Combining ERP, Lean Philosophy and ICT: An Industry 4.0 Approach in an SME in the Manufacturing Sector in Spain

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Abstract

This study aims to identify the impact of a work methodology that combines ERP with the benefits of using lean philosophy. A sectored approach takes into account highly traditional manufacturing SMEs, such as metal fabrication, that are particularly vulnerable to new market trends. In addition, from these vulnerabilities new challenges have to be faced regarding the Industry 4.0 concept and the strategies toward their digital manufacturing workshop transformation, focusing not only on producing improved manufacturing processes but also on gaining added value. A case study was conducted on a Spanish company aiming at showing and analyzing its transformation model. The results showed greater management capacity and efficiency improvements in production-related processes.

Keywords

Digital transformation, Industry 4.0, manufacturing Sector, ERP, Lean Manufacturing.

Introduction

Manufacturing at small and medium-sized enterprises (SMEs) is particularly vulnerable to the increasingly demanding markets, and these companies have to seek more agile and intelligent production solutions within a context of economic uncertainty. The industry of the future demands the exploration of new business and production models through digital transformation (DT), an increase in innovative activity, and exponential adoption of appropriate technological equipment to gain a competitive edge over rivals (Müller et al., 2018). Therefore, the possible solutions must be approached from a sector perspective, with the maximum use of the technologies available in each company, to facilitate the creation of a new industrial model. However, if the information and guidelines provided are inadequate, this process can easily become a complicated, uncertain goal with many questions, problems, and doubts. In this sense, it is also important to consider how SMEs implement Industry 4.0, and how it impacts industrial value creation in SMEs. As indicated by some authors, the complexity of the industrial environments and their conversion process to Industry 4.0 favors a sector-specific approach that is adapted to the contextual reality of each company, its products and processes, the required managerial capacities, and the selected technologies (Moeuf et al., 2018; Müller, 2019).

The solutions adopted must be integrated with the tools commonly used in these companies. One of the most implemented is enterprise resource planning (ERP) which is the model of computing in a modern business environment organization (Bradford, 2010), and it is identified as a key tool by which companies set up their competitive business process upgrades (Caruso, 2003; Ho et al., 2004). It also offers a way to efficiently manage and plan the resources of an entire company through integration into a single system of information and information-based business processes across functional areas, as well as beyond organizational boundaries (Buonanno et al., 2005; Davenport, 1998). This allows SMEs to make decisions that enable them to reach their business objectives accurately and in real time. All of this makes ERP a perfect framework to continue working on the transformation toward Industry 4.0 in SMEs.

ERP systems usually cover the basic business processes, but they have a high cost when adapting them to production. In this sense, SMEs must define the role of their ERP legacy systems and include new features to control manufacturing-related processes such as product data management (PDM), integration of product data (Lee et al., 2011), Product Lifecycle Management (PLM), Supply Chain Management (SCM) integration with suppliers and tracking supply data (Kelle & Akbulut, 2005) and customer relationship management (CRM) integration to personalize customer service. In addition, the challenges of Industry 4.0 require the adoption of systems aimed at taking data from the production plant such as the Manufacturing Execution System (MES) or others that help the company to control the process itself.

Having faced the aforementioned paradigm, it is essential to address new production models that are far from the traditional ones and are based on the optimization of the production system and continuous improvement. Global competition and growing customer expectations have increased the interest of SMEs in the use of Lean Manufacturing (LM) methodology because it offers many advantages (Stankalla et al., 2018). LM is a set of techniques that were born in the automotive industry. The goal is to adapt them to each company's necessities and focus on eliminating activities that do not add value (Demirkesen & Bayhan, 2020). Thus, the companies that implement them could reach high levels of profitability and competitiveness.

As Jituri et al., (2018) indicate, the SMEs often use one of these two solutions (ERP or LM) to run the manufacturing systems, but it is difficult to find companies that use both at the same time. This paper aims to combine ERP and Lean philosophy through an experience carried out in an SME of metal fabrication and equipment goods in the North of Spain.

Purpose of the study

This paper attempts to show the efficiency gained in the manufacturing processes by combining ERP and LM philosophies which will create added value in the organization. A case study to analyze the impact of a work methodology that combines ERP with Lean Manufacturing Techniques (LMT) and information and communication technology (ICT) solutions is proposed in this paper. Therefore, this research tries to answer the following question:

> *Can the combined use of ERP, LMT, and ICT improve the efficiency of the production processes and create value in an SME?*

Related work

There are an extensive number of contributions regarding the implementation of ERP models. However, despite the fact that SMEs have been adopting ERP in recent years, little attention has been given to this research in SMEs (Ruivo et al., 2012) and even less to cross-specific industrial sectors as conducted in this study. Choosing an ERP model to be applied to a company is a complex process since a detailed analysis of critical factors for implementation as well as rigorous efforts, careful thinking, and proper planning are needed (Mahraz et al., 2020). This is even more complicated in the case of SMEs because, as Chatti et al. (2020) indicate, “they have their own contingencies in addition to the scarcity of resources which may lead to the failure of ERP implementation”. Therefore, in order to select the most appropriate model in each case, SMEs have to do a thorough analysis of all of them.

There are some studies devoted to comparing and discussing the adoption of ERP based on vendors/systems, deployment types, implementation outcomes, benefits, critical success factors, risk factors, and the effects on different enterprises. In this sense, some authors have indicated that effective ERP must be configurable, adaptable, and integrative (Wamba et al., 2018; Hwang et al., 2015). Ram et al. (2014) considered several antecedent factors that are critical to the adoption stage of ERP and concluded that they can significantly influence the achievement of a subsequent competitive advantage. Al-Sabri et al. (2018) also compared different ERPs based on criteria such as scope, purpose, simplicity, availability, ease of use for model matching, or target audience. Likewise, Oltra-Badenes et al. (2018) developed an innovative methodology to choose ERP systems based on literature and the experience of different experts in the sector. No references have yet been found that address legacy ERPs in SMEs. In relation to its implementation, Ahmad and Cuenca (2013) mention the critical success factors (CSFs) to take into account, where organizational CSFs play a more important role than operational CSFs in this phase.

The ERP software industry for SMEs is a special market with different offerings. These systems have evolved rapidly in recent years and include greater accessibility through web environments. Thus, some authors focused their studies on the implementation of the most used commercial ERP software packages in manufacturing companies (Ruivo et al., 2015; Parhizkar & Comuzzi, 2017). Other authors reflected the trend of companies to design their own ERPs that are adapted to the working environment of the analyzed companies. Thus, Wen (2019) developed a dynamic mobile SME ERP platform to improve the efficiency of real-time dynamic management of enterprises. In the case of Amran et al. (2017), the inefficiency of the information system for managing the local orders led the authors to consider web-based local components that support ERP to satisfy important requirements for SMEs.

