Towards the Definition of an Impact Level Factor of SME Features Over Digital Transformation

Melissa Liborio Zapata, Lamia Berrah, Laurent Tabourot

Towards the definition of an Impact Level factor of SME features over Digital Transformation

Melissa Liborio Zapata[1,2] (✉), Lamia Berrah[2] and Laurent Tabourot[1]

[1] Laboratoire Systèmes et Matériaux pour la Mécatronique (SYMME), Université Savoie Mont Blanc, Annecy 74940, France
[2] Laboratoire d'Informatique, Systèmes, Traitement de l'Information et de la Connaissance (LISTIC), Université Savoie Mont Blanc, Annecy 74940, France
melissa.liborio-zapata@univ-smb.fr

Abstract. Companies are experimenting change at a fast pace in the business environment due to the evolution of technology. As a result, they require solution approaches designed to guide their Digital Transformation (DT) efforts. However, several factors must be considered in their design, notably how the particular features of companies impact positively or negatively their DT. In the case of Small and Medium Enterprises (SMEs) in manufacturing, this is particularly relevant, as their vulnerabilities, such as the lack of resources, seem to have a significant impact over the success of DT initiatives. Defining this impact as an indicator of this effect will provide valuable information to control the DT to better achieve its objectives. For this reason, the aim of this paper is to introduce the impact level performance indicator for the specific scenario of manufacturing SMEs' DT. An Impact Analysis is presented with this purpose using a qualitative approach. Conclusions of this work lead to further develop the Impact Level indicator using a quantitative approach that enables its use in the control of the DT process.

Keywords: Industry 4.0, Digital Transformation (DT), Small and Medium Enterprises (SMEs), Impact Analysis, Impact level Performance Indicator

1   Introduction

Just some years ago, a company could have periods of stability only interrupted by a few radical changes that required immediate action in order to remain competitive [1]. Nowadays, change is constant and the evolution of technology is an important reason behind its speed [2]. New digital technologies as Artificial Intelligence, along with other trends such as faster Internet service, represent many opportunities for companies searching to lower costs by improving performance or capturing new income by creating value through new products and services [3]. Despite the advantages, companies also face critical challenges in the implementation of these new technologies [2]. In this context, a Digital Transformation (DT), defined as "*the use of new digital technologies to enable major business improvements*" [4], has become the goal for every company.

Programs like Industry 4.0, born in Germany in 2011 [5], and other initiatives in research and practice, are looking for the right approach to succeed in this transformation. Numerous frameworks and models are also proposed to assist companies of all sizes and sectors with their efforts [6,7,8]. However, the DT process is highly complex, not only because it involves changes in many business dimensions [9], but also because the degree of the complexity that companies will face depends on their specific situation [3]. Companies, therefore, need to know how their particular features impact positively or negatively their approach of the DT process and the achievement of the associated objectives.

The answer is highly relevant for Small and Medium Enterprises (SMEs), companies with a set of characteristic features related to their size that make them seem vulnerable in the face of a DT [7,8,10]. Features, like the lack of financial resources to invest in the new technologies or the human resources with the right skills to implement them, are at the source of those vulnerabilities [3]. Defined by the European Commission as companies with a staff of only 250 people or less [11], SMEs, despite their size, hold great importance as a group, as they account for more than 99% of the businesses in Europe [10]. Consequently, their success is a source of economic growth for the region and their DT is considered as an important avenue to achieving it [10]. Inside the SMEs category, the DT of those in manufacturing is particularly crucial, as they are not only the users but the producers of the new digital technologies. They are also a critical part of supply chains of Business to Business markets that have already started their digitalization process and are demanding the same from their supply chain participants [12].

Given the background, the quantification of the level of impact that manufacturing SMEs features have over the DT is critical in controlling the process and the achievement of its objectives. For this reason, the concern of this work is the introduction of the impact level as an indicator to be used by decision-makers in SMEs with this purpose. To start its development, the aim of this paper is to present the impact level using a qualitative approach that shows its general behaviour. Therefore, the organization of the paper is as follows. In Section 2, a brief description of the dimensions of a DT are presented, along with the specific features that characterized manufacturing SMEs. This information is followed by the qualitative analysis of the impact level in Section 3. In Section 4, feedback from France industry experts regarding the analysis is shared. Finally, conclusions are proposed in Section 5, along with the perspectives towards the further development of the Impact Level performance indicator using a quantitative approach.

2 Digital Transformation and Manufacturing SMEs elements

2.1 DT dimensions

Solution approaches for DT, in research and practice, propose each a set of business dimensions or aspects that experiment change during the transformation process. Once focused only on the technological side of the change, current works understand the need to have a broad business perspective of the process [7]. However, no consensus has been reached regarding the specific dimensions that must be included, as some works

choose a broad and general scope [7], others focus mostly on the operational [8] or technological [3] aspects of the transformation. In consequence, to define a set of dimensions for this work, the following procedure was performed.

