Transforming DIGROW into a Multi-attribute Digital Maturity Model. Formalization and Implementation of the Proposal

Paolino Di Felice[1(✉)], Gaetanino Paolone[2], Daniele Di Valerio[2], Francesco Pilotti[2], and Matteo Sciamanna[3]

[1] Department of Industrial and Information Engineering and Economics, University of L'Aquila, 67100 L'Aquila, Italy
paolino.difelice@univaq.it
[2] Gruppo SI S.c.a.r.l, 64100 Teramo, Italy
{g.paolone,d.divalerio,f.pilotti}@softwareindustriale.it
[3] Selfresh S.r.l., Via Alcide de Gasperi 9, Penna Sant'Andrea, 64039 Teramo, Italy
m.sciamanna@selfresh.it

Abstract. SMEs form the backbone of the economy of most countries all over the world. Increasing their performance is therefore essential to increase the well-being of peoples. The adoption of digital technologies is universally recognized an essential component to achieve this objective. Unfortunately, European SMEs are lagging behind in the transition to digital. The Digital Europe Programme has been started at the end of 2021 to speed up such a transition. As part of the Programme, a network of so-called European Digital Innovation Hubs (EDIHs) is under construction in order to lend a hand to SMEs in the process of increasing their digitalization awareness and capabilities. The availability of a digital maturity assessment tool would be of great help for EDIHs to accomplish their mission. This paper gives a contribution in such a direction. It starts from an already published framework suitable to assess the digital maturity level of SMEs, as well as the capabilities associated to each level that are necessary for promoting a digital enabled growth. Then, the framework is transformed into a qualitative multi-attribute digital maturity model and the latter is implemented by means of a freeware software. The proposed model returns transparent indications to SMEs about where they are on their digital transformation journey, together with eventual strengths and weaknesses. SMEs should take these indications into account before allocating the budget for future investments.

Keywords: Digital transformation · Digital maturity model · Digital maturity assessment · Multi-attribute model · SME · DEXi

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1 Introduction

Small and medium-sized enterprises (SMEs) are the backbone of the economy of most countries all over the world. "They represent 99% of all businesses in the EU. They employ around 100 million people, account for more than half of Europe's GDP and play a key role in adding value in every sector of the economy."[1] "SMEs are made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million."[2] A 2021 report by Innovation Finance Advisory states that in Italy, for example, there are about 4.4 million SMEs which account for 99.9% of the total number of active companies (95% of which are micro-enterprises – firms with fewer than 10 employees and less than €2 million of turnover), 80% of employment and 70% of value added [1].

In the today world of emergent and continuous changes, SMEs, in order to be competitive, must equip themselves with IT technologies and adopt new information processes capable of favoring the sharing of resources and the engagement of all corporate stakeholders, including their customers [2].

[3] is a recent paper which analyzed 58 peer-reviewed studies published between 2001 and 2019, dealing with different aspects of digital transformation. From such a study, Nadkarni and Prügl concluded that digital transformation is an actor-driven organizational transformation (touching capabilities, structures, processes and business models of the firm) triggered by the adoption of suitable digital technology. It follows that, to exploit IT potentials, SMEs must embed "IT-capabilities" in themselves. Unfortunately, for most SMEs this is not true as stressed, for example, in a 2020 document of the European Commission: "SMEs often must [...] overcome structural barriers such as a lack of management and technical skills [...]".[3] At present, the level of digitalization of European SMEs is still around 20%, which is highly unsatisfactory [4]. The situation is even worse in Italy where productivity of SMEs is lower than the EU average and its closest peers (i.e., France and Germany). In light of the findings in [4], awareness and capabilities are the primary knowledge gaps that limit the ability of SMEs to adopt digital solutions. Drawing on the evidence coming from case studies carried out in several European states, authors of [5] confirm that making digital maturity assessment tools available to SMEs is a way to raise their awareness on the competitive advantages implied by a digital transformation.

Through the Digital Europe Programme (DIGITAL),[4] started at the end of 2021, and European Regional Development Funds, important amounts of funding are foreseen to strengthen a network of European Digital Innovation

[1] https://ec.europa.eu/growth/smes.en.

[2] Definition based on Article 2 of the Annex to Commission Recommendation 2003/361/EC; https://ec.europa.eu/docsroom/documents/42921.

[3] User Guide to the SME Definition. Publications Office of the European Union, Luxembourg 2020. https://op.europa.eu/en/publication-detail/-/publication/79c0ce87-f4dc-11e6-8a35-01aa75ed71a1 (Accessed on January 23, 2022).

[4] https://digital-strategy.ec.europa.eu/en/activities/digital-programme.

