Towards an Open Ecosystem for Maturity Models in the Digital Era: The Example of the Data Quality Management Perspective

Completed Research

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Abstract

What many enterprises lack today is an appreciation of where they stand in terms of their own digitization level. Maturity models are tools recognized both in science and in practice as a means of determining the current state of development for an application domain. However, considering the complexity of digital transformation, an "attempt" to classify digitization levels with a single maturity model consistently fails. Therefore, we recommend an open ecosystem of maturity models focusing on digital transformation as holistic toolset. The contribution of our paper lies in providing a procedure model for identifying and selecting different maturity models to better assess an enterprise's digitization level in its entirety. More practically, we include a step-by-step exertion of the procedure model. Since master data represents a valuable asset in the digital era and therefore, must be managed efficiently and effectively—we apply our procedure model to the perspective of data quality management.

Keywords

Maturity Model, Data Quality Management, Digitization, Digital Transformation, Ecosystem.

Motivation: Digital Transformation – The Ongoing Challenge

Nowadays, society and, therefore, enterprises face a complex environment with rapid and profound changes. According to (Bajer 2017), one of the main drivers of these changes is exponential technological development, which is often strongly related to buzzwords like digital transformation, digital age, or digital change. These advanced technological opportunities result in new and fundamental paradigm shifts. Without a doubt, nearly all enterprises must undergo some type of digital transformation to remain competitive in global markets and to gain momentum in digital innovation (Bley et al. 2016; Kane et al. 2015; Leyh et al. 2017b; Mathrani et al. 2013; Pagani 2013). Hence, the increasing transformation of everyday business is not without risk. Therefore, the enterprises have to evaluate and assess their current situation in the right way to make the right investments (Bley et al. 2016).

However, what many enterprises lack today (often smaller and young enterprises due to a lack of know-how and experience) is an appreciation of where they stand. Knowing their own digitization level, especially from different perspectives – since digitization does not only affect the information and communication technology (ICT) structure of enterprises – is still a challenge for many (Leyh et al. 2017b). If companies do not understand their current position, they may not be able to cope with the ongoing digital transformation in different business fields. From this, the question arises of how an enterprise landscape (e.g., ICT infrastructure; business model; organizational aspects; work environment)

must be designed so that a company can "move" and compete in the ongoing digital transformation. This is where our long-term research is heading. We aim for a holistic toolset/approach to support enterprises while (self-)assessing their constitution regarding digital transformation in its entirety. This results in the main research questions (RQs) for our long-term research focus:

RQ1: *What is an appropriate and supporting approach/toolset for enterprises for comprehensively assessing their digitization level?*

RQ 2: *What should the structure/design of this approach/toolset look like?*

As a first try to answer these questions we started by focusing on the ICT landscape of an enterprise facing the challenges of digital transformation. Therefore, we developed a maturity model (MM) that enables companies to classify their own IT system landscape in terms of the needs of an Industry 4.0 IT system landscape – the maturity model *SIMMI 4.0*. However, solely classifying the IT system landscape of an enterprise in the context of Industry 4.0 (as only a fraction of the complex field of digital transformation) by incorporating Industry 4.0 requirements of the ICT perspective results in a complex MM. Here, it would become difficult to incorporate and cover further requirements from other perspectives, such as organizational aspects or business process issues. Considering the complexity of digital transformation and the multitude areas affected during the transformation processes, an "attempt" to classify digitization levels by covering and incorporating the variety of respective requirements into ONE maturity model must fail. Therefore, we recommend, as a holistic toolset, an open ecosystem for MMs with a focus on digital transformation. This ecosystem (illustrated in Figure 1) shall contain a variety of MMs to cover the multitude of perspectives affected by digital transformation.

