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A Maturity Model for Enterprise Data Quality Management

Enterprises need high-quality data in order to meet a number of strategic business requirements. Permanent maintenance and sustainable improvement of data quality can be achieved by an enterprise-wide approach only. The paper presents a Maturity Model for Enterprise Data Quality Management (Enterprise DQM), which aims at supporting enterprises in their effort to deliberately design and establish organisation-wide data quality management. The model design process, which covered a period of five years, included several iterations of multiple design and evaluation cycles and intensive collaboration with practitioners. The Maturity Model is a hierarchical model comprising, on its most detailed level, 30 practices and 56 measures that can be used as concrete assessment elements during an appraisal. Besides being used for determining the level of maturity of Enterprise DQM in organisations, the results of the paper contribute to the ongoing discussion in the information systems (IS) community about maturity model design in general.

1 Introduction

Data quality management (DQM) as an organisational function comprises all practices, methods, and systems for analyzing, improving and maintaining the quality of data. DQM basically aims at maximizing the value of data (customer data, supplier data, or material data, for example) (DAMA 2008). Over the last 15 years DQM has been the subject of analysis in many publications both by researchers (Batini and Scannapieco 2006; Otto et al. 2007; Wang 1998; Wang et al. 1998) and practitioners (English 1999; Loshin 2001; Redman 2000). Although data quality is widely recognized as a strategic success factor, the majority of companies consider DQM in their organisation as ‘being in the early phases of maturity’ (Pierce et al. 2008). Particularly certain business requirements, such as effective supply chain management (Kagermann et al. 2010; Tellkamp et al. 2004; Vermeer 2000), improved decision-making (Price and Shanks 2005; Shankaranarayan et al. 2003), compliance with legal or regulatory provisions (Friedman 2006; Salchegger and Dewor 2008), or efficient customer relationship management (Reid and Catterall 2005; Zahay and Griffin 2003)

demand an enterprise-wide approach to DQM, as such requirements cannot be met by isolated solutions or single business units alone.

In order to be able to establish enterprise-wide DQM in the following referred to as Enterprise DQM, changes are needed on a strategic, on an organisational, and on an information systems level (Baskarada et al. 2006; Bitterer 2007; Lee et al. 2002; Ryu et al. 2006). In their effort to bring about these changes companies need support and assistance, particularly with regard to monitoring the progress in establishing Enterprise DQM.

Taking this into account, the research question examined in this paper is how companies may deliberately design Enterprise DQM. The word *deliberately* refers to the need that companies are capable of identifying areas for improvement and deriving appropriate action with regard to Enterprise DQM. The research objective is to design a model that allows assessing the maturity of Enterprise DQM, with the research process following the principles of design science research (Hevner et al. 2004; Österle and Otto 2010).

Maturity models support organisational change insofar as they represent an instrument for decision-

makers to assess an organisation's actual state, derive actions for improvement, and evaluate these actions afterwards in terms of their effectiveness and efficiency (Crosby 1979; Gibson and Nolan 1974; Nolan 1973).

The following section of the paper outlines the theoretical foundations underlying the research and compares existing maturity models from the DQM domain. After that the research methodology and the process of designing the Maturity Model for Enterprise DQM are elaborated. Then the design rationale of the structural specification of the Maturity Model (i.e. the conceptual model) is discussed, alongside with procedural guidelines for applying this conceptual model. Afterwards, a first evaluation of the Maturity Model is provided, and findings and implications are discussed. The paper concludes with a short summary and recommendations for further research on the topic.

2 Theoretical Foundations

2.1 Data and Data Quality

Singular pieces of data specify discrete characteristics of objects and processes from the real world. In this sense, data is free of context (Boisot and Canals 2004; Davenport and Prusak 1998; Spiegler 2000). Business distinguishes between master data and transaction data. Master data consists of attributes describing a company's core business objects. It constitutes the basis for both operative value creation processes and analytical decision-making processes (Smith and McKeen 2008). Typical classes of master data are supplier master data, customer master data, or product master data (Mertens 2000). Transaction data describes business processes. It relates to master data, and therefore its existence is dependent on this master data (Dreibelbis et al. 2008). It is master data that is of particular importance to Enterprise DQM, as the quality of such data is critical for meeting the business requirements mentioned above. Thus, master data needs to be defined for the whole of an organisation and must allow to be identified unambiguously.

When data is used within a certain context or when data is processed, it turns into information (Boisot and Canals, 2004; van den Hoven, 2003). Although the terms *data* and *information* are clearly distinguished in theory, a clear definition on what quality means to either aspect does not exist. Both information quality and data quality is seen as a context dependent, multi-dimensional concept, describing the 'fitness for use' of information and data as determined by a user or user group (Wang 1998). The fact that information quality and data quality is considered to be context dependent emphasizes the notion that it is up to the user to decide whether certain information or data is useful (Wang and Strong 1996). Hence, 'fitness for use' can be perceived in different ways, manifesting itself in so-called data quality dimensions. Numerous scientific studies have dealt with the identification and description of such data quality dimensions (Price and Shanks 2005; Wand and Wang 1996; Wang and Strong 1996; Wang et al. 1995). Among the most important ones are accessibility, accuracy, completeness, and consistency (DAMA 2008).

2.2 Data Quality Management

Data Management Association (DAMA) defines DQM as 'application of Total Quality Management (TQM) concepts and practices to improve data and information quality, including setting data quality policies and guidelines, data quality measurement (including data quality auditing and certification), data quality analysis, data cleansing and correction, data quality process improvement, and data quality education' (DAMA 2008). DQM aims to achieve the following goals: establish DQM as an organisational function, design DQM to cover the organisation as a whole, establish a continuous improvement process for DQM, qualify and authorize staff for executing DQM tasks, provide appropriate techniques and guidelines for DQM (Batini and Scannapieco 2006; English 1999; Wang 1998; Zhang 2000). In order to emphasize the imperative to establish DQM in an enterprise-wide approach, the paper at hand refers to DQM as Enterprise DQM.

2.3 Maturity Models and Organisational Change

Maturity models represent a special class of models, dealing exclusively with organisational and information systems related change and development processes (Becker et al. 2010; Crosby 1979; Gibson and Nolan 1974; Mettler 2010; Nolan 1973). Maturity models consist of an organized set of constructs serving to describe certain aspects of maturity of a design domain (Fraser et al. 2002). The concept of maturity is often understood according to the definition of Paulk et al. (1993), who consider maturity to be the 'extent to which a process is explicitly defined, managed, measured, controlled, and effective'. Most maturity models explicitly or implicitly follow this definition, taking a process oriented view when looking at how a design domain can be assessed and optimized. The sole focus on the process perspective has been controversially discussed in literature (Bach 1994; Gillies and Howard 2003; Jones 1995; Pfeffer and Sutton 1999). What is demanded by critics of this approach is an all-encompassing, integrated concept for measuring levels of maturity, taking into account technological and cultural aspects as well (Christensen and Overdorf 2000; Saleh and Alshawi 2005).

