Using wastes as driver to integrate digital and engineering practices maturity in the product development process: an application case

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Abstract: The increasing competition in manufacturing industry has pushed many SMEs to adapt their processes in order to embrace Industry 4.0 and Lean Management practices. The paper aims at presenting an integrated implementation of four analytical and diagnostic methods to facilitate a supported digital transformation by taking into account both the review of processes in a more effective and efficient way and the reduction of manufacturer's wastes. The research has been developed by applying the DREAMY, CLIMB and MyWaste suite to an Italia manufacturing SME specialized in the design and production of highly customized machineries for the processing and packaging of tubes. The analysis encompassed three main steps: an assessment of digital maturity and of the product development process, an analysis of the main wastes and a mapping of the overall process from the RfQ to the production of the good. The main criticalities were related to the lack of formal procedures and coordination protocols, a misuse of digital tool for budgeting, project management (PM) and designs storage and a related increase of the time devoted to non-adding-value activities.

Keywords: Industry 4.0, Manufacturing SME, digital readiness, maturity assessment, process waste

1.Introduction

With the advent of the fourth industrial revolution, manufacturing companies have been constantly pushed to radically change either business model or processes to incorporate digital technologies. Collecting data and exploiting the value given by their analysis has become a key element of competitive advantage (Castelo-Branco, Cruz-Jesus and Oliveira, 2019). This paramount concept stands at the basis of the concept of Industry 4.0. Indeed, although a common and universally accepted definition of Industry 4.0 is still missing (Culot *et al.*, 2020), it is widely recognised that it impacts all the activities and processes characterizing the manufacturing industry. According to (Balocco *et al.*, 2019), there are 3 main areas of application of Industry 4.0 solutions (vertical and horizontal value chains; product and service offerings; business model and customer access).

To achieve one or more of the scopes identified above, eleven main technologies have been identified (Bortolini *et al.*, 2017), including IoT, AI, Cloud Computing and Manufacturing, Big Data, CPS and so on. The implications for manufacturers are huge and various, depending also on the specific characteristics of the individual market of reference (Shrouf, Ordieres and Miragliotta, 2014). However, in parallel to the understanding of the technologies available, great focus should be devoted on other factors. In fact, the implementation of a Digital Transformation Journey must be anticipated by a deep identification of the digital *status quo* of the firm (Sassanelli, Rossi and Terzi, 2019; Sassanelli and Terzi, 2020). Hence, a comprehensive set of assessment, aimed at understanding the so-called AI-IS and identifying the strengths and weaknesses of an organization in terms of digital maturity, turns out to be and essential starting point for a successful transition described so far.

In this direction, many frameworks have been defined in the extant literature. The DREAMY model (Digital REadiness Assessment MaturitY) is a method aimed at assessing the digital readiness level of manufacturing firms with the objective of developing a Digital transformation roadmap once analysed the specific characteristics of the practitioner (De Carolis *et al.*, 2017). In particular, the model provides a 5-scaled rank by analysing 6 main core processes and, on the basis of the results obtained and an analysis of the current best practices adopted in industry, proposed a roadmap to be adopted by manufacturers to fill the gaps identified.

Similarly, the CLIMB model (Chaos-Low-Intermediate-Mature-Best practice) assesses the maturity of manufacturing firms in the product development activities (Rossi and Terzi, 2017). In particular, the model is aimed at practically providing a support in adopting the most suitable best practices (e.g. lean approaches) taken for industry concerning the new product development process.

In light of this, MyWaste and MyTime are formalised and structured methods to identify wastes and lead designers to improve and streamline the process (Rossi, Taisch and Terzi, 2012).

The four above mentioned methods have been already integrated in a unique approach by (Sassanelli, Rossi and Terzi, 2020). However, in this context, the gap is the lack of integration of the results of these methods with the model analysis of the product development process.

