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Digital maturity model for research and development organization with the aspect of sustainability.

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Abstract

Many organizations are trying to assess how they progress on their digital transformation journey. One of the methods to assess this progress is to apply the concept of digital maturity. In this article authors describe how they discovered the need to develop a digital maturity model tailored to research and development organizations and share their experience from testing the first version of this model. Digital maturity can be assessed to determine the current state of the organization and to develop roadmaps helping organizations evolve and respond to market dynamics. The authors firmly believe that there is no responsible digitalization without considering the dimension of sustainability and therefore they included it in their maturity model. A digitally transformed company becomes more efficient, generates less waste, and uses fewer resources, which makes it more sustainable.

Keywords: digital maturity; digitalization; sustainability; R&D;

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1. Introduction

Organizations face enormous pressures to change. How they respond to such pressure will define their long-term survival, relevance and competitiveness on fast changing global market [1]. The need to become more efficient and more sustainable created demand to develop and employ new technologies. The presence of such technologies created the drive for companies' transformation which often is called "Digital Transformation" or "Digitalization"[2,3]. At the same time there is a growing focus on reduction of carbon footprint and overall sustainability [4]. Responding to this pressure, organizations create their strategies for sustainability as well as for their digitalization. Recent research demonstrated that these two strategies are interconnected [5–7]. It can be stated that by employing modern technologies companies become more efficient and more sustainable.

This pressure is even bigger for Research and Development (R&D) departments – it is them who push the boundaries of science and research in all fields and industries. They try to continuously reinvent themselves to apply their creativity and innovation to drive progress of their parent organizations. One of the ways for progressing with the digitalization is to apply the concept of digital maturity. Using the digital maturity assessment companies can measure their current state of transformation and create roadmaps to help them become more mature. There are several digital maturity models developed by both practitioners and academia. Authors however discovered the gap related to the digital maturity model tailored to research and development organizations. They attempted to close this gap by developing a maturity model that addresses the specific needs of R&D organizations. In this publication authors explain the steps they took from the literature review, through the development of initial model, validating its key elements with experts, preparing a first prototype and finally testing it in real life in the R&D organization of multinational corporation.

2. Literature review

The literature review served two purposes. First one was to validate if there was indeed a gap in the existing literature when it comes to digital maturity of R&D organizations. Second purpose was to develop the initial set of model dimensions learning from the models already developed and used by both practitioners and academics. Out of several popular methods for literature review, authors used the guidelines of Kitchenham at Keele University [8]. After conducting the initial steps and applying relevant filters, authors analyzed 259 publications and found 8 most relevant listed in the Table 1.

Table 1. Publications selected during the literature review process

Paper name	Year	Authors
Multi-Attribute Assessment of Digital Maturity of SMEs [9]	2021	Kljajić Borštnar, M., Pucihar, A.
Digital Maturity Models: a systematic literature review [10]	2021	Ochoa-Urrego, R.-L., Peña-Reyes, J.-I.
Industry 4.0 Roadmap: Implementation for Small and Medium-Sized Enterprises [11]	2020	Cotrino, A., Sebastián, M.A., González-Gaya, C.
Towards a Comprehensive Exploration and Mapping of Maturity Models in Digital Business: A Systematic Literature Review [12]	2020	Gandhi, A., Sucahyo, Y.G
Digital Transformation Maturity: A Systematic Review of Literature [13]	2019	Teichert, R.
Digital Maturity Models for Small and Medium-sized Enterprises: A Systematic Literature Review [14]	2019	Williams, C., Schallmo, D., Lang, K., Boardman, L.
An Industry 4.0 maturity model proposal [15]	2019	Santos, R.C., Martinho, J.L.
Development of an Assessment Model for Industry 4.0: Industry 4.0-MM [16]	2017	Gökalp, E., Şener, U., Eren, P.

The publications listed in Table 1. were analyzed in depth to list the most suitable maturity models. As a result, authors selected 9 models shown in Table 2. Some other models found were eliminated due insufficient level of detail which, in authors' opinion, made them too open and potentially prone to driving unpredictable results.

