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A Review of Maturity Models Perspective of Level and Dimension [†]

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Abstract: The importance of adopting digital transformation for manufacturing companies is increasing day by day. In order to implement digital transformation process effectively, companies need tools based on Maturity Models (MM). This paper aims to present existing MMs in the literature in terms of their maturity levels and dimensions. According to the literature, it can be said that the maturity levels which are given in this study are similar to other categorical papers. On the other hand, the dimensions discussed herein represent more different perspectives than the maturity levels.

Keywords: digital transformation; maturity model; Industry 4.0

1. Introduction

Globally, the production industry is transforming traditional manufacturing into smart manufacturing with dramatic changes, referred to as "The Fourth Industrial Revolution". This revolution, called Industry 4.0, can be observed in Germany in the form of the government's digital transformation strategy (Industrie 4.0) and will lead to full automation, the use of electronics and information technologies (IT) and digitalization processes [1]. Hence, companies have a great opportunity to transform their current manufacturing processes toward smart manufacturing. Smart manufacturing includes several digital transformation technologies, such as Internet of Things (IOT), artificial intelligence (AI), cloud systems, robots, and vertical and horizontal integration, labeled Industry 4.0 technologies. In order to exploit the advantages of digital transformation, many manufacturing firms have started to implement Industry 4.0 concepts [2].

The digital transformation consists of multi-disciplinary activities and requirements. This makes it tough for many companies to grasp the Industry 4.0 vision and to implement comprehensive strategies towards digital transformation [3]. Hence, there is a need for methods to support companies in starting and accelerating their digital transformation journey. Here, MM can be considered an initial step in this journey. The main goal of MM is to provide an evaluation of a company's status from different perspectives and plan a development roadmap. In addition, the MM should be tailored towards the distinctive characteristics of the sector [4] and the contextual characteristics of the adopter companies [5,6].

The fundamental concept behind MM is to guide to decision-makers to reach the desired digital maturity level for the defined dimensions. Several maturity models describing the readiness of digitalization status with different levels and dimensions have been published in the literature. Levels can be described in terms of dimensions which include different aspects of functions, which in turn indicate the general digitalization state of companies. This paper aims to present the existing MMs in the literature by com-

paring their maturity levels and dimensions. It is expected that the fulfillment of the objectives of this study will contribute to recommendations regarding the next step in the development of MMs.

2. Literature Review

This section includes a discussion of the maturity models for Industry 4.0 presented in the literature, which have different characteristics. Table 1 presents a summary of these.

Table 1. Summary of the literature review.

Maturity Model	Maturity Levels/Stages	Dimensions	Author(s)
DREAMY Model	(1) digital-oriented (2) integrated and interoperability (3) defined (4) managed (5) initial	(a) organization (b) technology (c) monitoring and control (d) process	De Carolis et al. [7]
Industry 4.0 Maturity Model	(1) optimizing (2) predictable (3) established (4) managed (5) performed (6) incomplete	(a) organizational alignment (b) process transformation (c) application management (d) data governance (e) asset management	Gokalp et al. [8]
SMSRA Model	Index Value	(a) information technology (b) information connectivity (c) organizational (d) performance management	Jung et al. [9]
IMPULS Model	(1) performer (2) expert (3) experienced (4) intermediate (5) beginner (6) outsider	(a) strategy and organization (b) smart products (c) smart operations (d) smart factory (e) employees (f) data-driven services	Lichtblau et al. [10]
Industry 4.0 Maturity Model	level 5: state-of-the-art of required attributes level 1: complete lack of attributes	(a) leadership (b) people (c) technology (d) strategy (e) products (f) governance (g) customers (h) culture (i) operations	Schumacher et al. [11]
Three-stage maturity model	(1) detailed (2) transform (3) defined (4) managed (5) initial	(a) product (b) value network (c) process (d) market	Ganzarain & Errasti [12]
Maturity and Readiness Model	(1) maturity (2) survived (3) existence (4) absence	(a) strategy and organization (b) smart products and services (c) smart business processes	Akdil et al. [13]
Maturity Model for Digitalization	(1) digitalization awareness (2) smart networked products	(a) innovation culture (b) cooperation	Klötzer & Pflaum [14]

