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Towards a document-driven approach for designing reference models: From a conceptual process model to its application

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ABSTRACT

In IS research, reference models have demonstrated to be a beneficial instrument for providing blueprints for a reasonable, good design of information systems and underlying organizational settings. Researchers assume that the application of reference models allows time savings, cost savings, and quality increases. But these effects may only appear when providing a research-based and empirically evaluated reference model that is profoundly documented. However, research criticizes the often missing identification of similarities in related work and preexisting knowledge, which might lead to arbitrariness. Moreover, linking existing knowledge during development and evaluation processes of reference models can bring new and fruitful insights. Therefore, this paper uses a scientific approach consisting of four steps. First, we develop a requirements framework for designing reference models. Second, we use this framework as a basis for the comparison of well-documented reference models. Thereafter, the gained insights from step one and two are consolidated into a conceptual process model that has a strong regard to preexisting knowledge. Finally, a case study will show the applicability of the determined model. With this paper, we enrich research by a valuable guideline for developing methodologically well-designed reference models that support users to take full advantage of the above mentioned benefits.

1. Introduction and motivation

Conceptual information models constitute important artifacts within the domain of information systems (IS) research and have been studied by scientific institutions and by practice (e.g., Chen, 1976; Scheer and Hars, 1992; Cash and Wilkerson, 2003; Keller and König, 2014) for many decades. With the development of information models, the intention is to build manageable artifacts that enable decision makers to understand the complexity (Thomas, 2006) and to increase the transparency of the underlying IS processes (Becker et al., 2010). For the adoption of information models, there are various areas of application, ranging from initial software development to advanced business process reengineering. Thereby, conceptual information models reconstruct a piece of reality.

The paper at hand focuses on one specific type of conceptual information models, namely the reference information model or *reference model* (RM) to use the more common term. In general, RMs have their origin in the need for creating an abstract of in-depth company or project-specific IS in order to reuse this abstract in other applications or to transfer it on other environments (Frank, 2007). According to Thomas (2006), a RM always constitutes an initial model as a point of reference for the construction of other and more specific models. Such an initial model promises the model users time savings, cost savings, and quality increases (Fettke and Loos, 2005). In spite of these advantages, research still struggles with providing a common understanding of RM. Furthermore, research literature argues that reference modeling may consist of specific IS methods, IS languages, and IS tools. But these specifications vary from author to author, which leads to a broad fluctuation range within the RM paradigm.

However, it is common sense that the effectiveness and efficiency of the application of a RM is strongly determined by the quality of the initial RM. In order to be able to properly translate the model and to ensure clear model guidance, according to Thomas (2006) and Becker et al. (2010), there are two basic quality conditions: an adequate *degree of universality* and an adequate *degree of recommendation* for the users. But it is unclear how these quality characters can be verified. Vom Brocke (2003), Fettke et al. (2006), as well as Möller et al. (2011) discover a lack of assessability for the content of universality and recommendation in RMs. In this regard, Thomas (2006) as well as Fettke and Loos (2004) motivate scientific research to provide adequate approaches for measuring and evaluating the quality of RMs, as operational and practical users are not in a position to assess the universality and recommendation quality of suchlike models. To be more precise, Fettke and Loos (2003) also refer to the research outcome

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"reference model" that can be understood as a theory in the IS area. Hence, it is indisputable that the construction of RMs should strongly and systematically be based on already existing knowledge. This strong knowledge regard (e.g., involving research in science and practice, expert knowledge) constitutes the starting point of our paper, as we intend to meet both conditions (universality and recommendation) in a document-driven way. Stating very clearly, the purpose of our work is not to call into question the valuable outcomes of existing RM research. Moreover, we believe that there cannot be a one-way-fits-all approach on the complex domain of RM research. Thus, we strive to contrast with the other already existing and well-known conceptual models for designing RM (e.g., Fettke, 2005; Vom Brocke, 2003). Given a rich knowledge base, we intend to provide a document-driven process model that might bring new insights for RM developers and users by linking the RM to the underlying body of knowledge. Herein, document-driven means that the design process of RM is in addition to the modelerś subjective intuition or personal experience effectuated by documentsćontents (e.g., scientific and practical literature, transcripts of expert interviews, postings in social media networks).

Moreover, our paper goes in line with the argumentation of the recently developed research on inductive RM development (e.g., Ardalani et al., 2013, Martens, et. al. 2014, 2015) by stating that the *identification of similarities* between already existing knowledge is compellingly needed for deriving abstracted RMs in order to meet the above mentioned two conditions. Towards this end, statistical analysis and data mining constitute important RM development and evaluation methods for enabling a higher level of objectivity and for reducing arbitrariness. In classic research on RMs, only few authors of such RMs reveal the procedural methodology with which they developed and evaluated the presented models. This leads to models that are only loosely anchored in scientific literature and practice knowledge. Fettke and Loos (2004) consider it essential to perform the evaluation and assessment procedure already during model creation and not only at the final phase, since this is the only way to enable an iterative creation and evaluation process. Therefore, we aim to present a more complex RM design life cycle that involves related knowledge by a metric-based evaluation. The underlying research questions (RQ) of this paper are as follows:

RQ1: What characteristics of a conceptual process model are necessary for the design and evaluation of RMs that are, contrary to many already existing RMs, deeply anchored in related knowledge?

RQ2: How can objectivity be ensured and arbitrariness be avoided during the design and evaluation of RMs?

In terms of the paper's structure, we adopted Becker et al. (2009) who provided a general procedure model for the development of maturity models, while criticizing preexisting arbitrariness in model development as well. In Section 2, we explain the relevant theoretical background, which leads us to the general requirements of reference modeling. In Section 3, we use the determined requirements as a basis and compare various selected RMs. Thereafter, we extend the existing body of knowledge by presenting the conceptual process model for the development of RMs. In Section 5, we experimentally apply the model on the topic of cloud usage in supply chains. The paper ends with a conclusion in Section 6.

2. Theoretical backgrounds

2.1. Related work

The synthesis of the reference modeling research field has brought much valuable insights to the existing body of knowledge. Within this section, we focus on research that discusses procedures and approaches for designing RMs (*research methodologies*), whereas the analysis of finished RMs, as an aid for end users (*research outcomes*), is covered in Section 3. For identifying relevant work, we used two scientific databases (Science Direct, Springer Link) and the following searching terms: (reference model OR reference modeling) AND (methodology∗ OR research). Moreover, we took only publications from the year 2000 and ongoing into account as we were interested in the latest research progress, assuming that prior work (< year 2000) was implicitly involved in the latest research. Further, the term reference model has widely been used with different meanings. Therefore, we took only papers that go in line with our understanding of the term (cf. Section 2.3) and focus RM methodologies and/or procedures instead of RM applications (research outcomes). In the next step, we excluded papers that show only minimal additional contribution to existing literature (e.g., proceedingsṕapers similar to extended journal papers of the same authors or similar papers in different languages). Herewith, we got 16 relevant papers.

Hence, we have identified important studies that could, despite of some significant differences, be compared to ours. These 16 studies are summarized in Table 1 and compared to our approach according to the following attributes:

- Semantic approach: Does the study provide any ontology to analyze RM processes?
- Literature regard: Does the study compare related work?
- Evaluation: Does the study discuss an evaluation approach and, if so, is there a new evaluation approach determined?
- Major issue: What is the problem domain of the study and what is the main difference between this approach and ours?

