International Journal of
Information Systems and Project Management

ISSN (print):2182-7796, ISSN (online):2182-7788, ISSN (cd-rom):2182-780X

*Available online at ijispm.sciencesphere.org*

# A multi-dimensional model to the digital maturity life-cycle for SMEs

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**Abstract:**
As companies try to maintain and strengthen their competitive advantage, they should be aware of the level of their digital maturity. The study aims to present a methodology that helps to determine the position of a small and medium-sized enterprise in the digital maturity life-cycle. This is performed on the basis of maturity and digital maturity models, and company growth theories. A number of studies and models have been prepared to determine digital maturity on the basis of various sectoral criteria, but these are all one-dimensional. The study therefore proposes a multi-dimensional model for determining the digital maturity life-cycle of small and medium-sized enterprises that takes into account companies' digital maturity, the IT intensity of various sectors and their organizational characteristics. The model defines five maturity levels together with their relevant characteristics, classified into three levels in terms of data-information. It can help small and medium-sized enterprises adopt more accurate decisions regarding areas in need of development.

**Keywords:**
digitalization; digital transformation; digital maturity; SME; life-cycle model; life-cycle functions.

**DOI:** 10.12821/ijispm100303

**Manuscript received:** 12 May 2021
**Manuscript accepted:** 20 March 2022

## 1. Introduction

The global pandemic has accelerated digital transformation, affecting both internal and external corporate processes, potentially reflected in corporate performance. According to the analysis of Dell Technologies [1], companies use several digital technologies in response to the digital emergency. Their digitalization level should be assessed for strengthening their current competitive position and to advance further development [2].

As all changes, digital transformation is not free of problems. Companies face a number of transformation related difficulties, as they need to rethink their day-to-day operations, which requires a shift in attitudes. Additionally, organizational culture and firm management are key to digital transformation [3], [4]. It follows that an all-encompassing corporate attitude is needed for successful transformation. Beyond high costs, one of the biggest difficulties is the extraction of information from data, and its use for decision-making. In this new and rapidly changing environment, intellectual capital is gaining appreciation, companies gain a competitive advantage if they are capable of transforming data-information, and ultimately of making decisions more efficiently and faster.

The Digital Maturity Models (DMMs) help to assess the digitalization of companies by determining their current position on the basis of different factors and identifying areas of development, providing guidance for reaching the target status. They also contribute to the transformation of organizations and the improvement of their competencies by launching process of change. Most digital maturity models, such as those of [5],[6],[7],[8],[9],[10],[11],[12], apply a linear approach and are one-dimensional. In digital transformation, however, the digitalization evolution paths are not linear [13]. Companies, namely, undergo changes at various phases of the life-cycle. Among other things, their competitive strategies, market position and organizational structure change. During their life-cycle, however, they do not necessarily pass each phase – phases may skip in some cases. In relation to digital transformation it is also important to consider the sector in which the company operates, as companies in the financial sector have a greater need for digitalization than those in the construction industry.

Our study therefore aims to define a digital maturity life-cycle model that helps developing companies in determining their current position in digitalization. This is a true-value, multi-dimensional model that takes into account parameters of the corporate growth and maturity models, and the digital intensity of various sectors. This model helps small and medium-sized enterprises (SMEs) to take appropriate decisions for facilitating their development, as a higher digital maturity level increases their competitive advantage. It also contributes to efforts of SMEs to become more conscious and systematic at company level.

The research focuses on SMEs instead of large companies, as the latter tend to have a stronger digital maturity as their organization is better structured and their business processes are accurately described. In contrast, even SMEs' main processes are unclear in many cases, their organizational structure is less modeled and clear, and they do not have control over their digital situation [14], so we want to provide them with a model on which software simulation can be easily built. The model allows the company to monitor its operations with exact calculations and determine where it is in the digital maturity lifecycle, making decision-making faster and more accurate, and it can more effectively identify areas where intervention is needed to operate more efficiently.

The model, therefore, provides a medium-term assessment of SMEs' digital position. This medium-term phase can be a quarter, a half-year, or a year. During this time, the model can be considered static, but the phases change/may change dynamically, and in this regard, the model is indeed dynamic over a longer period.

The study briefly discusses the importance of life-cycle models, the characteristics of maturity models, and then assesses the different digital maturity models in terms of the types of models developed so far, on the one hand, and the number and substance of maturity levels, on the other. We then examine the digital intensity of different sectors, which has an impact on digital maturity. In the part on methodology, we present the developed digital maturity life-cycle model with definition of the five maturity levels with precise metrics. Finally, we present options for the further development of the model.

## 2. Background

### *2.1 Life-cycle models*

In literature a number of theories explore the life-cycle of companies, which attempt to identify their life-cycles [15], [16] [17].

The corporate life-cycle may be divided into different phases, which are built on each other and characteristics of the individual phases are relatively uniform. The life-cycle is determined by age, sales growth, dividend yield and capital expenditures. Additionally, the characteristics of organizations change in different life-cycle phases. Life-cycle models generally cover the period from the establishment of the business until its termination. In the breakdown of phases, similarly to product life-cycle curves, only in a significantly more complex form, and often the growth of a company is expressed by changes in its size [18].

The growth theory of companies developed by Penrose [15], was used by Greiner [17] to develop one of the most often cited models – the evolution/revolution model of corporate growth [19], [20].

The general growth models include the above mentioned and further developed Greiner [17] model, and the models of Scott [21], and Lippitt and Schmidt [22]. These models can be typically applied irrespective of company size and apply a multifaceted approach, with diverse areas of application [23].

According to Greiner [17], many companies struggle with problems rooted in past strategic management decisions and are not caused by current events or dynamic market trends. The termination of evolutionary problems in different phases of organizational growth provides the theoretical basis for his model (Fig. 1).

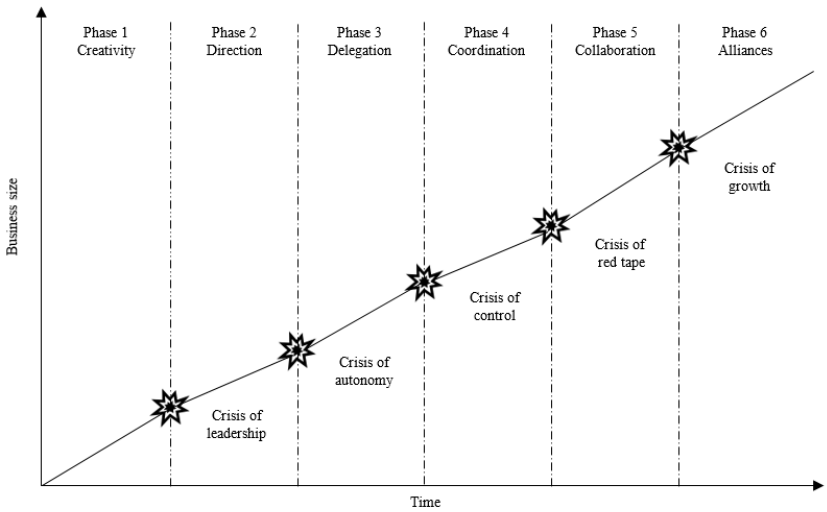


Fig. 1. Greiner model (adapted from Greiner [17])

Each growth phase consists of a relatively stable period of growth (evolutionary phase), which is followed by a "crisis", when major organizational changes are needed to continue the company's growth (revolutionary phase). In this phase the company struggles with management and control problems, among other things. It is important to note that each phase is the result of the previous phase and cause of the next phase. Greiner [17] originally proposed this model with the five phases of growth in 1972, and added the sixth phase in the updated version of his original study published in 1998.

Companies in faster growing industries generally experience all five phases at a faster pace, while those in slower growing sectors will experience only two or three phases in the span of many years [17].

His model importantly draws attention to problems arising in the individual phases, yet fails to address the declining path of the company. The model therefore fails to map the entire life-cycle of the company. As noted by Levie and Lichtenstein [24], during their life-cycle, companies do not necessarily pass through each phase – they may skip certain phases.

We will aim at bifurcation in relation to the digital maturity levels, i.e. follow an SME (which is a complex, dynamic system) from a stable condition through an unstable condition (a level up in our case) to another stable condition, where the new stable condition is created by bifurcation with two options available for the system (moving forward or backward) to regain the stable condition. It is never possible to determine in advance the condition the system will actually end up in [25].

### *2.2 Maturity models*

Similarly to the growth models, maturity models help to assess and evaluate the current status of the company, and provide guidance as to the areas in need of development to achieve transformation and a higher level of maturity [10], [26]. They also support companies in monitoring progress and in deciding when and what to do to make progress. These models are based on the general qualitative model (evaluated on the basis of qualitative characteristics) [27].

Literature refers to a number of maturity models developed for different purposes, most of these are based on the five-level model of Capability Maturity Model Integration (CMMI), which classifies development phases into five levels of maturity. In addition to scientific maturity models, there are also many maturity models developed by advisors and associations [12].

