Integrating Processes, People and Data Management to Create a Comprehensive Roadmap Toward SMEs Digitalization: an Italian Case Study

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Abstract. Digitalization is increasingly gaining interest among manufacturers. Focusing on manufacturing, this interest already turned into a necessity that cannot be further postponed. This explains why digitalization or Industry 4.0 transition characterizes most of the strategies for manufacturers irrespectively of their size or maturity level. Nevertheless, size and maturity do matter in such kind of transition. Literature and practice advocate that Small and Medium Enterprises (SMEs)s face huge barriers to keep high the competitive advantage of their products, thus they first need to act on their processes and internal resources. Among them, lack of competencies and limited data exploitation are threatening the competitiveness for the medium-long term the most. Thus, the present contribution aims to present the results obtained from the integrated application of three maturity models focused on the skills gap, data management, and operations management within the scope of digital maturity. These maturity models were developed as stand-alone tools focusing the attention on a specific need (i.e. operations, people, or data). In this contribution, they were integrated to provide an overarching view to develop a unique roadmap towards social and economic sustainable industrial environments. The integrated model was applied to an Italian SME.

Keywords: Manufacturing, Maturity Models, Resource Management.

1 Introduction

The wave of digitalization has spread in every branch of today's society as well as Industry. This led to the development and distribution of objects and services that are more and more often associated with the term “smart”. Looking at the manufacturing sector, the digital transition has encompassed operations processes, monitoring and control, organizational structures, communication channels, HR management, and many other fields [1]. However, such dramatic change does not come without investments of practitioners in terms of financial resources for assets (both hardware and software) and time. In this sense, the lack of sufficient financial resources is one of the main barriers that damper the diffusion of digitalization, often referred to as Industry 4.0 (I4.0) [2]. However, other major causes regard skill and cultural aspects that characterize companies [3]. Indeed, [4] argued that a digital advancement of processes must be supported by a proportionate increase in the capability of the organization to use, manage and understand both technology and the data around them. This bifocal perspective appears even more critical when analyzing Small-Medium Enterprises (SMEs) as they traditionally struggle in both the dimensions aforementioned [5]. Hence, literature has proposed models and methodologies to support this transition starting from an understanding of the current situation in which the company lies. These tools, referred to as Maturity Models (MMs), are indeed defined as "*the state of being complete, perfect or ready*" [6]. From the definition, it can be argued that the field of applicability is wide and may encompass all three struggling points to the I4.0 transition, namely: Process-related [1], People-related [7], and Data-related [8]. However, although these 3 dimensions are often analyzed individually, a plan toward higher levels of Digital Maturity shall not tackle them as independent silos rather it must consider and integrate them holistically. Indeed, literature has provided a rich multitude of MMs for digital transformations focusing on specific aspects of it. However, few contributions have been lavished towards the integration of the different perspectives in one single method. For this reason, this paper proposes an integrated methodology to assess the digital maturity of manufacturing SMEs and, consequently, delineate a roadmap by considering holistically Process, People, and Data management dimensions. The study was conducted by focusing on 3 MMs already developed by the authors but not integrated into one single tool. The methodology presented has been validated in an Industrial case with an Italian SME (2 plants) and the results have been reported in this contribution.

The rest of the paper is structured as follows: Section 2 depicts the theoretical background of the MMs for each macro-dimensions; Section 3 describes the roadmapping methodology, named P.P.D. Digital Roadmapping Model proposed in this contribution. Then, Section 4 reports and discusses the results from the Industrial case, and finally in Section 5 conclusions and limitations of the study are disclosed.

2 Theoretical Background

The present section delineates the theoretical background of the three methodologies employed to create the overall assessment model covering three fundamental areas for the digital transformation of manufacturing companies: i) processes (see sub-section 2.1.), ii) people (see sub-section 2.2.), and iii) data management (see sub-section 2.3.).

2.1 Process Digital Assessment

The digital transition was pushed especially to improve the efficiency of manufacturing processes [9]. Among all, I4.0 enabling technologies are gaining momentum [10] for instance the diffusion of the Internet of Things used to improve eco-efficiency in manufacturing [11] but also additive manufacturing, blockchain, advanced robotics, and artificial intelligence [12]. The technological-related opportunities for manufacturing companies' operations are many although these are also backed by some challenges such as resistance from the workforce and huge financial investments [12]. In addition, to pursue a structured and successful digital transformation, it is required to rely on a solid digital backbone through the integration of existing information and communication technologies.