Looking at Table 1, which contains studies of some of the most influential researchers on RM development, it is obvious that research on RM covers a quite broad range and includes various semantic approaches, evaluation methods, and IS issues. Furthermore, there are various papers that discuss general guidelines in RM development, and hence, seem to be similar to our study. Our paper distinguishes from the existing literature by two main aspects: (i) there is no paper on RM research that discusses the RM development and evaluation from a business process modeling notation (BPMN 2.0) perspective, which would enable an intensive analysis of the RM developer and the RM user role; and (ii) there is no metric-based RM evaluation presented. Highly depending on the amount and the quality of the underlying documents, this evaluation phase might bring novel insights by analyzing RM contents in preexisting knowledge (e.g., testing the discussion intensity in documents of specific connection points in the RM). The recently created metric-based approaches by Ardalani et al. (2013) and Martens et al. (2014, 2015) are helpful especially for *inductive RM development* of individual projects, while (by nature) allowing a high degree of encapsulation from existing adjacent knowledge. In contrast, the metric part of our approach focuses particularly on the *RM evaluation processes* and allows virtually inductive (e.g., involving transcripts of expert interviews around one common process) and deductive (e.g., involving practice research and/or scientific theories) evaluation. But although a large part of the referenced papers have a related work section (literature regard), most of the approaches have been developed independently from each other, which is criticized by Becker at al. (2007) and Vom Brocke et al. (2014). With our approach, we aim at a comprehensive involvement of related work during the whole RM creation process.

2.2. Characterization of knowledge involvement

The Oxford dictionary defines knowledge as awareness or familiarity of facts, information, or skills, which are gained through experience or education; the theoretical and practical understanding of a subject. Hence, knowledge may be documented in various forms such as scientific and practical literature, social networks or transcribed

Table 1
Summary of related work.

Reference	Semantic approach	Literature regard	Evaluation	Major issue
Becker et al. (2000)	Yes, event-driven process chain (EPC) and entity-relationship-modeling (ERM)	No	Yes, via simulation; no new evaluation approach is presented	Study determines guidelines for RM development while focusing on the functional, the organizational and the data view
Fettke and Loos (2003)	No, structural/argumentative study	No	Yes, argumentative proposals of several evaluation types	Study provides an evaluation framework
Vom Brocke and Buddendiek (2004)	Yes, event-driven process chain (EPC) and entity-relationship-modeling (ERM)	Yes	Yes, exemplary software application; new evaluation approach is presented	Study focuses on the adequate usage of languages and tools
Fettke and Loos (2005)	No, structural/argumentative study	No	Yes, need is discussed; no new approach is presented	Study analyzes the helpful link between RM and business engineering
Fettke et al. (2006)	No, structural/argumentative study	Yes	Yes, study discusses mainly lack of evaluation; no new approach is presented	Study provides qualitative evaluation criteria for analyzing existing RMs
Thomas (2006)	No, literature review	Yes	No	Study aims to explain the research field RM
Becker et al. (2007)	Yes, event-driven process chain (EPC) and entity-relationship-modeling (ERM)	Yes	Yes, exemplary adaption of a new approach is described	Study focuses on the integration of configurative adaption methods
Frank (2007)	No, structural/argumentative study	Yes	Yes, proposals for various evaluation perspectives such as economic or knowledge sharing	Study provides an extensive evaluation catalogue
Ahlemann (2009)	Yes, unified modeling language (UML)	Yes	Yes, exemplary excerpt of new evaluation type	Study discusses software development for project management
Houy et al. (2010)	No, literature review	Yes	No	Study provides an analysis of empirical research of RM development
Walter et al. (2013)	No, structural/argumentative study	Yes	Yes, within the life cycle, no new approach shown	One of the first studies that presents an inductive strategy for RMs
Ardalani et al. (2013)	Yes, event-driven process chain (EPC)	No	Yes, new evaluation type through an user interface example is presented	Study presents inductive RM development that bases on existing individual projects
Malinova et al. (2014)	Yes, unified modeling language (UML)	Yes	No	Study provides organizational support for process mapping
Martens et al. (2014)	Yes, formal model using minimal graph-edit distance	Yes	Yes, new procedure is tested via software prototyping	Study presents new procedure for inductive RM development
Vom Brocke et al. (2014)	No, structural/ argumentative study	No	No	Study provides framework for business process management
Martens et al. (2015)	Yes, formal model using factor analysis	Yes	Yes, in various application scenarios, new evaluation type is shown	Study presents new procedure for inductive RM development

expert interviews. And consequently, our approach may include virtually any written form or document. In the following, we distinguish between qualitative and quantitative analyses.

While a qualitative analysis may be seen as an ex-ante analysis prior to RM creation, a quantitative content analysis may be used as a metric-based evaluation of preexisting knowledge via data mining. A qualitative analysis constitutes a review of the existing relevant literature or documents and is an elementary feature of any research project as it facilitates theory development and accelerates research knowledge (Webster and Watson, 2002). In IS research literature, there are many papers guiding a systematic document analysis (e.g., Webster and Watson, 2002; Levy and Ellis, 2006; Okoli and Schabram, 2010). As an adequate knowledge building is strictly linked to existing knowledge in related work (e.g., published IS articles, transcript interviews), the execution of the analysis should follow a clear structure. For instance Fettke (2006) proposed a five-stage model that consists of issue description and definition of the research field, document search, document evaluation, document analysis, and interpretation. In order to ensure relevant results and to better understand the nature and characteristics of the model artifacts, developers of RM should search for similar issues in scientific and practical documents (e.g., by keyword-oriented searches in scientific and practical data bases). Moreover, it is important to find similarities and differences in RM literature in order to avoid redundant work and uncover new application possibilities. Unfortunately, the term RM is not clearly defined in literature, which makes it necessary to search for adjoining terms and research fields. Although the leading papers on the issue of literature analysis provide orientation tables and best practices (e.g., Frank, 2007; Vom Brocke et al., 2014), the fact that there are vast amounts of documents as well as unclear terms may lead to a relatively high degree of subjectivity in both document search and document evaluation. Thus, although the execution of qualitative document analyses is time-consuming and requires a considerable analysis effort, it is compellingly needed for the design process of RMs. Further, the inclusion of other information sources such as social/expert networks may lead to valuable insights for qualitative analysis as well.

In contrast, the quantitative content analysis, which we equate to the bibliometric analysis, leads to more objectivity. Due to the computer-assisted processing, also vast amounts of papers, books, transcripts and other documents can be involved. This should, however, not tempt a researcher to increase the amount of documents indiscriminately. The computer-assisted evaluation process runs in a clearly defined way, which ensures at least reliability. Acknowledging Lijphart (1971), the quantitative content analysis constitutes a suitable methodology for knowledge development and theory proof, particularly when having an imprecise underlying theoretical background. Towards this end, we go in line with Becker et al. (2004) who understand theory as consensus theory. They further consider a theory to be proved as valid when all related parties accept it under optimal conditions. Towards this end, quantitative data analysis can help to grasp the general theory acceptance of the related parties by analyzing the relationship of contents more in detail and on a wide basis. Moreover, an adequate quantitative content analysis of textual

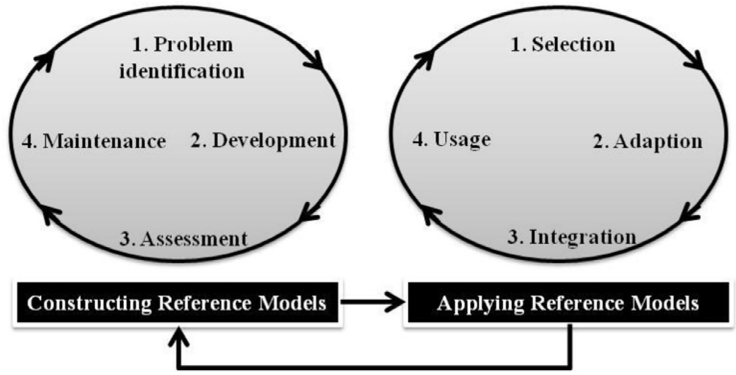

Fig. 1. Reference modeling process (adapted from Fettke and Loos, 2005).