Typically, a maturity model consists of a domain model and an assessment model. The domain model comprises criteria by which the design domain can be partitioned into discrete units to be assessed. The assessment model provides one or multiple assessment dimensions, each of which defining an assessment scale. What is basically assessed is to which extent certain criteria comply with the scale for each assessment dimension. In order to structure the assessment process some maturity models also provide appraisal methods (e.g. Standard CMMI Appraisal Method for Process Improvement, SCAMPI) (SEI 2006b). Basically, two types of maturity models can be distinguished. Staged models build on best practices to explicitly specify an ideal path of development of a design domain (Paulk et al. 1993). Continuous models are used to review

certain quality features of a design domain at regular intervals, determine the level of maturity for different features or criteria, and derive actions for improvement. In the case of continuous models the path of development is dynamic, i.e. it is not predefined by the model (EFQM 2009).

3 Related Work

3.1 DQM Approaches

In recent years a number of methods have been developed both by the research and the practitioners' community supposed to offer support and assistance in selecting, adapting and applying techniques for improving data quality (Batini et al. 2009). These methods describe best practices for the DQM domain and can be used to derive criteria for designing a Maturity Model for Enterprise DQM.

The Complete Data Quality Methodology (CDQM) sees DQM as being composed of a series of singular projects for data quality improvement (Batini and Scannapieco 2006). These projects are results oriented, i.e. the data quality to be achieved is put in relation to the costs that are likely to occur in the process. Only those projects are realized which promise to be reasonable and profitable from a business perspective.

Redman (2000) developed the Data Quality System (DQS), focusing on the provision of an organisational framework (strategy, training concepts, etc.) and the development of business and technical capabilities (data quality planning, data quality measurement, data models, etc.).

Total Data Quality Management (TDQM) is the name of a research program at the MIT. TDQM sees information as a product (known as the information product (IP) approach) that needs to be produced according to the same principles physical goods are produced, including exact specification of requirements to be met by information products, control of the production process along the entire lifecycle of information products, and naming of an information product manager (Wang 1998; Wang and Strong 1996).

Total Quality data Management (TQdM) is a method that offers support when information needs to be optimized for business purposes (English 1999). TQdM follows the principles of the IP approach and focuses even more on the definition of requirements to be met by information products.

To sum up, it can be said that all of these methods refer to results oriented, cultural, process related, or technological aspects of data quality management.

3.2 Maturity Models for DQM

Beside the methods described in the previous section also maturity models for DQM have been developed. Lee et al. (2002) have proposed a methodology for information quality assessment (AIMQ), which can be used as a basis for information quality assessment and benchmarking. This methodology uses 65 criteria to evaluate results to be achieved by DQM.

DataFlux (2007) has come up with a maturity model comprising four criteria (people, policies, technology, and risk & reward) by which companies can assess the progress of DQM establishment in their organisation.

Bitterer (2007) aims at the same objective with their maturity model, using quite vague definitions of individual levels of maturity instead of clearly defined criteria.

Ryu et al. (2006) and Baskarada et al. (Baskarada et al. 2006) have developed maturity models on the basis of the Capability Maturity Model Integration (CMMI) approach (SEI 2006a). The scope of both models is quite narrow with regard to DQM. While the former defines 16 criteria for specifying and maintaining metadata (which is seen as a prerequisite for achieving high quality of data), the latter focuses on information systems for the mechanical engineering industry, for which it defines 19 technical criteria.

As Tab. 1 shows, none of the maturity models examined covers all aspects of Enterprise DQM.

Guidelines for designing actions for improvement are offered by two approaches only. Also, all maturity models examined are characterized by a rigid, predefined path of development. This, however, stands in contrast with the view of DAMA (2009) that states '[...] how each enterprise implements [DQM] varies widely. Each organisation must determine an implementation approach consistent with its size, goals, resources, and complexity. However, the essential principles of [DQM] remain the same across the spectrum of enterprises [...]'. Taking this into account, a Maturity Model for Enterprise DQM must provide a dynamic path of development, which each organisation may adapt to its individual needs and requirements.

4 Research Approach

4.1 Research Method

The work presented in this paper is an outcome of design oriented research, following the methodological paradigm of Design Science Research (DSR). DSR aims at designing artefacts (constructs, models, methods, or instantiations, for example) in order to solve problems occurring in practice (Hevner et al. 2004; March and Smith 1995). The artefact to be constructed is a maturity model that allows to deliberately design Enterprise DQM.

When developing a reliable maturity model a critical factor is the level of maturity of the design domain itself. The less developed a design domain is, the higher is the uncertainty in terms of having valid and reliable knowledge about this design domain, and the higher is the need for a maturity model that is capable of guiding the path of development for designing the domain. If this is the case, usually only few cases are available that help identify possible criteria and evaluate the model, resulting in maturity models of limited reliability only. So access to practitioners' knowledge is critical for being able to define and evaluate relevant criteria. Therefore, the overarching research method selected for designing a Maturity Model for Enterprise DQM is consortium research,

Source	Results oriented criteria	Culture related criteria	Process related criteria	Technology-related criteria	Guidelines offered	Path of development
(Lee et al., 2002)	●	○	○	○	No	Staged
(DataFlux, 2007)	○	●	●	●	Yes	Staged
(Bitterer, 2007)	○	◐	◐	◐	Yes	Staged
(Ryu et al., 2006)	○	○	●	○	No	Staged
(Baskarada et al., 2006)	○	○	○	●	No	Staged

Key: ● = Criteria formally defined - ◐ = Criteria informally defined (embedded in textual descriptions) - ○ = No criteria

Table 1: Existing DQM Maturity Models in Comparison

which represents a collaborative form of DSR and which is based on having access to and using practitioners' knowledge (Österle and Otto 2010).

Fig. 1 gives an overview of the research approach, which follows idealized design research processes (Peffer et al. 2008; Verschuren and Hartog 2005). The research process consists of four activities: analysis, design, evaluation, and diffusion. The research context is provided by the Competence Center Corporate Data Quality (CC CDQ) a consortium research project consisting of 13 user companies, the Institute of Information Management of the University of St. Gallen and the European Foundation for Quality Management (EFQM).

