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Information Systems for Industrial Processes Support and Optimization

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Abstract

This paper presents the Document Management Systems (DMS) as a support decision tool to optimize Toyota Caetano Portugal S.A. (TCAP) processes performance. The created systems were developed on the best practices of a Business Project Management (BPM), for better structural implementation. The first system implementation was related to the warehouse materials requirement process, where an excel template with VBA functions for fill automatization was built. It had a reduction of the overall paper consumption and time execution optimization, which means the gain of approximately of 0,10€ and 2,09€ per unit produced, respectively. It was also obtained an elimination of 4538 paper sheets per year. A second system was also developed, in order to provide a Decision Support System (DSS) for documental management. Several User Forms were developed in VBA code in order to provide a flexible and intuitively user interface experience. It reduced the users time decision making and the administrator maintenance, by a total of 26 minutes, corresponding to a 1,61€ reduction per unit built, which means an efficiency increase of 42%. The present work fits in the company's strategy for a more sustainable environment being a positive driver of Industry 4.0 implementation.

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). The constant change at the industrial level related with the Industry 4.0 leads to the need for optimization of various systems and processes in the factory, with a view to promote the gradual monitoring of this global change. With the excessive use of physical documentation, which remains as one of the negative points present in the factory, several projects can be done to combat this by optimizing different flows inherent to its use, reducing overall physical documentation and associated costs (Ward, 1994).

The present project consists into optimizing decision-making from some process already stablished and reduce the overall physical documentation spread around the different sectors in Toyota Caetano Portugal, S.A. (TCAP) 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 situation and using the resources available by the company, it was possible to develop and implement several solutions able to improve the process performance.

2 Literature Review

An Information System (IS) is constituted by people, procedures, data and IT components (like hardware, software and communication), which collect, process, store, analyse and distribute information with specifics functionalities. Therefore, it is understood that a system is an organized and dynamic process with input functions, which are processed to organize and structure data, giving information as output (M. T. R. Pereira, 2003). The process workflow of an IS can be observed in Figure 1.

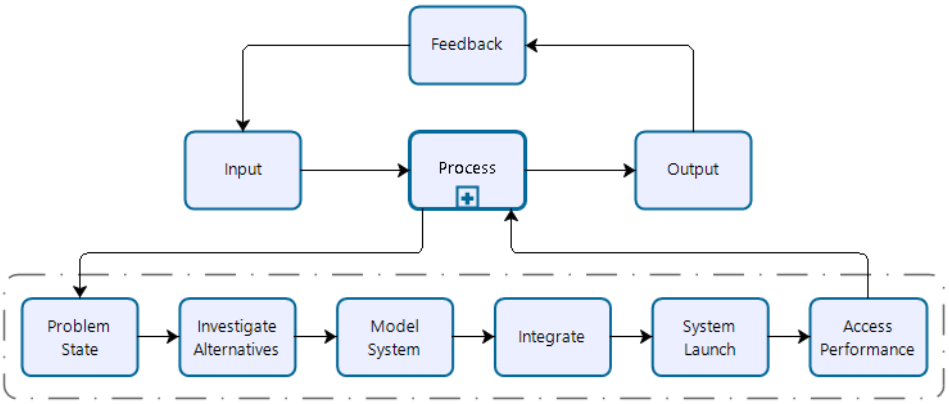

Figure 1: Information System process workflow

An IS has as main goal to gather and disseminate information with the main purpose of providing it to the users. It should be designed to filter irrelevant data, providing a better decision making due to the reduce of waste involved in all process. The main objectives adjacent to the implementation of an information system are the follow ones (Gräßler & Yang, 2016):

- Support and assist the organization's strategies and objectives;
- Ensure greater control;
- Expand security processes and productive processes;
- Minimize associated risks such as lack of screening and loss of information;
- Broaden overall performance;
- Improve resource applications;
- Reduce costs associated with processes;
- Support decision making.

These systems facilitate dialogue with users, when they consider alternative solutions a problem. The system also provides database access and constructed models to present information.