Therefore, to fill this gap, this research consisted of the application of these integrated methods within a manufacturing firms specialised in the design, production, and assembly, of machineries for the processing and packaging of industrial tubes. Indeed, the main objective of the research is to exploit the results obtained through the adoption of these methods in the product development process. To do this, two sub-objectives have been identified. The first aim is to provide a comprehensive but, at the same time, detailed overview of the company both in terms of digital maturity as well as of efficiency and effectiveness of the order process (being an engineering to order industry), decomposed in three main sub-processes: 1) Budgeting and final balancing, 2) PM and 3) New product development. The second one is to use the concept of waste to integrate digital and engineering practices maturity in the product development process.

The paper is structured as follows. Section 2 presents the research context. Section 3 describes the method adopted to conduct the research. Section 4 shows the results obtained and Section 5 discusses them. Finally, Section 6 concludes the paper also unveiling the next steps to be pursued after this analysis.

2.Research context

The assessment methods (DREAMY and CLIMB), together with the analytical methods (MyWaste, MyTime and MyKnowledge), are specifically designed and based around the concept of digital readiness and maturity of the company (i.e. DREAMY), of the level of adoption during the development process of the extant design practices and methods (i.e. CLIMB), and of the concept of waste in the same process (i.e. MyWaste, MyTime and MyKnowledge). All of them, together, share the aim of providing the input to the company for setting the path toward the continuous improvement, lean management and Industry 4.0 transition. However, a clear integration of how the results obtained through the adoption of these four methods could be used to streamline the product development process still needs to be enlightened. A possible solution is to exploit the waste concept during the modelling of the process.

3.Research methodology

To assess the level of digital maturity of manufacturing SME and then increase it by implementing digitally advanced solutions, an explanatory case study has been conducted. Due to the strategic relevance and the high concentration of value adding processes, a greater focus has been devoted to the New Product Development (NPD) process. The research conducted has been designed according to single-case design approach and included semi-structured interviews and supervised questionnaire sessions to gather data (Yin, 2009)](Table 1 summarises the phases of the research).

Based on the primary aim of the research, the first step has been the definition of the unit of analysis. The authors selected the company A (referred as Company).

Table 1: Phases of the research conducted

Activity	Aim	Employees involved
CLIMB – Interviews	To evaluate the design and engineering process, appraising its readiness and analysing its main criticalities	CEO and top management
DREAMY – Interviews	To assess the digital readiness and maturity of the company	CEO and top management
MY WASTE suite – Workshop + remote survey	• To detect wastes, their causes and effects • Raise the awareness about these wastes in the company	Individual interviews with 2 from marketing, 6 from Technical department and R&D, 2 from Purchasing department, 2 from Production department and 3 Top Managers
Mapping the AS-IS process – Workshop + interviews	• To map the product development process. • To define duration and tools employed along the activities	Individual interviews with 2 from marketing, 6 from Technical department and R&D, 2 from Purchasing department, 2 from Production department and 3 Top Managers
Final Workshop	To raise the awareness of both CEOs and top management	CEO and top management

3.1 The application case

The Company is an Italian engineering to order (ETO) SME specialized in the engineering, development and assembly of machineries for the processing and packaging of industrial tubes. The sales function of the firm is indeed divided according to these two kinds of machinery offered. The market of reference is dominated by large international companies that typically offer their products by catalogue at competitive prices. Hence, the key success factor of the Company is due to its ability to absorb the remaining demand that large players are not interested to satisfy by providing highly customized systems. Hence, the products offered are characterized by low-volume and high-value added.

The Company develops two main typologies of machines:

1. Semi-standard machines: 50% of the orders
2. one-of-a-kind ad hoc machines: 50% of the orders

In order to compete in the market, the firm expressed the need for optimizing NPD process and the overall workflow management thus identifying both its critical success factors and weaknesses. As a consequence, the firm was interested in undertaking the right corrective action needed to strengthen its competitive position. Indeed, over the years the firm exacerbated its inefficiencies in the NPD process in favor of an outstanding customization offered to its customers. Therefore, the research approach adopted, composed by the integration of DREAMY and CLIMB models with MyWaste, MyTime and My Knowledge methods, defined in Section 2, was used to conduct the case study, providing the following results.