1. A literature review was conducted and 21 DT models were identified.
2. An evaluation of the models according to the design principles proposed by Pöppelbuß [13], resulted in the selection of the top 7.
3. A comparative analysis of the different dimensions proposed by the 7 models [3,5,7,8,14,15,16] was performed.
4. A proposal of a set of business dimensions affected by a DT was created based on the ones most mentioned by the selected models. This proposal shares a view of the wide scope of the changes involved during a DT.

Table 1 presents the set D of the 12 dimensions d_j, $j \in \{1,2,3,4,5,6,7,8,9,10,11,12\}$, proposed by this work with a brief description of the changes expected in each of them during a DT.

Table 1. DT dimensions.

ID	Dimension	Expected Changes
d_1	Strategy	Digital Strategy definition and implementation
d_2	Business Models	Innovation of the organization's value proposition
d_3	Investment	Planning related to the realization of the Digital Strategy
d_4	Customer	Digital Experience definition
d_5	Products and Services	Creation of Smart and Connected Products and Services
d_6	Business Process	Processes creation, redesign and automation
d_7	Culture	Change towards Innovation and Collaboration
d_8	Organizational Structure	Flexibility, Agility and Cross-functional Collaboration
d_9	Leadership	Leaders aware and prepared for the Digital Era
d_{10}	(Strategic) Partnerships	Collaboration with customers and competitors
d_{11}	Employee Competences	Digital Competences
d_{12}	Technology	Digital Technologies selection and implementation

2.2 Features of Manufacturing SMEs

Manufacturing SMEs possess a set of particular characteristics that define their behaviour. Their specific features are enlisted to better understand their particular conditions when they are faced with challenges such as a DT. The definition used in this work (Table 2) is based on a previous research work that assembled a list of their features as a result of a literature review on the subject [6]. The following set F of the ten features f_i, $i \in \{1,2,3,4,5,6,7,8,9,10\}$, conceptualize manufacturing SMEs as companies with low availability of resources and a strong focus on the performance of day-to-day operations.

Table 2. Manufacturing SMEs features.

ID	Feature
f_1	Limited resources (financial, technical, human)
f_2	Organizational Structure less complex with informal strategy & decision making
f_3	Culture with low flexibility for change and experimentation
f_4	Personnel engaged in multiple domains of the organization
f_5	Low regard for business processes and standards
f_6	Product development with high levels of customization
f_7	Industry Knowledge focused in a specific domain
f_8	Strong Customer/Supplier Relationships
f_9	Low investment in R&D and lack of alliances with Universities
f_{10}	Low adoption of new technologies

3   Impact Analysis

The proposed approach is to assess, through a qualitative analysis, the level of impact of the effect that SMEs features have over the DT dimensions, based on the theoretical definition of these two elements, respectively, presented in Table 1 and Table 2. For the purposes of this work, the Impact Level $ILij$ is conceptualized as a performance indicator that shows the level of the positive or negative effect that a given feature f_i has over a given dimension d_j. Therefore, IL_{ij} can be defined as the set I and as the result of the following function:

$$ImpLev : F \; x \; D \rightarrow I$$

$$(f_i,d_j) \rightarrow ImpLev \; (f_i,d_j) = IL_{ij}$$

The objective of this analysis is to understand the nature and intensity of the Impact Level IL_{ij} using the given set of SMEs features defined by their current stereotypical characterization. This approach provides a point of departure to draw the preliminary conclusions towards the development of the IL_{ij} as a numerical value.

3.1   Methodology

In order to generate the required information for the analysis, a matrix was built with the individual qualification of the impact level of all the possible combinations between features f_i and dimensions d_j. This qualification was performed with a 4-level scale composed by 2 *criteria*, an intensity of the impact, Low "*L*" or High "*H*" and a sense of this impact, Positive "+" or Negative "–". The 4 levels are described as follows.
- **L+:** Low influence of the feature in support of the change in the dimension.
- **L-:** Low influence of the feature against the change in the dimension.
- **H+:** High influence of the feature in support of the change in the dimension.
- **H-:** High influence of the feature against the change in the dimension.

The qualification of IL_{ij} is based on the state of the art on the subject and validated by experts in the related fields. Additional meetings were held when there were conflicting positions in order to reach a consensus. The analysis was performed by the qualification of both criteria for each combination. For example, it is expected that a *Culture with low flexibility for change and experimentation f_3* will be a determinant barrier for the design and especially the implementation of the DT *Strategy d_1*, hence its "*H-*" value, in other words, $IL_{31} = ImpLev\ (f_3, d_1) = H\text{-}$. The combinations that do not relate or present any impact between them were left empty, as a way to maintain the focus on the real issues during a DT.