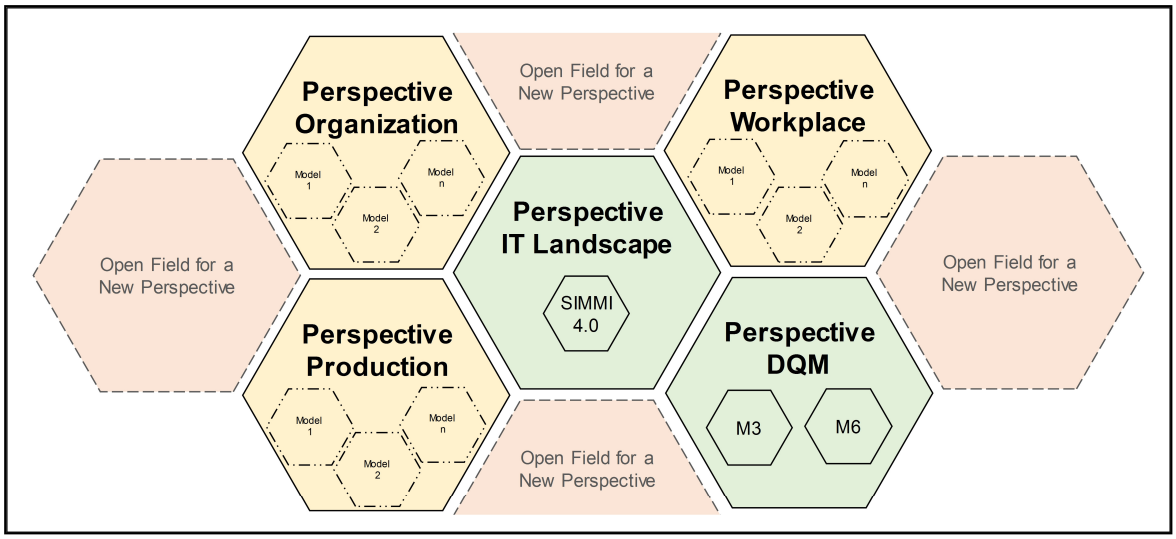

Figure 1. The Open Ecosystem for Maturity Models with Focus on Digital Transformation

As a starting point, with the maturity model SIMMI 4.0 we developed a new MM focusing on the ICT perspective by addressing the respective digitization requirements. However, it is not always necessary to develop a completely new model for a perspective. Several approaches focusing on maturity models in the field of digital transformation already exist with different perspectives, objectives, model types, and target audiences (e.g., (Berghaus et al. 2016; De Carolis et al. 2017; Ganzarain and Errasti 2016; Kane et al. 2015). Hence, not all MMs follow a concrete and comprehensible process model in their development, and most lack a thorough evaluation, especially with regard to their usage in practice (Pöppelbuß and Röglinger 2011). At this point, the question of what MM can/should be integrated in the ecosystem, and on the basis of which requirements, arose. Therefore, we developed a procedure model to identify and assess existing MMs, focusing on aspects of digital transformation.

Within this paper, we aim to describe this procedure model in detail by applying the procedure model to the perspective of data quality management (DQM) as a further important part of digital transformation. With a more practical focus, we show which maturity level models exist within master data management (MDM) and DQM and categorize these maturity models regarding the requirements of the ecosystem.

Therefore, the paper is structured as follows. Following this motivation, Section 2 provides a conceptual background of the key terms and especially points out the importance of master data quality in the era of digital transformation. Section 3 provides an overview of our procedure model. Afterwards, in Section 4 we describe each procedure model step in detail and we are applying the steps to the DQM perspective before the paper finishes with a short discussion and an outlook on future tasks in our long-term research.

Conceptual Background

Digitization/Digital Transformation and its Characteristics

In short, digitization/digital transformation can be characterized as "the encoding of analog information into digital formats" (Yoo 2010a) and therefore can be seen as a mandatory but not the sole requirement for digital innovation. In contrast, digital innovation is referred as "a new combination of production factors that introduce discontinuity to product technology, organizing principle, market or set of behaviors" (Yoo 2010a), which is only made possible by using digital technologies (Yoo 2010b). Therefore, the field of digitization/digital transformation affects many sections of enterprises, even across company borders. This means digitization cannot solely be addressed by restructuring or optimizing the enterprises' ICT landscapes, though this is one main aspect of digitization. Linking departments, as well as the contact to customers or suppliers, is important in the context of digitization. ICT triggers and enables this "transformation" of the company towards a holistic network. The strategic benefits of efforts in a changing business environment can only be achieved with the efficient use of the right information and communication technology (Mathrani et al. 2013).

Maturity Models

Maturity models (MMs) are reference models that deal with the current state of development and the changes in organizations and their technologies. The main purpose of a MM is the structured, systematic elaboration of best practices and processes that are mostly related to the functioning and structure of an organization. A model is divided into different levels, which are then used as benchmarks for the maturity of a company. The structure of the MM is similar in each case: principal requirements are defined for processes/functions/domains; these requirements are placed on different levels of maturity; and, depending on which requirements are fulfilled, a certain degree of maturity is awarded. The maturity level defines a certain stage of development within a scale range. The MM serves as an assessment tool and contains the relevant characteristics of predetermined objects and their required characteristics (Becker et al. 2009).