Furthermore the research methods draws upon Action Design Research (ADR) as proposed by Sein et al. (2011). ADR addresses the interaction with practitioners and the organisational context the design artefact is supposed to be used for. In particular, the maturity model design shares the perception of design and evaluation being an integrated stage within a design science research project rather than separated, sequential phases. The integration of building activities, (organisational) intervention activities, and evaluation activities (BIE according to ADR) is depicted in Fig. 2 by the bidirectional arrows connecting analysis, design, evaluation, and diffusion activities.

4.2 Research Process

4.2.1 Analysis

Analysis activities began in November 2006, comprising the identification of the problem and the specification of requirements to be met by the solution to be developed. EFQM joined the consortium as a strategic partner during this first activity of the research process, after the decision was made to use the well-established EFQM Model for Excellence as a basis for developing the Maturity Model for Enterprise DQM. EFQM is a non-profit aiming at establishing quality oriented management systems in Europe. Among other things, EFQM organizes the annual European Quality Award (EQA), in the course of which companies are assessed by means of the criteria of the EFQM Model. Relevance of the research to be undertaken was confirmed by representatives from the user companies of the consortium in a focus group interview and a series of expert interviews as well as by a literature analysis (cf. Related Work). The central outcome of the Analysis activity was a set of functional requirements to be met by the Maturity Model as specified by both the user companies of the consortium and EFQM.

4.2.2 Design

The Maturity Model was built in the course of three integrated design/evaluate iterations (Fig. 2).

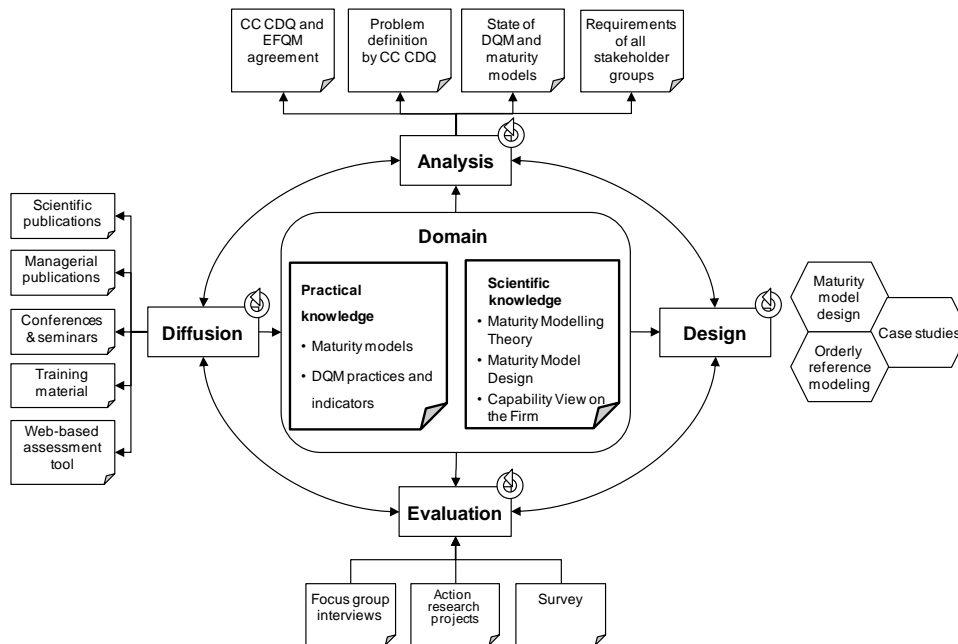


Figure 1: Research Process

All three iterations included building activities, organisational intervention activities (mainly through action research projects), and evaluation activities. The concrete model design process was guided by procedure models for the development of maturity models (Becker et al. 2010; Bruin et al. 2005). Adaptation mechanisms of reference modelling (Brocke 2007) allowed systematic design of the Maturity Model on the basis of the EFQM Model, following the Guidelines of Modeling (GoM) (Schuette and Rotthowe 1998). Knowledge about *things that worked* and *things that did not work* was used to draw up a catalog of criteria. This knowledge was gained from related work and from a number of case studies conducted in the context of CC CDQ.

4.2.3 Evaluation

Following the BIE principle of ADR, the evaluation of the Maturity Model was inseparably interwoven with the design of the Model. Evaluation within the three design/evaluate iterations was done by focus groups comprising different

stakeholders (organized within consortium workshops) and in the course of ten action research projects (cf. Evaluation). Both ex-ante and ex-post evaluation measures were applied, i.e. the artefact design theoretical contribution (interior mode) and its practical use (external mode) were studied (Sonnenberg and Vom Brocke 2012). Evaluation activities concluded with a survey on the criteria and maturity levels of the Maturity Model. A questionnaire was sent to 128 subject matter experts from the DQM domain, who were selected from the address database of the Institute for Information Management of the University of St. Gallen. 32 of these experts responded, confirming the criteria previously identified. Twenty of them declared to be willing to actively support the Maturity Model with their names and the names of their organisations by means of a joint publication with EFQM (2011). 49 subject matter experts from 24 user companies, four consulting companies, and EFQM joined to evaluate the Model. Basically, the focus groups and the survey served to optimize and verify the components and elements of the Maturity Model (in terms

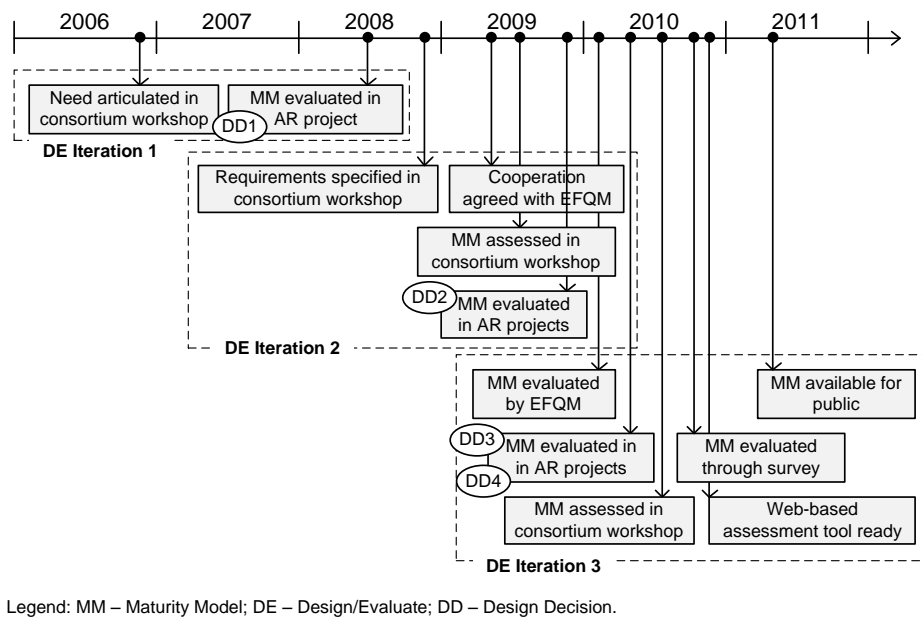


Figure 2: Design/Evaluate Iterations and Design Decisions

of optimized wording, above all), whereas the action research projects aimed at demonstrating the Model's applicability and benefit (relating to the ability to derive improvement actions).