Hubs (EDIHs) that will geographically cover the whole territory of Europe. Each EDIH will be at working distance of their stakeholders, speak their language, and will help firms to become more performant by improving their business/production processes, products (and services) through digital technology. A EDIH is a regional multi-partner cooperation built around: Competence Centers; Technical universities and Research and technologies organizations; and Local Knowledge and Innovation Communities. In collaboration with: Vocational training institutes; Industry associations; Public administrations/National and regional authorities; Incubators, Accelerators, Investors; Clusters; Chambers of commerce; Enterprise Europe Network; Business development agencies and others. DIHs were funded for the first time within the H2020 EU Programme to support SMEs with experimentation and testing of advanced digital technologies. To distinguish them from other DIHs, the label European has been added.

EDIHs are called to provide the following four main categories of services to the local SMEs/public sector beneficiaries: Test before invest; Skills and training; Support to find investments; and Innovation ecosystem and networking. These categories are described in detail in [4], here we restrict our attention to the first one to remain within the scope of the present study. Services under the "Test before invest" category include: awareness raising and digital maturity assessment. In addition, EDIHs will act as European Regional Development Funds intermediary for providing SMEs with vouchers to be spent to progress in their internal digitalization [4] (p. 17).

Fletcher and Griffiths, talking about digital transformation during lockdown [6], stated that organizations must improve their digital maturity, because organizations with higher levels of digital maturity are generally more flexible, while less digitally mature organizations are more fragile. In this paper, we address the problem of digital maturity assessment of SMEs. Today many (digital) maturity models ((D)MMs) are available, however they weren't developed to fit the above mentioned needs of EDIHs. To fill the twofold gap, we propose assessing the digital maturity level of SMEs as a multi-attribute decision problem, where the characteristics of the SMEs are mapped into their digital maturity level. Among available methods, in this paper we adopt the so-called DEcision eXpert (DEX) method [7–9]. Modeling the (expert) knowledge about the firm's digital maturity using the DEX method offers the following advantages: it is easy to be used; it provides convincing explanations about the final score; it allows multiple interactive analyses; it is largely accepted by users; and finally it has been implemented in the DEXi freeware software [10]. DEXi supports two basic tasks: development of qualitative multi-attribute models; application of these models for the evaluation and analysis of decision options.

Very recently, North et al. [11] introduced the DIGROW framework as a conceptual tool useful to assess the digital maturity level of SMEs, as well as the capabilities associated to each level, that are necessary for promoting a digital enabled growth. DIGROW has a solid theoretical basis, but the underlying data analysis might result tricky in real contexts. For example, North et al. [11] carried out descriptive analysis using the IBM SPSS software whose technical

documentation is quite complex to be mastered. To keep things as simple as possible on the EDIHs'/SMEs' side, we rearranged the DIGROW framework into a multi-attribute DMM, then the latter was evaluated by making recourse to the DEXi software tool. The theoretical soundness of the DIGROW framework combined with the advantages featured by the DEX method make our proposal appropriate for assisting the nascent EDIHs in the activities devoted to awareness raising and digital maturity assessment of SMEs (two services belonging to the "Test before invest" category [4]), as well as in the evaluation process for awarding vouchers to SMEs.

The remaining part of the paper is structured as follows. Section 2 (Materials and Methods) recalls the DIGROW framework. Section 3 (Results) discusses its mapping into a multi-attribute DMM based on the DEX method. The implementation of the model by means of the DEXi open-source tool [10] is part of this section, as well as a brief discussion of an example of usage of the model. Section 4 concerns the relevant related work, while Sect. 5 ends the paper.

2 Materials and Methods

As mentioned in Sect. 1, in this paper we adopt the DIGROW framework described in [11][5] which combines Teece's "sensing" (i.e., the ability to detect changes and to learn quickly), "seizing" (i.e., the ability to address new opportunities in the marketplace), and "transforming" triple [13], on one side, and Valdez-de-Leon [14] digital maturity model, on the other side.

Van Veldhoven and Vanthienen identified three types of frameworks: conceptual, transformation, and maturity frameworks [15]. The latter describe the different stages of digital maturity in organizations. This category of conceptual tools is useful to assess an SME's maturity, strengths, and weaknesses, or as a comparison tool between competitors. In light of such a classification, DIGROW is a maturity framework. In fact, DIGROW allows to assess the digital maturity level of SMEs and the capabilities associated to each level, that are necessary for promoting a digital enabled growth. In other words, the framework provides guidance to SMEs to detect and capture digitally enabled growth opportunities, as well as start a project based learning process to transform the firm in order to remain competitive in the global market. The framework by North et al. [11] overcomes the limits of most previously available frameworks regarding digital transformation, which lack a sound theoretical foundation and do not consider the specific features of SMEs. The theoretical underpinnings of the DIGROW framework come from dynamic capabilities theory and from digital transformation studies especially those referred to SMEs. Teece et al. [16] define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities are an established approach in the investigation of firms. For example, Yeow et al. [17] applied it to model the business-to-business company's aligning process to enact an Internet-based business-to-consumer digital strategy over