#### *2.2.1 Capability Maturity Model Integration*

Originally aimed at analyzing the quality of software development processes, the Capability Maturity Model (CMM) developed at Carnegie Mellon University gained popularity in the 1980s in the assessment of organizational capabilities. Process maturity concepts can be generally also applied to non-software processes. During the past decade this measurement methodology was adopted in a number of scientific disciplines [28].

CMMI is the integrated version of CMM, a process development framework allowing application to both software and system development, introduced in the second half of the 20th century. The CMM and CMMI standards now also use maturity models qualifying the given company or organization, and its projects. Since its initial version, a number of its extensions have been used as a general and effective method for understanding and future improvement of general business performance [29].

CMMIs are represented in two different ways: stepped/phased representation and continuous representation (Table 1).

Table 1. Capability and maturity levels of CMMI (adapted from Linstedt and Olschimke [30])

| Levels | CMMI staged representation | CMMI continuous representation |
|---|---|---|
| 0. | | Incomplete |
| 1. | Initial | Performed |
| 2. | Managed | Managed |
| 3. | Defined | Defined |
| 4. | Quantitatively Managed | Quantitatively Managed |
| 5. | Optimizing | Optimizing |

Stepped representation focuses on the whole of the organization. It defines roadmaps for each phase. These phases are called maturity levels, which also indicate the maturity of the organization in relation to a process area. Once the organization meets all requirements on the maturity level, it can move to the next level to continue the improvement of its processes. The continuous model varies from the phased model, as it provides less guidance on the order of process areas to be implemented and developed. This type of approach defines capability levels for characterizing the status of organization processes. The combined models combine these models [31], [30].

At the present, the maturity models are no longer related to certain areas of application, but rather refer to different dimensions, such as people, processes and organizational capabilities. Greiner's [17] growth model – noted above – is also a good example of this, where certain growth phases lead to "crises", specific management problems, and these must be resolved for achieving further growth.

### *2.3 Digital maturity models*

A holistic approach is necessary for achieving digital maturity, as the company needs to coordinate factors relevant in terms of the company's operation through use of available technologies within and outside of the organization [32]. Digital capabilities are required for continuous adaptation; these help advance the digital maturity of the company. Maturity, as a qualitative parameter, continuously changes over time, where companies learn to appropriately respond to the digital competitive environment [33].

Thordsen et al. [34] argue that the correlation between maturity and organizational performance can be interpreted as being directly proportional, i.e. a higher maturity level is associated with higher performance. There is also a correlation between management style and maturity, where controlled management is associated with lower maturity than is the case with more free management, which potentially allows a higher maturity level [35]. Consequently, digital maturity is interpreted as the joint result of strategy, culture and management.

The level of the application of technology by SMEs significantly depends on the orientation of the owner/manager. Decision-making in their case is predominantly based on intuition; for example, in the course of digital transformation greater emphasis should be placed on the availability of competent specialists. The adaptation of SMEs to a rapidly changing environment tends to be slower and iterative in contrast to a precise series of clear steps and decisions [36], [12].

It is necessary to apply digital maturity models to be able to determine a company's digital maturity, which enable identification of areas with deficiencies, in need of development, on the one hand, and key areas the company needs to focus on, on the other [37]. Thus, the chief purpose of digital maturity models is to assess the current status of the company achieved in digitalization, where different levels are determined in terms of evolutionary phases. Generally speaking, different organizations apply these models to assess their current capabilities and to achieve further development. It is also important to consider that digitalization evolution paths are not linear [13].

In the course of reviewing the relevant literature, we used the following key words and terms applied in the Web of Science, Emerald, ScienceDirect and Google Scholar databases for analyzing the levels of different digital maturity models:

"Digital Maturity", "Digital Maturity Model", "Digital Maturity Levels", "Digital Maturity Framework"

The searches cover the period between 2015 and 2020. In relation to IT, it is important to ignore studies older than 5-10 years due to the rapid development of technology, and owing to the novelty of the topic, searches produced results for a retrospective period of 5-6 years. After analysis of the titles and abstracts of the articles, we found 31 studies focusing on digital maturity models. Most of the articles were related to Industry 4.0. Following the thorough reading of the articles, 18 studies were chosen with relevance for the research (Table 2).

The relevant models found not only include scientific models, but also models developed by consultancy firms, as digitalization is very much practice-oriented. We therefore manage these together.

Table 2. Digital maturity models

| Reference | Year | Type of maturity model | Maturity stages |
|---|---|---|---|
| Ganzarain and Errasti [5] | 2016 | Industry 4.0 | (1) initial (2) managed (3) defined (4) transform (5) detailed business model |
| Gill and VanBoskirk (Forrester 4.0) [6] | 2016 | General | (1) sceptics (2) adopters (3) collaborators (4) differentiators |
| Berghaus and Back [39] | 2016 | General | (1) promote & support (2) create & build (3) commit to transform (4) user-centered & elaborated processes (5) data-driven enterprise |
| PwC [40] | 2016 | Industry 4.0 | (1) digital novice (2) vertical integrator (3) horizontal collaborator (4) digital champion |
| Valdez-de-Leon [7] | 2016 | Telecommunications Service Providers | (0) not started (1) initiating (2) enabling (3) integrating (4) optimizing (5) pioneering |
| de Carolis et al. [41] | 2017 | Manufacturing | (1) initial (2) managed (3) defined (4) integrated & interoperable (5) digital-oriented |
| Kane et al. [33] | 2017 | General | (1) early (2) developing (3) maturing |
| Klötzer and Pflaum [8] | 2017 | Manufacturing Industry's Supply Chain | (1) digitalization awareness (2) smart networked products (3) the service-oriented enterprise (4) thinking in service systems (5) the data-driven enterprise |
| SAP [42] | 2017 | General | (1) non-existent (chaotic) (2) ad hoc (isolated) (3) managed (systematic) (4) defined (strategic) (5) optimized (data-driven) |
| Lloyds Bank [43] | 2017 | General | (1) passive (2) getting started (3) established (4) high (5) advanced |
| Colli et al. [9] | 2018 | Industry 4.0 | (1) none (2) basic (3) transparent (4) aware (5) autonomous (6) integrated |
| Mittal et al. [26] | 2018 | Smart Manufacturing | (1) novice (2) beginner (3) learner (4) intermediate (5) expert |
| Issa et al. [44] | 2018 | Industry 4.0 | (1) no Industry 4.0 or only "ad-hoc" (2) departmental level (3) organizational level (4) inter-organizational level |
| North et al. [10] | 2019 | General | - |
| Schumacher et al. [11] | 2019 | Manufacturing | - |
| Gurumurthy et al. (Deloitte) [45] | 2020 | General | (1) lower (2) medium (3) higher |
| Albukhitan [46] | 2020 | Manufacturing | (1) unaware (2) conceptual (3) defined (4) integrated (5) transformed |
| Kuusisto et al. [12] | 2020 | General | (1) preliminary (2) defined (3) managed (4) excellent |

The number of dimensions was a criterion in assessing the different models, as the term "maturity" is in most cases signified as being one-dimensional in literature examining maturity models. In various models the number of dimensions refers to the various factors/capabilities of digital maturity, such as human resources, strategy, culture.

In our case, dimension carries a classic geometric meaning, i.e. the value of a given function produced by three independent parameters. We therefore illustrate the model in an orthogonal system.

Maturity levels represent the maturity level of a given dimension. Each level must have guidance that clearly defines expectations related to the level and a detailed description of its characteristics [38].

Based on Table 2, there is an average of five model levels, irrespective of the industry.

In the case of four models, the number of levels were based on CMMI principles. These were chosen because the CMMI provides a specific structure for maturity levels, defining the capabilities of a company at individual levels [11], [25], [40], [41]. We will also follow this principle in relation to the model we developed.

Data-driven operation, as the highest maturity level, is present in a total of three models [7], [38], [41]. This criterion is important in relation to our model as well, because we believe that the highest maturity level should be data-driven, as acceptance of being data-driven enables greater objectivity and reveals correlations that are not necessarily straightforward. It follows that being data-driven is important by allowing the drawing of conclusions supported with data and the adoption of substantiated decisions instead of the reliance of company managers and experts purely on experience and intuition. The other advantage of being data driven is the capacity to assess, test and optimize processes in advance through simulations before live application. A data-driven enterprise represents in any event a paradigm shift [8],[47].

Five of the models focus on SMEs [4], [9], [11], [25], [42]. Two of these models are based on the CMMI [12], [26].

The multi-dimensional approach is applied only by Mittal et al. [26], where an intelligent manufacturing maturity model is developed for SMEs by assessing three dimensions. The *x* axis represents organizational dimensions, the *y* axis represents the set of tools and the *z* axis represents the five maturity levels. With these the company is capable of assessing its maturity level and identifying steps necessary for reaching the next maturity level within the organizational dimension. We apply this approach as well.

### *2.4 IT intensity of sectors*

Digitalization affects sectors in different degrees. Digital maturity significantly depends on the company's sector, as not all sectors require high levels of digitalization.