3.2 Impact Analysis

Table 3 presents the qualification of the IL_{ij} of the manufacturing SMEs features f_i over the DT dimensions d_j.

Table 3. Impact analysis of DT dimensions vs. Manufacturing SMEs features.

Dimension/ Feature	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}
d_1	H-	H-	H-		H-	H+	H-	H+	H-	H-
d_2			H-	H-			H-	L+		
d_3	H-	H-	H-				H-		H-	H-
d_4	H-		H-		H-			H+	H-	H-
d_5	H-		H-	H-		H+	H-	H+	H-	H-
d_6	H-	H-	H-	H-	H-		H-	H+		
d_7	H-		H-	L+				H+	H-	H-
d_8	H-	H-	H-	L-						
d_9	H-	H-	H-							
d_{10}		H-	H-					H+	H-	
d_{11}	H-		H-	H-			H-		H-	H-
d_{12}	H-	H-	H-			H+	H-	H+	H-	H-

General conclusions of the impact analysis are presented from two perspectives. The first one highlights the dimensions where potential issues can arise during the DT, considering the effect of the given features. The second one, on the other hand, shows the features that hold the most critical influence over the dimensions. The management of these conditions could represent a higher success rate of the DT initiatives.

Dimensions Perspective. The analysis considers the following relevant findings.
- The dimensions that are more impacted by the features are *Strategy d_1*, *Products and Services d_5* and *Technology d_{12}*.
- *Strategy d_1* definition, and particularly its implementation, will challenge almost every feature of SMEs and will require change management tools.

- *Technology d_5 and the *Products and Services d_{12} that it enables will be the source of the major changes during the DT.
- These 3 dimensions will have the advantage of *Product development with high levels of customization* (f_6) and *Strong Customer/Supplier Relationships* (f_8).

Features Perspective. The analysis considers the following relevant findings.
- The features that make the strongest impact over the dimensions are *Limited resources f_1, Culture with low flexibility for change and experimentation f_3* and *Low investment in R&D and lack of alliances with Universities f_9*.
- *Culture with low flexibility for change and experimentation f_3* and *Limited resources f_1* could have a strong impact as they touch most of the DT dimensions.
- The *Limited resources f_1* of all sorts will affect all the dimensions that need them in order to achieve the necessary changes required by the DT.
- The *Low investment in R&D and lack of alliances with Universities f_9* will demand a significant effort to implement a culture of innovation, crucial in a DT.
- Only 2 features have a positive effect: *Product development with high levels of customization f_6* and *Strong Customer/Supplier Relationships f_8*.

The results of the analysis are not completely surprising as it confirms the disadvantaged position of SMEs in front a DT challenge, but the global view of the IL_{ij} reveals in detail a degree of magnitude of the effect between features and dimensions that it was not evident at the beginning of this work. From this insight, numerous possibilities arise to deepen the understanding of the relationship between them, like, for example, the variations in the IL_{ij} with different configurations of SME features (e.g., a more formal structure, a culture more open to change). As patterns in the table become evident, it becomes clear that the development of this indicator could provide the information to design a DT experience more consistent with the Manufacturing SMEs scenario.

Once collected the necessary insight through this qualitative approach, the next stage of this research will focus on translating this information into a numerical model using a quantitative approach to calculate a more accurate performance expression of the IL_{ij}. The model will provide a quantification of the "High" and "Low" levels in different scenarios and conditions, taking into account the specific factors that define the magnitude of the effect of the features over the dimensions. A model of these characteristics will enable the simulation of different scenarios and, in consequence, will support decision-making when managing DT initiatives, facilitating the achievement of its objectives.

4 Industry feedback

French manufacturing industry holds a leadership position in Europe [12], however as it happens with many sectors of the economy, in order to boost their growth, the digitalization of manufacturing SMEs is a priority for the region [10]. Accordingly, competitiveness clusters as Mont-Blanc Industries in the French region of Auvergne-

Rhône-Alpes, are active in promoting their DT with the participation of a network of universities and other industry actors [17]. As this research work is focused on the participants of this region, a series of interviews were conducted with industry experts to discuss the outcome of the impact analysis, as well as the list of SME features and DT dimensions to verify if those elements correspond to the reality of the sector.

The industry experts confirmed that the findings issued from the analysis make sense according to their practice. They recognize that the limitation of resources is a big issue, but not as big as the type of leadership in the organization that, in their opinion, defines their organizational culture. Often they also see that some types of leadership, present in family-owned SMEs, are a strong barrier to pursue a DT due to a poor vision of the future and lack of willingness to risk their still comfortable positions. These remarks are also consistent with the general characterization of SMEs as companies focused on managing day-to-day operations.