[5] [12] provides a preliminary description of DIGROW.

a five-year period; Inan and Bititci [18] postulated that dynamic and organizational capabilities are the pillars of the organizational capabilities of SMEs; while Canhoto et al. [19] adopted such a lens to examine digital strategy alignment in SMEs to identify the practices that allow them to take advantage of digital technologies.

The DIGROW framework is structured as a sequence of four "steps" (called "stages" in the following), each denoting a "challenge for" (/ "capability of") the firm:

- Stage 1: Sensing digitally enabled growth potentials;
- Stage 2: Developing a digitally enabled growth strategy and mindset;
- Stage 3: Seizing digitally enabled growth potentials;
- Stage 4: Managing resources for digital transformation.

In turn, each stage of DIGROW is defined in terms of four "capacities". Figure 1 depicts the stages (visualized as a "wheel of digitally enabled growth" in [11]) and the capacities. Each capacity is evaluated starting from level 0 up to level 5. In a pre-test with firms, the results of which are reported in [11], it was found that this number of levels allows a sufficient degree of differentiation among firms. Tables AI-AIV in the Appendix of [11] detail the DIGROW maturity model evaluation grid.

By browsing through the rows of the four stages of DIGROW, it emerges that such a DMM embeds in itself the seven key attributes that, according to a report published by the Digital Transformation Institute of Capgemini [20], are the constituent elements of the digital culture of a digital mature organization, namely: Customer Centricity; Innovation; Data-driven decision making; Open Culture; Digital-first mindset; Agility and Flexibility; and Collaboration.

DIGROW has been extensively validated in the reality, which represents the exception rather than the rule, as pointed out, for example, in [21]. In 2018, North et al. tested the applicability of their framework in two distinct pilot studies. The first study involved 52 sample SMEs [11], while the second one involved 427 SMEs [22]. In both cases, the firms were located in the Basque region of Spain. These studies have contributed to get to the final version of the questionnaire collected in the Appendix of [11].

As mentioned in Sect. 1, in this paper the DIGROW maturity framework is rearranged as a multi-attribute DMM by adopting the DEX qualitative multi-criteria decision analysis method, developed by a research team led by Bohanec, Bratko, and Rajkovič [7]. In DEX, all attributes are qualitative and can take values represented by simple words (e.g., "bad", "good" or "excellent"). Attributes are organized in a tree-like hierarchy. The *leaves* of the tree, which describe the options (also named the alternatives), are the *basic* attributes (in the context of this study, the leaves denote the levels corresponding to the four capacities for each of the four stages of DIGROW), while the internal attributes are the *aggregate* attributes. All attributes are assumed to be described by discrete and ordered values, so that a higher ordinal value represents a better preference.

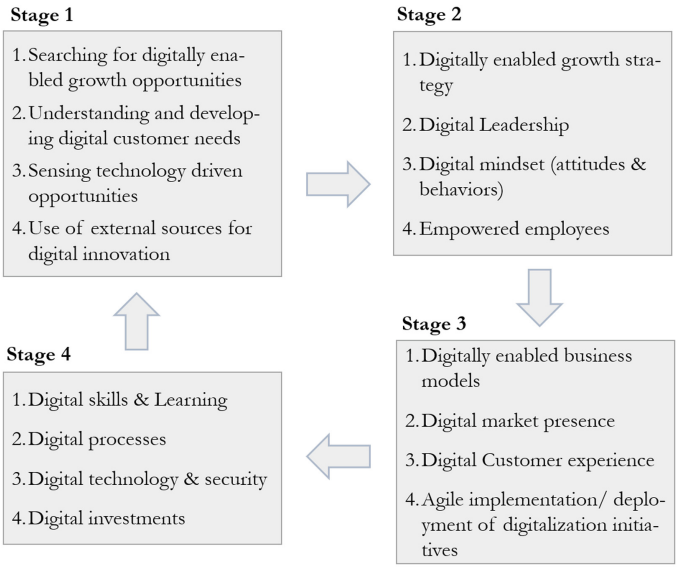

Fig. 1. The four stages of the DIGROW digital maturity framework.

The digital maturity level of a SME is evaluated through a bottom-up approach that aggregates the basic attribute values of the leaves up to a single root node value. The evaluation of decision alternatives is carried out by *utility functions*, which are represented in the form of "if-then" decision rules.