Calvino et al. [47] examined the prevalence and development of technology in different sectors in 36 sectors of 12 countries (Australia, Austria, Denmark, Finland, France, Italy, Japan, Netherlands, Norway, Sweden, United Kingdom, USA) based on data related to the 2001-2015 period. This is the only relevant research on this topic that also pointed out that the level of digital transformation in specific sectors mainly depends on investment in "digital" tools, company relations maintained with customers and suppliers, and changes in human capital.

The following factors played a role in determining digital intensity:

- Rate of ICT tools and investment in software;
- Intensity of ICT tool and service purchases relative to output;
- Rate of robots per employee;
- ICT specialist intensity;
- Level of propensity for online sales.

The individual sectors were classified into four categories based on their relative economic ranking, depending on their digital intensity. These are distinguished as "low", "medium-low", "medium-high" and "high" (Table 3). Sectors are classified according to the ISIC Rev.4 (International Standard Industrial Classification of All Economic Activities). The taxonomy has the benefit of its development with use of currently available sectoral aggregates.

Sectors with a high digital intensity include, inter alia, transport vehicles, financial and insurance activities, and telecommunications. Transport vehicles include, for example, rail, waterway vehicles and aircraft, and military vehicles. In their case, up-to-date digitalization and use of state-of-the-art technologies is essential. In contrast, the least intensive category includes, for example, agriculture, forestry and fisheries, accommodation and catering activities, which do not necessarily need higher levels of digitalization for successful operation.

With our model the intensity period may be determined by classification of the IT intensity of difference sectors.

Table 3. Sectoral taxonomy of digital intensity: global indicator (2013-15) (adapted from Calvino et al. [47])

| Sector | Quartile of digital intensity 2013-15 | Sector | Quartile of digital intensity 2013-15 |
|---|---|---|---|
| Administrative and support service | High | Basic metals and fabricated metal products | Medium-low |
| Advertising and other business services | High | Chemicals and chemical products | Medium-low |
| Finance and insurance | High | Coke and refined petroleum products | Medium-low |
| IT and other information services | High | Education | Medium-low |
| Legal and accounting activities, etc. | High | Human health activities | Medium-low |
| Other service activities | High | Pharmaceutical products | Medium-low |
| Scientific research and development | High | Residential care and social work activities | Medium-low |
| Telecommunications | High | Rubber and plastics products | Medium-low |
| Transport equipment | High | Textiles, wearing apparel, leather | Medium-low |
| Arts, entertainment and recreation | Medium-high | Accommodation and food service activities | Low |
| Computer, electronic, optical products | Medium-high | Agriculture, forestry, fishing | Low |
| Electrical equipment | Medium-high | Construction | Low |
| Furniture; other manufacturing; repairs | Medium-high | Electricity, gas, steam and air cond. | Low |
| Machinery and equipment n.e.c. | Medium-high | Food products, beverages and tobacco | Low |
| Public administration and defence | Medium-high | Mining and quarrying | Low |
| Publishing, audiovisual and broadcasting | Medium-high | Real estate | Low |
| Wholesale and retail trade, repair | Medium-high | Transportation and storage | Low |
| Wood and paper products, and printing | Medium-high | Water supply; sewerage, waste | Low |

## 3. Digital maturity life-cycle model

In contrast with existing maturity models generally focusing on a single "layer", we concluded that these are insufficient, that is, they do not provide a sufficiently detailed picture of SMEs. Consequently, we aim at developing a three-variable, true-value model that can determine the given company's position within the life-cycle, i.e. the stage of its digitalization, to enable it to take more accurate decisions during digital transformation.

Thus, the model examines SMEs on the basis of three criteria – digital maturity, organizational maturity, IT intensity – and it is possible to determine the maturity level of the given company with the help of an accurate metric. We define five levels for the life-cycle, which are based on the Greiner growth model and CMMI model.

### *3.1 Methodology*

Different components are needed to determine the digital maturity and companies' digital maturity in their lifecycle. To determine the components, we conducted primary research with a pairwise comparison questionnaire necessary for the Guilford method [48], which is not a statistical questionnaire, but a conclusion based on the opinions of a well-selected group of experts. There is no need for stratified sampling and a minimum sample limit; the only major consideration is finding expert knowledge and the experts. Not all factor groups participate with equal weight in the maturity model. There is no uniform selection criteria system for choosing the weighting procedure. From a mathematical point of view, the most well-established procedure is the Guilford procedure. It is based on the pairwise comparison already mentioned, which can be used to weight the evaluation factors on an ordinal scale [48].

It is divided into three main areas:

- Recording expert opinions,
- Processing expert opinions using individual and then group preference matrices,
- Determination of weights.

1. Weighting of evaluation factors

All possible pairs:

$$\binom{n}{2} = \frac{n(n-1)}{2} \tag{1}$$

Systematic error in the arrangement of pairs and any learning distortion resulting from a regular arrangement should be avoided. Therefore, a random arrangement or a Ross [49] arrangement with even less distortion should be used.

2. The decision-maker indicates which evaluation factor they prefer in each pair. Based on theoretical considerations, indifference is not allowed (same preference). The same preference is not allowed because Thurstone [48] has shown that most people can differentiate between two things in terms of preference.

3. Compilation of the preference table. The evaluation factors are listed in both rows and columns in the preference table. The intersection of each row and column indicates the preference relationship of that pair, with the convention that the sign in the field represents the preference of the factor corresponding to that row over the factor corresponding to that column.

For a given assessment factor, the row sum and the column sum must be a numeric value of $n$-1.

Since the unconditional transitivity of the preference relation is not specified in a normative manner, it can be assumed that there are inconsistent triads among the decision-maker's preferences. The consistency index of decision-makers should be calculated this way.

4. Calculation of the numerical value of the consistency index for an even-number of result set

$$K = 1 - \frac{24d}{n^3-4n} \tag{2}$$

where $d$ is the number of inconsistent triads.

This can be calculated using the following formula:

$$d = \frac{n(n-1)(2n-1)}{12} - \frac{\sum a^2}{2} \tag{3}$$

where $a$ is the sum of the rows in the preference table.

5. Determination of preference rates. Each $a$ value is increased by 0.5, and the number is divided by the number of evaluation factors.

6. Preference ratios are transformed to $u$ values of the standardized normal distribution.

7. As this is an interval scale, it is better to convert it to a scale with a starting point of 0 and an endpoint of 100. This is corrected in our solution because an endpoint of 0 would not play a role in digital maturity, so the scale is corrected at the end.

The preference table is obtained in aggregate form by aggregating the individual preference tables. Based on the aggregated preference table, the degree of agreement of decision-makers can also be calculated.

Square deviation:

$$\Delta = \sum_j (R_j - \bar{R}_j)^2, \tag{4}$$

where

$\Delta$ is the square deviation,

$R_j$ is the individual sum of the ranks,

$\bar{R}_j = \frac{k(n+1)}{2}$ is the arithmetic mean of the sum of the ranks,

where

$k$ is the number of decision-makers,

$n$ is the number of evaluation factors.

It can be proved mathematically that $\Delta$ takes on the maximum value if the decision-makers have a complete agreement.

The value of $\Delta_m$ of the total agreement can be calculated directly from the following equation:

$$\Delta_m = \frac{k^2(n^3-n)}{12}, \tag{5}$$

where

$k$ is the number of decision-makers,

$n$ is the number of evaluation factors,

If necessary, the actual $\Delta$ value is compared to the $\Delta_m$ value of the total agreement. The resulting ratio ($w$) is *Kendall's* coefficient of concordance; in short, *Kendall W*.

$$w = \frac{\Delta}{\Delta_m} \tag{6}$$

It can be seen that the value of $w$ [0; 1] is within a closed interval on both sides. In case of complete agreement $w$=1, in case of complete opposition $w$=0. Of course, there is another calculation method in which we can form the coefficient of concordance using the elements below the diagonal in the aggregate preference matrix [48].

Based on the method detailed above, we determined the weights of the components required for digital maturity in an earlier paper [50] and organizational maturity, which are essential for creating the digital maturity life-cycle model.

That is why this paper will only present the important results of the earlier research of digital maturity. Digital maturity consists of the strategic, technical, technological, and human resource characteristics of a digital organization.

Table 4 shows the sub-components and main components of digital maturity together with identified weighting factors.