Finally, in addition to their comments regarding the results of the analysis, industry experts stressed the importance to keep in mind that the generalization regarding the manufacturing SME features could not apply to manufacturers in all sectors, as the ones in the automotive and aerospace sectors seem to have a different characterization. Companies in those sectors, as well as those who already started their DT, may have a different level of maturity in their features as a consequence of the changes implemented during their transformation process or because of pressures of their specific environment. This relevant feedback confirms the vision of the design of the future quantitative model that considers the building of a model flexible enough to adapt to the different situations and conditions of manufacturing SMEs.

5   Conclusions and Perspectives

Digital Transformation describes the efforts of the enterprises that want to take advantage of digital technologies to improve their competitive position. However, benefits do not come easy, as the speed in the evolution of these technologies is turning the economic landscape in one full of challenges, especially for manufacturing SMEs. This type of company is struggling to transform, due in theory to the vulnerabilities related to their characteristic features. The contribution of this paper, therefore, is focused on understanding the effect that their features have over the business dimensions of a DT in order to use this insight to improve the success of this process.

Relevant findings include the identification of Strategy d_1 and Culture f_3 as the top critical dimension and feature, respectively. But beyond the obvious, the value of this research is focused on the insight that a global view of the 1 to 1 interaction between features and dimensions provide for the study of the impact level as a performance indicator of the success of a DT. This preliminary work on the subject will be followed by a more in-depth study of the dynamics of the impact between features and dimensions to get the necessary information to translate it into a quantitative approach that provides a model that guides decision-makers to a successful DT. This model will be part of the efforts of a research project whose main objective is to provide manufacturing SMEs in France with a DT framework.

References

1. Brown, S. L., Eisenhardt, K. M.: The Art of Continuous Change: Linking Complexity Theory and Time-Paced Evolution in Relentlessly Shifting Organizations. Administrative Science Quarterly, 42(1), 1 (1997).
2. Kagermann, H., Wahlster, W., Helbig, J.: Recommendations for implementing the strategic Initiative Industrie 4.0. In: Final Report of the Industrie 4.0 Working Group (2013).
3. Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., et al.: IMPULS Industrie 4.0 Readiness. VDMA's IMPULS-Stiftung. Aachen, Cologne, (2015).
4. Fitzgerald, M., Kruschwitz, N., Bonnet, D., Welch, M.: Embracing digital technology: a new strategic imperative. MIT Sloan Manage. Rev. 55 (2), 1–12 (2014).
5. Schuh, G., Anderl, R., Gausemeier, J., Hompel, M., Wahlster, W.: Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies. In: Acatech Study. Munich (2017).
6. Mittal, S., Khan, M. A., Romero, D., Wuest, T.: A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). Journal of Manufacturing Systems, 49, 194–214 (2018).
7. Schumacher, A., Erol, S., Sihn, W.: A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP, 52, 161–166 (2016).
8. Akdil, K.Y., Ustundag, A., Cevikcan, E.: Maturity and readiness model for industry 4.0 strategy. In: Ustundag, A., Cevikcan, E. (eds.) Industry 4.0: Managing The Digital Transformation. SSAM, pp. 61–94. Springer, Cham (2018).
9. Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., Haenlein, M.: Digital transformation: A multidisciplinary reflection and research agenda. Journal of Business Research (2019, Article in press).
10. European Commission: European SME Action Programme, https://ec.europa.eu/docsroom/documents/36142/attachments/1/translations/en/renditions/pdf
11. European Commission: What is an SME, https://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en
12. Khurana, A., Al-Olama, B., Shaban, M., Wijeratne, D.: The Future of Manufacturing – France. Global Manufacturing & Industrialization Summit (2018).
13. Pöppelbuß, J., Röglinger, M.: What makes a useful maturity model? A Framework of General Design Principles for Maturity Models and its Demonstration in Business Process Management. In: ECIS 2011 Proceedings. 28 (2011).
14. Geissbauer, R., Vedso, J., Schrauf, S.: Industry 4.0: Building the digital enterprise. 2016 Global Industry 4.0 Survey. PwC (2016).
15. Lee, J., Jun, S., Chang, T.W., Park, J.: A smartness assessment framework for smart factories using analytic network process. Sustainability 9(5), 794–808 (2017).
16. Scremin, L., Armellini, F., Brun, A., Solar-Pelletier, L., Beaudry, C.: Towards a framework to assess the maturity for Industry 4.0 adoption in manufacturing companies. In: Brunet-Thornton, R.; Martínez, F. (eds.) Analyzing the Impacts of Industry 4.0 in Modern Business Environments, IGI-Global, Ch. 12 224-254 (2018).
17. Mont-Blanc Industries Homepage, https://www.montblancindustries.com