The DEX method can be formalized as follows. Let $A = a_1, a_2, \ldots, a_n$ be the finite set of attributes, and $O = o_1, o_2, o_3, \ldots$ be the (potentially infinite) set of options. The domain value of $a_i \in A$ belongs to the finite set of discrete values $D_i = v_{i_1}, v_{i_2}, \ldots, v_{i_j}$, with $v_{i_1} < v_{i_2} < \ldots < v_{i_j}$. An option ($o \in O$) is described by a vector of n values, where each value corresponds to an attribute in the set A, measured by the domain values from set D. Let $a_0 \in A$ be an aggregate attribute and $a_1, a_2, ..., a_n \in A$ be its children in the hierarchy, the utility function $f_0(a_1, a_2, ..., a_n)$ denotes the values of the aggregate attribute a_0, that is $a_0 = f_0(a_1, a_2, ..., a_n)$. A utility function maps *all* the combinations of the lower-level attribute values into the values of the direct aggregate attribute a_0. The mapping can be represented in a table, where each row gives the value of f for one combination of the lower-level attribute values. Rows are called *decision rules*, because each row can be interpreted as an if-then rule of the form: $if\ a_1 = v_1$ and $a_2 = v_2$ and ... and $a_n = v_n\ then\ a_0 = v_0$, where $v_i \in D_i$, $i = 0, 1, ..., n$. Through utility functions, decision-makers can model their knowledge and preferences.

3 Results

By applying the DEX method to the DIGROW maturity framework, we obtained the multi-attribute DMM of Fig. 2. The model consists of four distinct trees corresponding to the stages of DIGROW. Each tree has a root and four leaves (the basic attributes of the hierarchy), one for each capacity of the corresponding stage. Overall, the multi-attribute model is composed of 16 basic attributes and 4 aggregate attributes (the four trees), totaling 20 attributes.

Domain Values
The domain values of all the basic attributes of the four trees belong to the ordered set of qualitative values: $0, 1, 2, 3, 4, 5$; while the domain values of the four aggregate attributes (i.e., the roots of the four trees) are the ordered set of qualitative values: Non-existent (0), Initial (1), Encouraged (2), Practiced (3), Managed (4), Optimized (5). The choice of these six values is inspired to the maturity models in [23] where these six degrees of maturity levels are adopted.

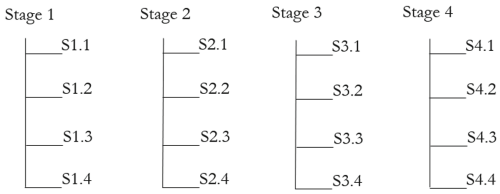

Fig. 2. The four trees defining the multi-attribute DMM based on the DIGROW framework, structured according to the DEX method.

Utility Functions
Column DMM in Table 1 collects summary data about the number of nodes and number of if-then rules for the four trees in Fig. 2.

Table 1. Summary data about two multi-attribute modeling of the DIGROW framework.

Tree levels	DMM		DMM restructured	
	Number of nodes	Number of if-then rules	Number of nodes	Number of if-then rules
h = 0 (the roots)	4	$6^4 \times 4$	4	$6^2 \times 4$
h = 1	4×4		2×4	$6^2 \times 8$
h = 2 (the leaves)		5184	4×4	432

This combinatorial explosion of the DEX model makes it unsuitable for actual usage. To overcome this problem, it was necessary to restructure the four hierarchies by introducing new aggregate nodes as it is shown in Fig. 3. For space reason, the figure shows only two restructured trees.



Fig. 3. Restructuring of the trees of the multi-attribute DMM of Fig. 2.

Table 1 collects summary data about the restructured trees. As we can see, the number of leaves (i.e., the number of basic attributes) is unchanged (16), while the number of aggregate attributes increased from 4 to 12. The positive side effect brought by this increase is the drastic reduction of the number of if-then rules (432 vs. 5184), which makes the second solution of practical utility.

3.1 Implementation of the DIGROW Digital Maturity Model

We have implemented the four restructured trees of the DIGROW DMM by means of the DEXi open source tool (Fig. 4).