Table 4. Weights of digital maturity sub-components (adapted from Sándor and Gubán [50]

| No. | Component | Weight | No. | Component | Weight |
|---|---|---|---|---|---|
| 1. | Knowledge application | 0.10223 | 15. | Organizational decision making | 0.02816 |
| 2. | Innovation capability | 0.08032 | 16. | ERP | 0.02813 |
| 3. | Web page/webshop | 0.07223 | 17. | Chatbot | 0.02772 |
| 4. | Adaptability | 0.06691 | 18. | Own server usage | 0.02611 |
| 5. | VPN connection | 0.05282 | 19. | Corporate culture | 0.02446 |
| 6. | Contact with customers | 0.05059 | 20. | Social media usage | 0.02408 |

| No. | Component | Weight | No. | Component | Weight |
|---|---|---|---|---|---|
| 7. | Search Engine Optimization | 0.04564 | 21. | Mobile phone consumerization | 0.02137 |
| 8. | Own domain name | 0.04366 | 22. | Contact with suppliers | 0.01897 |
| 9. | Mobilapp | 0.03958 | 23. | Internal communication | 0.01897 |
| 10. | Cloud usage | 0.03617 | 24. | Internet usage | 0.01862 |
| 11. | BI | 0.03458 | 25. | CRM | 0.01809 |
| 12. | Agility | 0.03408 | 26. | Telephone communication | 0.00925 |
| 13. | (IT) strategy | 0.03407 | 27. | Isolated machines | 0.00870 |
| 14. | Unique email address | 0.02969 | 28. | Business phone | 0.00480 |

Based on the opinion of experts, in relation to sub-components, digital maturity is primarily determined by appropriate expertise and the capacity for development.

Table 5. Weights of the main components of digital maturity (adapted from Sándor and Gubán [50])

| Component | Weight |
|---|---|
| Peopleware | 0.28354 |
| Online presence | 0.18153 |
| Technical solutions | 0.17731 |
| Orgware | 0.17523 |
| Software | 0.11697 |
| Hardware | 0.06543 |

The weighting factors of the main components (Table 5) also support the above, namely, that the human factor prevails over technology.

Digital maturity metric for the analyzed SME:

$$d = \sum_{i=1}^{28} d_i w_i \tag{7}$$

$d_i (\in [0;1])$: is the value for the given component for the analyzed SME:

$w_i$: is the weighting factor of the *i* component in the above Table 5.

Below we focus on the other two components. The sector (IT intensity) variable is included on account of dependence on the SME's scope of activity. It is very important to note that activities determine digital expectations. Certain activities do not require an IT environment and solutions at a higher level; higher maturity can be achieved faster and easier in relation to these. In relation to activities built on and sensitive to digitalization and IT, expectations are significantly higher and achievement or maintenance of a higher maturity level is more difficult. Thus, dependence on such variable can also be simply defined, qualitative classification can be easily mapped for the [0;1] period on the basis of Table 3, allowing us to work on a quantitative scale. Moreover, the above quartiles can be further fine-tuned (this study does not detail this). In a short (1-2-year) $\Delta T$ period, an SME commonly does not aim to change digital intensity (it may be triggered by changes to the scope of activity, or the regulatory environment, such as connection of cash registers to the tax authority), particularly to increase the digital maturity level. By contrast, expectations are higher for higher levels of the life-cycle in relation to activity based on more intense IT activity.

The third variable is the organizational dimension. This variable was included among function variables, because it is significantly affected by the organization's internal structure, operation and management structure, and also limits the digital internal structure's status and options for development. For this reason, an organizational change in the right direction may improve qualitative changes to the digital structure, thereby raising the organization's maturity level and options for maintaining it at a high level. This component is evaluated similarly to the one related to digital maturity.

We applied the pair-wise comparison method [48] for determining the weighting factors of sub-components. The sub-components are as follows:

- Division of labor: number of elements contained by the core activity;
- Number of decision-making levels: types of decision-making levels at the given company (senior, middle, operational levels);
- Level of regulation: extent to which sub-tasks and functions within the organization are regulated in writing;
- Segmentation: extent to which scopes of activity, and their subordination and interdependence are distinct from each other;
- Leadership vision: future status of the company, means and steps, and milestones necessary to achieve it;
- Employee commitment: extent to which the employee is capable of facilitating achievement of the general corporate target with his/her professional skills and commitment;
- Human resources: measures aimed at hiring and retaining appropriate human factors necessary for achieving corporate goals (wage compensation, physical, emotional, intellectual well-being).

We sent the comparative questionnaire mainly to leading SME experts, and also to teachers and researchers with experience in HR theory and management. The experts include university experts, respected teachers and researchers of tertiary education. IT and management professionals working for SMEs and with different qualities. and having IT insight. They were selected on the basis of their professional respect. We applied a transformed Guilford method for evaluating the questionnaires, where responses showing contradictions – i.e. which did not have an acceptable level of consistency – were filtered.

A total of 53 responses were received from experts (at a ratio of 30-23 between the two groups). Most of these included consistent responses. There were 26 and 32 responses at a 95% and 90% consistency level, respectively. There are no major differences in this regard, as we had available acceptable responses at the 95% level as well. We received a rather low 0.17 value for the calculated agreement indicator, nevertheless we accept the received adjusted weighting factors (adjustment factor *k* =3). We accordingly calculated the following weighting factors for the sub-parameters (Table 6).

Table 6. Weights of organizational dimension

| **Sub-component** | **Weight** |
|---|---|
| Division of labor (la) | 0.148386 |
| Number of decision-making levels (dl) | 0.105105 |
| Level of regulation (lr) | 0.114767 |
| Segmentation (sg) | 0.095097 |
| Leadership vision (lv) | 0.181416 |
| Employee commitment (ec) | 0.203392 |
| Human resources (hr) | 0.151837 |

$$o = 0.148386la + 0.105105dl + 0.114767lr + 0.095097sg + 0.181416lv + 0.203392ec + 0.151837hr \quad (8)$$

In terms of methodology, we applied heuristic adjustment for determining the life-cycle function. In the present case, by this we mean that we surveyed the characteristics of the function (*M*) and sought a continuous function corresponding to such characteristics. This also means that the function should also allow parameterization to ensure the best adjustment, on the one hand, and during parameterization the produced function may not lose the characteristics. Based on the foregoing, the function to be produced has three independent non-negative true value variables and one true value.

$$M(d; o; a) = M(D(d); O(o); A(a)) \quad (9)$$

i.e. it is produced as a function of the appropriate component functions and analyzed in one $\Delta T$ period. In the analysis it does not change in either the $o$ or the $a$ $\Delta T$ period (meaning that it is given in terms of the maturity level).

Furthermore, the function values indicating the "status" of the given SME life-cycle (hereinafter "status function") should have a value between 0 and 1 due to normalized input values and for the sake of simpler comparison and uniformity:

$$M(d; o; a) \in [0; 1] \quad (10)$$

where

$d \in [0; 1]$ is the metric of SME digital maturity,

$o \in [0; 1]$ is the metric of organizational maturity,

$a \in [0; 1]$ is the value of digital expectation related to the company's scope of activity.

The function does not necessarily have to reach either the value of 0 or 1, as companies in an "absolutely perfect" and "inappreciably poor digital state" do not exist. During parameterization, however, we need to ensure that it arbitrarily approximate these two extreme values. As an additional expectation related to the function, its behavior based on *d* (digital maturity) – i.e. with fixed *o, a* values – should strictly increase, and in the initial "phase" the start-up should be convex, as changes to lower digital values should be followed by greater changes to the life-cycle, thus the function should be convex in this case, and should have a concave start-up in case of a higher digital value. It is also obvious that similar observations may be made in relation to the organizational maturity variable (*o*), with fixed *d, a* values. Such rules are not applicable to the third variable, as digital expectations for all scopes of activity are specific, depending on the sector, location of the activity, staffing etc. Furthermore, the SME changes only minimally, i.e. to a negligible extent, in terms of organization and scope of activity with an impact on the digital level.

It is obvious that application of a simple product function does not provide a true picture of the situation, i.e.

$$M(d; o; a) = D(d)O(o)A(a) \quad (11)$$

In case of a function of such structure, namely, it is not possible to ensure the above conditions, that is, appropriate monotony and convexity along the function's axial plane sections. So it is not possible to ensure that for all values of *a*, the function *M* take up the maximum value for high *d* and *o* values.

### 3.2 Digital maturity life-cycle and life-cycle level functions

According to our interpretation, the definition of digital maturity life-cycle is a scale of up to 10 levels of digital development that shows the place of an SME in the examined environment.

For creation of the two functions, we define a possible function based on criteria defined by the methodology:

At analyzed time $t \in \Delta T$

Accordingly, we define how the status function can be created using the component functions of the independent variables. It is obvious that application of a simple product function does not provide a true picture of the situation.

We chose the logistics function, as its structure corresponds to changes in parameters, that is, in the initial phase – it is difficult to advance upward at the start of the life-cycle and the same holds true for the top phase.

$$M(d;o;a) = \frac{1}{1+e^{\left(\beta_1 - k_1\beta_1 \frac{d}{1-\frac{a}{2}}\right)}} \frac{1}{1+e^{\left(\beta_2 - k_2\beta_2 \frac{o}{1-\frac{a}{2}}\right)}} \tag{12}$$

With $\beta_1 \in \mathbb{R}^+$ we can regulate the "gradient" of the *d* variable curve, while $k_1 \in \mathbb{R}^+$ marks the place of the inflection point; if this value is 2, then the value is *d* = 0.5. The same applies to the $\beta_2 \in \mathbb{R}^+$ and $k_2 \in \mathbb{R}^+$ parameters, except on the basis of the *o* variable.