As Yadav et al. (2019) indicated, there is little research on the implementation of LM in SMEs. Valente et al. (2020) discussed the positive effects from the implementation of lean practices in Portuguese manufacturing SMEs as well as the impact of these improvements in a company's global performance. On the other hand, Hu et al. (2015) focused their research on aspects such as employee empowerment and the development of a supportive strategy into their Lean implementation plans. Sharma et al. (2016) conducted a study identifying the enablers for Lean implementation in the manufacturing sector and concluded that training could be the most significant factor when implementing LM in SMEs. Sahoo and Yadav (2018) studied the acceptability of LM in SMEs using three constructs (process improvement, flow management and waste minimization) and concluded that the SMEs have a good understanding of these type of concepts, but there is still room for improvement in them. In the same vein, Tiwari and Tiwari (2018) stated that the key barrier to implementing LM in SMEs could be inadequate Lean planning.

The Lean IT concept combines the use of the Lean philosophy and ICT, which have to be aligned to the business needs. This concept is of great interest in digitizing manufacturing plants and generating data to control equipment, machines, and employees. These data are used in the productive process and the employees have access to them, so the quality of intra-company communication is improved, and the processing of data is facilitated (Houy, 2007). The latter will help to a company to control the processes. In this sense, Maguire (2016) identified a number of potential conflicts between Lean and IT and concluded that the most impact in SMEs could be related to business process management: avoiding complexity, learning, and adopting a change culture.

However, there are not many studies available in the literature regarding the combined use of LM-IT-ERP. In Powell (2013), an analysis was carried out to determine whether these concepts are complimentary or contradictory technologies. Houti et al. (2016) stated that LM is often characterized by coordination and decentralized control, and ERP is usually the best system to support the planning of centralized production.

This paper explores the combined use of ERP, LM, and IT as applied to SMEs which can be considered as "highly traditional". The study takes into account the ERP-legacy of these companies, complementing it with new tools and techniques to analyze their possible benefits.

Materials and methods

Regional context of the research

This research is focused on SMEs of metal fabrication and equipment goods, which are the most representative activities in the manufacturing sector in the region under study (Asturias, Northern Spain). These types of SMEs share similar processes and can represent an evolution toward a business model with greater added value. Furthermore, capital goods are considered to be the main export of the Asturian and Spanish economy (Sercobe, 2018).

Therefore, the metal manufacturing sector is strongly rooted in this region, playing a fundamental role as a driver of its economic activity. As indicated by Femetal (2019), this sector represents 11% of the Gross Domestic Product (GDP) and 46.44% of the industrial employed population. It contributes 68% of the volume of all external sales (98.7% is from micro-enterprises and SMEs). The 2009–2019 sector data show little economic turnover, where exports have only exceeded the levels of the 2009 crisis. This situation tested the limits of the SMEs with limited resources, manifesting their underlying problems and forcing the abandonment of structures inherited from the past toward new business models linked to the industry of the future. Therefore, they need business opportunities offered by new technologies focused on adding value over the chain of productive activities (Schmidt et al., 2015).

According to Acero-Álvarez (2017), the progress of the DT in the Asturian companies is very low, so it is necessary to continue working on basic solutions to address the implementation of technologies related to Industry 4.0 in the future. Although 75% of the companies have integrated economic and financial process management systems with ERP tools, the digitization of manufacturing plants is nil or scarce (only 3%). The poor implementation of Lean processes is also appreciated, not only in the implementation of LMT but also because of the benefits that can be obtained in processes and operations, which are crucial in Industry 4.0. This transformation cannot ignore the technical office, due to its special connection with manufacturing. In this sense, almost 80% of these companies have implemented technological tools, showing the high degree of digitization in the design process. However, barely 17% use collaborative platforms that facilitate communication between different agents during the design phase. Only 50% of the companies have an incipient level of using solutions for the agile transmission of information with the production plant. In addition, the 80% of them track production in the traditional way, and only 40% get benefits from the data obtained from previous projects as SME knowledge.

Participant

A traditional manufacturing SME located in the Asturias region was used to test and validate the work methodology described in this research. The core activity of the SME is the manufacturing of a wide range of custom-made metal products designed by engineers following customer specifications. The processes include soldering and assembly and other outsourced work related to cutting, forming, and machining structures.

The SME has two production centers (1,220 m^2 and 1,800 m^2) physically distanced from the headquarters where decisions are made. It also has a basic Information Technology (IT) infrastructure and a traditional ERP (Microsoft Dynamics NAV®) whose work is focused on financial management, controlling human resources, and processing orders. An average of 49 workers out of a total of 56 participated in this study. This includes employees with different positions in the organization who carry out different tasks in the manufacturing of SME products distributed in its three centers.

The Technological Solutions Used

In order to explore the weaknesses of the manufacturing processes mentioned above, this study proposed an increase of digitization in the SME combined with the technological solutions which are described below.

GESPROY

This collaborative web environment has been developed by the authors of this paper as an extension of the usually existing ERP in the SME, without affecting daily operations (Facin et al., 2016; Ataseven et al., 2014). For its development, an in-depth study of the company processes has been taken into account aiming at reducing customization and implementation times.

As shown in Exhibits 1 and 2, the employed open-source libraries enable an intuitive, reliable, and user-friendly Windows interface to collect, store, transfer, manage, and support the integration of data from periodic activities, incorporating this new set of tools organized in work modules. In addition, the web environment allows obtaining quick access to real-time data, transferring files and databases, and facilitating communication between users (Villalba-Diez & Ordieres-Meré, 2015) and with other systems such as those in charge of capturing data from the production plant or from the ad-hoc software usually used in the project design phase.

Exhibit 1. GESPROY desktop overview. A) Module Icons B) Desktop C) Module window type D) Taskbar E) Start button F) Start menu G) Working with windows.