4.2.4 Diffusion

The Diffusion phase began in the middle of 2008. The results of the research were disseminated via various channels. Scientific publications on the topic deal with the gap in research to be closed, requirements to be met by a maturity model for DQM, possible areas of application of such a model, and the literature research that was conducted (Hüner et al. 2009; Ofner et al. 2009). The present paper documents the entire research process, the design objectives, design decisions, and the process of evaluating the artefact. Apart from being documented in writing, the Maturity Model was presented at various conferences and seminars and was discussed with participants, among them the ACM SAC in 2008, the American Conference of Information Systems (AMCIS) in 2009, the German Information Quality Management Conference (GIQMC) in 2010, and the Stammdaten-Management Forum in 2009 and

2010. Besides, both the Maturity Model and the appraisal method have been implemented as a web based assessment tool, which was made publicly accessible in April 2011 and which allows organisations to conduct self-assessments regarding Enterprise DQM. The assessment tool also serves as a platform for diffusion of the Model.

5 Model Design

5.1 Scope and Requirements

The Maturity Model for Enterprise DQM aims at enabling companies to deliberately design Enterprise DQM in their organisation. Requirements to be met by the artefact were identified by the representatives from the user companies of the consortium and by EFQM (cf. Tab. 2).

5.2 Conceptual Model and Design Decisions

Fig. 3 illustrates the conceptual elements of the Maturity Model. Model elements adopted from the EFQM Excellence Model are indicated with the EFQM namespace prefix. Tab. 3 lists the design decisions made during different design/evaluate

No.	Requirement
R1	Improvement guidelines: The Maturity Model provides practices how to reach the next, higher level of maturity of Enterprise DQM. It is supposed to be used as a management tool enabling companies to deliberately design Enterprise DQM in their organisation.
R2	Objectivity: The Maturity Model uses a hierarchical model to partition the design domain of Enterprise DQM into smaller entities which can be assessed independently of each other. Also, fuzziness of assessments can be reduced by subdividing the design domain into smaller entities (de Bruin et al., 2005). However, it has to be noted that a maturity model always contains a certain degree of fuzziness.
R3	Dynamic path of development: The Maturity Model is non-prescriptive and allows to identify a dynamic path of development regarding Enterprise DQM. It is important that each company needs to find its own path of development. A maturity model cannot and should not set a predefined path of development to be followed by any company.
R4	Multiple dimensions: The Maturity Model provides multiple dimensions to assess the level of maturity of Enterprise DQM, as progress in organisational change cannot be captured by a single dimension (as progress may refer to the way DQM has been implemented, to business units affected by DQM, etc.).
R5	Assessment methodology: The Maturity Model provides a comprehensive assessment methodology (i.e. a process model, techniques, and tools) for being able to make reliable assessments and to avoid 'finger in the wind' assessments. The assessment methodology is supposed to allow both self-assessments and assessments by external experts.
R6	Flexibility: The Maturity Model provides configuration mechanisms to reflect specific requirements. It must be applicable for any company, regardless of size or industry. Explicit configuration mechanisms must consistently specify how the Maturity Model may be adapted to company specific requirements.
R7	Conformity with EFQM standard: The Maturity Model complies with EFQM standards and is based on the EFQM Model for Excellence in order to be adopted into the EFQM model family and to be recognized as an official EFQM standard (EFQM, 2003b). Conformity with EFQM standards also ensures connectability with other methods, techniques, and tools.

Table 2: Functional Requirements to be met by the Model

iterations, leading to more model elements being added (highlighted with gray background color in Fig. 3). In the following sections the design decisions are explained in more detail. In order to illustrate every design decision, each explanation includes a vignette (Stake 1995) giving a concrete Enterprise DQM related example from one of the user companies taking part in the action research projects or in the focus groups.

5.2.1 Design decision 1: Use EFQM Excellence Model as a base model

The first design decision referred to the Maturity Model for Enterprise DQM to be developed on the basis of the EFQM Model for Excellence (EFQM 2009). The EFQM Model is an assessment model that can be used to identify a dynamic path of development. What has been adopted in particular is the overall structure of the EFQM Model and the content of its assessment model, whereas

the domain model of the Maturity Model to be developed needs to be *filled* with Enterprise DQM specific content. Adoption of the EFQM Model's generic structure ensures compatibility of the Maturity Model with existing EFQM methods and techniques for assessment and analysis. The assessment dimensions developed by EFQM and its partners have been used and continuously reviewed for over twenty years. The content of the domain model of the Maturity Model is explicated in the following paragraphs. The Maturity Model is built upon the logic that an organisation that defines goals for Enterprise DQM requires certain capabilities in order to be able to achieve these goals (cf. Fig. 3). At its core, the Maturity Model defines 30 *Practices* and 56 *Measures* for Enterprise DQM that can be used as concrete assessment elements during an appraisal. Whereas *Practices* are used to assess if and how well certain Enterprise DQM capabilities are established in an organ-