The defined life cycle function is the result of a multi-step selection process. We did not find any recommendations or solutions for the function in the literature, so we relied on our analyses. Considering its nature, the function gives a characteristic diagram not necessarily symmetric to the center in a strictly monotonic convex to the concave manner with an inflection point for *d* and *o*, i.e., digital maturity and organizational dimension. Furthermore, there are neither perfectly bad nor perfectly good (0 and 1, respectively) values in practice, so the sigmoidal function results in a very good solution for these two dimensions. Experience has shown, but we have also indicated earlier, that two dimensions can be created to be independent of each other, so they are listed as a sequence function in the solution function. In contrast, IT intensity ($a$) already affects both dimensions. If we examine only this dimension, it is no longer described by a sigmoid function. With a constant value of $d_0; o_0$ our function takes the following form:

$$M(d_0;o_0;a) = \frac{1}{1+e^{\left(\beta_1 - k_1\beta_1 \frac{d_0}{1-\frac{a}{2}}\right)}} \frac{1}{1+e^{\left(\beta_2 - k_2\beta_2 \frac{o_0}{1-\frac{a}{2}}\right)}} = \frac{1}{\left(1+e^{\left(\beta_1 - \frac{c_1}{2-a}\right)}\right)\left(1+e^{\left(\beta_2 - \frac{c_2}{2-a}\right)}\right)} = \frac{1}{\left(1+c_3 e^{\frac{2-a}{c_1}}\right)\left(1+c_4 e^{\frac{2-a}{c_2}}\right)} =$$
$$\frac{1}{(1+c_3 e^{c_5 - c_7 a})(1+c_4 e^{c_6 - c_8 a})} = \frac{1}{(1+c_3 e^{c_5 - c_7 a})(1+c_4 e^{c_6 - c_8 a})} = \frac{1}{\left(1+\frac{c_9}{\alpha^a}\right)\left(1+\frac{c_{10}}{\gamma^a}\right)} \tag{13}$$

where $\alpha, \gamma > 1$

and: $c_1 = 2k_1\beta_1 d_0;\ c_2 = 2k_2\beta_2 o_0;\ c_3 = e^{\beta_1};\ c_4 = e^{\beta_2};\ c_5 = \frac{2}{c_1};\ c_6 = \frac{2}{c_2};$

$$c_7 = \frac{1}{c_1};\ c_8 = \frac{1}{c_2};\ c_9 = c_3 e^{c_5};\ c_{10} = c_4 e^{c_6};\ \alpha = e^{c_7};\ \gamma = e^{c_8}.$$

The robustness test can also be performed, first as a function of the changes in the parameters. According to the $\beta$ parameters:

$$M(d;o;a) = \frac{1}{1+e^{\beta_1\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}} \frac{1}{1+e^{\beta_2\left(1-k_2\frac{o}{1-\frac{a}{2}}\right)}} = \frac{1}{1+e^{\beta_1 \left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}} \frac{1}{1+e^{\beta_2 \left(1-k_2\frac{o}{1-\frac{a}{2}}\right)}} \tag{14}$$

$$M(\beta_1) = \frac{1}{1+\beta_1^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}} c \tag{15}$$

where $0 < c < 1$

Therefore, the $\beta$ parameters in the sigmoid function change the base of the exponential function.

$$|M(\beta_1+\Delta\beta_1) - M(\beta_1)| = \left|\frac{1}{1+e^{\beta_1+\Delta\beta_1}{}^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}} - \frac{1}{1+e^{\beta_1}{}^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}}\right| c = \left|\frac{1}{1+e^{\mu(\beta_1+\Delta\beta_1)}} - \frac{1}{1+e^{\mu\beta_1}}\right| c =$$
$$\left|\frac{1}{1+\alpha^{(\beta_1+\Delta\beta_1)}} - \frac{1}{1+\alpha^{\beta_1}}\right| c < \left|\frac{1}{1+\alpha^{\beta_1}\alpha^{\Delta\beta_1}} - \frac{1}{1+\alpha^{\beta_1}}\right| \tag{16}$$

where $0 < \beta_1 + \Delta\beta_1$ since $\alpha > 1$ and $\beta_1 > 0$

$$|M(\beta_1+\Delta\beta_1) - M(\beta_1)| < \frac{\alpha^{\beta_1}\left|1-\alpha^{\Delta\beta_1}\right|}{1+\alpha^{\beta_1+\Delta\beta_1}\alpha^{\beta_1}+\alpha^{\beta_1}\alpha^{\Delta\beta_1}+\alpha^{\beta_1}} < \frac{\left|1-\alpha^{\Delta\beta_1}\right|}{\alpha^{\beta_1}\alpha^{\Delta\beta_1}+\alpha^{\Delta\beta_1}+1} < \frac{\left|1-\alpha^{\Delta\beta_1}\right|}{\alpha^{\Delta\beta_1}(\alpha^{\beta_1}+1)} < \frac{\alpha^{\beta_1}\left|\alpha^{\Delta\beta_1}-1\right|}{\alpha^{\beta_1}+1}$$

So, the change as a function of $\beta$ is exponential.

The examination of the parameter $k$ is much more complicated, as it depends very much on the relation of the variables $d; o; a$ to each other; for this reason, we do not examine it in the study.

In the second step by dimensions, that is:

$$\Delta_d M = M(d;o;a) - M(d+\Delta d;o;a)$$
$$\Delta_o M = M(d;o;a) - M(d;o+\Delta o;a)$$
$$\Delta_a M = M(d;o;a) - M(d;o;a+\Delta a)$$

The details of this are not the subject of our study; in any case, it can be stated that for more advanced dimension values for $d > k_1$, $\Delta_d M < \Delta d$, and for $o > k_2$, $\Delta_o M < \Delta o$. In the case of real enterprises, $\Delta_a M \approx \Delta a$ can also be stated.

So it fulfills the expectation of monotony and exponentiality, which can be expected to provide a higher maturity for a higher level of value in a sector with a higher IT demand (of course, the model also allows the function to be linear with proper parameterization).

Based on these, the given $M$ function behaves as expected with the other constant values and takes its values within the desired interval for all three dimensions. Verification of absolute correctness can only be done with empiricism. In contrast, creating empirics required a theoretical model that could be accepted as a starting function (later, this will be replaced by a neural network built based on the collected samples, but this will require a basic model).

Fig. 2. shows the $M$ function with a fixed value for $a$; $a = 1$ in the first case, $a = 0.1$ in the second case.

Fig. 3. shows the $M$ function with a fixed value for $o = 1$ in the first case, $o = 0.3$ in the second case and , $o = 0.1$ in the third case.

Since we already took into account the limits of the final maturity levels in dependence on the variables of the function $M$, it will be sufficient to apply a linear scale for their determination. As a result of the above analysis, we define five levels for the life-cycle, which are based on the Greiner growth model and CMMI model. The five levels are easy to use and well categorized. It can be further increased or decreased and changed dynamically.

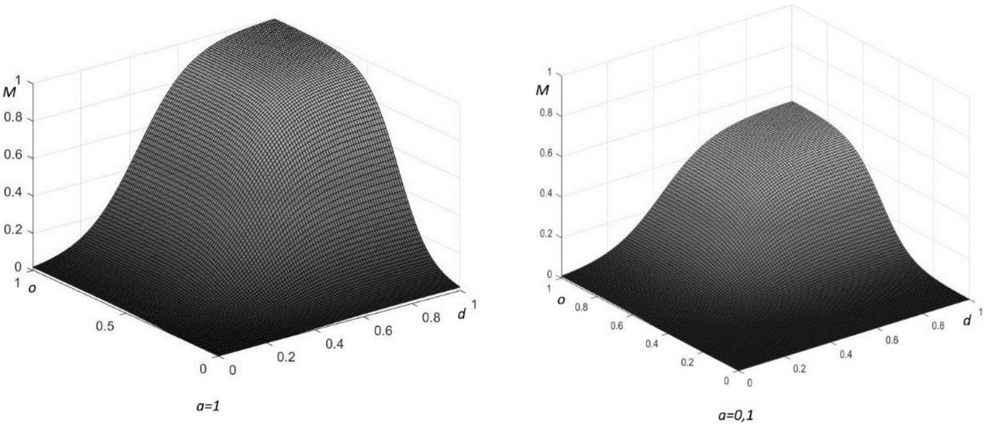


Fig. 2. Function sections with fixed IT intensity values (in sequence: a=1; a=0.1)