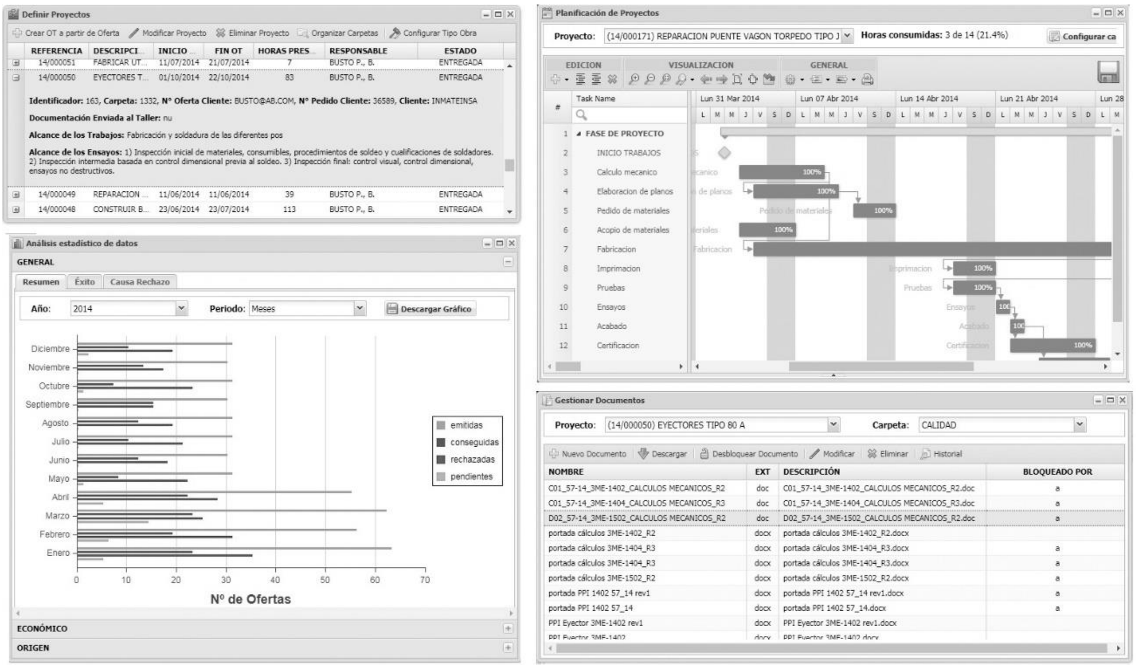

Exhibit 2. View of different GESPROY work modules

Manufacturing processes involve the development of different cross-departmental tasks. The work methodology followed by each user affects the type of access to GESPROY, customizing the tools available to satisfy the requirements of a robust product lifecycle management that has been previously planned.

CAPTURE

ICTs are also used to incorporate the Lean philosophy. A system called CAPTURE consists of a point of sale touch-screen monitor, a barcode reader, and a printer (see Exhibit 3). It was acquired with the aim of capturing data in the production center. This model, which is based on the type of work conducted in the SME, was considered to be the most suitable one because each employee is responsible for interacting with the system. In addition, CAPTURE will share the database with GESPROY to facilitate its connectivity.

Exhibit 3. View of touch screen (left), printer and barcode reader (right)

CAPTURE will be in charge of reading the employee's barcode and the time invested in each project task. Similarly, the supplies received at the production plant were linked to the system by the storekeeper for each Bill Of Materials (BOM). Concerning the digitization of machinery in the company, this represents an extra problem due to its variability and age (in many cases, second and third hand machinery) which would involve creating "ad hoc" solutions for each of them. In this case, the system focuses on managing the machinery maintenance and other representative parameters in production by entering the data manually through the different menu options, such as the kilograms of consumables used in welding processes as well as workers' tools and Personal Protective Equipment (PPE).

The data obtained are exchanged and updated in real time with the GESPROY database. This action helps to create efficient measurement indicators to control machines, people, and processes. Moreover, GESPROY also facilitates traceability and monitoring the products and supplies over the entire value chain.

Proposed Work Methodology

Yin (1989) defines the case study methodology as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident and the investigator has little control over events”. On this basis, this methodology was selected aiming at evaluating the objective of this research. Therefore, a representative company of the studied sector was evaluated during a period of three years (2017-2019). This SME was chosen because it has a very traditional production processes, and it is interested in operating in smaller markets. Also, it has the IT required to implement the proposed solutions.

The procedure for each analyzed period was as follows (Exhibit 4):

- Period 1 (2017): The company organization was maintained as well as the usual workflow methodology for its production plant, which is based on the use of traditional management and communication channels to carry out the tasks and printing the documentation of the projects.

- Period 2 (2018): The organization of the company was also maintained as well as its usual workflow methodology. However, during this period the SME's Digital Transformation Plan (DTP), which is described in the next section, was developed.

- Period 3 (2019): The DTP was executed, and it incorporated the two technological solutions with the LMT integrated in the operation of the company.

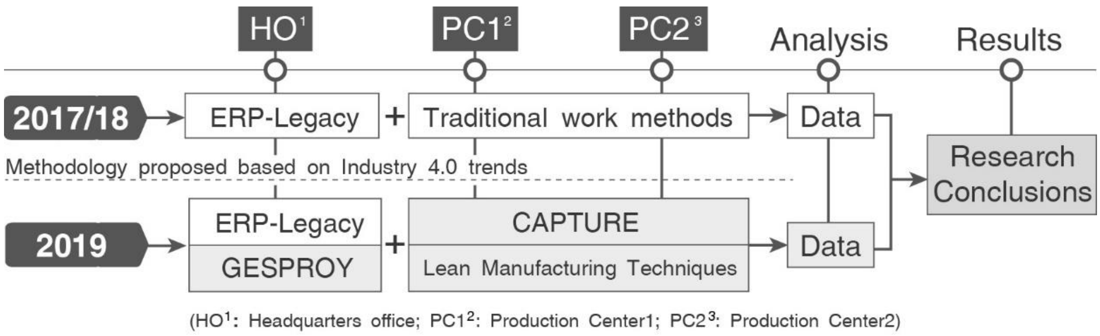

Exhibit 4. Methodology of the research

The Digital Transformation Plan

A DTP was created to define the path of the SME toward Industry 4.0. Aspects such as core competencies, capabilities, motivations, fears, goals, intent, priorities, budget, and resources (Crema & Nosella, 2014) were defined as well as the development of an integrated digital strategy and the transformation of the business model from a digital base. The latter was carried out by a multidisciplinary working group that included the CEO, the head of the R&D department (as director of digital strategy), the manager responsible for each department involved, the workers of the company, and the authors of this research.

To achieve the planned objectives, the DTP was divided into five phases including the implementation and performance of the proposed technological solutions and the chosen LMT (see Exhibit 5). A communication, awareness, and leadership process was established through the Organizational Change Management (OCM) strategy, including departmental task reorganization, cultural changes to abandon old methodologies, and the development of digital training activities in the so-called training and education (TED). Exhibit 6 shows the functional chart of the SME, the participation of the different employees, and their type of access to GESPROY and CAPTURE.

Task	Objective	Procedure	Actions/Results
Phase 1: Analysis of current production processes (CPP) and its standardization			
1.1	**Previous SWOT analysis**	Analysis of processes involving manufacturing.	Processes noted as highly traditional in manufacturing and technical office. Potential impact of its digital transformation which result fundamental to change SME business model.
1.2	**Standardization of productive processes**	CPP analysis using VSM (Value Stream Mapping) tool & AutoCAD.	Ambiguities & bottlenecks detected in CPP; Standardization is inconclusive due to variability in production; Outline new processes and information flows through task 2.1 and 4.2.
Phase 2: Organizational Change Management (OCM) and definition of the objectives of the DPT			
2.1	**OCM**	SME chart reconfiguration (Exhibit 6).	Reassign new tasks and functions; Minimize impact based on 4.2 and 4.5; The new technical area is created.
2.2	**KPI's definition for the DTP**	During implementation and subsequent performance of systems and techniques.	Related to the evolution, achievements and impact on the proposed strategy (economic budget terms and effects on SME activity).
Phase 3: Measures for the Production plant: Lean IT and LMTs implementation			
3.1	**LMT implemented at Working Areas (WAs)**	Due to the small size of WAs and the problems shown in task 1.2; Layout (1); 5S (2) and cellular manufacturing (3).	(1) Configure flexible WAs depending on workload (basics restrictions), (2) Create and maintain order, cleaner and secure WAs & (3) creation of WAs focus on equipment goods production.
3.2	**Digitalization of Production Plant (Lean IT)**	Installation of CAPTURE at production centers.	POS Touch Screen monitor, barcode reader and PC with data interpretation software (Exhibit 3).