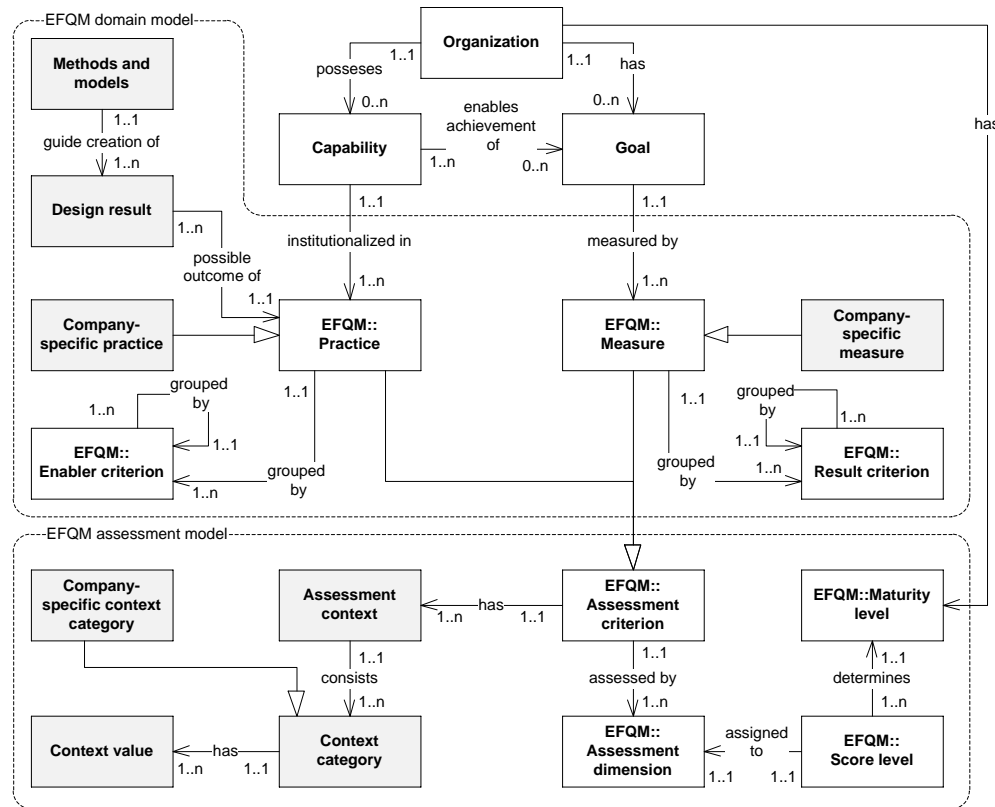


Figure 3: Conceptual Model of the Maturity Model

No.	Design decision	Model elements
DD1	Use EFQM Excellence Model as a base model	EFQM::Enabler criterion, EFQM::Result criterion, EFQM::Practice, EFQM::Measure, EFQM:Assessment dimension, EFQM::Assessment scale, EFQM:Score level, EFQM::Maturity level
DD2	Integrate assessment context	Assessment context, Context category, Category value
DD3	Strengthen common understanding of practices	Design result, Methods and models
DD4	Allow company specific configuration	Company-specific context category, Company-specific practice, Company-specific measure

Table 3: Overview of Design Decisions (DD)

isation already, *Measures* allow assessing if and how well the *Practices* support the achievement of Enterprise DQM goals.

Vignette 1. Use EFQM Excellence Model as a base model

A German supplier from the automotive industry wants to establish central Enterprise DQM as part of a program for company-wide process harmonization. Certain tasks and activities related to Enterprise DQM are already being done by regional business units. The company now wants to conduct a systematic analysis in order to find out who is doing what already and what needs to be improved. Both the analysis and the continuous improvement process is to be assigned to the company's quality management department, which is already using EFQM methods and models.

Another company (from the chemical industry), which established Enterprise DQM as a central management function some years ago, is planning to integrate DQM oriented objectives into the goal structure of certain executive employees. A reliable, standardized methodology is necessary for determining the achievement of objectives to be broadly accepted by the employees affected.

For reasons of clarity, both *Measures* and *Practices* are hierarchically grouped on two levels of detail (as shown in Tab. 4) whereas *Measures* are arranged by *Result criteria* and *Practices* by *Enabler criteria*. To give examples, 'Running an adequate Enterprise DQM training program to develop people's knowledge and competencies regarding their current and future needs to manage enterprise data' is a *Practice* related to the *Enabler criterion 3c* (which itself is part of the *Enabler criterion 3*), or 'Success rate of enterprise data quality related training and development of individuals' is a *Measure* related to *Result criterion '8b. Performance of people results'* (which itself is part of the *Result criterion 8*) [for a complete list of *Practices* and *Measures* see EFQM (2011)]. *Enabler*

criteria describe which areas need to be dealt with in order to establish Enterprise DQM. 'Strategy' addresses leaders to recognize the importance of high-quality enterprise data as a prerequisite for being able to respond to business drivers (compliance with regulatory and legal directives, integrated customer management, strategic reporting, or business process integration and standardization, for example). Leaders are required to promote a culture of preventive Enterprise DQM. 'Controlling' is about the quantitative assessment of the quality of enterprise data. Moreover, the interrelations between enterprise data quality and business process performance are identified and monitored. 'Organisation and People' ensures that clearly defined roles, which are specified by clearly defined tasks and decision-making rights, are assigned to competent people. Appropriate assignment of Enterprise DQM responsibilities allows to efficiently and effectively perform DQM related projects and activities. 'Processes and Methods' ensures through the use of Enterprise DQM related processes and services—that expectations are fully satisfied and that increased value for customers and other stakeholders is generated. 'Data Architecture' refers to planning and managing the enterprise data architecture in order to be able to ensure enterprise data quality in terms of enterprise data storage and distribution. 'Applications' for Enterprise DQM are supposed to provide functionality that supports DQM tasks.

Results criteria account for the fact that the way the *Practices* are realized has an effect on the people of a company, its customers (including internal customers, like e.g. business units or project teams), the society, and a company's overall business performance, respectively. EFQM provides an appraisal method for the assessment process, consisting of a procedure model and techniques for assessment and analysis (EFQM 2003). The appraisal method uses a series of interviews and focus groups as well as document analysis for determining the level of maturity. The most comprehensive technique offered is 'Results, Approaches, Deploy, Assess and Refine' (RADAR),

Criteria	Subcriteria
1. Strategy	1a. A strategy for Enterprise DQM is developed, reviewed and updated based on the organisation's business strategy 1b. Leaders are personally involved in ensuring that an Enterprise DQM system is developed, shared, implemented, continuously improved, and integrated with the overall organisational management system
2. Controlling	2a. The business impact of data quality is identified and related enterprise data quality measures are defined and managed 2b. The quality of data is permanently monitored and acted upon 2c. Developing, implementing and improving methods of measurement for enterprise data quality metrics
3. Organisation and People	3a. People resources for managing and supporting Enterprise DQM are defined, managed, and improved 3b. People's awareness for Enterprise DQM is established and maintained 3c. People are empowered to assume Enterprise DQM responsibilities
4. Processes and Methods	4a. Enterprise DQM processes are systematically designed, managed, and improved 4b. The use and maintenance of enterprise data in core business processes is systematically identified, improved and actively managed 4c. Designing, improving and documenting data creation, use and maintenance (as-is and to-be) for a better understanding of the enterprise data use within the organisation
5. Data Architecture	5a. A common understanding of a data model for the business entities is developed, permanently assessed, and made available to people 5b. Data storage and distribution is systematically designed, implemented and managed
6. Applications	6a. The application landscape is planned, managed, and improved to support Enterprise DQM activities 6b. A rollout plan for closing the gap between the as-is and the to-be application landscape is managed and improved to support Enterprise DQM activities 6c. A roadmap for strategic planning of the application landscape is managed and continuously monitored and improved
7. Customer results	7a. Perception of customer results 7b. Performance of customer results
8. People results	8a. Perception of people results 8b. Performance of people results
9. Society results	9a. Perception of society results 9b. Performance of society results
10. Key results	10a. Strategic outcomes of Enterprise DQM 10b. Performance of Enterprise DQM