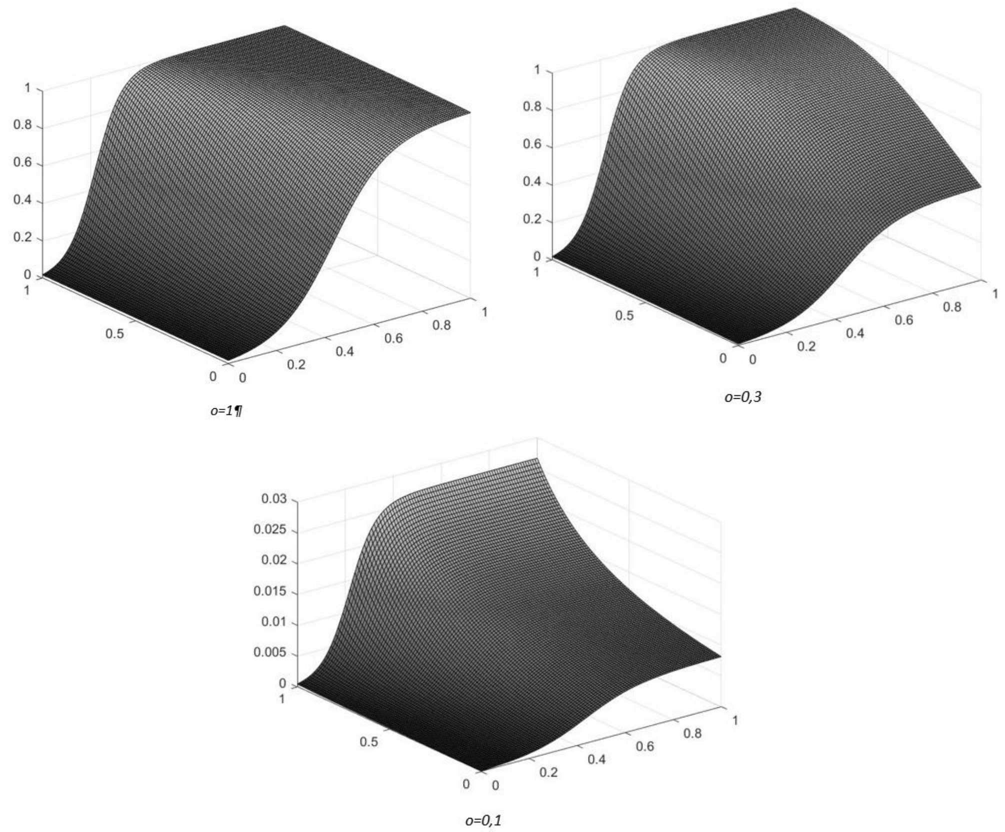


Fig. 3. Function sections with fixed organization values (in sequence: o=1; o=0.3; o=0.1)

In terms of the number of levels, it is important to note that the few levels do not show a sufficiently subtle picture, and the “jumps” are based on big changes that do not inspire SME leaders to make smaller changes. On the other hand, too many levels make the situation unclear, and even a very small change can be seen as a significant achievement by managers. In the case of the model, the number of levels can be changed at any time, ensuring the flexibility of the model.

1. initial: An SME is at this level if it is a start-up or has changed its activity, where the new activity is at a higher level in terms of digitalization, or the business has not yet focused sufficient attention on digital development. In this phase, the primary task is the setting of goals.

2. pathfinder: At the pathfinder maturity level the business is already showing a need for digital development/growth, and the first steps have been taken, but it lacks a developed concept as to the method of change, steps to be taken and the resources to be invested in. Therefore, at this level it is necessary to define detailed implementation solutions and plans for the goals, and to review these to determine whether they correspond to market levels, solutions on the market and of competitors.

3. advanced: A business at an acceptable level of digital maturity and development, but with several variations from the market environment and well-performing competitors. At this level it is necessary to define tasks for criteria, that is, to adapt to the analyzed environment and competitors, enabling achievement of a higher maturity level relative to them.

4. managed: The digital maturity level of the SME is of good quality; it is ahead of some competitors, and the system now internally detects deficiencies and attempts to correct these in the right direction.

5. optimized and providing feedback: At the highest level it is now very important to monitor and analyze changes in the environment, and to develop it through feedback, so as to avoid falling back to a lower maturity level. This not only involves maintaining the level, as development of the environment entails further development. These must be detected and responded to as soon as possible.

The five maturity phases may be classified into three levels in terms of data-information (Fig. 4):

1. Data searches, interpretation of information, queries;
2. Data analysis with statistical methods, statistical prospective analysis;
3. Data-driven BigData technologies, use of business intelligence.

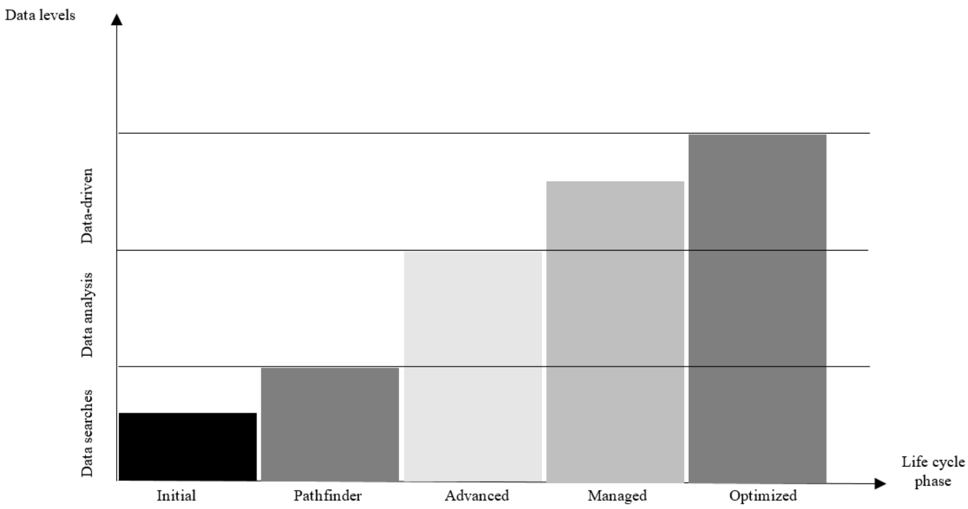


Fig. 4. Classification of maturity levels

We then perform the mapping:

$$L = \begin{cases} initial & if \quad 0 < M \leq 0{,}2 \\ \text{pathfinder} & if \quad 0{,}2 < M \leq 0{,}4 \\ advanced & if \quad 0{,}4 < M \leq 0{,}6 \\ managed & if \quad 0{,}6 < M \leq 0{,}8 \\ optimized & if \quad 0{,}8 < M \leq 1 \end{cases} \tag{17}$$

Accordingly, the sectional layer functions will be as follows in relation to some parameters. In the first case $a = 1$, in the second case $a = 0.5$, in the third case $a = 0.1$. (Fig. 5.)

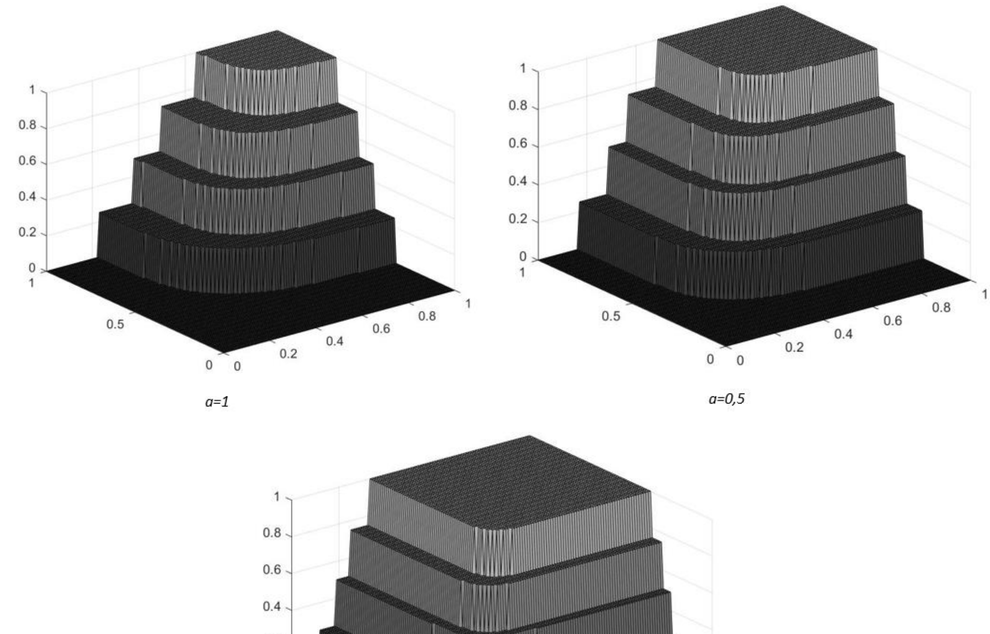


Fig. 5. Maturity levels with fixed IT intensity values (in sequence: a=1; a=0.5; $a$=0.1)

Or in the first case $o = 0.3$, in the second case $o = 0.7$ (Fig.6.)

The life-cycle levels are fully interoperable with each other. In other words, theoretically any level may be reached from any level. Obviously chances are much higher that the change will result in movement to a neighboring level. If the change is significant, a larger jump cannot be ruled out, either.