Table 2. Digital maturity models selected

Model	Maturity levels	Dimensions	Context
IMPULS Industry 4.0 Readiness	6 maturity levels (Outsiders, Beginner, Intermediate, Experienced, Expert, Top performers)	6 dimensions (Strategy & Organization, Smart Factory, Smart Operations, Smart Products, Data-driven Services, Employees)	Industry 4.0 readiness
Industry 4.0 / Digital Operations Self-Assessment	3 maturity levels (Vertical Integrator, Horizontal Collaborator, Digital Champion)	6 dimensions (Business Models, Product & Service, Portfolio Market & Customer Access, Value Chains & Processes, IT Architecture, Compliance, Legal, Risk, Security & Tax, Organization & Culture)	Digital readiness for Industry 4.0
SIMMI 4.0	5 maturity stages (Basic Digitization, Cross-departmental Digitization, Horizontal and Vertical Digitization, Full Digitization, Optimized Full Digitization)	3 dimensions (Vertical Integration, Horizontal Integration, Cross-sectional Technology Criteria)	Industry 4.0 maturity
Acatech Industry 4.0 Maturity Index	6 maturity stages (Computerization, Connectivity, Visibility, Transparency, Predictive Capacity, Adaptability)	4 structural areas (Resources, Organizational Structure, Information Systems, Culture)	Industry 4.0 maturity
DREAMY (Digital REadiness Assessment MaturitY model)	5 maturity stages (Initial, Managed, Defined, Integrated and Interoperable, Digital-Oriented)	5 structural areas (Design and Engineering, Production Management, Quality Management, Maintenance Management, Logistics Management)	Digital readiness for Industry 4.0
A maturity model for Industry 4.0 Readiness	Likert scale maturity levels (from rating 1= "not important" to rating 4 = "very important")	9 dimensions (Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance, Technology)	Industry 4.0 maturity
360 Digital Maturity Assessment	6 maturity stages (None, Basic, Transparent, Aware, Autonomous, Integrated)	5 digital dimensions (Governance, Technology, Connectivity, Value Creation, Competence)	Digital readiness for Industry 4.0
HADA http://hada.industriaconectada40.gob.es/	6 maturity stages assigned by point system 0–1000 based on survey results (Static, Aware, Competent, Dynamic, Reference, Leader)	5 dimensions (Strategy and business model, Processes, Organization and people, Infrastructures, Products	Model developed by Spanish Government

		and services)	
Multi-Attribute Assessment of Digital Maturity	4 maturity stages (Lagging behind, Initial, Advanced, Digital winner)	2 dimensions (Digital capability, Organizational capability)	Digital Maturity of SMEs

Literature review confirmed growing interest and effort of academia and industries dedicated to further research and application of digital maturity. Interestingly authors noticed that terms “digital maturity” and “industry 4.0 readiness” were overlapping. “Industry 4.0” was more mentioned in the context of industrial application and “digital maturity” could be used in a broader way (for example for government, not-for-profit or other organizations). The review also confirmed that there was a gap in research related to digital maturity tailored for research and development organizations.

The further details of how the literature review was used to arrive at the initial set of dimensions is described in section 3. However, one of the initial observations was that none of the existing models included a dimension of sustainability. Authors decided to include it in their initial set and then verify with experts if it should be considered as part of the digital maturity model for R&D organizations.

3. Research design

The research questions formed by authors were the following:

- What are the key dimensions of Digital Maturity Model tailored to the needs of Research and Development organization?
- Should Sustainability be included in Digital Maturity dimensions?

To address them authors divided their work into three phases:

- Phase 1: authors conducted the review of the existing literature checking if digital maturity models for R&D already exist and looking for the set of dimensions that could form the initial foundation to build such model [17]. In parallel during the Phase 1 authors searched for methods that could be applied to verify this initial set and help with building the model further.
- Phase 2: authors interviewed experts from various companies and locations to validate the initial findings and obtain information which then was used to build the model further. In this phase the “Means-End Chain” method [18] was used to dive deeper into the elements that finally formed the basis for the digital maturity model tailored to R&D. After the interviews authors entered the output (attributes, benefits and goals/dimensions) into LadderUX software [19] to analyze the results. Ladder UX generated the implication matrix (IM) as tabular representation of the results and hierarchical value map (HVM) which links attributes, benefits and dimensions. The importance of elements was calculated using their centrality. This centrality was then used to build an algorithm to calculate the level of maturity (value of the dimension between 0 and 1) depending on the value of the contributing attributes. Based on this algorithm authors built a questionnaire to be filled out when assessing the digital maturity. This part of the research is now considered for a separate publication.
- Phase 3 – in this phase authors tested the model starting from the Minimum Viable Product (MVP). To achieve their goal authors interviewed employees of research and development organization and gathered the results of the assessments as well as the opinion from the pilot users about the questions used. Using these initial interviews, authors improved their model including the formulation and clarification of the questions and then tested it further with three separate research centers of the above company.