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 information systems (IS) (Ward, 1994). 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 Document Management System (DMS) (Elói, 2010). This system follows a sequence of processes, beginning with the dematerialization. These is where the electronic documents, which are a photograph of the paper, 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 register 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 (Manuel, Hernad, & González, 2013). 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. (Salam & Khan, 2016). 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 (Prasad & Ratna, 2018).

In Industry 4.0, it is the customer who dictates how a product is designed, manufactured and delivered. Customer Relationship Management (CRM) systems help manufacturers understand the purchasing habits of their customers. In order to provide production flexibility for mass customization, manufacturers need firstly to know what their customers require. A good customer relationship provides a better understanding of his needs, leading the company to new strategies. There are three different types of CRM: the Operational, which focus on customer solutions, the Analytical, where data is collected for posterior analysis and the Collaborative, which integrates all points between company and customer (Fróis, Pereira, & Ferreira, 2019). Most of the time, CRM systems are used to find new customers or sell to the existing ones. But customer relationships require a lot of paperwork. The employees may have to generate new sales contracts, find existing paperwork, or add specific sales orders to the customer files. Then it is important to find a DMS that synchronize all of it. While a CRM system is essential for business, a DMS is an essential office solution for information management, providing an effectively use of it and easier access to it. The posterior use of a DSS typically consolidate customer information from a variety of systems into massive data warehouses and use various analytical tools to organize it into different segments. They can guide about pricing, customer retention, market share and new revenues. (Fróis et al., 2019; Misdolea, 2010; Park & Kim, 2003).

Companies need to measure business performance and to understand if the CRM tool is helping them to improve their results. It should measure organizational performance through customer satisfaction, set Key Performance Indicators (KPI's), efficiency and market effectiveness (Fróis et al., 2019). It also allows storage and analysis of information and consequently a better system management of the relationship with the customers (Pereira et al., 2018).

In the literature review, it's possible to find several articles about analysis, design and implementation of different IS. By adopting the business process strategies, capable of significantly increase its decision-making capability along with the optimization of all document management, the following articles, Table 1, were studied with more emphasis.

Table 1: Article analysis for the literature review

References	Article Description
(Courtney, 2001)	Decision Support Systems (DSS) must embrace procedures that can deal with this complexity and go beyond the technical aspect. Organizational decisions of the future may include social, environmental and economic concerns. This paper discusses the DSS designed to deal with wicked decision situations and knowledge management in organizations.
(Gräßler & Yang, 2016)	In this article, Systems Engineering (SE) methodology is discussed. This type of engineering is used in product development to support interdisciplinary collaboration and to manage rising complexities at a given time and cost. Based on a comparison between current production system

	development procedures and Systems Engineering (SE) methodologies. Potential improvements are identified and a tailored production system development approach is presented.
(Lin et al., 2002)	This paper proposes a generic structure for modeling business processes to capture essential concepts of business process and represent them structurally. The generic structure possesses two main features suitable for business process modeling: one represents a business process in various concerns and multiple layers of abstraction and the other lowers the barriers between process representation and model analysis by embedding verification and validation with the model.
(Murray & Lynn, 1997)	The inflexibility of older IS/IT constrained growth and competitiveness, leading to a substitute processes development. Newer IS/IT provides better flexibility, however to leverage this for competitive advantage, business processes and IS/IT must be brought together. Therefore, organizations must turn to Business Process Reengineering (BPR) and successfully deal with the resulting change management issues.
(OBrien, 2004)	Information Technology provides a powerful managerial resource that can help in the management of business operations, make better decisions and gain competitive advantages. Its goal is to help students become managerial end users who can propose and participate in developing information systems solutions to business problems. This text is distinguished from the competition by its extensive use of up-to-date case material.

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 (Karout & Awasthi, 2017). 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 2.

Table 2: BPM workflow implementation

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 new 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 model design of technological implementation and organizational interdependence architecture. To this supported method, the scientific research call it Business Process Model and Notation (BPMN) (Kalpič & Bernus, 2006).

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 (Gräßler & Yang, 2016).