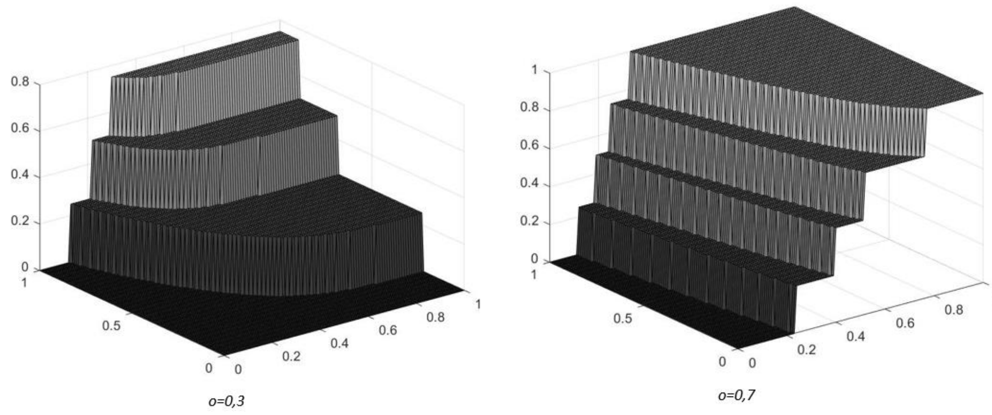


Fig. 6. Maturity levels with fixed organization values (in sequence: o=0.3; o=0.7)

Let's take intensive smart farming as an example, specifically an investment in livestock farming (such types of development are possible for SMEs and family business as well). In this case, the transition is from livestock farming performed with traditional, manual activities and human-controlled machinery to smart farm solutions based on Industry 4.0 and IoT, which are two extremes of the maturity level. Traditional solutions do not require major digitalized solutions, and are even possible without these. It follows that the ($d$) value of digital maturity may be close to zero, or is very low. Organizational maturity is not expected to be at a high level, either; available human resources perform many tasks and tasks are coordinated on the basis of own experience and circumstances. IT intensity is very low.

As a result of a major smart farming project, the digitalized IT-driven solution significantly relies on IoT, network communication, consumerization of tools, and utilization of services (GPS, internet, cloud services, BI solutions, AI forecasts and controls). This entails large-scale IT (hardware, software, orgware, peopleware) development, potentially resulting in a very high digital maturity level. These solutions require the structuring of the organization and the designation of management levels, i.e. organizational maturity ($a$) will also have a high value.

Despite IT intensity changing only to a moderate extent, in the life-cycle model the SME may reach the highest level if it also reaches the upper level of the market and competitors. Obviously, during the project the organization will progress through the entire life-cycle, but will remain at the levels only for a short time, and possibly go back and forth between levels on a cyclical basis. Secondly, another misconception is clearly debunked, that a very significant technical development (hardware and/or software) will not automatically raise the digital maturity life-cycle level. As shown in Table 5, the weighting factor of these two components is 0.1824, which does not represent a major level in the $d$ value, either.

### *3.3 Further development of the model*

The model may be applied in practice, if we can determine how it is possible to move upward from a given life-cycle level or to stay on level, and how a decline can be avoided. We can provide a solution only if a sufficiently large sample of SMEs is collected, that is, we know their digital maturity, organizational maturity levels, and can also determine their position within the digital maturity life-cycle, together with its value. In this case we receive appropriate values $(\beta_1, \beta_2, k_1, k_2)$ for parameters of the $M$ function, on the one hand, and can clarify the function itself, on the other. In knowledge of the known input-output data pairs, the arbitrary $M$ function applied so far can be substituted. With the above we can acquire experience on how we can more successfully step up a level by changing the given input parameter (or by joint fine-tuning of parameters).

## 4. Conclusion

In the course of digitalization, it is essential for companies to attempt to respond to external environmental factors as soon as possible. Digitalization offers a major opportunity for SMEs as well, enabling, among other things, easier outreach to customers. One of the most frequent problems occurring during digital transformation is companies not knowing how to begin with development. The various digital maturity models support this process.

A number of such models – based on maturity models – have been developed over the years. These models, however, are one-dimensional; they do not assess in due detail the relevant processes of companies, especially in relation to SMEs.

The developed digital maturity life-cycle model examines companies' digital maturity, organizational characteristics and the IT intensity of scopes of activity based on three dimensions. Companies do not necessarily progress linearly between levels; they may skip certain levels to reach the level of highest digital maturity, or the reaching of a given level does not guarantee that they will not fall back to a lower level at a later time. There are five maturity levels distinguished on the basis of the model: initial, repeatable, defined, managed and optimizing. We then classified these levels into three groups based on data-information (data-seeking, data-analytical, data-driven). The data-driven company is at the highest level, which is capable of fully analyzing available data and taking decisions even by means of simulation.

The life-cycle levels are fully interoperable with each other. At the various levels the approach and vision of the owner/manager related to digitalization plays a key role. Obviously the extent to which necessary technical developments are implemented by a company to at least maintain its current position over competitors also depends on the given sector. The model may help company executives to better understand factors requiring conscious management for improving digital maturity.

This model provides a theoretical description for a preprocessing tool, based on which the preparation of a system design no longer takes a long time, and the resulting IT application can also be easily implemented as a tool. Consequently, the application that can be made and is not part of the paper helps easily and quickly determine SMEs' digital maturity and lifecycle position for later use. The model helps start the digital transformation because the model indicates which areas a given company needs to develop for a successful transformation.

As a further aspect of the model's potential development, the position of the company within the digital maturity life-cycle could be determined on the basis of an adequately large sample and we could gain a picture of the digital maturity of SMEs.

### Acknowledgments

This work was supported by "Future Value Chains" Center of Excellence.

### References

[1] D. Technologies, "Digital Transformation Index 2020," 2020. https://www.delltechnologies.com/en-us/perspectives/digital-transformation-index.htm#pdf-overlay=//www.delltechnologies.com/en-us/collaterals/unauth/briefs-handouts/solutions/dt-index-2020-executive-summary.pdf.

[2] McKinsey, "How COVID-19 has pushed companies over the technology tipping point—and transformed business forever," 2020. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever.

[3] J. Kääriäinen, O. Kuusisto, P. Pussinen, M. Saarela, L. Saari, and K. Hänninen, "Applying the positioning phase of the digital transformation model in practice for smes: Toward systematic development of digitalization," *International Journal of Information Systems and Project Management*, vol. 8, no. 4, pp. 24–43, 2020, doi: 10.12821/ijispm080402.

[4] P. Parviainen, M. Tihinen, J. Kääriäinen, and S. Teppola, “Tackling the digitalization challenge: How to benefit from digitalization in practice,” *International Journal of Information Systems and Project Management*, vol. 5, no. 1, pp. 63–77, 2017, doi: 10.12821/ijispm050104.

[5] J. Ganzarain and N. Errasti, “Three Stage Maturity Model in SME’s towards Industry 4.0,” *Journal of Industrial Engineering and Management*, vol. 9, no. 5, pp. 1119–1128, 2016, doi: http://dx.doi.org/10.3926/jiem.2073.

[6] M. G. and S. VanBoskirk, “The Digital Maturity Model 4 . 0,” *Forrester*, 1–17, 2016.

[7] O. Valdez-de-Leon, “A Digital Maturity Model for Telecommunications Service Providers,” *Technology Innovation Management Review*, vol. 6, no. 8, pp. 19–32, 2016, doi: 10.22215/timreview1008.

[8] C. Klötzer and A. Pflaum, “Toward the Development of a Maturity Model for Digitalization within the Manufacturing Industry's Supply Chain,” *Proceedings of the 50th Hawaii International Conference on System Sciences*, pp. 4210–4219, 2017, doi: 10.24251/hicss.2017.509.

[9] M. Colli, O. Madsen, U. Berger, C. Møller, B. V. Wæhrens, and M. Bockholt, “Contextualizing the outcome of a maturity assessment for Industry 4.0,” *IFAC-PapersOnLine*, vol. 51, no. 11, pp. 1347–1352, 2018, doi: 10.1016/j.ifacol.2018.08.343.

[10] K. North, N. Aramburu, and O. J. Lorenzo, “Promoting digitally enabled growth in SMEs: a framework proposal,” *Journal of Enterprise Information Management*, vol. 33, no. 1, pp. 238–262, 2019, doi: 10.1108/JEIM-04-2019-0103.

[11] A. Schumacher, T. Nemeth, and W. Sihn, “Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises,” *Procedia CIRP*, vol. 79, pp. 409–414, 2019, doi: 10.1016/j.procir.2019.02.110.

[12] O. Kuusisto, J. Kääriäinen, K. Hänninen, and M. Saarela, “Towards a Micro-Enterprise–Focused Digital Maturity Framework,” *International Journal of Innovation in the Digital Economy*, vol. 12, no. 1, pp. 72–85, 2020, doi: 10.4018/ijide.2021010105.