The Challenge of Master Data Quality

Another concern with continued digital transformation in enterprises is data quality in various enterprise systems within enterprises themselves and along their supply chains (Bley et al. 2016). More today than in the last decade, to become and stay competitive in the global business environment, companies must exchange large amounts of data on an automated basis between internal departments and across organizational borders with business partners (Schäffer and Stelzer 2017a). Therefore, a certain level of data quality is necessary to ensure efficient company-wide and inter-organizational business processes (Schäffer and Stelzer 2017b). In a previous study (Schäffer and Leyh 2017) we showed and discussed the changing requirements of master data quality in the context of digital transformation, especially in inter-organizational information sharing. There is, however, the question of how master data quality management (MDM) must be designed so that a company can "move" in the era of digital transformation. Recognizing and evaluating what data quality is needed, and in which way and for what purpose, still embodies a challenge for companies. This is where the present paper comes in. By applying our procedure model to the perspective of data quality management (DQM), we analyze existing MMs that aim at optimizing MDM and DQM so that companies can overcome these challenges.

Master Data Quality, Master Data Management, and Data Quality Management

The concept of **master data quality** is the combination of two concepts: master data and data quality. Master data consists of attributes that describe the core business objects of a company. Typical master data classes are vendor master data, customer master data, and article or material master data (Ofner et

al. 2013). **Data quality** is "a measure of the adequacy of the data for specific requirements in business processes, in which they are used. Data quality is a multidimensional, contextual concept, as it cannot be described with a single feature, but on the basis of different data quality dimensions and measures" (Otto and Österle 2016). The most important dimensions for determining data quality are accuracy, completeness, correctness, consistency, and timeliness (Schäffer and Stelzer 2017a). **Master data management** is regarded as an application-independent process. To ensure the consistency and accuracy of master data, MDM provides a specific set of policies for its management. In this way, MDM creates a common view of important company data (Loshin 2008). **Data quality management** helps maintain and sustainably improve the quality of master data (Ofner et al. 2013). From the viewpoint of data management, DQM is quality-oriented master data management; i.e., the generation, processing, storage, modelling, and presentation of data with the intention of ensuring high data quality. The design elements of a corporate DQM are: DQM strategy, DQM controlling, data governance, data quality, DQM architecture, and DQM systems (Otto and Österle 2016).

Procedure Model – Overview

As stated in the motivation, we see a large need for the provision of a holistic toolset/approach to support enterprises while (self-)assessing their constitution regarding digital transformation in its entirety. With the recommended open ecosystem for MMs we can enable companies to assess their degree of maturity for digital transformation per perspective or holistically. Therefore, the ecosystem is based on a best-of-breed approach. Thus, it is possible that for the respective perspectives of digital transformation: **a)** MMs are available, **b)** the practical application is not too complex, **c)** a high flexibility exists due to the modularity of the ecosystem, **d)** an investment protection is ensured due to tested and evaluated MMs, and **e)** the continuous advancement of the ecosystem is guaranteed.

However, the prerequisite for this is to provide suitable MMs for specific perspectives. A selection decision must be made for different MMs that meet the requirements of the respective perspective and can be integrated into the ecosystem. In order to ensure this, we developed a procedure model based on (Becker et al. 2009) and design science research (Hevner 2007; Peffers et al. 2007). By means of this procedure model (see Figure 2), a systematic selection of MM(s) to be integrated in the ecosystem is provided, and if no appropriate MM for a perspective is identified the need for the development of a new MM is pointed out.

Step 1 defines the perspective to be considered and specifies the requirements for MMs. The requirements can be divided into two categories: Requirements necessary for integration in the ecosystem that have to be fulfilled independent from the perspective (basic requirements), and requirements representing the specific perspective (specific requirements). In step 2, systematic literature analysis is used to search for existing MMs with focus on the perspective. In step 3, the so-identified MMs are assessed by means of a classification scheme. In step 4, a comparison between the requirements and the fulfillment within the MMs is conducted. In step 5, a decision is made as to whether an existing MM is sufficient or an existing MM should be adapted, or whether a totally new MM must be developed in order to meet the requirements. In step 6, the individual results of steps 1 to 5 and the recommendation for the selected MMs are published.