4.Results

4.1 Assessment: digital and engineering practices maturity

Form the assessments conducted through the DREAMY and the CLIMB emerged that the firm turned out to have an overall level of digital maturity lower than the average of its sector of reference and also to pay a remarkable gap in terms of knowledge management compared to all the benchmark used for the evaluation (Figure 1).

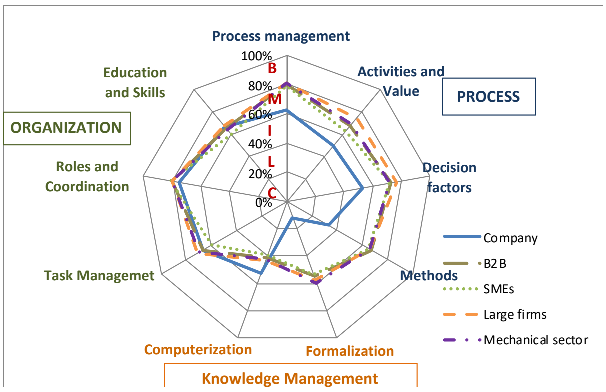

Figure 1: CLIMB chart of the firm compared to the benchmark used.

In terms of digital infrastructure, the company mainly relied on mere share folders for the collection of the most valuable data, namely designs and specifications of the customized components, thus creating huge inefficiencies especially along the engineering processes. Moreover, even if the company followed an ETO approach, no PM tool nor specific practice was established before the assessment. Hence, all the management of the order was monitored through standard programs like Excel sheets. In addition, the lack of a formal knowledge management system was another key weakness of the firm. However, the great experience of the sales office, due to the strong technical background. Could partially cover the inefficiencies highlighted during the assessment.

4.2 Analysis: waste detection

Among the 33 wastes identified through the MyWaste suite, 3 of them turned out the be particularly relevant (Figure 2).

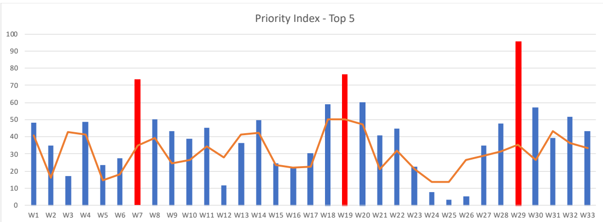

Figure 2: Evaluation of the 33 wastes compare to the average of past analysis

In particular, these three wastes highlighted in red (form left to right) refer to: Waiting times, Change of requisites or priorities and Reworking activities. Despite the overall results presented in figure 2, it is worth noticing that the Priority index of the wastes as well as the related roots causes identified differed remarkably according to the category of interviewees involved in the workshop. However, in line with the assessment described in paragraph 4.1, the lack of a structured IT system and an overall formalization proved to be constant elements of the analysis.

4.2 Analysis: mapping the product development process

Once performed the assessments and the analysis of the product development process, a complete mapping of the overall process has been performed as well. The 8 macro-blocks identified are reported in Appendix A. The analysis of the entire process shown that, overall, all the tasks performed were conducted in series. This approach seemed reasonable for the first half of the processes, namely the acquisition of requirements and the generation of the proposal but in the subsequent phases related to the actual product development and related production the same approach adopted generated inefficiencies along the process. In particular, the sequential approach together with the reduced synergies among the functions have been identified as the main sources of reworking activities (the most impacting waste). Moreover, also the already mentioned lack of formal procedures, a structured knowledge management system and a proper IT infrastructure made the control over the overall process of product development and the possibility to set continuous improvement particularly difficult.

5.Discussion

The work conducted resulted in a systematic integration of the methodologies above mentioned. They allowed the authors to develop not only a comprehensive assessment of the key adding-value processes of the firm but also to identify the most impacting wastes and criticalities affecting them. Such issues in fact, turned out to represent a barrier to the digital transformation journey of the company and most importantly compromised its order development process effectiveness and efficiency. Nevertheless, the tools described, if properly exploited, could represent for the firm a critical opportunity to move towards a more aware and structured approach driven by product centric Knowledge Management and continuous improvement. In fact, the final objective is to provide the practitioner with a roadmap of potential yet feasible interventions to be undertaken to improve the current situation and gain competitiveness. Then, the analysis performed have been enriched by using some relevant benchmark shared with the firm itself that allowed the research not only to focus on the specific AS-IS but to contextualize it through an external comparison.