	(3) the service-oriented enterprise (4) thinking in service systems (5) the data-driven enterprise	(c) strategy development (d) process organization (e) complementary IT system (f) smart product/factory (g) offering to the customer (h) competencies (i) structural organization	
Industrie 4.0 Maturity Index	(1) computerization (2) connectivity (3) visibility (4) transparency (5) predictability (6) adaptability	(a) information systems (b) organization culture (c) resources (d) organization structure	Schuh et al. [15]
Building the Digital Enterprise Model	(1) digital novice (2) vertical integrator (3) horizontal collaborator (4) digital champion	(a) organization, employees and digital culture (b) data and analytics as core capability (c) customer access and digital business models (d) compliance security, legal and tax (e) digitization of product and service offerings (f) agile IT architecture (g) digitization and integration of horizontal and vertical	Geissbauer et al. [16]

2.1. The DREAMY (Digital Readiness Assessment MaturitY) Model

The model's primary aim is to evaluate a manufacturing company's status in terms of beginning the digital transformation process. The secondary aim is to identify a manufacturing company's strengths, weaknesses, opportunities and create a roadmap towards digitalization. The model consists of five maturity levels ((1) digital-oriented, (2) integrated and interoperability, (3) defined, (4) managed, and (5) initial) and four analysis dimensions ((a) organization, (b) technology, (c) monitoring and control, and (d) process) to evaluate the company's digital readiness [7].

2.2. Industry 4.0 Maturity Model

This model for manufacturing processes includes six readiness levels ((1) optimizing, (2) predictable, (3) established, (4) managed, (5) performed, and (6) incomplete). The model architecture consists of five dimensions ((a) organizational alignment, (b) process transformation, (c) application management, (d) data governance, and (e) asset management) [8].

2.3. Smart Manufacturing System Readiness Assessment (SMSRA)

The model has four dimensions ((a) information connectivity, (b) information technology, (c) organizational, and (d) performance management). The model considers the index value instead of the categorical maturity level [9].

2.4. IMPULS Industrie 4.0 Readiness Model

This model is based on six maturity levels ((1) performer, (2) expert, (3) experienced, (4) intermediate, (5) beginner, and (6) outsider) and six dimensions ((a)strategy and organization, (b) smart products, (c) smart operations, (d) smart factory, (e) employees, and (f) data-driven services). A total of 18 items are measured using the suitable indicators [10].

2.5. Industry 4.0 Maturity Model

This model includes five maturity levels for manufacturing companies. However, the authors mention only boundary levels (level 5: state-of-the-art of required attributes; level 1: complete lack of attributes). The model consists of nine dimensions ((a) leadership, (b) people, (c) technology, (d) strategy, (e) products, (f) governance, (g) customers, (h) culture, and (i) operations) [11].

2.6. Three-Stage Maturity Model in SMEs (Small and Medium Enterprises) towards Industry 4.0

The model aims to guide and train firms by specifying opportunities for diversification in areas within Industry 4.0. A diversification strategy focuses on three stages (envision, enable and enact), with five level maturity levels ((1) detailed, (2) transform, (3) defined, (4) managed, and (5) initial). At the envision stage, a company-tailored Industry 4.0 vision is developed. Within the enable stage, a roadmap to Industry 4.0 is prepared in terms of four strategic perspectives ((a) product, (b) value network, (c) process, and (d) market). Lastly, the Industry 4.0 projects are enacted in the final stage [12].

2.7. Maturity and Readiness Model for Industry 4.0 Strategy

The model has four maturity levels and three dimensions. The maturity levels are (1) maturity, (2) survived, (3) existence, and (4) absence. The model reaches each maturity level via three dimensions ((a) strategy and organization, (b) smart products and services, and (c) smart business processes) [13].