Procedure Model – Detail Exertion for the Perspective DQM

In this section, the six process steps of the procedure model (see Figure 2) are presented in detail. Each process step is described briefly by first outlining its purpose (italics and gray background) followed by a short explanation of the concrete exertion of the selection of a MM from the DQM perspective.

Step 1: Problem Identification and Requirements Definition

In the first step of the procedure model, the specific needs of a new MM are derived and the necessary requirements for the new MM are established. The requirements can be divided into two categories: basic requirements for practical use and specific requirements derived from the specific perspective. The basic requirements are essentially composed of characteristics for the integration of a MM into the ecosystem, which are valid for all MMs, independent of perspective.

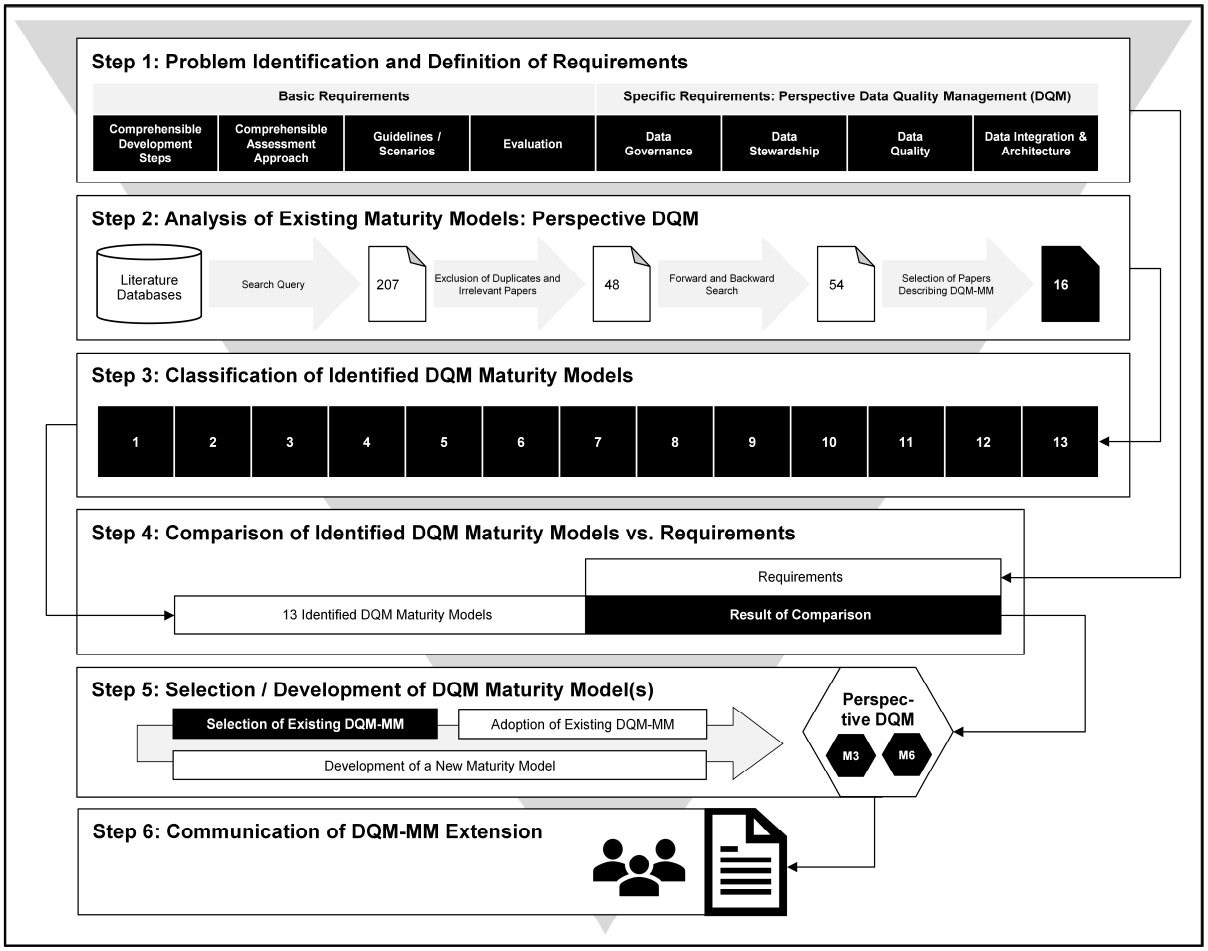

Figure 2. Procedure Model for the Identification and Selection of Maturity Models