messages has to fulfill certain requirements (Neuendorf, 2002, pp. 10), which are determined as: objectivity, intersubjectivity, a priori design, reliability, validity, generalizability, replicability, and hypothesis testing. There are various document mining software solutions available (e.g., WordStat by Provalis, 2010), yet comprehensive solutions require a lot of preparation work, such as spell checking of the individual documents, removal of hyphens and hyphenation, removal of brackets and braces, as well as lemmatization or stemming reduction. Once a data basis has been generated, various analyses can be performed (e.g., total word or term frequency or inverse document frequency). In the context of this paper, there is one specific feature that is especially promising, as it provides more objectivity during the metric assessment phase of constructing RMs: This feature enables calculating the conjoint appearance of words (1:1, 1:n, n:n) and is called co-occurrence. Formally, the co-occurrence (*CO*) is a weighted, undirected calculation of the form:

$$co = (w, c, f)$$

where *W* is the set of all words in the sample or corpus, and *C* is the set of all pair-wise co-occurrences across words deduced from the episodes in the corpus. The underlying co-occurrences calculation in the corpus is indicated by the function *f*. The co-occurrence count for two words is defined by $w_i, w_j \in W$. For analyzing these interrelations, e.g., the Jaccard's index (*JI*) similarity coefficient can be used. This kind of measure is especially appropriate for word analyses in a sample of documents (Murguia and Villasenor, 2003; Tan et al., 2005) and is defined by:

$$JI = \frac{a}{a + b + c}$$

where *a* represents a document's paragraph in which both words w_i *and* w_j occur, and *b* and *c* represent paragraphs in which one word is found but not the other (Tan et al., 2005). Hence, when having created a first piece of the RM, it is possible to calculate the co-occurrence of the related terms in the RM in order to investigate the interrelations of the terms. For instance, when using the entity relationship model as the RM language, the co-occurrences of specific attributes and their entities may be calculated for investigating the data base's most discussed attributes of entities. As some attributes may have higher co-occurrences, they may hence have a higher discussion relevance than others. Contrary, when having significantly high co-occurrences that are missing in the RM, the completeness and fit of the actual RM can be questioned. This procedure will allow an additional and more objective evaluation step by grounding developed RMs stronger in related scientific and practical work.

2.3. Understanding the reference modeling process

As mentioned in Section 1 of this paper, there is no clear definition of the RM terminology. But there is general consensus that RMs constitute aggregated models, generic models, or theoretical models that have to be adapted to the specific conditions of enterprises and projects. For the upcoming determination of requirements, especially the universal process model on RM design proposed by Fettke and Loos (2004) constitutes an adequate basis, which we briefly explain. Looking at the construction process in Fig. 1, the *problem has to be identified* by investigating the key issue in the IS by means of the relevant resources, roles, responsibilities, and interrelations. Derived from the identification of the problem, a viable model artifact has to be *developed*, which demands an adequate degree of abstractness with a clear communication. Fettke and Loos (2004) emphasize that the quality of the artifact has to be ensured before completion of the RM. Herewith, reliable and valid *assessment* measures have to be selected and applied. The assessment should be carried out as neutral and objective as possible in order not to mislead potential users. The *maintenance* phase constitutes the last step of the construction process and comprises correction, adjustment, and/or extension of the model artifact. The extent to which amendments have to be made is thereby highly dependent on the outcome of the assessment phase. In order to apply a RM, the user has to *select* an adequate RM, *adapt* it to the specific issue, and *integrate* it. The assessment results do not only support the developer during the construction process, they also help the user to select the correct RM. Finally, the experiences gained from applications should be traced back to the abstracted constructing process, which ensures an evaluation of the RM. In Section 2.4, we link this process model to the general requirements on design science by Hevner et al. (2004), and we extend the existing body of knowledge by considering a stronger qualitative and quantitative regard to related work in the overall RM construction process.

2.4. Determining the requirements for viable reference model design

In this section, we intend to investigate and establish a general requirements guideline for RMs. Towards this end, we use the design science guidelines provided by Hevner et al. (2004) as a basis and transfer them to the RM requirements guideline. According to March and Smith (1995) and Peffers et al. (2007), design science is about creating innovative problem-solving artifacts, such as model, methods, and constructs. Hence, we argue that reference modeling may constitute a subgroup of design science research. Not surprisingly, we found that papers on RM coincide with papers on design science in one major aspect: In both cases there is a more or less intensive separation in two sub processes (Vom Brocke, 2003; Fettke and Loos, 2004; Becker et al., 2010; March and Smith, 1995; Hevner et al., 2004), namely the *construction process* and the *application process*.

For the improvement process in design science, Hevner et al. (2004) describe seven generally accepted guidelines. We take these guidelines as a basis (cf. Table 2) and transfer them to the context of

Table 2
Reference model requirements.

Guideline from Hevner et al. (2004)	Reference model requirement (RMR)	Role	Description of reference model requirement
Problem relevance	RMR1: Problem definition	From the developer perspective	The key issue has to be investigated with its related resources, roles, responsibilities, and interrelations.
Research contributions	RMR2: Qualitative document verification	From the developer perspective	The problem of the outstanding RM has to be set in relation to existing literature (and – if any – with existing RMs) via a qualitative document analysis. It has to be clear whether the new RM aims to extend, replace, or improve already existing RMs.
Design as a search process	RMR3: Iterative construction	From the developer perspective	The new RM must be developed iteratively; through searching for solutions in related work, adopting RM, and/or proposing new ways; and, if necessary, through refinement.
	RMR4: Iterative selection	From the user perspective	The RM has to be substantiated iteratively via a search and selection process. Compared with other models, it is necessary to explain how and why the new model is accepted as a reference.
	RMR5: Iterative adaption	From the user perspective	The generic RM needs to be adapted iteratively to a company- or project-specific model. The adjustments, replacements, or extensions as well as the implementation/integration process have to be clarified in width and depth.
Research rigor	RMR6: Selection of methodologies	From the developer perspective	The new RM may have various abstraction levels and may include methods, languages, and tools, which have to be selected and adopted accordingly to the underlying issue.
Design as an artifact	RMR7: Development of sections	From the developer perspective	Due to the multifaceted nature of RMs, the new model can normally not be produced from one single source only. It rather has to be created in sections, whereby every section has to be based on preexisting knowledge gained from documents and tested for validity prior to integration into the overall RM. Only in this way it will be possible to create a viable artifact.
Design evaluation	RMR8: Knowledge-based evaluation	From the developer perspective	As a new RM always constitutes a new theory, it is necessary to evaluate the RM through an IS knowledge-oriented perspective. This may include analytical evaluations (e.g., meta-model-based evaluation (RMR8a)), and metric-based evaluation (e.g., quantitative data analysis of documents and/or transcripts (RMR8b)).
	RMR9: Empirical assessment	From the user perspective	After having applied the RM in empirical environments, the usefulness, the quality, and the effectiveness of the intermediary outcomes need to be measured with scientific methodologies.
Communication of research	RMR10: Literature enrichment	From the developer perspective	The results from RMR1 to RMR9 must adequately and scientifically be documented in a technology-oriented as well as management-oriented way.

designing RMs. Furthermore, we augment the guidelines by stronger anchoring RMs in related work. We explicitly stipulate that a qualitative document review is indispensable in reference model requirements (RMR) 2. Further, we follow Fettke and Loos (2003) by calling for a multi-perspective analytical evaluation. This includes not only a qualitative document review prior to the construction phase, but also an evaluation of preexisting IS knowledge (RMR8) after the construction phase, which may include paradigmatic evaluation (such as the guidelines of modeling by Becker et al., 1995; Frank, 2007), meta model-based evaluation, or metric-based evaluations (such as quantitative content analyses, cf. Section 2.2). Moreover, literature argues that there are two more or less separated model processes in the design of RMs, namely *construction* and *application*. Therefore, we distinguish between the developer role and the user (or applier) role, which, however, may ultimately be one and the same actor. This abstraction helps us to indicate that a certain process is categorized as construction or as application process.