3.3	**Employee training**	Create workshop pilot areas in each workshop, focus on TED of LMT & Lean IT.	TED emphasizing the advantages of its application in WAs & operator interaction via barcode (bottom right of the Exhibit 3).
3.4	**Standardization**	LMTs Implementation in all WAs.	Monitor & improve during the practical experience.
Phase 4: Web-enabled GESPROY implementation			
4.1	**Installation**	On-Premise deployment (SME server), establishing a cloud computing.	Users work on both corporate legacy ERP and new GESPROY-CAPTURE, each within its scope of action.
4.2	**Customization**	Adapt systems to SME needs.	Database information updates between systems to integrate functions and it adaptation to user tasks.
4.3	**Testing-validation**	Verify expected results (KPIs), solve deviations.	Systems synchronization (critical).
4.4	**Information gathering**	Use of information from previous works as knowledge	Create library of drawing blocks in AutoCAD (more than 3000) and work templates for different programs according with their ISO-9001.
4.5	**TED**	Working group help employees during the study.	Training of modules functions. Support, communication and education to 2.1.
Phase 5: Performance of the measures taken (Exhibit 7) based on TED (4.5)			

Exhibit 5. Phases taken into account in the DTP

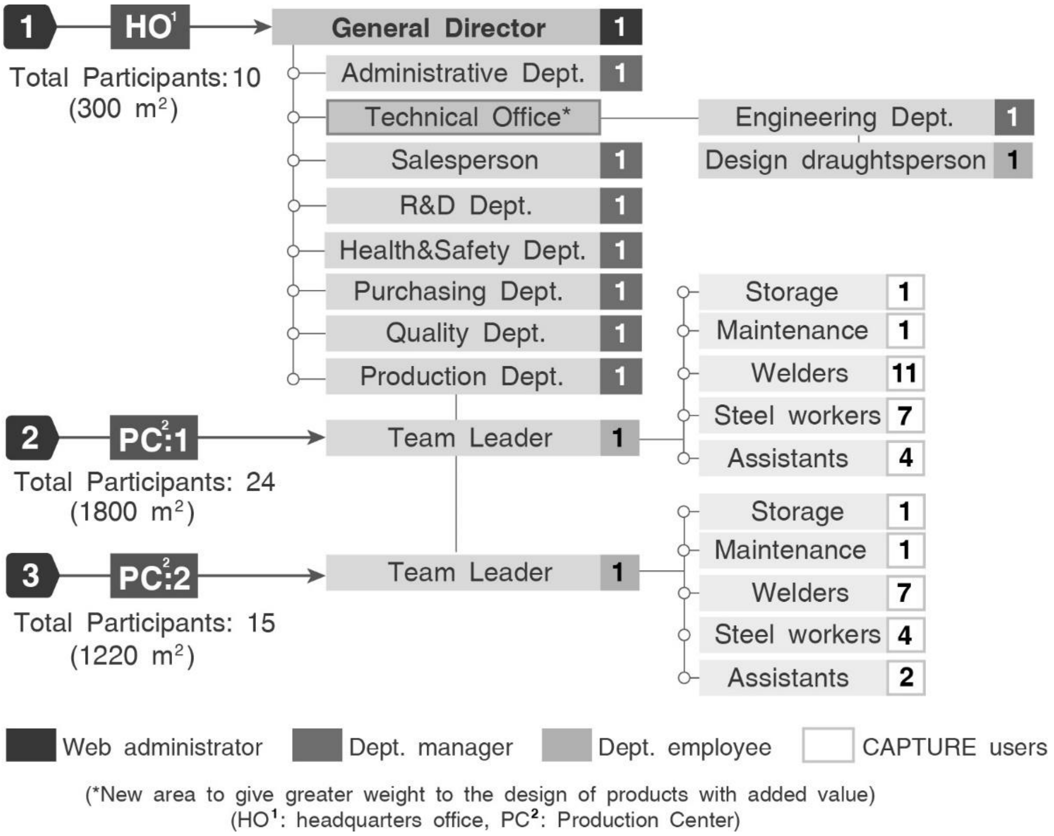

Exhibit 6. Functional chart of the company, people involved in research and their profile access to GESPROY-CAPTURE

The strategy of the DTP implementation was focused on maintaining the existing ERP and incorporating GESPROY and CAPTURE to reinforce the production centers and create a new technical office department to give greater importance to the design of products with added value. The tools were adopted by the SME to reach a better integration of the workforce, cross-departmental tasks, communication, resources, and providers. The following key points of the work conducted must be highlighted (see Exhibit 7).

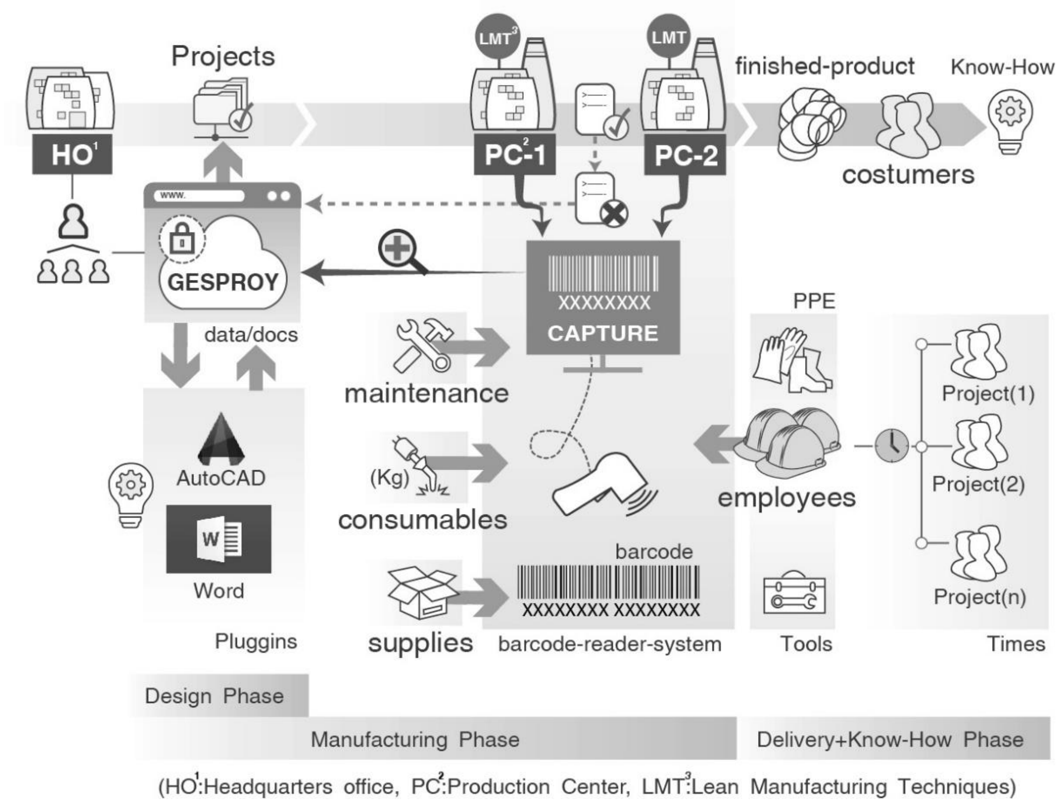

Exhibit 7. Work flow proposal for SME

(1) The collaborative system allowed the technical office to coordinate with the different agents allowing them to manage the design and project documentation as needed by PDM for product manufacturing. Moreover, it also makes the most commonly used programs in this company, such as AutoCAD (See Exhibit 8) (Esan et al., 2013) and Word, available for different users. This is crucial because many drawing blocks and templates in the form of know-how from other previous work can be easily shared (Routley et al., 2013).