Unified Modelling Language (UML) is a standard modelling language applied in software engineering. It is used to specify, visualize, modify, construct and document the artifacts during the development phase of an object-oriented software, so that the project meets all requirements (Chonoles, 2018)

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 Case Study

Two different information systems were developed at TCAP, both with positive results. The company has its mission defined in a very explicit way, presenting its general strategic purposes and its reason for existing. TCAP also transmits its basic philosophy of operation, providing indications for its future, that guides all its employees towards a common purpose, "Improve our corporate DNA, doing more and better, supported by curiosity, creativity and passion. The complete satisfaction of our client and the consistent profitability of our operations are our goals, working by side with our consumers.", quoted by Salvador Caetano.

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.

The system development process workflow interaction can be seen in Figure 2, with its chronological steps.

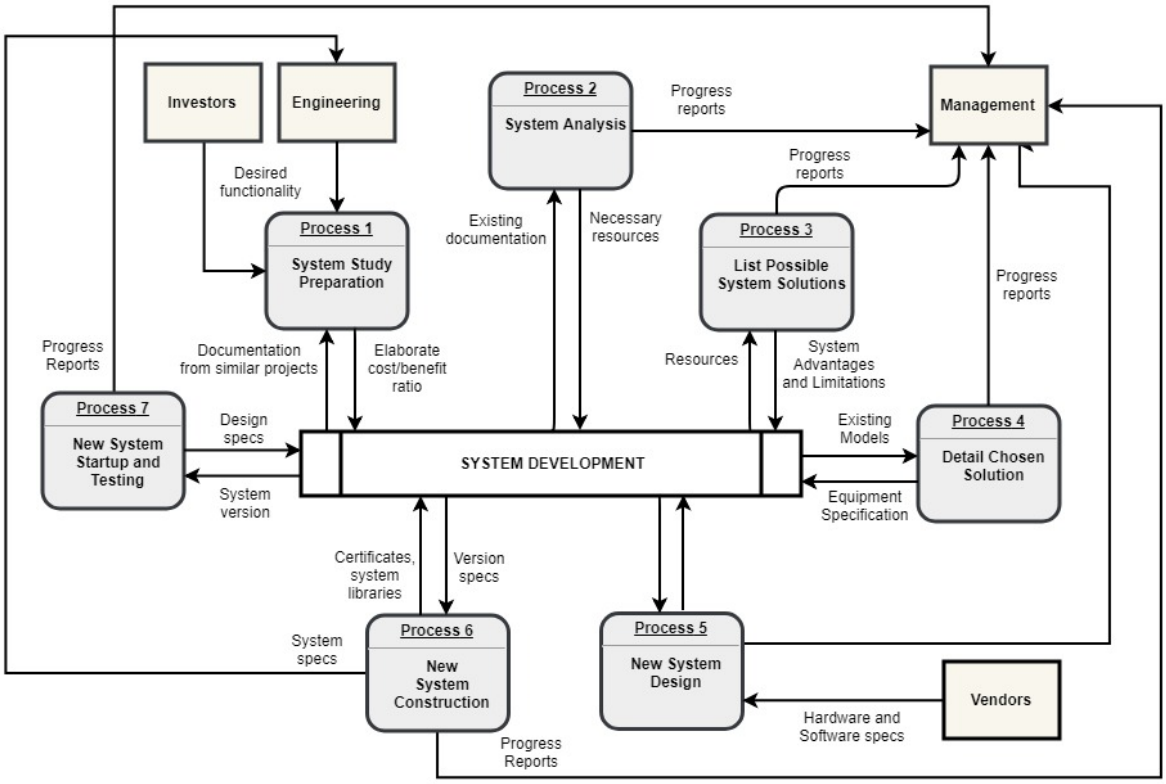

Figure 2: System development processes' interactions.

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;
2. Application of the lean methodology to these documents and associated tasks;
    a. Transform obsolete documents into simplified and current templates;
    b. 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 support 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.

During all the development process, an analysis of the functional and non-functional requirements for the new developed systems was done.

The functional requirements describe what the system is expected to do, the functionality the system should perform or which information should be kept. They cover the description of inputs and outputs of information that result from the interaction between users and systems.

On the other hand, non-functional requirements are 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, the functional requirements of the first system are described:

- Elimination of information that does not generate value;
- Automatic application of formulas and functions that make the program smarter and the output generated more appropriate;
- Adjusting the document layout to the need for the process concerned;
- Automatic generation of observations and particulars, in accordance with the specificities required;
- Automatic mail generation, with required document attached, ready to be shipped, with all the necessary specifications for the warehouse.