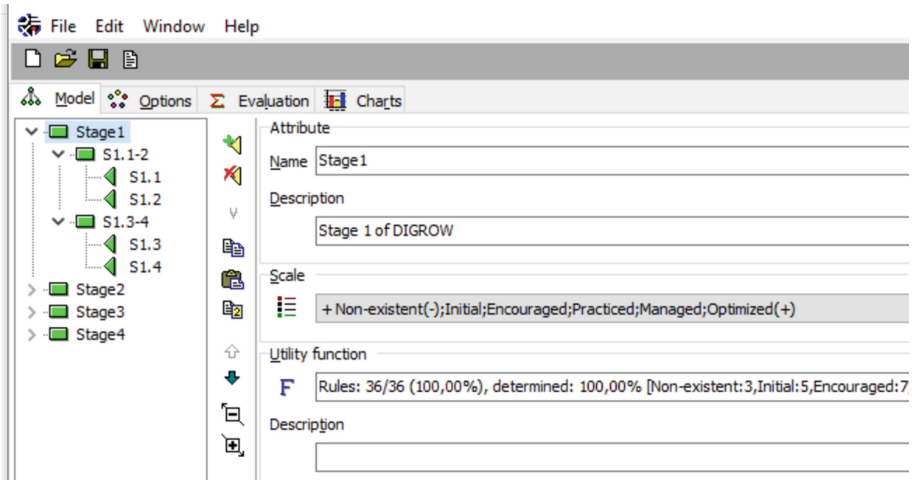

Fig. 4. The DEXi main screen showing the four trees of the multi-attribute DMM implementing the DIGROW framework.

Figure 5 shows the domain values of the basic and aggregate attributes (the latter both at height 1 and height 0 – the root of the tree) for Stage 1. The remaining three stages (namely, Stage 2, Stage 3, and Stage 4) of the multi-attribute model take the same values.

Attribute	Scale
Stage1	**Non-existent**; Initial; Encouraged; Practiced; Managed; ***Optimized***
├**S1.1-2**	**Non-existent**; Initial; Encouraged; Practiced; Managed; ***Optimized***
├─S1.1	**0**; 1; 2; 3; 4; ***5***
└─S1.2	**0**; 1; 2; 3; 4; ***5***
└**S1.3-4**	**Non-existent**; Initial; Encouraged; Practiced; Managed; ***Optimized***
├─S1.3	**0**; 1; 2; 3; 4; ***5***
└─S1.4	**0**; 1; 2; 3; 4; ***5***

Fig. 5. The domain values with regard to Stage 1 of the multi-attribute proposed DMM.

Utility functions were defined for all the aggregate attributes belonging to the four hierarchies. Equation 1 defines the criterium adopted for the computation of the utility functions referring to the aggregate attributes at depth 1 (i.e., nodes S1.1-2, S1.3-4, ..., S4.1-2, S4.3-4 – Fig. 3), while Eq. 2 defines the criterium adopted for the computation of the utility functions referring to the aggregate attributes corresponding to the roots.

$$if\ a_1 = v_1\ and\ a_2 = v_2\ \ then\ \ \rightarrow\ \ \lfloor (v_1 + v_2)/2 \rfloor + 1 \tag{1}$$

$$if\ v_1 = v_2\ \ \begin{cases} then \rightarrow v_1 \\ else \rightarrow max(v_1, v_2) \end{cases} \tag{2}$$

where $v_k (k = 1, 2) \in [0..5]$.

Figure 6 and Fig. 7 show the rows corresponding to the evaluation of the utility functions for, respectively, the aggregate attributes sons of the root and the root itself, with respect to Stage 1. In both cases, the utility functions are represented in terms of complex rules [10]. If expressed as simple rules, both these functions give rise to 36 rows (see Table 1). Converted to weights, Fig. 6 and Fig. 7 confirm that in the final assessment both aggregate attributes have the same weight (i.e., 50%). This result is an obvious consequence of the symmetry of the four trees that implement the DIGROW stages.

DEXi uses four types of weights: Local, Global, Loc.norm., and Glob.norm. Local weights refer to a single aggregate attribute and a single corresponding utility function, therefore the sum of weights of the attribute's immediate descendants is 100%. Global weights, on the other hand, take into account the structure of the tree and relative relevance of its sub-trees. A global weight of an attribute is calculated as a product of its local weight and the global weight of the attribute that lies one level above. From Fig. 8, we see that the global weight of the root attribute is 100%, while the global weight of Stage 1 is 25%: 50% (its local weight) × 50% (the global weight of S12), which gives 25%.

	S1.1	S1.2	S1.1-2
	50%	50%	
1	0	<=1	Non-existent
2	<=1	0	Non-existent
3	0	2:3	Initial
4	<=1	2	Initial
5	1	1:2	Initial
6	1:2	1	Initial
7	2	<=1	Initial
8	2:3	0	Initial
9	0	>=4	Encouraged
10	<=1	4	Encouraged
11	1	3:4	Encouraged
12	1:2	3	Encouraged
13	2	2:3	Encouraged
14	2:3	2	Encouraged
15	3	1:2	Encouraged
16	3:4	1	Encouraged
17	4	<=1	Encouraged
18	>=4	0	Encouraged
19	1:2	*5*	Practiced
20	2	>=4	Practiced
21	2:3	4	Practiced
22	3	3:4	Practiced
23	3:4	3	Practiced
24	4	2:3	Practiced
25	>=4	2	Practiced
26	*5*	1:2	Practiced
27	3:4	*5*	Managed
28	4	>=4	Managed
29	>=4	4	Managed
30	*5*	3:4	Managed
31	*5*	*5*	*Optimized*

Fig. 6. Utility function at the root level.

