actions and functions and immediate access to visualize the data information. This simple layout UI allows faster and effective maintenance of all data. Besides these main UFs, several UFs were designed and built in order to provide the best user experience.
- What does the program do? The program allows the user to visualize in a faster and more effective way all the necessary information of the components, regarding their location in the logistic warehouse. All the monitoring and maintenance of this data information was simplified, thus making all necessary actions, such add, remove, edit and search in a more user-friendly way. On the other hand, a data security policy has been considered. Therefore, a program entry system was created with login data tracing, allowing the administrator to view the history of visits and the changes that were made.
- Who enjoys the developed work? The Engineering department benefits from this optimization, since they are the ones who monetarize and maintain all this data, reducing the time decision making from the logistic collaborators.

6. Result Analysis

The database maintenance of the LC70 series components was made in an Excel sheet, consisting of 3000 lines and 40 columns, leading to a lack of traceability, very little flexible and agile data research and edition and none historic record of changes made. Then, it was developed a DSS for documental management, which allowed the user to add, edit, duplicate, delete and search in a flexible and fast way every data needed, leading to an increase of productivity. The user, when searching by component, has also access to the corresponding image for better identification and decision making. The administrator is the one who will do all the database maintenance in a very intuitive and effective way. The table presented below, Table 2, shows that the IS developed was successfully implemented by providing a better workflow of information and by reducing the time decision making from the user: an average of 65 minutes to 38 minutes, equivalent to a cost reduction of 1.61 € per unit built.

Table 2 - Results from LC70 database Information System implemented

Variables	Before (min)	After (min)	Reduction (€/hour)	Reduction (€/year)	Reduction (€/unit)
Admin	50	30	-1.17	-2464	-1.19
User	15	8	-0.41	-862	-0.42
Total	65	38	-1.58	-3326	-1.61

7. Conclusion.

Nowadays, to compete in a highly competitive market, it is essential that the organization take on the performance, which is the challenge of continuous improvement related to lean thinking methodology [23]. The constant demand for process optimization allows the organization to respond to the growing needs of it owns customers. The goal is to manufacture the best product at the lowest cost as quickly as possible. These new systems used information and communication for extensively autonomous information exchange, being able to combine production with business processes. Following the Industry 4.0 trend, these implemented systems decentralized manufacture in a smart way. They provided self-decision optimization, better data organization and, consequently, supply chain traceability.

The elaboration of this project demonstrated that to achieve relevant improvements, substantial investments or complex solutions are not needed. Using the resources available by the company, it was possible to reach the defined objectives and to present results that support the improvements obtained.

The results achieved show the fulfilment of the objectives and the constraints proposed, where the system reduced the users time decision making and the administrator maintenance, from 65 to 38 minutes, corresponding to a 1.61€ reduction per unit built, which means an optimization in the efficiency of 41%.

Therefore, it was demonstrated with the implementation, that the solution developed was accessible to all stakeholders in the process, the systems management was simple and it was autonomously assumed by the employees involved.

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