Perspective DQM: Master data forms the basis of the digital economy and is essential for the exchange of information within corporate networks (Otto and Österle 2016; Schäffer and Leyh 2017). Achieving and ensuring an adequate level of master data quality is a critical prerequisite for efficient and effective business processes in digital transformation (Schäffer and Leyh 2017; Schäffer and Stelzer 2017a, 2017b). With the help of a MM, the current state of development can be evaluated in order to derive further measures. The requirements for a MM within the DQM perspective are listed in Table 1.

Step 2: Analysis of Existing Maturity Models for the DQM Perspective

According to (Becker et al. 2009), the necessity of developing a new MM must be justified. Therefore, in the second process step, existing MMs are identified for the specific perspective. Systematic literature analysis is appropriate to find relevant publications/models.

Perspective DQM: The methodology for conducting the literature analysis is based on the procedure presented by (Webster and Watson 2002). In addition, we also applied a reverse and forward search. As a first step, we examined IS journals and IS conference proceedings using the AIS Electronic Library (AISel), Association for Computing Machinery Digital Library (ACM), Google Scholar (GS), IEEE Xplore Digital Library (IEEE), and ScienceDirect (SD). We conducted electronic searches in titles and abstracts for the following search terms: [(“master data“ OR „data quality“ OR “information quality”) AND „maturity model”)]. We deliberately chose not to set a temporal limitation as it does not matter when the MMs were created or reported. These searches identified a total of 207 publications. After analyzing each article’s abstract and keywords as well as a review of the full article when necessary, we excluded 159 articles that were either duplicates or did not appear to be particularly relevant to our research focus. We

then performed forward and backward searches in relevant articles to identify further sources. A total of 54 publications were read in full and coded. We excluded all papers that were not peer reviewed publications or only stated the keywords mentioned in the search term without elaborating on these concepts. We also excluded all papers that did not discuss the issues, limitations, and weaknesses of MMs, or master data management, respectively. Out of the 54 coded articles, 16 included passages of interest. A complete list of all papers and the documentation of the coding procedure is available from the authors upon request. The column *reference* of Table 3 contains the 16 publications that elaborate on MMs for data quality management. In the remainder of this paper, we focus on these papers.

ID	Type	Requirement	Description
R1	Basic Requirements	Comprehensible Development Steps	The MM has a comprehensible development process and describes the implemented method and strategy.
R2		Comprehensible Assessment Approach	The MM has a comprehensible assessment approach and describes, in detail, how the maturity level is determined.
R3		Guidelines/Scenarios	The MM provides a possible user with guidelines or application scenarios and explains in which form an assessment could be conducted.
R4		Evaluation	The MM has been evaluated and is compared with the defined targets.
R5	Specific Requirements	Data Governance	The MM considers the aspects of data governance and evaluates the enterprise organization to master data quality.
R6		Data Stewardship	The MM considers the aspects of master data maintenance and evaluates for the permanent maintenance of master data.
R7		Data Quality	The MM considers the aspects for the sustainable assurance of master data quality.
R8		Data Integration & Architecture	The MM considers the aspects of data integration and architecture for efficient data exchange within and between companies.

Table 1. Overview of the Basic and Specific Requirements

Step 3: Classification of the Identified Maturity Models

In the third process step, the MMs presented and/or discussed in the identified publications of Step 2 are explained and classified. The classification of MMs is based on a particular scheme for MMs (for more details see Leyh et al. (2017b)).

Perspective DQM: After analyzing the 16 publications, 13 MMs were identified. Table 2 lists the MMs in descending order organized by the publication year of the primary reference. An abbreviation was added if it was explicitly named by the authors, and if available, we also included the development basis. A detailed overview of the 13 MMs classified according to our classification scheme will not be part of this paper but can be requested from the authors.