	S1.1-2	S1.3-4	Stage1
	50%	50%	
1	Non-existent	<=Initial	Non-existent
2	<=Initial	Non-existent	Non-existent
3	<=Initial	Encouraged	Initial
4	Initial	Initial:Encouraged	Initial
5	Initial:Encouraged	Initial	Initial
6	Encouraged	<=Initial	Initial
7	<=Encouraged	Practiced	Encouraged
8	Encouraged	Encouraged:Practiced	Encouraged
9	Encouraged:Practiced	Encouraged	Encouraged
10	Practiced	<=Encouraged	Encouraged
11	<=Practiced	Managed	Practiced
12	Practiced	Practiced:Managed	Practiced
13	Practiced:Managed	Practiced	Practiced
14	Managed	<=Practiced	Practiced
15	<=Managed	*Optimized*	Managed
16	Managed	>=Managed	Managed
17	>=Managed	Managed	Managed
18	*Optimized*	<=Managed	Managed
19	*Optimized*	*Optimized*	*Optimized*

Fig. 7. Utility function at the level of the sons of the root.

3.2 Examples

Aim of this section is to make use of the proposed multi-attribute DMM to show how simple is its usage and, at the same time, how simple to be interpreted are the outcomes.

The first example concerns the assessment of the digital maturity level of a single SME (called SME1). Figure 9 reports the numerical evaluation values; while Fig. 10 shows, pictorially, the corresponding attribute values. This test can be carried out either by a referent of a EDIH or by the manager of the SME. It is sufficient a rapid look at the radar chart of Fig. 10 to understand where the SME is, what its weaknesses are, and what should be done next in the digital transformation journey.

DEXi allows to compare several SMEs. As second example, Fig. 11 reports the numerical evaluation values of four SMEs; while Fig. 12 shows, pictorially, the corresponding attribute values. To save space, only Stage 1 is shown. We can think of the need to compare the digital maturity level of a set of SMEs as the preliminary step in the process of evaluation awarding vouchers to SMEs to support their digital transformation. Figure 13 provides the full picture about

Attribute	Local	Global	Loc.norm.	Glob.norm.
Stage1				
├─**S1.1-2**	50	50	50	50
│ ├─S1.1	50	25	50	25
│ └─S1.2	50	25	50	25
└─**S1.3-4**	50	50	50	50
├─S1.3	50	25	50	25
└─S1.4	50	25	50	25

Fig. 8. The average weights of aggregate attributes belonging to Stage 1.

the digital maturity level of each of the four SMEs taken into account. From such a figure it is easy to rank the SMEs.

4 Related Work

This work builds a multi-attribute DMM by transforming the DIGROW framework. Since the latter is already published, it is not necessary to defend its validity. Vice versa, it is necessary to compare the transformed model with potential competitors. Therefore, this section is organized as follows. We limit ourselves to recalling recent review articles about MMs, in particular those concerning the context of SMEs to which the reader is referred; then we compare our proposal with a very recent multi-attribute DMM referring to SMEs.

Section 2 in [11] classifies MMs for digital transformation according to the three application-specific purposes introduced in [24]: descriptive, prescriptive and comparative.

[25] is an up-to-date review about business MMs for SMEs covering the period 2001–2020 (first trimester). Only articles published in peer-reviewed journals and stored into the Scopus and the Web of Science databases were taken into account. Initially, 160 articles were selected. The classification process introduced in [26] was used to limit the article group to the articles that proposed a new MM in the SME context. At the end of the classification process, 20 articles were study in depth. Authors carried out a systematic literature review which allowed them to give an unbiased and more balanced summary of the literature compared to traditional reviews. They found that most of the articles used five maturity levels in their MMs; while in the remaining ones either three, four or six maturity levels were used. As said in Sect. 2, the DIGROW MM is structured in four stages, each of them has six levels that we mapped into the values Non-existent (0), Initial (1), Encouraged (2), Practiced (3), Managed (4), Optimized (5) of the proposed multi-attribute DMM (Sect. 3).

Previous papers reporting on the state of the art about (Digital) MMs are [27] and [28]. Below, few sentences about these studies are given to better emphasize the merits of the proposed multi-attribute DMM.