In the same way, the first system non-functional requirements are mentioned bellow:

- Program code access requires password input;
- Only the system administrator is allowed to edit the file, with the possibility of, at the end, to save the changes made;
- Acceptable processing speed (few seconds from the initial boost to the program execution);
- Common language and knowledge, therefore available to all stakeholders in the process (Microsoft Excel);
- User-friendly Interface that is intuitively used (visual structure implemented on the Excel sheet itself, which is supported by macros and programming in VBA);
- Database (Excel) support for code searching and different view from all the stock materials, located in the same folder where the programs are, applying immediately informatic 5S's;
- Database (Access) creation as a domain motor to be maintained by restrict access users, leading to the data security policy. This Database allows a simple and fast management, reducing drastically the execution time maintenance by the team.

The following list presents the second developed system 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 appropriate;
- User friendly layout providing an easier and faster maintenance;
- Data and User Traceability, providing a better control of the system.

The non-functional requirements adjacent to this second system were:

- Program code access requires Administration and a User password input;
- Only the system administrator is allowed to edit the file, with the possibility of, at the end, to save the changes made;
- The administrator will have access to an historic traceability data, for a better control of the system;
- Common language and knowledge, therefore available to all stakeholders in the process (Microsoft Excel);
- User-friendly Interface that is intuitively used (visual structure implemented on the Excel sheet itself, which is supported by macros and programming in VBA);
- Database support for code searching and different view from all the LC70 series stock materials.

5 Results

The first developed system had as main goal the functions and time optimization of the entire materials requirement process from the warehouse, to satisfy the line production needs. An DMS was created, providing a better organized way for all the workflow inherent to this process. An IS was built to support the DMS developed, where input data for order support could be done and send automatically to the warehouse for posterior receiving. Before this implementation, the whole process was done by filling a paper for each requirement order and then every team member could receive the package. After the new IS implementation, all the process was changed, passing to electronic documents with historic data, being restricted for the GL only use.

As results of this IS implementation, it was noticed that in a worst-case scenario, 4538 paper sheet's consumption per year are going to disappear, having a cost reduction of approximately 208,00€.

It is shown, in Table 3, that the DMS implemented brought several reduction costs. In one way by reducing the overall paper utilization, 0,10 € per unit produced, and on the other hand by optimizing time execution process by the user and the warehouse operators, 2,09 € per unit produced.

Note: All the obtained results are based on the next assumptions: Annual production of 2070 units; Average salary of 3,5 € per hour; Block of sheets price of 4,16 €; Consumption mean of 52 blocks per year.

Table 3: Results from Materials Requisition and Returns Information System implemented

Variables	**Before (sheet)**	**After (sheet)**	**Reduction (€ / hour)**	**Reduction (€ / year)**	**Reduction (€ / unit)**
Paper	7800	650	----	-208	-0,10
Variables	**Before (min)**	**After (min)**	**Reduction (€ / hour)**	**Reduction (€ / year)**	**Reduction (€ / unit)**
User	45	25	-1,17	-2471	-1,19
Warehouse	30	15	-0,88	-1859	-0,90
Total	**----**	**----**	**-2,05**	**4538**	**-2,19**

Relatively to the second problem, a database maintenance of the LC70 series components were 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 an 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 4, 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 4: Results from LC70 components 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**

6 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 with lean thinking methodology. The constant demand for process optimization allows the organization to respond to the growing needs of its 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 an 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. The first system implementation, related to the warehouse materials requirement process had a reduction of the overall paper consumption and time execution optimization, less 0,10€ and 2,09€ per unit produced were gained, respectively. The elimination of 4538 paper sheets per year was also obtained. On the other hand, the second 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.

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.

7 Future Optimization

Since all methodology of continuous improvement is adjacent to the Toyota spirit, the projects carried out will never be completed and there is always room for improvement over time. In the first system developed, the real time synchronization with the ERP system of the company, is one of the main improvements listed to be done. This will provide a constant database update, eliminating information errors. Relatively to the second system, the creation of an action which leads to a print document of all the necessary items listed is the optimization to be made.

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