Table 4: Enabler and Results Criteria

which defines seven *Assessment dimensions* for *Practices* and for *Measures*, respectively (EFQM 2009). The level of maturity is always determined according to the same principles, regardless of the assessment technique used. For each *Practice* and each *Measure* a score is determined for each *Assessment dimension* using an *Assessment scale*. The total result is hierarchically calculated according to predefined calculation schemes (EFQM 2009) and then entered on a 1000-point scale and assigned to one of the three *Maturity levels* defined by the EFQM (cf. Fig. 4).

5.2.2 Design decision 2: Integrate assessment context

As a second design decision it was agreed that the idea of an *Assessment context* needed to be integrated into the model design, as every single maturity assessment relates to a certain context (e.g. management of customer and supplier master data in regions North America, Europe, and Asia) that should be predefined prior to the assessment. What context is specified has an effect on the selection of experts to be interviewed. If for certain reasons (e.g. limited human resources or budget) certain interview participants cannot be included in the appraisal (e.g. experts for the European and Asian regions are not available), the specified context needs to be revised. It is important that all results recorded from each expert interview or focus group must always be interpreted in relation to the context specified (e.g. when an interviewee's assessment refers only to customer master data related practices of Enterprise DQM in North America).

In order to be able to consolidate the data collected (from various expert interviews), the context each interview refers to needs to be annotated unambiguously. Three generic context categories plus context values were identified for the Maturity Model: data class, geographic affiliation, and IT system (cf. Fig. 5).

Vignette 2. Integrate assessment context

A global provider of telecommunications services aims at establishing Enterprise DQM in order to be able to meet the need for high-quality master data for the new business environment. The company management decided to conduct a maturity assessment to determine the current level of maturity of its Enterprise DQM. To do so, 66 persons from six organisational functions (finance, IT, sales, etc.) in five countries were selected for being interviewed. But one interviewee referred to supplier master data for North America, whereas another interviewee talked about customer master data for the European market. This was taken as an indication that experts always relate their individual assessment to a certain context.

5.2.3 Design decision 3: Strengthen common understanding of practices

The third design decision relates to each *Practice* being assigned with a set of appropriate *Methods* and *models* (plus *Design results*) allowing to execute each *Practice* in a structured way. Specifying *Design results* (strategy documents, measurement systems, etc.) beforehand helps to reduce subjectivity of assessments, as interviewees are given hints as to what type of formal results (documents, templates, reports, systems, etc.) can be expected to result from each *Practice*. Fig. 5 illustrates the assessment of a *Practice* and demonstrates how the additional information given about possible *Design results* strengthens a common understanding. Also, these sets of *Methods and models* can be used for planning actions for improvement (for a complete list, see (EFQM 2011)).

Vignette 3. Strengthen common understanding of Practices

A leading company from the glass industry is conducting a maturity assessment of its current Enterprise DQM strategy, organisation, and architecture, in order to develop an action plan for

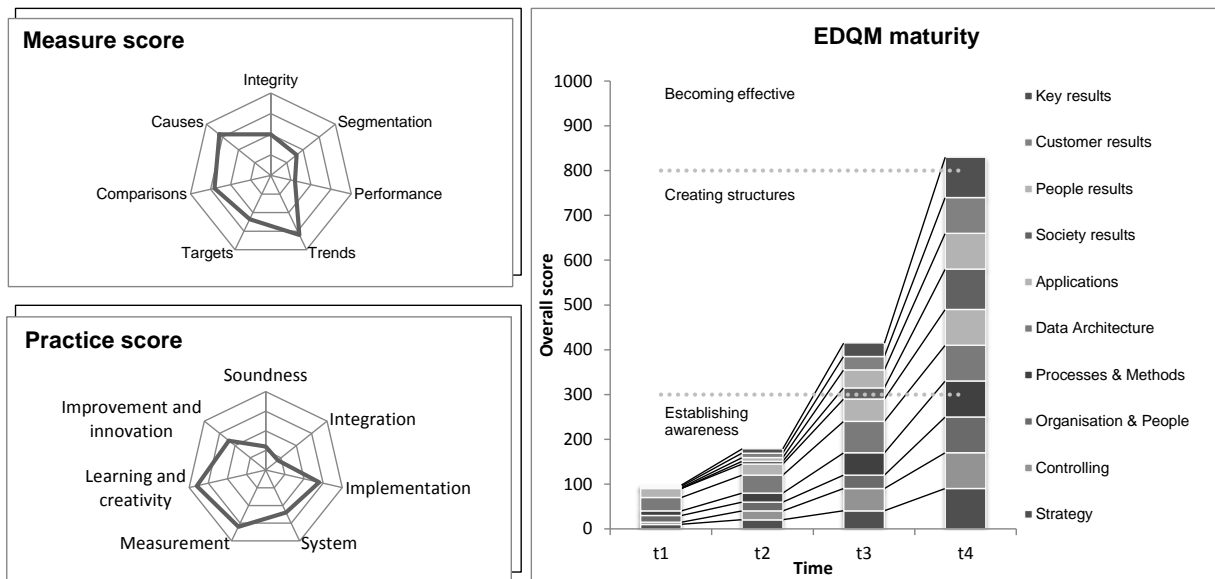


Figure 4: Score Assessment and Maturity Calculation

P8	Developing, implementing and improving methods of measurement for enterprise data quality metrics				
Assessment context					
Data class	Supplier data	Customer data	Product data		
Geographic	EMEA	NAM	APAC		
IT System	G1	ERP	HQ		
Possible design result		Models and Methods			
Measurement system	Measurement system to assess data quality and data quality measures by means of metrics. Generally speaking, metrics provide consolidated information on complicated phenomena from the real world on the basis of quantitative measuring. Metric systems are supposed to increase the meaningfulness of individual metrics by structuring them and defining relationships between them.		<ul style="list-style-type: none"> Method for specifying business oriented data quality metrics (Hüner, 2011) Methods and models for performance management (IMG, 1999) 		
Assessment					
Approach	0%	25%	50%	75%	100%
Sound					
Integrated					
TOTAL for Approach	37,5%				
Deployment	0%	25%	50%	75%	100%
Implemented					
Systematic					
TOTAL for Deployment	12,5%				
Deployment	0%	25%	50%	75%	100%
Measurement					
Learning and Creativity					
Improvement and Innovation					
TOTAL for Deployment	0%				
OVERALL TOTAL	25%				

Figure 5: Example of a Practice Assessment Form

improvement. 26 persons from three production sites in three different countries were selected for being interviewed by a group of assessors. As there was poor common understanding of each *Practice* among the assessors, the first assessments conducted were not comparable or summable.