(2) The proposed project management enables control, access, and modification of the project generated information via the web. It also stores the tasks that have to be performed at the production plant and establishes a rapid communication channel with the technical office. Thus, engineering drawings, BOM, safety, and quality

procedures can be easily consulted. This allows optimizing management times and reducing quality problems, waste, and loss of information.

(3) The planning optimization and monitoring of the work progress was carried out in GESPROY using a Gantt chart (see Exhibit 2) (Ong et al., 2016). In addition, real-time data in the production plant was captured and managed through CAPTURE. Both GESPROY and CAPTURE work in a collaborative environment. They have tools to measure the efficiency of the production process. These enable decisions to be made about the fulfilment of tasks, times, costs, or control of employees during the work.

(4) The data recorded by CAPTURE allow preventive and predictive maintenance of machines and tracking of their faults. This information is crucial for making decisions about substitutions or modifications of machines with recurrent failures. In addition, it allows control over the tools required for the different tasks that have to be performed, and it adapts the PPE to each employee in order for them to work safely.

(5) The proposed SCM (Metta & Badurdeen, 2013) complements the order management based on the BOM of the legacy ERP with control tools provided by GESPROY and CAPTURE for the reception of goods and stock maintenance in the workshop, providing information of orders, received materials, characteristics, data product, suppliers, product location, etc. It is aimed at increasing control over movement of goods and their traceability, reducing stock, and avoiding wait times and supply shortages.

(6) The CRM is aimed at improving the quality of communication and the customer services thanks to the information generated by previous work for the same costumer. Progress of work can be checked by using the Gantt diagram.

(7) Manufacturing experiences become know-how (Oun et al., 2016). Existing data in GESPROY related to manufacturing, such kilograms of consumables used in welding, customer experience and suppliers, are safeguarded so that they can be used to increase the chances of success regarding other competitors.

(8) LMT related to Layout, 5S, and cellular manufacturing are implemented at the workshop to create clean, organized, and secure work areas (Stålberg & Fundin, 2018).

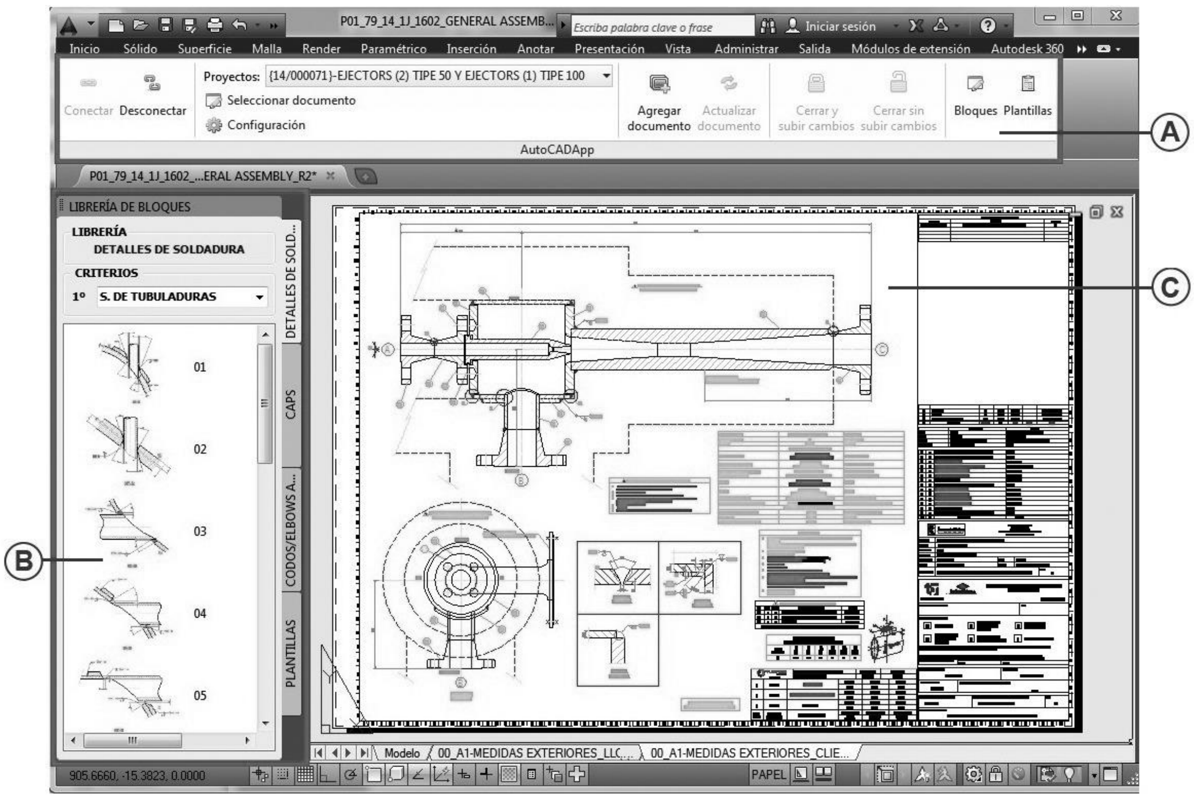

Exhibit 8. View of the AutoCAD Plug-IN functionalities. A) Command ribbon and GESPROY access B) Palette with block library C) Workspace

Results

A statistical analysis was carried out based on data extracted from a set of products manufactured in the 2017–2019 period. Three sets of products from different productions were set as variables. In this sense, aspects such as the different nature of the products, the monthly workload variability, and the interest concerning the generated added value were taken into account. The latter also helped to quantify the evolution and impact of the DTP in the SME alignment to the business strategy. Exhibit 9 shows the number of projects and clients for each type of production categorized by year and markets. In addition, for each variable the study will take into account the time (in hours) devoted to fabrication or "Production Hours", which is correlated with the "Type of Production" and "Year" of the experiment (Exhibits 10).