Evaluation results

Attribute	SME1-4Stages
Stage1	Initial
S1.1-2	Non-existent
S1.1	0
S1.2	1
S1.3-4	Encouraged
S1.3	1
S1.4	4
Stage2	Initial
S2.1-2	Initial
S2.1	1
S2.2	2
S2.3-4	Encouraged
S2.3	2
S2.4	2
Stage3	Encouraged
S3.1-2	Encouraged
S3.1	1
S3.2	3
S3.3-4	Encouraged
S3.3	1
S3.4	3
Stage4	Initial
S4.1-2	Initial
S4.1	1
S4.2	2
S4.3-4	Encouraged
S4.3	3
S4.4	1

Fig. 9. Evaluation results for SME1.

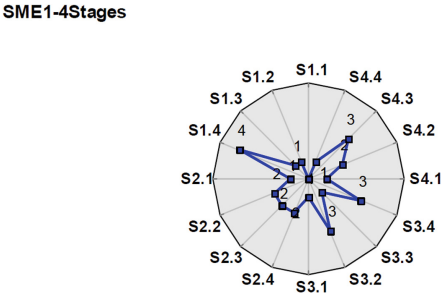

Fig. 10. The radar chart displaying the evaluation results in Fig. 9.

[27] reports on a systematic literature review on DMMs for SMEs. This study confirms the lack of validation and specific proposals for SMEs. Moreover, the authors discovered six basic DMM dimensions for SMEs: Strategy; Products/Services; Technology; People and Culture; Management; and Processes. The most significant dimension is People and Culture. Stages 2 and 4 of the multi-attribute DMM proposed in our paper assign great relevance to "People and Culture". [28] reveals that the majority of existing DMMs addresses the manufacturing sector. Other domains like service are clearly under-represented. The proposed multi-attribute DMM is general.

In [29], Borštnar and Pucihar designed a DMM to be used to assess the different levels of digital maturity of SMEs. In their study, the DEX method was adopted to design a multi-attribute model. Their model takes inspiration from the findings in [3], where authors identified "technology" and "actor" as the two aggregate dimensions of digital transformation. In [29], these two dimensions are called "Digital capability" and "Organizational capability". We summarize the DMM in [29] in the following. The DMM is composed of two subtrees, one for each dimension. The tree is structured in terms of 34 basic attributes and 17 aggregated attributes. The Digital capability dimension consists of four groups of attributes: Use of Technology, Role of Informatics, Digital Business Model, and Strategy; while the Organizational capability consists of three groups of

Evaluation results

Attribute	SME1-Stage1	SME2-Stage1	SME3-Stage1	SME4-Stage1
Stage1	Initial	Encouraged	Practiced	Managed
S1.1-2	Non-existent	Encouraged	Practiced	Managed
S1.1	0	2	3	4
S1.2	1	3	4	*5*
S1.3-4	Encouraged	Practiced	Practiced	Managed
S1.3	1	2	3	*5*
S1.4	4	4	4	4

Fig. 11. Evaluation results for four SMEs.

attributes: Human Resources, Organizational Culture, and Management. For each attribute in the tree, the corresponding domain value was defined. The domain values were ordered, discrete, and qualitative. The DMM in [29] is in a pilot stage. So far, after a preliminary validation by an expert group, a test involving seven Slovenian SMEs from different sectors has been carried out. Authors plan to survey a larger number of SMEs, then another round of model validation will be conducted and the model will adjusted accordingly if needed.

It is quite obvious to verify that both MMs take into account the same concepts; that is, it is easy to relate the (sixteen) capacities describing the four stages of DIGROW to the seven (aggregate) attributes of the DMM in [29]. However, there is a relevant difference between the two models which comes from the abstraction level at which they capture the firms' characteristics. The multi-attribute MM based on DIGROW is much more abstract than the other one. A positive side effect of abstraction is "model stability", that is a desirable feature of a multi-attribute MM referring to the fact that the number of basic attributes on which it is built remains stable over time. To make things clear, let us refer to the DMM in [29]. As already said, "Digital technology" is one of the items of such a model. It is specialized in terms of three attributes: Advanced technologies, SMACIT, and Basic business technologies. In turn, the theme "Advanced technologies" include: Blockchain; Industry 4.0; and Data analytics. A pertinent question is: Why Internet of Things (IoT) is not included in the list? Zhu et al. [30] say that IoT is one of the five most representative technologies. For sure, IoT is a disruptive technology that has the potential to transform the world's future. In [29] (Sect. 4. Discussion), authors admit that they faced criticalities in the model building process, in connection with the phases of constructing the tree, assigning the domain values to attributes, and then defining the utility functions.