5.2.4 Design decision 4: Allow company specific configuration

The fourth design decision refers to the Maturity Model to provide configuration mechanisms, as the Model is supposed to be applicable to practically any organisation, regardless of size, industry, or individual situation regarding Enterprise DQM. Furthermore, providing configuration mechanisms emphasizes the idea that each organisation should be given the opportunity to find its own path of development with regard to designing Enterprise DQM. Configuration mechanisms provided by the Model refer to selection and deselection of elements, variation with regard to naming of elements, and definition of new elements. Element selection and deselection allows to limit the scope of an assessment by masking certain *Practices* or *Measures*. Especially if the Model is used for the first time, it is recommended to work with a reduced scope. Variation with regard to naming of *Practices* and *Measures* allows to use synonyms, as each organisation prefers its own, individual terms for denoting certain concepts in order to increase the model's clarity and raise acceptance on the part of the users. Definition of new elements allow to fill in placeholders in order to add further, individual *Company-specific practices*, *Company-specific measures*, or *Company-specific context categories*.

Vignette 4. Allow company specific configuration

A German telecommunications provider is planning to assess the maturity of its Enterprise DQM related to supplier and customer master data maintained by the European ERP system.

An international glass manufacturer focuses on product master data in all regional and global ERP systems with a special interest in practices related to data migration projects (due to negative experiences in the past). A German automotive supplier is planning to improve Enterprise DQM maturity in order to reduce the amount of data related process incidents.

As these examples show, the Maturity Model is intended to be used by companies from all kinds of industries (chemicals, pharmaceuticals, manufacturing, retail, consumer goods, etc.) and with different experiences made in the past. Each company has its individual assessment context, aims at achieving DQM goals through individual practices, and prefers to use different measures to evaluate whether goals have been achieved. Therefore the Maturity Model needs to be configurable to meet company specific requirements.

6 Demonstration Case

A company, which is one of the world's leading telecommunications and information technology service companies, adapted its business strategy in order to factor in socio-economic developments, such as digitalization of central areas of life, personalization of products and services, and increasing mobility of individuals. To validate whether the strategy is met on a short-term basis, the company defined a number of goals, such as expanding its leading position in the broadband sector, entering into the entertainment market, or meeting its customers' expectations with regard to rendering certain products and services. As one measurable objective referring to customer satisfaction it was agreed that customer incidents be reduced by 25% within a year. Business and data management experts of the company supposed that problems in the management of customer data and product data had produced data defects which had a negative impact on business operations, leading to a growing number of customer incidents. Therefore, the company

initiated a project to assess the as-is maturity level of Enterprise DQM, identify interrelations between established practices of Enterprise DQM and the impact on the number of customer incidents, and derive improvement actions as deemed appropriate.

The project team, which was made up of business and data management experts, selected 30 *Practices* and three *Measures* from the Maturity Model for being used in the assessment. Moreover, two *Company-Specific practices* (e.g. 'Data integration guidelines are defined, communicated, and applied in relevant projects') and one *Company-specific measure* ('Number of customer incidents') were added to take into account the company's specific requirements, experiences, and goals. The assessment context, which also defines the scope of the assessment, was set to the *Context categories* 'Data class' ('Customer data', 'Product data'), 'Organisational affiliation' ('IT Shared Service department'), and 'IT System' ('Central ERP') and their respective values. Furthermore, the project team selected 'RADAR' as the assessment methodology to be applied (EFQM 2003). Twelve business and IT experts were selected for taking part in interviews in order to determine the assessment scores.

The company reached a total score of 305 (out of 1000), calculated as the average of the results for each single criterion (Strategy: 17%; Controlling: 40%; Organisation and People: 27%; Processes and Methods: 42%; Data Architecture: 32%; Applications: 72%; Customer Results: 25%; Society Results: 25%; People Results: 25%; Key Results: 0%; Overall: 30,5%). Hence, at the time of the assessment the company was in the transition process from maturity level one ('Establishing awareness') to maturity level two ('Creating structures'). Both the quantitative results as well as the findings from the interviews identified strategic deficits as potential root causes of the negative impact of data issues on the Key Results (and the increasing number of customer incidents). For example, it was discovered that the lack of an official mandate (allocated to a company's department) that

allows defining binding rules and guidelines on a company-wide level prevents effective Enterprise DQM. As a consequence, the project team decided to establish the *Practice* 'Formalize, review and update scope, strategy, objectives, and processes of Enterprise DQM that meets stakeholders' needs and expectations and is aligned with the business strategy' together with the *Design result* 'Strategy document' following the *Methods and Models* of the PROMET-BSD methodology (IMG 1998). The 'Strategy document' defines the scope, the value contribution, the mandate and a roadmap for Enterprise DQM, and is supposed to be verified, accepted and approved by the leaders of the company.

7 Evaluation

Generally, evaluating design artefacts must take into account the dual nature of Design Science Research aiming at both advancing the scientific knowledge base and providing results useful in practice. Sonnenberg and Vom Brocke (2012) have identified four different evaluation types by distinguishing between ex-ante evaluation in the course of artefact design activities and ex-post evaluation during artefact usage activities. Evaluation type 1 is concerned with problem identification, whereas type 2 mainly addresses the design objectives and the design approach. Evaluation type 3 can be understood as a proof of the artefact's applicability, and type 4, finally, as a proof of its usefulness.

Evaluation type 1 was mainly addressed by focus groups and expert interviews during the first design/evaluation iteration of the project. The need for a maturity model was articulated in late 2006, and specific requirements were revisited in mid 2008. Tab. 5 lists the results of the evaluation of the Maturity Model.