In this context, to support manufacturing companies in evaluating their current digital readiness, [1] developed a maturity model. In particular, the model aims to perform first a descriptive assessment to highlight the key strengths and weaknesses of all the functions covering the operations, to then add prescriptive suggestions based on the current state assessed. This maturity model is based on a 5-level maturity scale (i.e. initial, managed, defined, integrated and interoperable, digitally oriented) covering the following manufacturing areas: Design and Engineering, Production, Quality management, Maintenance management, and Logistics management (inbound, internal, and outbound).

2.2 People Digital Assessment

Digital transformation inevitably requires the involvement of the entire workforce, both operators [13] and managers [14] to ease the introduction of new technologies in production plants. Indeed, new skills and specific job profiles are emerging since the introduction in manufacturing companies of I 4.0 enabling technologies [15]. These new job profiles must cover soft and hard skills but also need to have the minimum knowledge in terms of Information and Communication Technologies (ICT) to be competitive [16]. In this context, the capability to assess to current digital maturity level of people becomes essential for companies to understand which profiles they need to invest in to align people and technologies within a unique path toward digitalization.

In this regard, [17], subsequently extended in [18], proposed a maturity model aiming at assessing the digital maturity of people, both at operative and managerial levels, operating in manufacturing companies. More in detail, the assessment is performed for every single profile (i.e., managers and operators of the following functions: design & engineering, production, quality, maintenance, logistics, and the data science and ICT managers) across 5 levels of maturity (i.e., basic, aware, practiced, competent, proficient) assessing the maturity for soft skills, hard skills, and ICT literacy skills. The authors opted for a prescriptive approach of the MM (in contrast with a comparative or descriptive one) as it enables the company to identify structured plans to undertake a digital path based on the emerged company's needs.

2.3 Data Assessment

The spreading of I4.0 enabling technologies in the industrial domain is pushing companies in exploiting data gathered from the field [19]. In this context, hence, data-driven decision-making processes can be established for asset management [20] and also for product life cycle management [21] to support both managers and operators in their daily activities. Indeed, proper data management by manufacturing companies can expedite the establishment of sustainable and circular strategies, for example, facilitating the adequate usage of natural resources in industrial processes [22].

For these reasons, researchers are trying to evaluate how to measure data productivity in data-driven decision-making processes[8]. Moreover, still in this view, data management assessment models, more in detail maturity models, have been developed to support manufacturing companies in accelerating their digital transformation from initial levels to optimized ones [23][24]. The assessment is performed through a 5-levels maturity scale by keeping into account several dimensions, like processes, people, and operations. This broad perspective aims to create the right awareness in manufacturing companies on the evaluation of how good they are at exploiting the data gathered inside their plants to facilitate their decision-making process.

3 P.P.D. Digital Roadmapping Model Development

The above-mentioned maturity models are specifically focused on the current state assessment of a certain aspect of manufacturing companies while keeping a silos perspective. The proposed integrated version of these models, the P.P.D. Digital Roadmapping Model, aims to provide a comprehensive view of the three elements (i.e., process, people, and data management) which are considered fundamental to be kept into account to create a structured roadmap facilitating the digital transformation of manufacturing companies. The P.P.D. Digital Roadmapping Model, hence, aims to investigate separately the three aspects to assess the maturity level of the company in a detailed way. Indeed, separated interviews are firstly performed with the area managers and their teams of the functions covering all the operations (i.e., design & engineering, production, quality, maintenance, logistics, and supply chain) to perform the process and data management assessments. More specifically, regarding process management the model proposed by [1] is used, while for data management those proposed by [23] and [24] have been used and revised to be aligned with the maturity scale and the dimensions covered by [1]. More specifically, also for the data management maturity model, the areas covered are design & engineering, production, quality, maintenance, logistics, and supply chain [1]. This is evaluated through the maturity scale of 5 levels looking at i) data collection and cleaning, ii) data storage, iii) data sharing, iv) data analysis, and v) data exploitation for decision-making processes. Then, all the managers and operators operating in the above-mentioned functions are asked to answer a self-assessment questionnaire to perform the skills maturity assessment (the one proposed by [17]). These three separate assessments generate separate radar charts which cover all the operations of the company. Then, based on these separate assessments, it is possible to perform a deep analysis of the overall maturity of the company and its concrete needs by keeping into account the current state from several perspectives. Indeed, the 5-level maturity scales of the three models are the same, even though they employ a different perspective. This alignment ensures to have a consistent and systematic assessment which sets the basis to create a unique roadmap. To report an example, the lack of sensorized machines on the shop floor is easily reflected in a lack of data available to perform deep analyses and also a lack of knowledge of the operators in exploiting data from the field. However, some of the operators might have the right knowledge about data exploitation, but they cannot exploit it due to the lack of specific technologies in the company. Thus, through the assessment emerges the potentialities these people have in becoming mentors for other colleagues in case that specific technology would be considered useful for the business of the company after the assessment on process and data sides. The following paragraph describes in detail the key characteristics of the models adopted.