3. Comparison of literature foundations and designs of selected reference models

In this section, we use the ten determined reference model requirements (RMR) for the purpose of comparing already existing RMs. In this way we determine to what degree these models fulfill the requirements. On the basis of this comparison, we extract the existing body of knowledge by presenting a generically applicable process model (cf. Section 4) for designing RMs that are strongly anchored in related work and meet the determined requirements. Subsequently, we exemplarily apply this conceptual process model on the use of cloud services in cross-company supply chain processes (cf. Section 5). In order not to exceed the limits, in our paper, we especially focus on RMs that investigate service-oriented architectures (i) because for these processes, the reusability is of extraordinary importance and (ii) because the service-oriented models differ substantially more from each other than in other application domains (Vom Brocke and Buddendiek, 2004; Becker et al., 2010), which calls for consolidations and a stronger evaluation between the documented service-oriented models. Towards this end, we define service-oriented architectures as a paradigm of structuring and using of distributed IT-functionalities that are assigned to diverse users (Brown et al., 2012). But at the same time, we emphasize that the upcoming conceptual process model for reference modeling may also be applied in various other research-driven environments. As a precondition for an adequate comparison, the existing service-oriented models need to meet RMR10, because only RMs with a clear documentation and communication can be compared with each other. Becker et al. (2009) have classified three ascending documentation degrees: (1) documentation includes comparison with existing models, (2) documentation roughly includes the steps of design and evaluation processes, and (3) documentation includes a comparison as well as the steps of design and evaluation processes in detail. In line with Becker et al. (2009), we considered only RMs that fulfill the third level.

As a source for comparing service-oriented RMs, we used the catalogue provided by Becker et al. (2010). They conducted a systematic literature review by searching for service-oriented RMs in various well-recognized conference proceedings and journals as well as in standard setting organizations. As a result, they found 18 service-oriented RMs (including 3 integrated RMs that discuss the intersection of services and physical goods). In order to identify relevant RM publications, we extended the search process by considering three scientific databases (EBSCO, Science Direct, Springer Link). Moreover, we took publications until 2014 into account. Finally, we conducted a forward and backward search (Webster and Watson, 2002). Due to the fact that the term "reference model" has been used very frequently in the meantime, we considered only papers that are in line with our understanding of reference modeling (cf. Section 2.3). By means of this approach, we yielded another 13 service-oriented RMs. Hence, we identified a total of 31 relevant models. In the next step, we excluded all those papers that do not distinguish between construction and application phase. Thereafter, each of the selected models was checked for compliance with the third documentation type in RMR10. On the basis of this appraisal, seven RMs proved to be well documented. These seven works have been checked synoptically in terms of RMR 1 to RMR 9. However, in more than three quarter of all published, service-oriented RMs the design and evaluation processes are not adequately documented. This fact reaffirms us in our intention to more strongly anchor RMs in preexisting research knowledge. As we used RMR 10 as filter for the identification of the 31 papers, this requirement will not be reinvestigated again. In the following, we briefly discuss the seven RMs and present an overview in Table 3.

The first model is the ECO-integral RM (Krcmar et al., 2000). It was designed as an open standard for linking ecological aspects with management information systems. Herein, various institutions, consulting companies, service providers, as well as case companies participated. The second RM constitutes a combination of organizational aspects and software development processes (Duarte et al., 2006), while the third RM represents a mixture of a reference model, a maturity model and a balanced scorecard (Martens and Teuteberg, 2009). The paper investigated fundraising activities at academic institutions with a strong focus on organizational responsibilities. Derived from an extensive literature review, the RM aims to create a management information system. The fourth model deals with a functional RM for increasing the quality at master data management (Otto et al., 2012). It stands out for being constructed over more than three years and having three iteratively developed versions. Furthermore, the results of the case company indicate that the model can easily be transferred with relatively low costs. This is indicated for the fourth RM as well. With this, Winkelmann (2012) proposes a new and effective way for RM maintenance. However, Czarnecki et al. (2013) provide an abstracted process guideline for telecommunication companies in a transformation process towards integrating and bundling new business models and innovative technologies. Finally, Keller and König (2014) created a model that supports risk identification in cloud computing networks.

It is noteworthy that the publication types of the respective RMs' results are manifold, ranging from a single conference paper (Keller and König, 2014; Mertens and Teuteberg, 2009), to chapters in books (Duarte et al., 2006), to research journals (Czarnecki et al., 2013; Otto et al., 2012; Winkelmann, 2012), and large processing reports covering several hundred pages (Krcmar et al., 2000). Beyond that, it is remarkable that in the design of all seven cases, the qualitative document review was made prior to the model development. This does not only support the RM developer and the RM user during the design process, it also allows the interested reader to understand the issue relevance and the contributions. Moreover, all RMs were constructed via an iterative process, in which expert interviews, standard setting bodies, or case studies led to valuable feedback and redesign. In general, this was well documented and communicated. In terms of knowledge-based evaluation (RMR8a), Otto et al. (2012) provide the most comprehensive theoretical evaluation, after having constructed the final RM. They describe the theoretical IS requirements for orderly modeling and assess their RMs accordingly. Nevertheless, neither the selected papers nor the remaining papers used a bibliometric-oriented assessment during the theoretical evaluation of the RMs (RMR8b). This creates the impression that the developers either do not attach importance to this research method or they deem it difficult to find and adapt adequate measurements to their RMs. Hence, in Section 4, we follow Fettke and Loos (2003), who encourage researchers to consider more metric orientation in the RM design evaluation. This entails useful and hidden insights in the RM creation.

4. Conceptual process model for designing bibliometric-oriented reference models

In this section, we propose a conceptual process model for the development of a RM that is strongly anchored in literature. Constructing a new process model or a method from preexisting methods is typically a research contribution in the domain of method engineering (Harmsen and Saeki, 1996; Hendersen-Sellers at al., 2014). In general, method engineering is a well-recognized classic research field that involves a broad range of approaches and concepts. As one of the first researchers in the domain of method engineering, Mayer et al. (1995) have proposed an approach that includes a more process-oriented view. Therefore, we take this approach as basis and align our upcoming model to the chosen method engineering process model (MEPM). By discussing the single connection points between the MEPM and our model, we aim to show the already existing implicit closeness between research on RM and method engineering (cf. Fig. 1 in the appendix for more details on MEPM).

The elements of the model (cf. Fig. 2) are mainly derived from the determined RM requirements (cf. Table 2) and from the insights gained from the presented, well-documented RMs (cf. Table 3). Therefore, our conceptual process model generalizes the design process of the reviewed, well-documented RMs and provides a great basis for the development of future RMs. For the depiction of our conceptual process model, we use business process model notation (BPMN) 2.0. In general, BPMN provides an intuitive and process-oriented notation that enables researchers from theory and practice to standardize and structure complex process semantics (Ko et al., 2009). Moreover, we link the single RMR to the specific elements by means of black circles in Fig. 2. In the conceptual process model (cf. Fig. 1), there is a differentiation between development phases and application phases. In the next paragraphs, we discuss the single phases. Moreover, we want to motivate research and practice to document every single event in the phases in order to be compliant with the third level documentation requirements (cf. Section 3).