ID	Name of Maturity Model	Abbre-viation	Development Basis	References
M1	Master Data Management Maturity Model	MD3M	COBIT	(Spruit and Pietzka 2015)
M2	Total Information Quality Management-Capability Maturity Model	TIQM-CMM	CMM, Delphi study	(Suhardi et al. 2014)
M3	Maturity Model for Enterprise Data Quality Management	-	EFQM Excellence Model	(Ofner et al. 2013)
M4	Master Data Management Maturity Model	Oracle MDM MM	-	(Butler and Naidoo 2011)
M5	Information Quality Maturity Model	IQMM	COBIT	(Kurniati and Surendro 2010) (Gunawan and Suhardi 2014)
M6	Master Data Management Maturity Model	-	-	(Loshin 2010)
M7	Corporate Data Quality Maturity Model	CDQ MM	CMMI, EFQM	(Hüner et al. 2009) (Ofner et al. 2009)

M8	Information Quality Management Maturity Model	IQM3	CMMI	(Caballero et al. 2008) (Woodall et al. 2012) (Gunawan and Suhardi 2014)
M9	Data Governance Maturity Model	DG MM	-	(DataFlux 2008) (Woodall et al. 2012)
M10	Information Quality Management Capability Maturity Model	IQM-CMM	CMM, Delphi study	(Baškarada et al. 2007) (Woodall et al. 2012)
M11	Data Governance Council Maturity Model		CMM	(IBM Software Group 2007)
M12	Information Quality Management Capability Maturity Model	IQM-CMM	TDQM	(Baškarada et al. 2006) (Suhardi et al. 2014)
M13	Data Quality Management Maturity Model	-	DQ MMM	(Ryu et al. 2006) (Hüner et al. 2009) (Woodall et al. 2012) (Ofner et al. 2013) (Gunawan and Suhardi 2014) (Suhardi et al. 2014)

Table 2. Identified DQM Maturity Models

Step 4: Identified DQM Maturity Models vs. Requirements

In the fourth process step, the identified MMs are compared to the requirements defined in Step 1. For this purpose, the publications are analyzed and an assessment is made for each requirement and MM. The scoring provides for three states: Requirement is formally fulfilled (3 points and tag with a full Harvey ball*), requirement is informally fulfilled (embedded in text descriptions) (1 point and tag with a half-filled Harvey ball), and requirement is not fulfilled (0 points and tag with an empty Harvey ball). The latter status is also used if a requirement is not explicitly mentioned in the publication. For further analysis, we recommend that only models that meet at least 75% of the requirements are considered. Thereby,* R1, R2 and R4 are mandatory criteria which must be at least informally met (1 point).

	Basic Requirements				**Specific Requirements**				
ID	Comprehens. Development Steps	Comprehens. Assessment Approach	Guidelines / Scenarios	Evaluation	Data Governance	Data Stewardship	Data Quality	Data Integration & Architecture	**Score**
M1	○	○	●	●	●	●	●	○	15
M2	◑	●	○	●	○	●	○	○	10
M3	●	◑	●	●	●	●	●	◑	22
M4	○	○	◑	○	○	●	●	○	7
M5	◑	◑	●	◑	●	●	●	○	15
M6	◑	◑	●	◑	●	●	●	●	18
M7	●	○	◑	●	●	◑	◑	○	12
M8	◑	○	◑	○	◑	○	●	○	6
M9	○	○	●	○	●	●	●	○	12
M10	◑	○	○	◑	◑	◑	◑	○	5
M11	◑	○	◑	○	●	◑	◑	○	7
M12	○	○	◑	◑	◑	◑	◑	◑	6
M13	○	○	◑	●	○	◑	◑	●	9

Table 3. Comparison of the Identified Maturity Models

Perspective DQM: The identified MMs are analyzed and categorized using a requirement matrix from Step 1 (see Table 3). Since there are eight requirements, the requirement score has a maximum of 24

points. The calculation of the requirement score reveals that the MMs M3 and M6 meet the 75% quota as well as the required mandatory criteria of R1, R2, and R4 to the required level. M3 and M6 are, therefore, candidates for further processing.

Step 5: Selection/Development of DQM Maturity Model(s)

In the fifth process step, a decision is made as to whether an existing MM is sufficient or whether a new MM must be developed in order to meet the requirements. This is based on the requirement score from Step 4. For a requirement score between 50% and 75%, we recommend an adaptation of an existing MM. With a requirement score of less than 50%, a development of a completely new MM has to be considered. For both adaptations and new developments, a recognized development process must be followed (Becker et al. 2009; de Bruin et al. 2005) and documented in terms of R1. For a requirement score of 75% or more, we recommend to use the model(s) to evaluate the specific perspective and integrate them "as is" in the ecosystem.