	Total	**General Works**	**Equipment Production**	**Equipment Design**
Year/No. of Projects				
2017	74	65(50r[a]-15n[b])	9(9r-0n)	0
2018	97	74(63r-11n)	19(19r-0n)	4(0r-4n)
2019	142	131(124r-7n)	8(8r-0n)	3(0r-3n)
Year/No. of Companies				
2017	9	8(4r-4n)	1(1r-0n)	0
2018	12	10(9r-1n)	1(1r-0n)	2(0r-2n)
2019	15	13(11r-2n)	2(2r-0n)	1(0r-1n)

Exhibit 9. Variables: number of projects, No. of companies and types of production per year ([a]r: local-regional market and [b]n: national market)

Production Hours [a]	No. of projects	Average	Median	Standard deviation
Year				
2017	74	703.77	130.5	1288.85
2018	97	792.31	193	1178.45
2019	142	234.33	51.75	478.38
Type of production				
General Works [b]	270	375.01	68.75	832.07
Equipment Production [c]	36	1652.36	1177.38	1399.63
Equipment Design [d]	7	210	83	368.93

[a]Production hours: the hours invested in production by workshop employees. [b]General Works: Projects that involve the generic production of boilers, pipes and metallic structures without added value. [c]Equipment Production: Manufacturing of equipment goods based on customer plans. [d]Equipment Design: Drafting and manufacturing of equipment goods, both of which contain added value elements.

Exhibit 10. Variables: production hours by types of production and year.

An initial analysis was carried out to determine whether the company has undergone a behavioral change over the 3-year period under study. A Kruskal–Wallis test was applied to detect statistically significant differences within the three-year period (p-value < 0.001). A post hoc test identified the specific differences between the first and third year ($p < 0.001$) and between the second and third year ($p < 0.001$). As shown in Exhibit 10, there was a decrease in the number of hours spent, except for the second year where there was a small increase in the number of hours. Similarly, statistically significant differences were detected according to the “Type of Production” (Kruskal–Wallis test, $p < 0.001$), specifically for “General Works”, contrary to “Equipment Production” ($p < 0.001$) and “Equipment Design” ($p < 0.001$).

A multivariate model was proposed to factor in variables such as “Year” and “Type of Production”. A linear model in Exhibit 11 shows the coefficients and their significance. Exhibit 12 shows the relationship between the production hours over the analyzed years. Correlating both variables and applying the bivariate analysis, the Kruskal–Wallis test detected differences with $p < 0.001$. The post hoc test of multiple comparisons for 2018 and 2017 and for 2019 and 2018 (in both cases, p-value < 0.001) detected a clear decrease at the end of the period. Finally, Exhibit 13 shows the relationship between the hours and the types of production. In terms of the “Type of Production”, the differences detected by the Kruskal–Wallis test (p-value < 0.001) may be attributed to differences in “Equipment Production” with regards to other types of production.

Production Hours	**Coefficient**	**Standard error**	**P value**
Constant	371.35	357.29	0.299
Year			
2017	Reference		
2018	9.29	138.68	0.95
2019	-38.86	128.18	<0.01
Type of production			
Equipment Design	Reference		
General Works	189.79	342.72	0.58
Equipment Production	1362.52	368.86	<0.001

Exhibit 11. Linear model. Variables: production hours, types of production and year