Starting with the construction phase and the problem identification (RMR1), all seven RMs discuss their issues with the related resources, roles, responsibilities, and interrelations and demonstrated very clearly the actual demand at that specific point in time for the new model. In most cases, this takes place in the introduction section of the works. Nevertheless, it is obvious that in models with a strong initiation by practice (e.g., Krcmar et al., 2000; Duarte et al., 2006) the problem descriptions have a higher relevance than in models that are mostly research driven and indicate a lack of practical experience (e.g., Keller and König, 2014; Winkelmann, 2012). Not surprising, the MEPM begins with document motivation as well [step 1], including almost the same issues such as the identification of shortcomings, opportunities and potential users.

After the problem identification, we propose to proceed with the qualitative document review of preexisting research knowledge (RMR2). In this regard, only the paper by Czarnecki et al. (2013) constitutes an extension of an already existing RM, whereas the other works obviously did not find comparable solutions, which especially Keller and König (2014) emphasize. Although the results of the qualitative document review were well-documented, we missed the documentation of the search process for the identification of relevant documents and comparable models for all seven cases. It thus remains unclear what publication organs were used and which research directions were included or excluded. Therefore, we would like to motivate research to apply a more scientific approach with respect to RMR2. At

Table 3
Comparison of selected reference models.

Reference model requirement (RMR)	Source						
	Krcmar et al. (2000)	Duarte et al. (2006)	Martens and Teuteberg (2009)	Otto et al. (2012)	Winkelmann (2012)	Czarnecki et al. (2013)	Keller and König (2014)
Problem identification (RMR1)	How can company-specific ecological data be generated and analyzed, and how can these data be integrated into the enterprise resource planning system? Further: How can top management be involved?	How can an organizational platform for a software provider be created that encourages a clear way to control and define software development processes?	How can academic institutions be supported in intensifying their fundraising activities?	How can the quality of companies' master data be increased, and how can adequate system support be provided for master data management?	How can a procedure model for updating and maintaining RMs be created with regard to the implicit system knowledge? (Knowledge within enterprise resource planning (ERP) software)	How can telecommunication companies be supported during their transformation process towards creating innovative services bundles?	How can cloud actors identify risks in cloud networks and increase the transparency in network structures?
Qualitative document verification (RMR2)	Use the principles and instruments from the "Eco-management and audit scheme (EMAS)" and "ISO 14001" as a basis.	The paper provides analyses on related work in terms of process-oriented organization and change management. RM is extension of own, previously created work.	Review the literature on fundraising from a psychological, organizational, technical, and economic perspective and evaluate the most important issues.	Review the literature on master data management and data quality management, before deriving business requirements of both fields for a functional RM.	Reviews the literature on the reuse of RM as well as parameterization and customization, before coming to own research objectives.	Analyze enterprise architectures (e.g., ANSI/IEEE Standard 1471-2000), and enterprise architecture frameworks (e.g., Zachman framework), RM is extension of existing RM.	Ground the model on an extensive literature review by including developments, actors and risks in cloud networks. No comparable RM was found in literature.
Iterative construction (RMR3)	Application in four case companies led to gradual modifications of the RM.	Iterative construction process is clearly described by customization of RM contents in order to meet user requirements.	Findings from an application at a university and participating academics led to iterative improvements.	Knowledge sources for the first design iteration are presented. Qualitative interviews and a participative case study led to three iteratively created versions.	Model consolidation is applied, namely by iterative integration of new elements and elimination of obsolete parts.	RM was applied in two case companies in emerging regions. After the application adjustments were needed at operational level.	Modeler applied a multi-method approach with two rounds of interviews and real world examples. The received feedback was incorporated into the model.
Iterative selection (RMR4)	The using companies accept the model as a reference, because it stands out by providing cost transparency and management support.	The RM was initiated by the case company, requiring an instantiation of their processes with the rational unified process (RUP) method. No other suitable RM was found.	The user demands an integrated solution with a "balanced scorecard" and a maturity model, which is provided by the RM.	The model is a suitable basis for identifying unnecessary application system licenses and potentials for consolidations.	A company with specialization on food retailing required a procedure model that allows ongoing maintenance of existing RMs without significant entry barriers.	An acknowledged standard setting body (TM Forum) included RM processes in its framework as they force standardization in service compositions.	Due to the newly emerging and mostly hidden risks from cloud networks, the developers create a RM that is confirmed by interview partners to be the new reference.
Iterative adaption (RMR5)	In-depth company-specific extensions have been made by defining and determining specific data, such as bill of material.	RM contains a reviewer part that continually refines the business processes as well as roles and responsibilities.	Institution-specific processes and roles have been considered, before creating an overall data base.	Based on the case companyś SAP application landscape, the RM was applied for rating functions and creating tables.	Two modelers collected and evaluated processes and data of the ERP system on the requirements derived from the case study.	A vast amount of adjustments and refinements were needed in order to align RM processes to company-specific information systems.	The model is instantiated with real world cloud actors by describing dependencies and extending the initial RM.

(*continued on next page*)

Table 3 (*continued*)

Reference model requirement (RMR)	Source						
	Krcmar et al. (2000)	Duarte et al. (2006)	Martens and Teuteberg (2009)	Otto et al. (2012)	Winkelmann (2012)	Czarnecki et al. (2013)	Keller and König (2014)
Selection of methodologies (RMR6)	Architecture of integrated information systems (ARIS) has been used as a method in combination with event-driven process chains (EPC) and function trees as semi-formal modeling languages. No additional tools have been used for RM design.	The use case models are determined with the help of UML activity diagrams. Formulas have been created for employees' compensation. Their roles and activities are depicted in simple tables. No additional tools have been used for RM design.	UML notation has been used for the overall RM. Sub-processes are explained with event-driven process chains (EPC). Neither overall methods tools nor theoretical tools have been used for RM design.	Architecture of integrated information systems (ARIS) has been used as a method. The modeling languages followed the principle of process maps in tabular form. No additional tools have been used for RM design.	The interaction patterns are formalized as event-driven process chains (EPC) and UML diagrams. Data requirements are formalized with entity relationship models (ERM) and UML diagrams.	Semi-formal process mapping figures have been used. Took the existing tool "enhanced telecom operation map (eTOM)" as a basis and integrated additional reference process activities in various levels.	A simplified version of UML notation with class diagrams has been used as a semi-formal modeling language. For displaying actors and risks, tree based structures were applied. Neither overall methods tools nor theoretical tools have been used for RM design.
Development of sections (RMR7)	Various aspects such as legal requirements or financial conditions have been derived from literature and integrated as sections into the RM.	Researchers start the real life application with the relevant organizational units before coming to business objects and other business artifacts.	The reference model consists of seven sections, such as maturity model, balance scorecard, data base, or roles.	The model comprises six function groups, where every function group bears reference to research and is described in detail.	The developer differentiates between an external view (e.g., system analysis, model consolidation) and an internal view (refinement of sub-processes).	Take service bundle definitions from literature as a base for classifying four sections in RM, namely customer, product, service, and technical network.	Overall RM consists of two partial models: connections between actors; causalities between hazards, risks, and reinforcement.
Knowledge-based evaluation (RMR8)	After the development phase, the overall RM has been evaluated, provided it is consistent with the generally accepted research guidelines.	The practice-driven RM was evaluated by quality assessments as milestones between phase transitions. No research guidelines proof.	The evaluation procedure is not described in detail in the paper, but expert interviews with various IS researchers approved the validity.	In order to evaluate the validity of the artifact design, the developer assessed the model with theoretical guidelines for orderly modeling.	The evaluation procedure is not described in detail in the paper, but expert interviews approved the validity.	Evaluation and approval have been made through the standard setting body (TM Forum).	In order to enhance the quality of the RM, the developer used the theoretical guidelines of modeling.
Empirical assessment (RMR9)	The usage at the four case companies indicates that the benefits from cost savings overcompensate the implementation costs, and reduce waste at the same time.	RM benefits the individual performance in software development processes as well as drives premium wages.	The application of the model decreases the efforts for structuring fundraising activities and created a better understanding through its integrated approach.	From the case companyś economic perspective, the application costs are low and from the deployment perspective the model is easy to understand and well applicable.	The paper indicates that the case company could maintain its ERP reference model more effectively by using the proposed consolidation method.	The two case companies are able to operate more efficiently without having any additional costs.	The real life application displays the dissemination of risks through the cloud network, where the actors are able to identify the impending risks.