Perspective DQM: Since the requirement score for the MMs M3 and M6 is at least 75%, both models can be used for the assessment of the DQM perspective.

Step 6: Communication of DQM-MM Extension

According to Design Science Research (Hevner 2007), in the case of artifact development, the selection decision of the MMs for the specific perspective is to be communicated as a recommendation in the sixth process step. The procedure model ends with the completion of this step.

Perspective DQM: A conference paper is chosen for communication. After completing Steps 1-5, there is a recommendation to implement two MMs from the DQM perspective as a means of fostering digital transformation requirements. The models are: M3: Maturity Model for Enterprise Data Quality Management and M6: Master Data Management Maturity Model.

Discussion and Future Aspects

In summary, the evaluation of companies' maturity levels in terms of digitization is a very complex and multi-layered process. However, since an assessment approach using a single MM (or other assessment tool) will unavoidably fail due to the complexity of digital transformation, a single MM is insufficient for capturing all the relevant information necessary to assess a company's maturity in this field. A multitude of perspectives and directions must be considered and evaluated to assess a company's digitization level. Therefore, we recommend an open ecosystem of MMs that focus on digital transformation (see Figure 1) where several MMs are used and we include multiple perspectives and their respective requirements for digital transformation. As a practical contribution, this ecosystem provides a powerful and useful toolset, especially for practitioners, to (self-)assess their company's maturity in all perspectives of digital transformation. However, the question arises which MMs are appropriate to be integrated in the ecosystem. Despite the fact that a variety of guidelines exist for the development of MMs (e.g. (Becker et al. 2009; de Bruin et al. 2005; Pöppelbuß and Röglinger 2011), there is also a lot of criticism. For example, Pöppelbuß and Röglinger (2011) criticize the lack of empirical foundation, which often leads scientist as well as practitioners to simply use the models or copy model structures without considering its conceptual foundation. Lasrado et al. (2015) further criticize a lack of validation when selecting variables or appropriate dimensions, as well as a missing operationalization of maturity measurements. Therefore, we set up a rigorous procedure model for how to identify MMs for a specific perspective, and we postulate several basic requirements that a MM has to fulfill at least to some extent in order for it to be "worth" integrating into the ecosystem. In addition, the MM has to fulfill specific requirements for the perspective; requirements stemming from digital transformation. Therefore, all in all, we see the theoretical contribution of the ecosystem and the procedure model as providing an identification/selection approach for combining several existing MMs as well as for adding and including new ones to foster the assessment of an enterprise digitization level in its entirety from multiple perspectives.

However, there are plenty of aspects that need to be addressed in future research steps. A further point of discussion should include the characterization and structure of the ecosystem. On the one hand, the structure of the ecosystem captures the complexity of digitization and maps it with the help of various

requirements. On the other hand, however, the MMs used constitute a restriction regarding the character of digitization. Most of the models presented here follow a "staged maturity model" approach, whereby a linear course of maturation is assumed in order to reach the highest level of maturity. This assumption, taking into account our aforementioned characteristics of digitization, is not applicable to every business sector. An alternative model, for example, would be a Focus Area Maturity Model (van Steenbergen et al. 2010). This model represents a maturity matrix consisting of several Focus Areas. Each area has its own development stages, which are characterized by predefined capabilities. As a result, different areas in the company can have different maturity levels, and the development focus can also be directed to individual areas. In addition, dependencies can be depicted between the areas. The interconnectedness or the interdependencies between MMs of different perspectives must be dealt with. In addition, there is a further need for more specific definitions of the basic requirements and guidelines for the MMs for their integration into the ecosystem. This is one of our next steps, as it determines the quality of the selected models and the accuracy of the result. Our main concern in the future is the evaluation of (potential) MMs of/for the ecosystem as presented in Figure 1 by adding different perspectives. Therefore, different research methods can be seen as appropriate, i.e. a practical evaluation of the models using an (online) questionnaire. This method was already applied for the evaluation of SIMMI 4.0 (see Leyh et al. (2017a)). Furthermore, we plan to create a technical repository for MMs for the ecosystem. This repository will facilitate researchers' and, especially, practitioners' choice and creates a uniform data basis.

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