2.8. Maturity Model for Digitalization

The model consists of two facilitators of digital transformation: smart product application and smart product realization. Both lead to two maturity models and consist of five stages ((1) the data-driven enterprise, (2) thinking in service systems, (3) the service-oriented enterprise, (4) smart networked products, and (5) digitalization awareness) via nine dimensions ((a) innovation culture, (b) cooperation, (c) strategy development, (d) process organization, (e) complementary IT system, (f) smart product/factory, (g) offering to the customer, (h) competencies, and (i) structural organization) [14].

2.9. Industrie 4.0 Maturity Index

The main goal of the model is to provide a means of establishing a company's current Industry 4.0 maturity stage. The maturity index considers six development stages ((1) computerization, (2) connectivity, (3) visibility, (4) transparency, (5) predictability, and (6) adaptability) and four dimensions ((a) information systems, (b) organization culture, (c) resources, and (d) organization structure) [15].

2.10. Industry 4.0: Building the Digital Enterprise Model

The model is based on four stages ((1) digital novice, (2) vertical integrator, (3) horizontal collaborator, (4) digital champion) and seven dimensions ((a) organization, employees, and digital culture, (b) data and analytics as core capability, (c) customer access and digital business models, (d) compliance security, legal, and tax, (e) digitization of product and service offerings, (f) agile IT architecture, (g) digitization and integration of horizontal and vertical) [16].

3. Conclusions

As stated in the Introduction, this paper aims to present existing MMs for digital transformation in the literature in terms of their maturity levels and dimensions. According to existing research, MM levels are described by a categorical display, excluding Jung et al. [9]. Some MMs utilize level names relating to digitalization status, such as initial, absence, and incomplete [7–13]; others utilize level names as positions within sequential

digitalization stages, such as digitalization awareness, computerization, and digital novice [14–16]. The MMs which are presented in this study involve four levels [13,16], five levels [7,11,12,14], six levels [8,10,15], and the index value [9].

Even though the maturity levels of MMs are not significantly different from each other, the dimensions of MMs are characterized by noticeably different aspects. Generally, the "organization" concept is emphasized in most of the MMs [7–10,13,15,16]. This shows that organization is crucial in the digital transformation journey. In a structure where organizational values are neglected, digital transformation cannot be carried out efficiently and resistance to change may occur. "Strategy" [10,11,13,14], "process" [7,8,12,14], "product" [10–13], "people—employees" [10,11,16], and "technology" [7,11] are other common dimensions of MMs. *Strategy* is important for companies to manage their digital transformation vision in their future planning. In a company that does not have a strategy, it seems impossible to realize digital projects in coordination with each other and achieve total success. *Process* facilitates the digital transformation journey by standardizing the activities of companies. Companies which successfully implement process management have an advantage in their digital transformation journey. Product can give clues about the digital maturity level of the company. It can be said that a company having digital value-added products can work more compatibly with digital technologies. People—employees can be evaluated both in the organizational dimension and as a separate dimension. In both cases, the human factor is vital for the digital transformation journey. If the human factor is ignored, resistance to change may be encountered.

The dimension of technology needs to be emphasized more comprehensively, although it is incorporated into only two MMs' dimensions. It can be said that dimensions which include information, data, IT, and smart technologies can be evaluated in terms of the technology dimension. The management of information and data ensures that the data which are obtained from production and the value chain are made meaningful. For this, it is very important to have an IT system that can fulfil these needs. Smart technologies describe any technology which can connect to users via internet networks. They are crucial in the journey of digital transformation thanks to this feature. Since the technology, which is the main element of the digital maturity level, appeals to a very wide area, it is normal to evaluate it in terms of different dimensions.

MMs are the first step in the digital journey. Then, companies should prepare a roadmap, considering the information obtained by the MMs. Eventually, if companies choose a suitable roadmap and manage a process that includes not only technology but also the whole organization, the probability of success on the path to digitalization will increase. A roadmap is a strategic plan that defines a target and includes the major steps or milestones needed to achieve it. While creating the roadmap, it is recommended to establish a team dedicated to this process. Since this team knows the structure of the company, targets and solutions which are suitable for the company can be determined faster and more realistically. After the roadmap is created, it is appropriate to proceed with pilot applications instead of extensive project investments. Thus, the results of possible defects can be detected and corrected earlier.

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