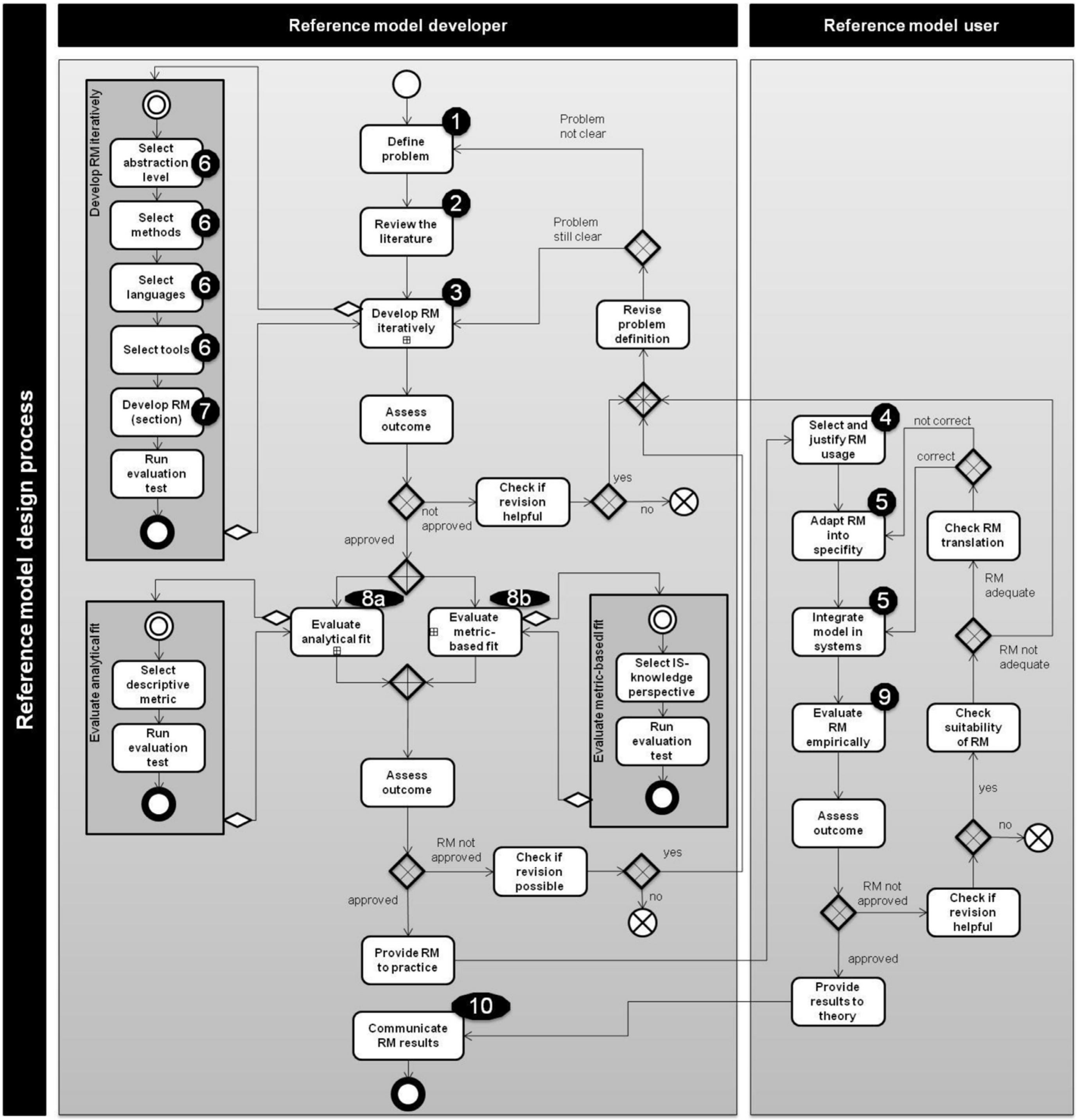

Fig. 2. Conceptual process model for designing reference models.

the MEPM, this phase is called "search for existing methods" [step 2], constituting the base for the important construction phase.

The main phase of our conceptual process model is the iterative RM construction, which is derived from RMR3. All of the synoptically investigated works provide more than one construction loop. Due to the diversity of the underlying issues, the conceptual processes within this phase are varying accordingly. In summary, the following sub-processes have been used: selection of abstraction level, methods, languages, and tools (RMR6). After these sub-processes the development of the RM takes place (RMR7). Concerning the abstraction level, for instance the RMs by Krcmar et al. (2000) or Czarnecki et al. (2013) display a more detailed structure than the RM by Keller and König (2014), which again may be led back to the strong initiation by practice of the former. The highest abstraction degree is needed for the overall RM architecture (Becker al., 2009). Moreover, none of the RMs discusses methods, languages, and tools at the same time, but all RMs are designed with a clear description of the underlying semi-formal languages. However, in most cases the model development cannot be based on one single source only, but has to be created section-wise. Thereby, every section has to be tested for validity, before it is integrated into the RM. The integration of a section may lead to exclusions or needed adjustments in other sections, which is indicated by the iterative process flow in the conceptual process model. Unnecessary sub-phases during the construction process can be left out, which is the case with all seven RMs. Afterwards, the developed construct must be tested for comprehensiveness, consistency, and problem relevance (Becker et al., 2009). During this phase, for instance, Keller and König (2014) conducted a first round of interviews, in which they asked questions with regard to the determined sections. Towards this end, Duarte et al. (2006) conducted quality assessments between every milestone. Comparing our model with MEPM, this phase is the most intensive, too. Basically MEPM proposes three exclusive ways before grouping them [steps 3–6], namely (i) adopt, or (ii) adjust existing methods, or (iii) develop new ones (creation of a new ontology, distillation of best practice, design of languages). It is obvious from both process models that the details of this phase are highly depending on the underlying issues; making it hard to provide more specifications and preserve the scientific manner at same time (we will be more precise on this phase in the application Section 5).

In the next phase, an analytical evaluation (RMR8a) takes place. Thus, it has to be assessed whether the overall model is in compliance with the generally accepted guidelines for reference modeling such as semantic correctness. Otto et al. (2012) entirely completed this evaluation. They used well-known frameworks (Becker et al., 1995; Frank, 2007) in order to test the theoretical validity. In parallel with the theoretical evaluation of the model via a qualitative approach, we integrate a metric-based evaluation in the next phase in order to motivate research to conduct objective measurements (RMR8b). Matured metrics have been proposed, e.g., by Moody (1998). Even if these kinds of measures do not allow for absolute conclusions (Fettke and Loos, 2003), they provide a great basis for the operationalization of the single elements and make hidden issues transparent. Hence, this subprocess contains the selection of adequate metrics, the evaluation process and the test of the RM elements. This two-sided evaluation step is one of the major contributions of the paper to research on RM. Whereas, most process models include an evaluation section (models in Table 1 and [step 7 in the MEPM]), the description of the evaluation phase is often vague and encapsulated from existing knowledge. The case study in Section 5 will show the exemplarily functioning of RMR8 and RMR8b more in detail.