In summary, our work as that by Borštnar and Pucihar [29] are meant to be used by DIHs as well as by managers of the SMEs to assess the firm's digital maturity level. Moreover, both studies adopt the DEX method. Hence, the two proposals must be considered as alternatives. It would be interesting to validate both models on the same set of SMEs to compare their effectiveness in real settings.

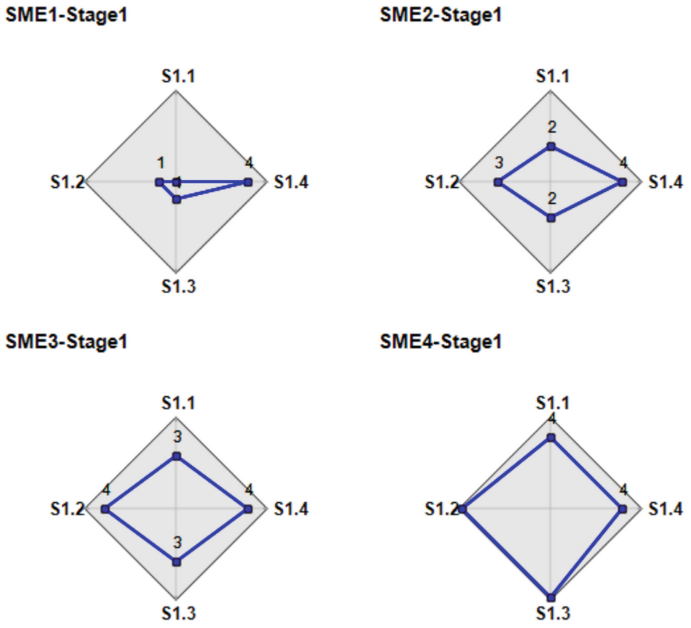

Fig. 12. The radar charts displaying the evaluation results in Fig. 11.

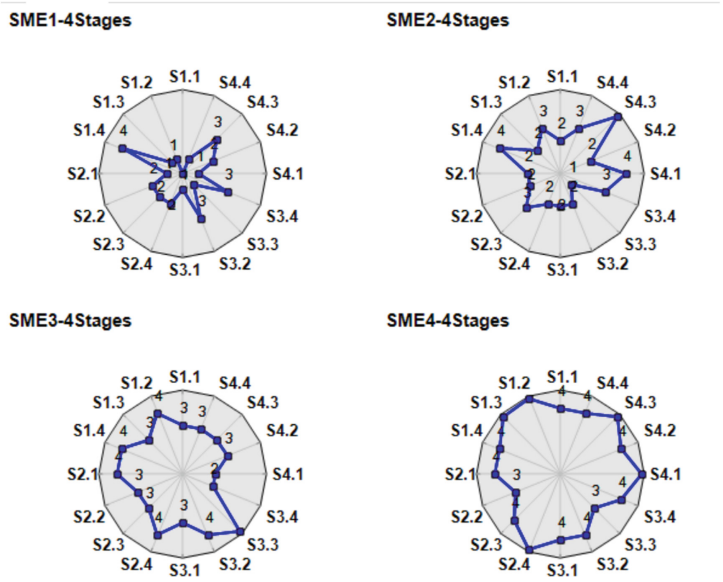

Fig. 13. The radar charts displaying the evaluation results about the four stages of the proposed multi-attribute DMM.

5 Conclusions

In February 2021, the SMB Group surveyed 761 North America Small and Medium Business (1–1,000 employee) decision-makers and mid-market (1,000–2,500 employee) organizations [31]. From the survey it emerged that, in the wake of COVID-19: (a) around 50% of American SMEs have established a digital transformation strategy and are executing on it; (b) 31% of their spending for technology solutions will increase in the 2022. Both these findings are good news, but it is important to recall that digital transformation does not imply better performance unless it goes with an adequate firm's digital maturity level, as it has been stressed, for instance, by Kane [32].

In this paper, we addressed the problem of digital maturity assessment of SMEs. Our proposal is based on a previously published DMM which we have transformed into a qualitative multi-attribute DMM in order to make it more simple to be understood and used. The model has been implemented as a DEXi model. Although many DMMs have been developed in the past, models that fit the needs of the EDIHs are rare. As said in Sect. 1, EDIHs are called to implement the "Test before Invest" service (which includes awareness raising and digital maturity assessment of SMEs), as well as to take charge of the awarding evaluation process for the assignment of vouchers to SMEs to be spent to progress in their internal digitalization. To achieve these goals the final score coming from the digital maturity assessment tool must be transparent in order to facilitate the interactions between the EDIH and the SME. The qualitative nature of our DMM ensures such a feature.

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