3.1 The methodology

As argued by [25], the first step of digitalization consists of an understanding of the status quo (AS-IS) of the firm.

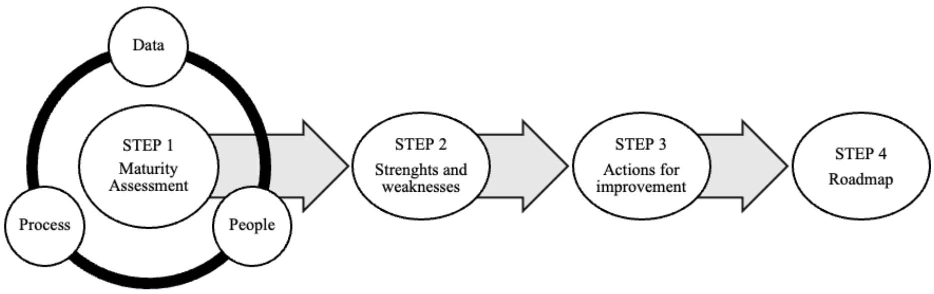

Fig. 1 Steps of the P.P.D. Digital Roadmapping methodology

Hence, as depicted in Fig. 1, the researcher will exploit the information collected to identify both strengths and weaknesses that characterize the processes analyzed and rank them according to a priority order. This phase turns out to be crucial for the effectiveness of the roadmap since it summarizes all the main elements that might be tackled and, in this sense, it must be strongly aligned with the company's business objectives and sector's needs (identified during the assessment phase). The prioritization of weaknesses is based on an initial sorting of them into root causes of the criticality and effects or rather those weaknesses that prove to be a consequence of other pain points. Then causes and effects are mapped and linked in graphical form and, starting from the map, each relationship is translated into a numerical matrix counting how many times a cause impact on an effect [26]. This mapping process, given its crucial role in the whole process, must be conducted with or validated by the company's experts [27]. The third step consists of the identification of the key actions for improvement to mitigate effects or directly eliminate the root causes detected. Step 4 aims to spread such actions along a given time horizon. This last phase proves to be crucial as well since it allows the beneficiary of the roadmap (the firm) to balance the effort needed and understand which are the logical sequence that linked actions might have [1].

3.2 Areas covered

The overall methodology, as previously mentioned, aims to cover 3 main dimensions (Process, People, and Data) however, this aim is too broad and generic when dealing with manufacturing contexts. For this reason, the 6 areas proposed by [1] (i.e. Design and Engineering, Production, Quality management, Maintenance management, Logistics management (inbound, internal and outbound), and Supply Chain management) are investigated to better contextualize the analysis performed. Each area is then further detailed into sub-areas (e.g. Production Planning) to maximize the capillarity of the assessment. It is worth highlighting that, since the areas are designed with a modular approach, they might be faced independently and some of them might be omitted as well. This last case applies to those realities that do not manage or are not interested in tackling all the departments of their organizations but rather want to rationalize resources only on specific key areas. Last, a seventh area that bonds all the previous 6 is given by Digital Backbone or rather an area that aims to assess and eventually improve IT-related departments which are usually cross-departmental or staff to the whole organizational structure. Regarding the People side of the methodology, focused on the evaluation and reinforcement of people's skills, the authors have introduced a 3 layers classification common for all the areas abovementioned. They are ICT literacy, Hard Skills (specific for each department), and Soft Skills.

3.3 The scale

To provide a comprehensive result, all the 3 dimensions of the assessment have been evaluated according to a 5-scale Likert scale. The selection of such a scale represents a standard for MM [28]–[30] as it allows to give a quantitative evaluation of multi-dimensional factors thus providing a comparable and homogeneous value. In particular, the authors opted to rely on scales already available in the literature and validated in previous studies as reported in the theoretical background (i.e. [1] for Process, [17] and [18] for People, and [23], [24] for Data).

4 P.P.D. Digital Roadmapping Model Application

The multi-perspective MM model presented was applied to an Italian manufacturing SME operating in the prefabricated building sector. The study was conducted lasted 3 months and involved the authors (as facilitators and evaluators), the heads of the areas abovementioned, and a sample of operators. The results are shown in **Fig. 2**.