In the phase following the theoretical design of the RM, the user has to substantiate his decision to use a specific model as reference prior to transferring the model (RMR4). Even if the initial problem identification and definition may be derived from practice, the user may not accept the theoretical model as suitable for his specific issue (which is unlikely in cases where the developer and the user are the same). The seven selected cases do not directly describe this phase, but they indicate that the uniqueness and relevance of their respective models constitute the best available solution for the user. Thereafter, the RM has to be translated and integrated into company-specific or project-specific environments (RMR5). In most cases, the application of the model requires software support, as the used information systems have to be replaced, adjusted, or extended in terms of the RM. This may include uploading of specific files and tables (Otto et al., 2013; Winkelmann, 2012), customizing of management information systems (Krcmar et al., 2000), or implementing new features (Czarnecki et al., 2013).

Furthermore, according to requirement RMR9, the empirical evaluation should establish whether the RM provides the assumed benefits and an improved solution for the defined problem. The defined goals are to be compared with real-life observations. Here again, objective scientific measures and methodologies are required. The advantages may be of a material and a non-material nature, whereby the latter is very difficult to measure. Not surprisingly, all seven cases presented the benefits in an argumentative–deductive manner, while two works highlighted the gained economic advantages (Czarnecki et al., 2013; Krcmar et al., 2000). The empirical results indicate the validity and suitability of the model from the application perspective. If the results turn out to be as expected, the model could serve as a reference and may be applied to related issues. This requires an adequate communication within research and practice. In order to be compliant with RMR3 and enable learning possibilities, we involved exclusive gateways after every "assess outcome" (cf. Fig. 2). Hence, the conceptual process model requires decisions for RM rejection, revision, or acceptance. This phase is assigned to "iteratively refine method design" [step 8] in the MEPM as the last phase.

Before coming to the application part in Section 5, we briefly explain the relation between our conceptual process model and the well-recognized models of design science research by Hevner et al. (2004) and MEPM by Mayer et al. (1995).

We start with seven guidelines of design science, out of which we derived ten RMRs (cf. Table 2). Further, design science research consists of three cycles (relevance, design and rigor cycle) that link the three underlying areas iteratively (Hevner, 2007): (i) *environment*, (ii) *knowledge base*, and (iii) *design science research*. To be more precise as to our conceptual process model, the *RM user elements* of our model (cf. right line of Fig. 2) could be interpreted as the *environmental* elements of Hevner's (2007) design science model. On the other hand, the *RM developer elements* of our model (cf. left line of Fig. 2) might involve the remaining two underlying areas (*knowledge base* and *design science research*). Although there typically is a clear separation between the two areas, this separation would not be beneficial in our model. This is because we focus on subsequent RM development process steps and switch between *knowledge base* and *design science research* often (instead of providing a general overview of important areas). Further, we aim to link the defined RMRs to specific process steps in our model, which is done by Hevner et al. (2004) on a more aggregated level as well. To sum up, we take another, more process-oriented perspective on the research of RM design.

Compared with MEPM, we go in line with Mayer et al. (1995) by aiming to advice activities, objectives and roles at every research phase. This alignment is the result of taking a more process-oriented view. However, MEPM is a strongly practice-driven approach and beneficial especially for modeling languages. As such, there is no clear separation between the construction phases and the application phases. As our approach is part of research on RM, we follow this strict requirement (cf. Fig. 1) and hence, we are more precise than MEPM in terms of the needed separation. Moreover, MEPM evaluation processes are much more encapsulated from existing knowledge, which is seen critical as well (Tolvanen et al., 1996; Hendersen-Seller, 2014).

5. Exemplary application of the conceptual process model

5.1. Problem identification

As already mentioned, in this section we apply the presented process model for developing a RM to the application specific topic of cloud usage in inter-company supply chains (SC). In order to keep the paper focused, we do not discuss all underlying development and evaluation phases in detail. However, we aim to explain the general functioning and the strong literature regard in the RM development and include scientific knowledge only. This section is a concise version of the original research made by Jede and Teuteberg (2014). Contrary to the original paper, we focus more on the RM development processes and describe the relevant evaluation steps more precisely (cf. Table 1 in the appendix for more details on every single RMR step during the RM design process).

In general, SCs face consistently big challenges as the complexity and the dynamics of contemporary SCs increase. At the same time stakeholders require SCs to be environmentally friendly, social, and profitable. Therefore, it is essential to select and adopt suitable information systems that support the preexisting challenges of specific SCs. Due to the fact that IT processes are becoming more and more stable and flexible, e.g., through scalability and virtualization (Bharadwaj et al., 2013, Hoberg et al., 2012, Pereira, 2009), both research and practice hope to obtain benefits from cloud computing (CC). [1] We are motivated by the circumstance that the mostly assumed advantages of CC usage at SC processes lack a profound theoretical basis, since the current research is still at an early stage in both theory and practice (Marston et al., 2011). Up to now, the bulk of publications on CC focus especially on the technical aspects (Böhm et al., 2010; Fremdt et al., 2013). Interdisciplinary conclusions and recommendations for specific business areas (Hoberg et al., 2012), such as supply chain management (SCM), are scarce (Blau et al., 2009; Leimeister et al., 2010). Notwithstanding that first noteworthy successes have been reached (Meer et al., 2012), the construction of cloud based SC systems remains significantly more challenging than of traditional systems. We argue that this is partially because researchers and practitioners suffer from the lack of aggregated or general models with a precise structure and vocabulary for explaining and describing the key architectural characteristics of CC usage in SCM. The underlying key issue is (RMR1): Which elements should be considered to design an adequate RM for integrating CC in SC processes? Eventually, derived from literature analysis and applied in a participative case study, we present a RM, that supports SC managers during the conceptual phase of CC implementation and serves as a solid base for further specific information models (Ahlemann and Riempp, 2008; Thomas, 2006; Otto et al., 2012). We discussed the lack of such RMs with industry experts in order to guarantee the relevance of the problem. Further, our intention meets the requirements for investigating CC in a more interdisciplinary context (Bardhan et al., 2010) by including the intersection of the science disciplines information systems (IS) and SCM as well as by using a multi-method approach during the development and evaluation of the RM.

5.2. Qualitative literature review

We pursued a systematic knowledge building that is strictly linked to the published work (RMR2). The execution of the analysis is closely related to the described five-stage model (cf. Section 2.2) of Fettke (2006) that contains problem description and definition of the research field, document search, document evaluation, document analysis, and interpretation. During the 2nd stage, we used keywords and considered 33 top rated IS journals and 31 top rated SCM journals, that were derived from selected journal rankings. By adopting this approach, we determined 99 papers in total. During the literature search phase, we identified no comparable RMs. The 99 papers have been completely reviewed and clustered via a predefined framework. Hence, the underlying taxonomies are grounded on existing literature in CC and SCM, and then elaborated with our own critical reflection. Within this framework, wherever possible, we included the single papersémpirical findings as well. Finally, with the predefined framework, we identified connections between actors and the causalities between different external and internal service resources.