[13] M. Mullaly, “If maturity is the answer, then exactly what was the question?,” *International Journal of Managing Projects in Business*, vol. 7, no. 2, pp. 169–185, 2014, doi: 10.1108/IJMPB-09-2013-0047.

[14] A. Garzoni, I. De Turi, G. Secundo, and P. Del Vecchio, “Fostering digital transformation of SMEs: a four levels approach,” *Management Decision*, vol. 58, no. 8, pp. 1543–1562, 2020, doi: 10.1108/MD-07-2019-0939.

[15] E. T. Penrose, *Theory of the growth of the firm*. Oxford: Basil Blackwell, 1959.

[16] I. Adizes, “Organizational passages-Diagnosing and treating lifecycle problems of organizations,” *Organizational Dynamics*, vol. 8, no. 1, pp. 3–25, 1979, doi: 10.1016/0090-2616(79)90001-9.

[17] L. E. Greiner, “Evolution and revolution as organizations grow. 1972.,” *Harvard Business Review*, vol. 76, no. 3, 1998, doi: 10.1111/j.1741-6248.1997.00397.x.

[18] M. M. Hasan and A. Habib, “Corporate life cycle, organizational financial resources and corporate social responsibility,” *Journal of Contemporary Accounting and Economics*, vol. 13, no. 1, pp. 20–36, 2017, doi: 10.1016/j.jcae.2017.01.002.

[19] S. Tam and D. E. Gray, "What Can We Learn from the Organizational Life Cycle Theory? A Conceptualization for the Practice of Workplace Learning," *Journal of Management Research*, vol. 8, no. 2, p. 18, 2016, doi: 10.5296/jmr.v8i2.9093.

[20] L. Mosca, M. Gianecchini, and D. Campagnolo, "Organizational life cycle models: a design perspective," *Journal of Organization Design*, pp. 3–18, 2021, doi: 10.1186/s41469-021-00090-7.

[21] M. Scott and R. Bruce, "Five stages of growth in small business," *Long Range Planning*, vol. 20, no. 3, pp. 45–52, 1987, doi: 10.1016/0024-6301(87)90071-9.

[22] G. L. Lippitt and W. H. Schmidt, "Crises in a developing organization," *Harvard Business Review*, vol. 45, no. 6, pp. 102–112, 1967.

[23] L. Sukova, "Greiner's Model and Its Application in Automotive Companies in the Czech Republic," *Acta Informatica Pragensia*, vol. 9, no. 1, pp. 18–29, 2020, doi: 10.18267/j.aip.129.

[24] J. Levie and B. B. Lichtenstein, "A terminal assessment of stages theory: Introducing a dynamic states approach to entrepreneurship", *Entrepreneurship Theory and Practice*, vol. 34, no. 2, 2010.

[25] J. D. Crawford, "Introduction to bifurcation theory," *Reviews of Modern Physics*, vol. 63, no. 4, pp. 991–1037, 1991, doi: 10.1103/RevModPhys.63.991.

[26] S. Mittal, D. Romero, and T. Wuest, "Towards a smart manufacturing toolkit for SMEs," *IFIP Advances in Information and Communication Technology*, vol. 540, no. August, pp. 476–487, 2018, doi: 10.1007/978-3-030-01614-2_44.

[27] S. Mosallaeipour, R. Nazerian, and M. Ghadirinejad, *Industrial Engineering in the Industry 4.0 Era*, September. 2018.

[28] T. Mettler, "Maturity assessment models: a design science research approach," *International Journal of Society Systems Science*, vol. 3, no. 1/2, p. 81, 2011, doi: 10.1504/ijsss.2011.038934.

[29] R. Caralli, M. Knight, and A. Montgomery, "Maturity models 101: a primer for applying maturity models to smart grid security, resilience, and interoperability," no. November, pp. 1–10, 2012, doi: 10.1111/j.1744-7429.2009.00516.x.

[30] D. Linstedt and M. Olschimke, "The Data Vault 2.0 Methodology," *Data Vault 2.0*, pp. 33–88, 2016, doi: 10.1016/b978-0-12-802510-9.00003-9.

[31] Z. Gaál, L. Szabo, N. Obermayer-Kovacs, and A. Csepregi, "Successful Knowledge Management an Knowledge Sharing in Hungarian Enterprises," *Club of Economics in Miskolc TMP*, vol. 6, no. 2, pp. 11–18, 2010.

[32] G. R. Kane, G. C., Phillips, N. A., Copulsky, and J. R. Andrus, *The Technology Fallacy: How People Are the Real Key to Digital Transformation*. 2019.

[33] G. C. Kane, D. Palmer, A. N. Phillips, D. Kiron, and N. Buckley, "Achieving Digital Maturity," *MIT Sloan Management Review Deloitte Univ. Press*, no. Summer, pp. 1–31, 2017, [Online]. Available: http://sloanreview.mit.edu/digital2017.

[34] T. Thordsen, M. Murawski, and M. Bick, *How to Measure Digitalization? A Critical Evaluation of Digital Maturity Models*, vol. 12066 LNCS. Springer International Publishing, 2020.

[35] U. S. Bititci, P. Garengo, A. Ates, and S. S. Nudurupati, "Value of maturity models in performance measurement Umit," *International Journal of Production Research*, vol. 53, no. 10, pp. 3062–3085, 2015, doi: https://doi.org/10.1080/00207543.2014.970709.

[36] R. H. Raja Mohd Ali, R. Mohamad, Y. Y. Abdul Talib, and A. Abdullah, "The roles of top management and users in strategic IS planning: A perspective of SMEs," *International Journal of Information Systems and Project Management*, vol. 6, no. 4, pp. 61–80, 2018, doi: 10.12821/ijispm060404.

[37] Deloitte, "Digital Maturity Model Achieving digital maturity to drive growth," no. February, 2018, [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Technology-Media-Telecommunications/deloitte-digital-maturity-model.pdf.

[38] L. D. Rafael, G. E. Jaione, L. Cristina, and S. L. Ibon, "An Industry 4.0 maturity model for machine tool companies," *Technological Forecasting and Social Change*, vol. 159, no. July, p. 120203, 2020, doi: 10.1016/j.techfore.2020.120203.

[39] S. Berghaus and A. Back, "A diversity compression and combining technique based on channel shortening for cooperative networks," *MCIS 2016 Proceedings*, vol. 22, 2016.

[40] PwC, "Industry 4.0: Building the digital enterprise," PwC , 2016.

[41] A. De Carolis, M. Macchi, E. Negri, and S. Terzi, "Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing : IFIP WG 5.7 International Conference, APMS 2017, Hamburg, Germany, September 3-7, 2017, Proceedings, Part I," *IFIP Advances in Information and Communication Technology*, pp. 13–20, 2017.

[42] SAP und ERICS, "Maturity Model and Best Practice: Skill Development for Digital Transformation," AP und ERICS, pp. 1–47, 2017.

[43] Lloyds Bank, "UK Business Digital Index 2017," Lloyds Bank, pp. 1–48, 2017.

[44] A. Issa, B. Hatiboglu, A. Bildstein, and T. Bauernhansl, "Industrie 4.0 roadmap: Framework for digital transformation based on the concepts of capability maturity and alignment," *Procedia CIRP*, vol. 72, pp. 973–978, 2018, doi: 10.1016/j.procir.2018.03.151.

[45] R. Gurumurthy, D. Schatsky, and J. Camhi, "Uncovering the connection between digital maturity and financial performance," *Deloitte Insights*, pp. 1–20, 2020.

[46] S. Albukhitan, "Developing Digital Transformation Strategy for Manufacturing," *Procedia Computer Science*, vol. 170, pp. 664–671, 2020, doi: 10.1016/j.procs.2020.03.173.

[47] A. Szalavetz, "Industry 4.0 and capability development in manufacturing subsidiaries," *Technological Forecasting and Social Change*, vol. 145, no. July 2017, pp. 384–395, 2019, doi: 10.1016/j.techfore.2018.06.027.

[48] J. P. Guilford, *Psychometric Methods*, 2nd ed. New York: McGraw-Hill Book, 1954.

[49] R. T. Ross, “Optimum orders for the presentation of pairs in the method of paired comparisons,” *Journal of Educational Psychology*, vol. 25, no. 5, pp. 375–382, 1934, doi: https://doi.org/10.1037/h0070754.

[50] Á. Sándor and Á. Gubán, “A Measuring Tool for the Digital Maturity of Small and Medium-Sized Enterprises,” *Management and Production Engineering Review*, vol. 12, no. 4, pp. 133–143, 2021, doi: 10.24425/mper.2021.140001.

[51] F. Calvino, C. Criscuolo, L. Marcolin, and M. Squicciarini, “OECD iLibrary | A taxonomy of digital intensive sectors,” *OECD Science, Technology and Industry Working Papers*, vol. 18, no. 4, 2018, [Online]. Available: https://doi.org/10.1787/f404736a-en.

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