The design decisions mentioned above were the result of different evaluation types at different stages of the research process. Fig. 2 shows that DD1 (Use of the EFQM Excellence model) resulted from an evaluation of the design approach (type

No.	Evaluation result	Model element(s)
R1	Improvement guidelines: The Maturity Model provides methods and models for executing each practice properly.	Methods and models
R2	Objectivity: Specifying an assessment context helps assessors and interviewees determine the score for a certain assessment element. Additional information, such as typical design results to be expected, ensures a common understanding of the criteria among all parties involved in the process.	Assessment context, Context category, Context value, Design result
R3	Dynamic path of development: The Maturity Model is based on the EFQM Model for Excellence. This model is a continuous model, which allows a dynamic path of development.	All EFQM model elements
R4	Multiple dimensions: Depending on the assessment technique used, the Maturity Model provides as many as 14 or just one single assessment dimensions. The assessment techniques and dimensions have been developed by the EFQM and its members and have been used for assessing organisations for over twenty years.	-
R5	Appraisal method: The assessment process is supported by a comprehensive assessment methodology provided by the EFQM. The methodology contains a procedure model as well as techniques for analysis, configuration, and assessment. The methodology and the Maturity Model itself have been implemented in a web based prototype.	-
R6	Flexibility: The Maturity Model provides placeholders for company specific adaptation of the Model. Techniques for configuration support the process of company specific adaptation and ensure semantic and syntactic consistency of the Model.	Company-specific context dimension, Company-specific practice, Company-specific measure
R7	Conformity with EFQM standard: The EFQM uses a standardization process ('EFQM branding') which ensures compliance of potential EFQM models with EFQM principles. The Maturity Model has passed this process successfully. It is now the official standard of EFQM for assessing the maturity of Enterprise DQM in organisations.	-

Table 5: Evaluation of the Model with regard to Functional Requirements

2) in the course of the first design/evaluation iteration, and that DD2, DD3, and DD4 resulted from evaluation activities taking place in the action research projects (type 3 and 4) in the second and third design/evaluate iteration.

Evaluation type 4, i.e. proof of the artefact's usefulness, was analyzed in greater detail. In particular, the question as to whether the demand for economic efficiency of the Maturity Model is met is difficult to answer. Depending on the scope of the assessment context that was defined, for a project team to apply the Maturity Model in an organisation takes five to thirty days if it is to comprise all phases of the appraisal method (from project preparation to training of staff to deriving actions for improvement) (cf. Tab. 6). Obviously, the effort required for training staff is higher if the Model is used for the first time, and gets lower

after repeated use. Applying a maturity model, in general, is a continuous process, for which appropriate organisational structures need to be created. Companies already using EFQM methods and models should be able to quickly understand the Maturity Model and use it regularly, and the staff of companies which have already established quality management should require training with regard to the principles and structures of the EFQM Model only. If there is neither quality management in place nor any knowledge about the EFQM Model at hand, companies need to create adequate organisational structures and build up certain knowledge which may generate substantial costs before they can apply the Maturity Model. From applying the Model some of the companies taking part in the action research projects have derived actions for improvement

Company	Date of assessment	Project duration [days]	Model coverage	Improvement actions derived (implemented)
Beiersdorf	05/10	8	Enabler criteria	Assessment only
Corning Cable Systems	02/11	25	Enabler criteria	18 (4)
Elektrizitätswerke des Kantons Zürich (EKZ)	06/10	5	Enabler criteria	Assessment only
Deutsche Telekom	03/11	20	Enabler and Results criteria	20 (1)
Partner Automotive	07/08	5	Enabler criteria	Assessment only
Siemens Enterprise Com.	07/10	30	Enabler criteria	15 (4)
Swisscom IT Services	11/10	10	Enabler criteria	13 (1)
Syngenta	11/11	8	Enabler criteria	Assessment only
Stadtwerke München (SWM)	05/10	24	Enabler criteria	10 (2)
ZF Friedrichshafen	08/08	5	Enabler criteria	5 (1)

Table 6: Action Research Projects

(ranging from five to twenty), of which some were actually implemented (depending on priorities, budget, or availability of resources).

8 Conclusions

8.1 Contribution of the paper

The paper presents a Maturity Model for Enterprise DQM, which aims at supporting enterprises in their effort to deliberately design and establish organisation-wide data quality management. The elements of the Maturity Model are based on principles of quality management in general and existing DQM approaches in particular. The Model's structure and assessment dimensions have been adopted from the EFQM Model for Excellence. The Model has been approved by EFQM as the official framework for quality oriented management of enterprise data. It comprises, on its most detailed level, 30 practices and 56 measures that can be used as concrete assessment elements during an appraisal. Although the design domain and the purpose of the Maturity Model are specific, findings gained during the artefact design process can be generalized in order to derive further patterns for designing maturity models (e.g. integrating an assessment context).

Moreover, through explication of the design process the results can be taken up by other researchers for verification and extension. Furthermore, due to the explication of the design process the model is open to be extended, adapted and reused by future design science research endeavours in related fields. Companies may use the Maturity Model for Enterprise DQM to conduct maturity assessments and derive actions for improvement. Specifying design results to be expected together with taking advantage of appropriate methods and techniques from research and practice is highly useful to support the planning of such actions. The Model's hierarchical structure allows detailed analysis of the results of a maturity assessment and presentation of these results to different stakeholder groups in an organisation.

8.2 Limitations

The Maturity Model for Enterprise DQM has been used and tested only by large companies so far. Hence, the findings presented in the paper basically apply to the structure and requirements of large companies and cannot be considered to be equally valid for small companies or single company units. Another aspect of limitation refers to the fact that the actions for improvement which were implemented by the companies in the

course of action research projects could not be verified (in terms of whether they have actually led to increased DQM maturity). As most of these actions started only recently and are expected to take some time until they start to become effective, the paper does not include any findings on this aspect.

8.3 Need for further research

Further research is expected to refer to continuous maintenance and optimization of the Maturity Model for Enterprise DQM. As the Model is a 'living' artefact, it must be reviewed and revised from time to time in order to keep meeting the requirements of different groups (i.e. the scientific community and the practitioners' community). A web based assessment tool is supposed to facilitate the collection of reference values for levels of maturity regarding Enterprise DQM (best-in-class, industry average, etc.) in order to support the benchmarking process in the future. In this respect, a central challenge lies in finding a balance between the Model's flexibility and ensuring comparability of results across company boundaries. Furthermore, future research should examine whether the findings presented in the paper can be transferred to other organisational domains and to smaller companies.

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