In particular, once collected the results from DREAMY, CLIMB and MyWaste Suite, these have been presented to the top management of the Company. During the face-to-face meeting all the main criticalities identified as well as the main strengths have been summarised according to 4 main areas: Execution, Control, Organization and Technology. Overall, the firm suffered a major gap in terms of control over the entire NPD and PM processes. This was due to the technical competences of the organization that although high proved to be fragmentated and prerogative of specific individuals (e.g. Head of Sales). This, in parallel with the poor level of formalisation of methods and knowledge led inevitably to make the control over the people particularly difficult and sometimes completely absent. Another cluster of critical factors was related to Technology area. It has been shown how the current IT systems used were not exploited effectively or were not the right tool for the given tasks. From the MyWaste suite emerged that the company was quite aware of the relationship between the wastes and their root causes. The method highlighted that the time devoted to adding-value activities represented the 23% of the total time spent against the 41% of the benchmark while data entry task accounted for 17% compared to the 7% of the benchmark. Overall, almost the 80% of the daily time resulted to be drastically reduced through the implementation of digital solution and a redesign of the NPD process. The analysis done stand at the basis of a further formalization of the process, to eliminate wastes and adopt a Stage & Gate configuration.

6.Conclusions

The aim of this paper has been to analyse the digital maturity level of a manufacturing SMEs and define strengths and weaknesses of the NPD and PM processes. A single-case design study has been proposed to validate the research. In this sense, the DREAMY, the CLIMB and the MyWaste Suite are the methods selected and combined for the analysis. As a consequence, the manuscript evidenced a successful integration of the methods that results in a comprehensive and multi-perspective assessment of manufacturing firms' processes. However, the research suffers the limitation of a single-case approach. Regarding the next steps of the study, four main activities could be undertaken: to implement a review of the organizational structure to support the changes required, to deepen the micro-processes to eliminate the macro-issues, to support the Company in the review of the processes and to evaluate the most adequate IT solutions for the processes analysed.

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Appendix A. Mapping of the Product Development process

Process	Input	Output	Duration	Main variables	Tools used
Marketing	--	RfQ	2 to 3 months	Market volatility; Customers; Type of product to promote	ERP/CRM; ISpeak portal; Market & Competitive analysis; Social networks & Mail
Sales	RfQ from marketing	Formulation of the offer	5 to 6 weeks	Level of customization; Customer; Workload of sales dept.	Autocad LT; CRM & shared folders; Excel; LibreOffice/LaTex; Telephone/Mail
Planning	Formulation of the offer from sales	Gantt of the project and technical specs	3 weeks	Level of customization; Availability of resources; Quality of the commercial specs	Thunderbird; Microsoft Office Suite; ISO modules
NPD 1/3	Project specs from KOM	3D development and M8.48	3 months	Level of customization; Quality of technical specs; Urgency	ProE Creo Elements 5 M280; FEM; Excel; Solid works; ISO modules; Mail & oral communication
NPD 2/3	3D development	Documents for Purchasing and Production dept.	3 weeks	Level of customization & complexity	ProE Creo Elements 5 M280; Autocad; Microsoft Office suite; ERP
NPD 3/3	M8.48 Motor & Sensor List	Documents for Purchasing and Production dept. Software	Documents: 4 weeks Software: 1 day	Level of customization; Quality of M8.48 Motor & Sensor List; Quantity of components encoded in the ERP	Excel; Spac automazione; ERP; Tia Portal
Purchasing	M8.11 modules	Purchasing order	2 weeks	Level of customization; Completeness of the BoM; Quantity of components encoded in the ERP	Excel; ERP; Telephone/Mail; MRP
Production	M8.11 modules	Purchasing order	1.75 months	Level of customization; Availability of technical dept.; Non-conformities; Value of incoming material	Gantt; Check list; Tia Portal; Mail/oral communication