4. Empirical data analysis and discussion

The output of the phase 2 was a set of 6 dimensions. Those dimensions, listed from largest to smallest centrality are “Smart operations and research” (centrality: 0.076), “People” (0.057), “Sustainability” (0.051), “Strategy and organization” (0.024), “Smart facilities” (0.020) and “Smart products and services” (0.013). Interestingly the dimension of “Smart operations and research” had largest centrality suggesting that it forms the main focus of the R&D organization. Second in line “People” suggests that regardless of tools and technologies it is extremely important to have the right culture to be able to maximize value from such tools and technologies. Third dimension in terms of importance was “Sustainability”. Although this dimension had not been considered until now in digital maturity models, the enquired experts remark that this topic is getting very important and that it should be considered for the model.

Looking at the benefits listed by the experts, the 5 most important by centrality were “Faster product development” (0.051), “Increased efficiency of operations” (0.051), “Innovative workforce” (0.047), “Faster process development” (0.046) and “Faster response to market dynamics” (0.037). Although most of these can be tied to efficiencies and the agility in responding to market dynamics, the third element with largest centrality was “Innovative workforce”, again pointing out the importance of the culture.

When it comes to the collected attributes the top ones by centrality are “Data management” (0.052), “Education of people” (0.035), “Analytics tools” (0.013), “Knowledge creation and management platform” (0.013). Placing “Data management” in first place by centrality shows that it is a foundation of any modern organization and it is required to be to become “data driven”. Placing “Education of people” in second place confirms the importance of workforce and creation of a learning culture.

Based on the above outcomes, authors created the initial algorithm to calculate the digital maturity of the R&D organization. To visualize the results of the assessment they propose a radar chart as shown for illustration purposes in the Fig. 1.

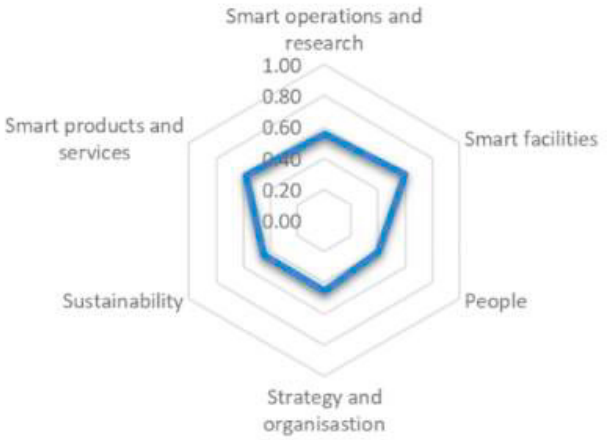

Figure 1. Proposed visualization of results.

The gathered attributes form a basis for the Minimum Viable Product (MVP) questionnaire, which is filled out during the assessment session. The assessed attributes influence various dimensions. An illustration of such dependencies is shown in the Fig 2.

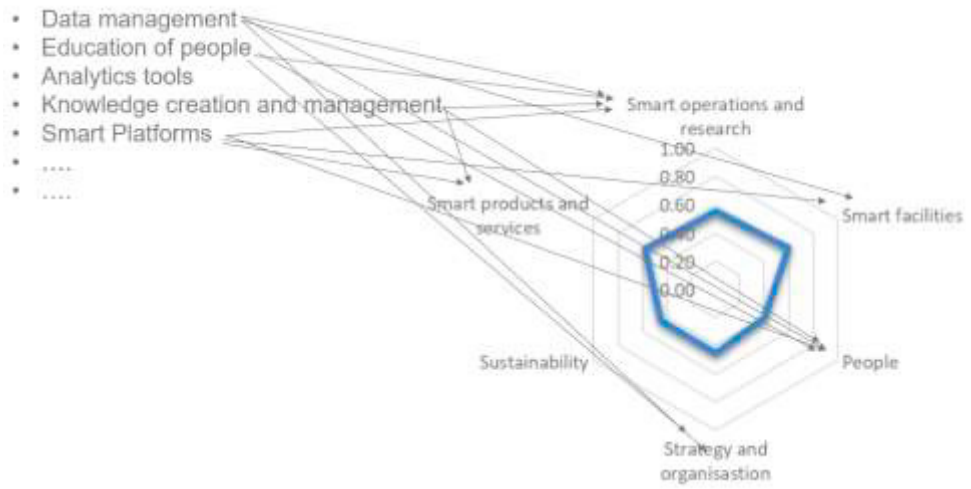

Figure 2. Illustration of how attributes influence model dimensions

To understand better the influence of each attribute on the dimensions, authors conducted a sensitivity analysis. It showed that first 4 attributes influence the digital maturity index significantly more than the remaining ones. Based on this, authors looked at the existing practices to assess them in higher granularity and to help with formulating the questions used in the assessment questionnaire. They found several maturity models related to data management, education (with emphasis on learning and development), analytics tools and knowledge creation and management. This helped with creating the first MVP which was a questionnaire to be used to gather data from various levels of the organization and feed it into the initial algorithm that calculates the maturity.