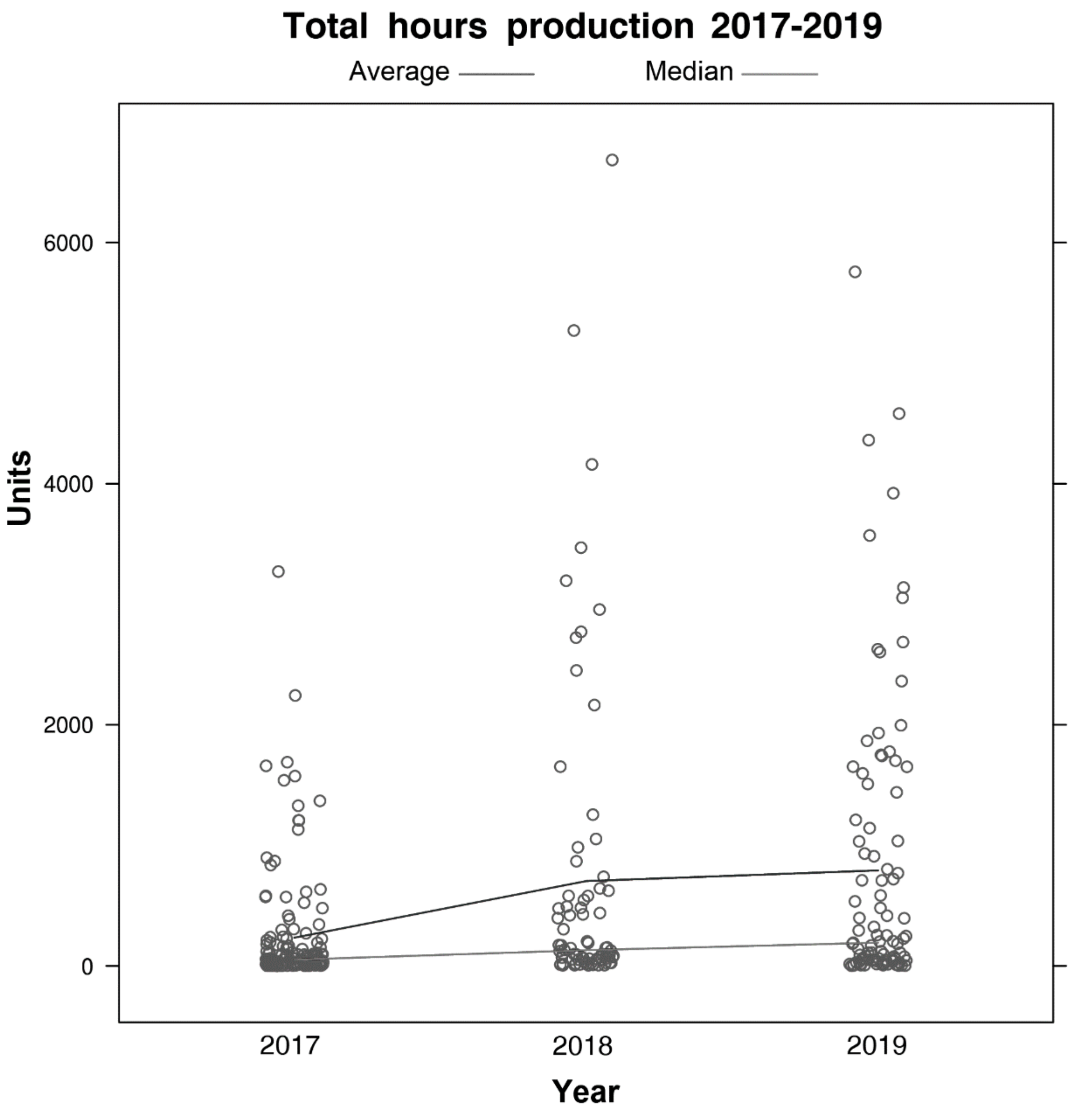

Exhibit 12. Relation between Hours of Workshop Production and Years

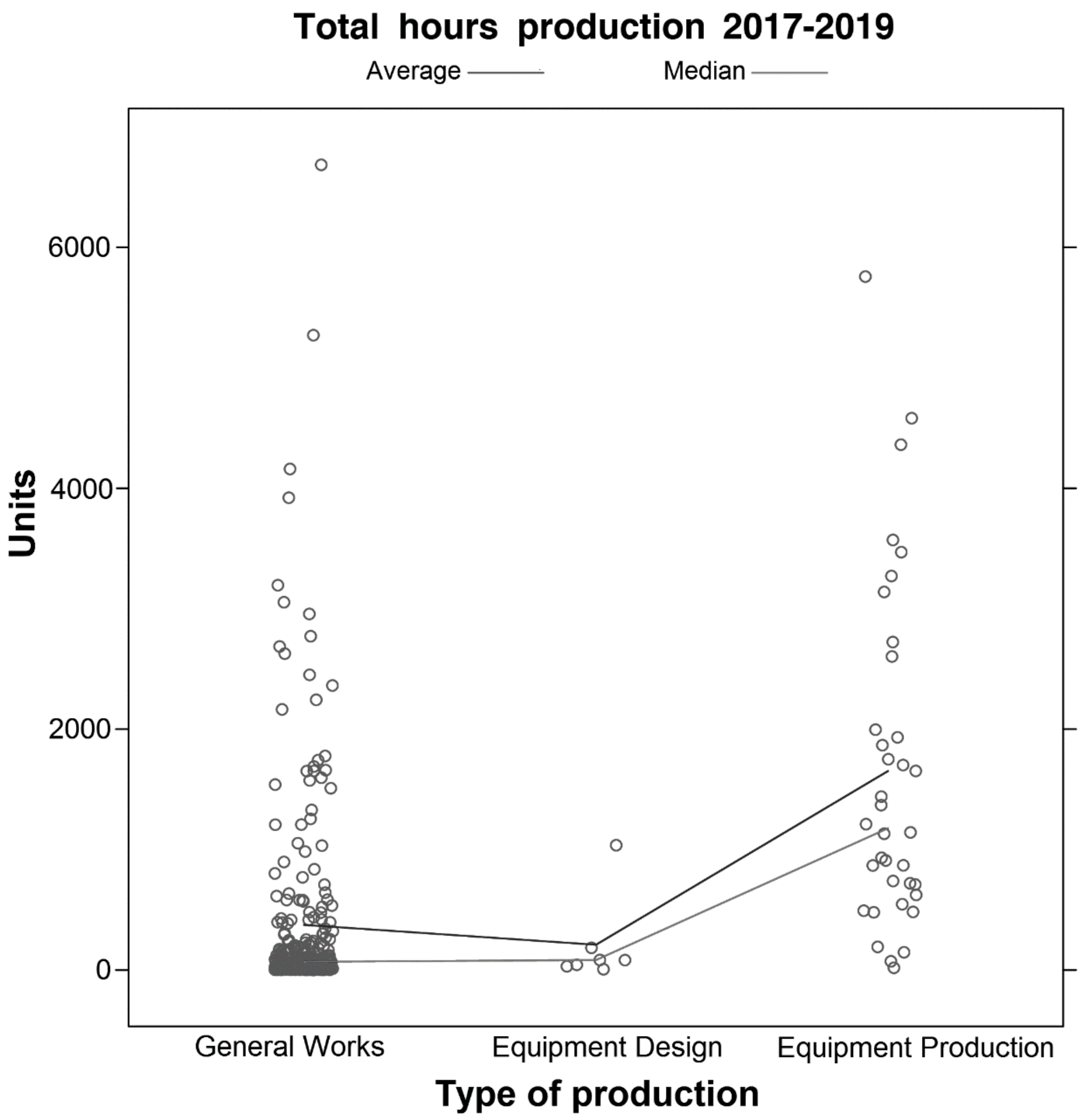

Exhibit 13. Relation between Hours of Workshop Production and Types of Production

Discussion

Interpretation of statistical analysis results

As seen before, the statistical analysis of the variables under study showed that there is a change in the trends during the 2017–2019 period. The different types of jobs help to interpret how effective the company’s technological transition was during the implementation of the DTP during 2019, where certain external SME factors have played a fundamental role.

The data shown in Exhibit 9 allow us to establish the influence exerted on the activity of the “General Works” projects in 2017. They generated 87.84% of the workload during that year, and 67.57% of the resulting products were oriented to the necessities of companies that operated in a local or nearby market. Besides, nine of these projects, associated with the fabrication of pressure equipment, had a special technological interest concerning the added value and know-how acquisition.

Data gathered in 2018 provide highly favorable results concerning the gradual transition towards operation in less crowded markets while maintaining the strategy followed by the SME regarding the manufacture and design of goods and equipment. The workload of this year represents an increase of 31.08% with respect to the previous year. It is interesting to note that twice the “Equipment Production” products had been made and four design and production projects had been distributed with two new companies that operate in national markets during this period. The analysis of the client portfolio continues to show dependence on a single company that accounts for 100% of the workload for making the equipment, but its influence was lowered to 60.32% in the case of “General Work” projects.

The analyzed SME underwent a period of change and adaptation to the uncertain economic surroundings during 2019. It carried out 47.42% more projects with respect to 2018, but it suffered a loss of contracts with local clients. As a result, only 13.80% of the “General Work” projects were contracted with its best client, and consequently more than half of the “Equipment Production” projects were lost as compared to 2018. This forced a search for new local markets without added value. On the positive side, the fidelity of the “Equipment Design” projects with a national company that operates in markets less affected by the economic crisis was noticeable.

As shown in Exhibit 12 and 13, there are significant differences in the time required for each type of job. The latter can be attributed to the fact that each project is unique, and it is adapted to the necessities of each client. The jobs that required a greater amount of production hours correspond to the ones with greater complexity and greater added value, such as “Equipment Production” and “Equipment Design”. The improvements introduced in the business processes could be seen reflected in the quantitative analysis of time invested in each type of project and the analyzed year (variable “Production Hours”).

General considerations of the experience

Considering the new market demands and the strong competition in the sector, the need for the SME transformation may be incompatible with the actual possibility to carry it out. The lack of vision regarding the different dimensions of the concept and technologies associated with Industry 4.0 hides the establishment of the strategy and technological solutions that have to be followed by the company, since their business model is based on the manufacture of a wide variety of metal products under customer demands. Besides, other intrinsic aspects have imposed on the “pace of transformation” of the SME. Some of these are the scarcity of resources, the fear and the indecisions in the constantly changing environment, the previous digitalization experiences, and the lack of qualified personnel.

Although there is still a long way to go, the DTP presented in this study has helped to start fitting and aligning the strategic vision of the SME toward Industry 4.0. Some actions were taken to abandon traditional structures while gaining experience in the manufacture of equipment, goods, or products with greater added value. The latter was conducted without reducing the flexibility of the production plant or losing workload (mixed production model). Besides, improvements and innovation (Hernandez-Vivanco et al., 2018; Marra et al., 2018) in three basic pillars (process, product, and business model) were established in order to gain competitiveness in more stable markets. These changes in the production plant can be essential in this type of highly traditional company.