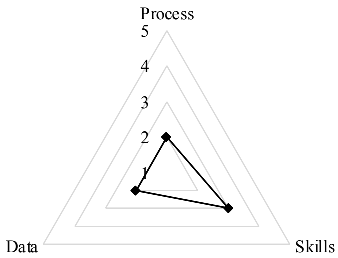

Fig. 2 Company's maturity level

The firm's processes and data management, distributed in 2 plants, presented an overall Maturity level of 2 as the processes resulted in partially controlled and mainly managed by the high experience technicians and managers that do not properly store and use data acquired on the field. The systems in use were not advanced, not integrated among the different functions, not suitable for the functionalities that were required to fulfill, and misaligned with the needs of the process built over time. Moreover, these shortcomings resulted in a proliferation of local documents and files, especially Excel, for the management of processes and, given their unreliability regarding the quality of the data recorded in them, a progressive distrust of current information systems. Regarding the skills analysis, the overall state of propensity to digitization showed a high level of knowledge of the internal systems (level 3) Soft skills were adequately high (around 4), assuming a future openness to the demand for change. On the other hand, as far as hard skills are concerned, regarding I 4.0, there was a medium-low level of competence (2) requiring ad hoc training courses based on the technological investments selected. Indeed, the level was consistent with the technologies currently present in the company, and it does not facilitate the identification of a mentor or a digital leader for the colleagues. To better identify the main pain points, the authors mapped the main criticalities and effects through the PCIM (Prioritized Criticalities based on Impact Matrix) framework [26]. This allowed us to visually and quantitatively identify the main areas of improvement of the company.

More specifically, the most impacting criticalities referred to: limited knowledge of all the managers about the potentialities derived from I4.0 technologies, limited data exploitation for the decision-making process, lack of quality and maintenance control plants, paper-based data sharing across functions, lack of integration among available information systems, lack of specific information systems (e.g. warehouse management systems). Given this AS-IS scenario, the methodology allowed to depict a roadmap to Digital Transformation **(Fig. 3**) which consisted of the following aspects: i) **Process**, review of business (green circles) processes and IT systems (purple circles); ii) **Skills** (red circle), identification of training and education modules for each category of worker assessed; and iii) **Data** (dark blue circles), identification of collectible data and design of a balanced scorecard for each process assessed. Such projects were plotted based on the expected effort (y-axis), defined with the interviewees, and time (x-axis).

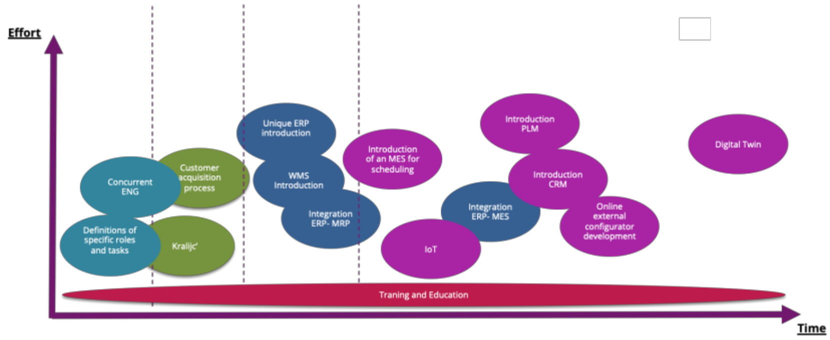

Fig. 3 Roadmap to digital transformation

5 Conclusions

This research aimed at presenting a methodology to support manufacturing SMEs in their Digital Transformation process. The methodology was designed to tackle in a holistic and integrated way 3 main viewpoints that must be taken carefully into account to ensure the success of the transition to I4.0, namely: Process, Skills, and Data management. To do it, the authors conducted a descriptive review of current MMs for Digital Transformation. It emerged that they were focused only on one out of the three dimensions abovementioned. Then, they focused their attention on three MMs. Hence, the new methodology was developed based on the extant scientific literature and validated in an Industrial case that involved Italian SMEs operating in the prefabricated construction sector. The methodology was designed to cover all the main steps of roadmapping: Assessment, Critical analysis, Solutions proposal, and Planning. The results of the research are deemed relevant from both a theoretical and managerial perspective. Indeed, it proposes an integrated and multi-dimensional MM and roadmapping methodology for manufacturing contexts; secondly, it provides tangible support to managers and C-levels in the definition of balanced and time-distributed investments and actions for improvement throughout their whole digital transition strategy deployment. The research presents some limitations as well given mainly by the reliance on a single-case study which will be overcome through future reiteration of the methodology and possible refinement based on feedback from companies. Additionally, the People-oriented MM adopted does not assess a valuable dimension such as the resistance to the chance of the organization.

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