For data management authors formed 20 questions grouped into data governance, information value chain, data quality, data modelling and information architecture. These questions are followed by 3 learning and development questions (tackling the education attribute) which are assessing the maturity at individual, team, and organizational levels. Then they are followed by assessment of analytics tools and knowledge creation and management platform. After that, the questionnaire assesses the following attributes from the list to finally calculate the score for all the dimensions. The first version of the assessment tool was tested and assessed by 3 pilot organizations in France, Spain and the US. During the assessment authors gathered data related to the level of digital maturity as well as they asked for feedback about the quality and clarity of the questions receiving a lot of valuable feedback to further refine the assessment questionnaire. The results of using the assessment MVP are shown in Fig 3.

Figure 3. Results of the initial assessment

5. Conclusions

The digital maturity assessment tool in its MVP form already brought a lot of valuable insights. When it comes to sustainability and how it should be measured for R&D organizations authors noticed that it is influenced in two ways. Firstly, by the attributes in both direct and indirect way. For example, "Data management" attribute that deals with how data is gathered, stored, and managed has big influence on sustainability – if emissions are measured, analyzed and reported, they can be tackled in more systematic way in order to minimize them. Similarly, just by implementing measures that make organization more efficient it leads to it being more sustainable. Secondly, sustainability is impacted by strategy, design tools and methods used by R&D organizations. An example could be when organization is integrating sustainability in their new product development process (Design for Environment) or using design tools that help measure the impact on environment like Life Cycle Assessment Process (LCA).

The MVP of the assessment questionnaire indicated that these aspects should be explored more and therefore authors will use these learnings when working on the next iteration of the assessment tool to reflect the sustainability aspect in more accurate way. Based on the responses and feedback from the interviews authors believe that the dimension of sustainability should be included also considering that more and more evidence emerges in literature about the convergence of digital transformation and sustainability into "Digitainability".

At the end of each assessment interview, authors asked users for their feedback about the results. All users stated unanimously that a tool that assesses the current state of their digitalization is invaluable pointing out that the method and questions used during the interviews were relevant. The assessment helps with benchmarking their efforts, correct their digital roadmaps, and eliminate their blind spots. 87% (13 out of 15) of the interviewees agreed that the result reflect the real state of digitalization for their organization. They also stated that just the process of going through the questions made them reflect on their current activities and note down the areas that may have been neglected for further assessment if they should be included in the updated digital roadmap. The suggestion from the interviewees was to apply the assessment on annual basis to see the evolution and also to adapt the assessment tool to the changing market conditions – for example to consider new technologies entering the market, new research related to the topic etc.

Participants also gave their feedback about the assessment questionnaire itself. They added a lot of input about how questions could be improved to make the tool even more comprehensive and objective. Interesting suggestion was that the result of the assessment could vary depending on who answers the questions therefore it could be beneficial to take the answers of 2 or 3 users working at different levels in the organization (for example a director of the research center, head of department and a researcher/technician). It was stated that this could refine the results and better influence digital transformation roadmaps.

To advance in the accuracy of the assessment authors suggest further research into the sustainability part of the tool. There is an emerging literature that suggests how technologies can influence sustainability and this could be

used as a basis to research how such technologies can help R&D organizations to drive their maturity including product and process design and strategy. This research could be combined with improvements and further development of the assessment survey. It can be refined using the suggestions from the users to make the tool more robust, user friendly and adaptable to various levels of the organization.

Generally, usage of digital maturity model is beneficial and can bring value to any organization. It is even more true for research and development where a lot of activities are targeting the future of their parent companies or customers. The output from digital maturity assessment can help streamline the operations, connect facilities, allow faster product and process development with sustainability in mind. It introduces focus and structure which today, in many cases is minimal. Building the roadmaps rely on the experience of people and in many cases, it lacks more formal methods to measure if transformation is proceeding as planned. This experience of people although very valuable can have blind spots that maturity assessments can detect and eliminate, contributing to more meaningful roadmaps.

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