The experience presented in this article has served to introduce the advantages of the DT and Lean philosophy in its production plant. Key aspects such as communication between employees (especially critical since the production centers are distant), access to information, and monitoring of products and workers to conduct process control were improved thanks to the application of the adopted technologies. From the study, one can highlight the importance of a quick response from the different departments (especially the technical office) to the production plant. Furthermore, there has been an enhancement of resource management, cost reductions, better planning, effective decision making, and organization empowerment as well as better quality and customer satisfaction which are confirmed by the results of the surveys conducted by the SME quality department. It has also had a positive impact on efficiency gains in the manufacturing processes thanks to LMT, which is beginning to show value gains in SME.

Technologies and techniques used

This study has proposed basic technological solutions to continue exploring digital solutions that would ensure the flexibility of the production plant, leaving for the future the adoption of technologies linked to Industry 4.0 for when they better define their products with higher added value. These solutions are aligned with the available business strategy of the company that has been adjusted to the transformation pace of the SME which has to continue working and improving over time.

Another aspect carefully analyzed in this study was related to the previous implementation of the on-premises ERP which is oriented to economic and financial subjects that can be considered as cumbersome, complex and costly, exceeding the initially estimated resources. Due to the economic context, the company is currently looking for new ways to consolidate their legacy ERP, services, and IT infrastructures. Moreover, it is also focused on increasing their return of investments (Johansson et al., 2015) with a clear preference for controlling and safeguarding the data generated in different deployment options, such as on-premises storage with a private cloud. This study has helped to define the best features for its ERP solution and avoids past errors where the trusted provider became the best strategic partner.

According to the results of this study, the use of the work environment aligned with the highly personalized ERP concept has been very important for this experience. Indeed, the specific design of the GESPROY work modules has allowed the system implementation to accelerate, aiming at adapting them to the reality of its production processes. In addition, thanks to its open web-based architecture, all of the users have quick access to the company's data and project documentation, creating synergy among them and optimizing their work during the production phase. These actions contrast with the services provided by their legacy ERP that was highly inaccessible with restricted access (Kwak et al., 2012).

The role of CAPTURE has been fundamental for the correct operation of GESPROY. The data capture in the production plant was carried out through interaction with the employees, either by reading bar codes or their manual introduction into the system.

Regarding the LMT, new techniques involving integral, organized, and safe work areas were adopted. This reduced displacements and delays through the implementation of the 5S philosophy (Hernandez-Matias et al., 2019). Besides, it was impossible to standardize the processes to maintain a flexible production system according to the workload. Therefore, the layout was adapted to the needs of the production plant with minimal restrictions, developing new dynamic capabilities (Hansen & Møller, 2016).

Organizational Change Management

Although the process of digital transformation is very advantageous for organizations, it entails huge efforts from all the employees because they have to include changes and cope with compliance to the recommendations in order to achieve the intended objectives (Flores et al., 2020). The employees should notice that the adopted solutions will help them on their work, and they are not an inconvenience. As indicated by Ahmad and Cuenca (2013), organizational Critical Success Factors have played a more important role than operational ones during implementation. Indeed, the cultural changes and the reorganization of tasks and functions in the business process have been especially critical and highly influenced by the economic context and the tradition of the sector.

The employees showed a positive attitude to the cultural change, as they had a previous experience in the implementation of ERP. Moreover, training and educational tasks were fundamental to reach the intended objectives which were motivated by the possibility of improving the company's expectations. On the other hand, one of the most critical factors was the restructuring of tasks and functions, in which certain employees distrusted sharing their know-how and breaking with inherited structures. The calibration of the data obtained from the barcode reader system regarding variables such as the "employee-hours-project" has also been especially critical, because of the importance of linking the data directly to the payroll in the legacy ERP. However, the premises carried out in the development of the GESPROY-CAPTURE system (Logan et al., 2018), that include an intuitive, reliable and user-friendly graphics interface, have facilitated rapid learning of the users (Pinedo-Cuenca et al., 2004).

It is also important to highlight that the employees of the production plants have shown a positive attitude toward compliance with the Lean philosophy, assimilating the new way of organizing and caring for the work areas or interacting with CAPTURE. However, they manifested problems with the new techniques. This was due to the lack of defined procedures and other aspects of the production system far from the flow production.

Implications for Engineering Managers

As indicated by Ghobakhloo (2018), "Industry 4.0 is no longer a hype, and manufacturers need to get on board sooner rather than later". In this sense, engineering managers have responsibility for transitioning from traditional manufacturing to Industry 4.0 because it is an integrative system for value creation in the company. Therefore, the developed strategic roadmap implemented in this study aims to encourage effective management in the traditional SMEs of the manufacturing sector so that companies can experience major achievements that can be applied to Industry 4.0 practices. In this study, it was shown that the relationship between the methodology used and the roadmap implemented, based on its own idiosyncrasy, have an enormous potential to develop a deeper understanding of how these companies face Industry 4.0 transformation and their technologies-techniques preferences. Moreover, the findings of this study are of special relevance due the novelty of the Industry 4.0 concept and its application in certain industries that can give rise to new models of transformation success.

Conclusions

For many manufacturing SMEs, the Industry 4.0 concept represents the best way not only to improve production but also to gain value and competitiveness in increasingly complex and uncertain markets. Defining the correct path that SMEs in the metal sector have to follow is a long and complex task which is full of doubts and uncertainties. Hence, it is difficult to carry out on its own. Indeed, factors such as the great variability of the manufacturing products under customer demand, limited resources, lack of qualified personnel, and highly traditional manufacturing processes are decisive.

The SME's strategic response has been adopted for the base technologies proposed in this case study. The digitization of its production plant has been explored in order to address technologies more linked to Industry 4.0 in the future as they better define their products with higher added value. This is one of the areas most impacted by digital transformation. A new work methodology was established. It is based on expanding the scope of action of their current ERP as well as data capture in the production plant using ICT and LMT.

The results for the period under study showed greater management capacity and efficiency improvements in production-related processes. The role of the ERP and IT extension (GESPROY) has been of primary importance, and they have contributed by giving easier access to project information and enhancing communication between departments. The latter provided a quick response to the needs of the production plant since the role of the technical office is aided by a web service of crucial relevance. The inclusion of the Lean philosophy in the system has improved efficiency in the control of machines, employees and process, and this facilitates decision making. In addition, LMT has allowed the creation of flexible workspaces according to the new requirements: integrity, organization, and safety.

Other relevant aspects are related to OCM in which previous ERP implementation processes, uncertain economic times, and TED have been decisive in the positive attitude of the SME's staff. In addition, the analyzed SME is looking for new ways to consolidate their legacy ERP, services, and IT infrastructures and to increase their return on investments with a clear preference for controlling and safeguarding the generated data.

Although there is still a long way to go, the experience has served to integrate the strategic vision by aligning technologies and employees toward Industry 4.0. Traditional structures are evolving toward other technological-based ones. The benefits of DT are already being noticed in the production plant as well as in the adaptation to the new market requirements.

In summary, the results for the studied period manifest greater management capacity and efficiency improvements in production-related processes. They also begin to show certain value gains. In fact, the research presented here can facilitate possible implementation of the proposed procedure in other companies of the metal sector.

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Biographies

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