However, literature foresees three specific advantages of using CC in SC networks: (i) agility, (ii) collaboration, and (iii) knowledge sharing. In terms of ***agility***, we pay special attention to interoperability, compatibility, configuration, deployment, portability, scalability, virtualization, automation, and the standardization degree (Cegielski et al., 2012; Wind et al., 2012, Bharadwaj et al., 2013, Blome et al., 2014). The second advantage is related to coordination and ***collaboration***. It is in particular the prevailing information asymmetry in cross-company supply chains that hinders an assigned employee to create, propagate, and coordinate a production or distribution plan for the entire supply chain (Leukel et al., 2011). Therefore, what is required for the overall SC success is the willingness of the parties involved to collaborate and coordinate. And CC is predestined to create transparency as well as a higher quality of data (Morgan and Conboy, 2013; Azevedo et al., 2013) along the entire SC. The third advantage is related to information and ***knowledge sharing***. Towards this end, CC acts as a medium for cross-company analyses of data, process planning, and finally for decision support systems (Cegielski et al., 2012). We further interpret the results in Section 5.3 with the aid of the eight underlying sub-models.

[1] Within this paper, we focus especially the public CC type, while emphasizing that other deployments such as community CC might be beneficial as well.

5.3. Iterative reference model construction and analytical evaluation

The forthcoming RM summarizes the most important research findings and provides a common ontological framework and standard for the characterization of CC usage in SCM. By drawing analogies between the reference components of the section models, various linkages, gaps, and points of overlap can be identified. For future research, it may serve as a basis framework for complementary or build-on models. For SCM practice, it embodies CC adoption suggestions.

Derived from the qualitative literature analysis and based on the sample's empirical and logical findings, in Fig. 3, we designed the first RM that represents the interconnections between CC and SCM (RMR3). The major preconditions, structures, and dependencies were aggregated to elements and linkages between the elements. We depicted the most important factors within the underlying research field as sub-models in grey boxes. These sub-models, emerged from qualitative analysis, constitute RM sections that were constructed and tested separately (RMR7).

Following the conceptual process model (cf. Fig. 2), for the abstraction level we used the highest possible aggregation level (RMR6), namely the architectural level, as we indent to increase the general understanding of CC usage in SCM processes on the holistic system. We select the unified modeling language (UML) as an object-oriented modeling language and use class diagrams for the presentation of the RM. In general, UML is directly compatible to object-oriented programming languages, which supports the upcoming application in ADOit (cf. Section 5.5). Hereby, our RM describes a structured semi-formalized application problem (Rosemann and Van der Aalst, 2007). In Table 4, we briefly describe the eight underlying sub-models that we identified in literature via the qualitative approach. At this point, we would like to stress that the literature sampleś major empirical findings were included wherever possible.

After the construction process, we applied well-known principles, conventions and standards in reference modeling (RMR8a) to enhance the quality (e.g., Ahlemann and Riempp, 2008; Frank, 2007; Becker et al., 1995). Especially due to the high degree of aggregation, we easily proved our overall RM to be correct, relevant, clear, compatible, and systematic (Becker et al., 1995).

5.4. Metric-based evaluation

As mentioned before, for years now research literature has been motivating the research community to use metric-based evaluations for RM design (e.g., Fettke and Loos, 2003; Moody, 1998). We tried to meet this requirement by applying a unique linkage between quantitative literature analysis and reference modeling, namely by co-occurrences (RMR8b). We used the 99 papers as a basis and followed the instruction made in Section 2.2. Herein, we used the document mining software called WordStat. We calculated the co-occurrences of the single elements in the reference model by using the Jaccard's index (JI) similarity coefficient. The calculation of the co-occurrences increased the transparency within our RM remarkably and enhanced the understanding of the most discussed linkages. After having calculated the first round of co-occurrences, we refined the model, structured the elements by co-occurrence values, and re-calculated the

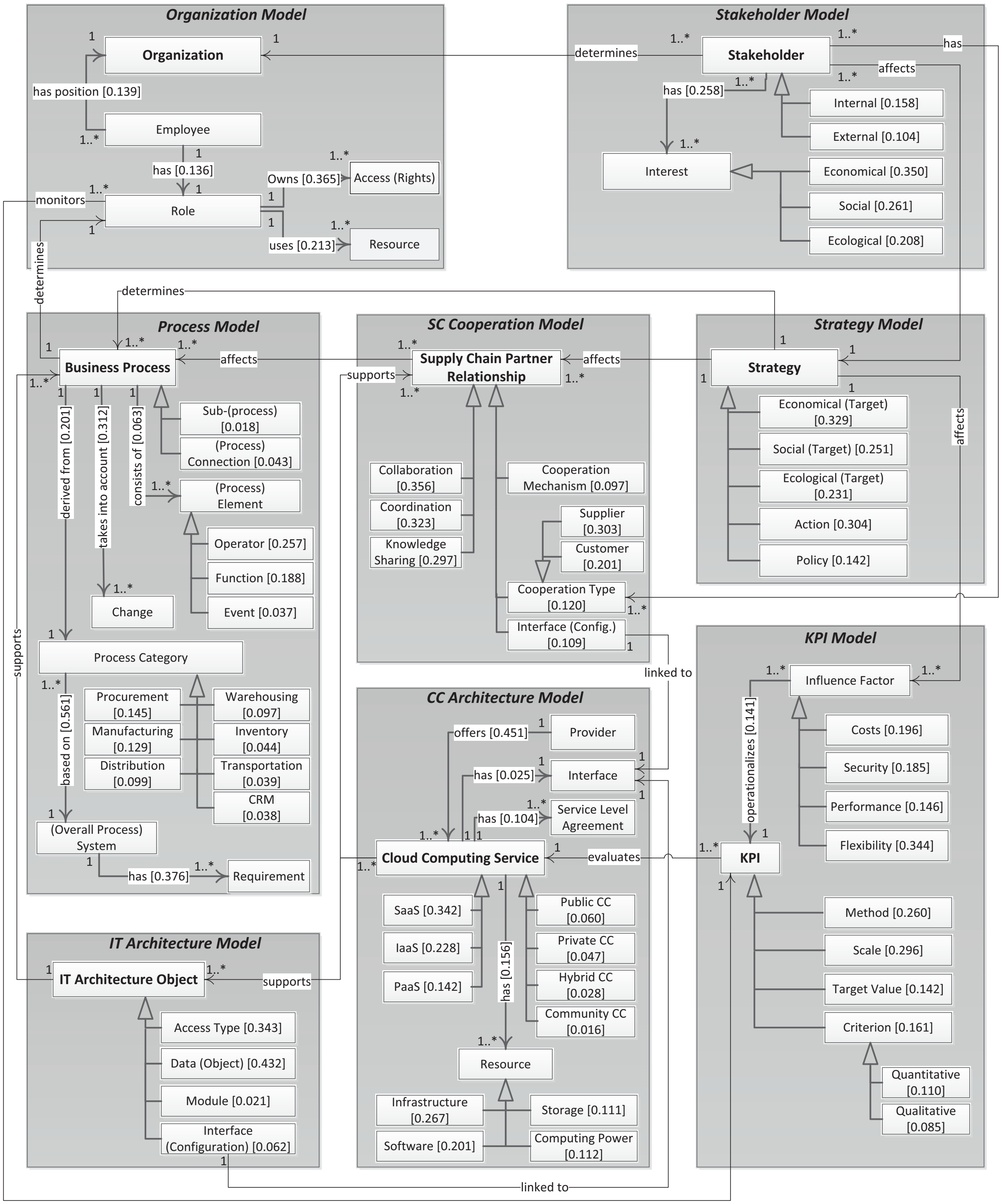

Fig. 3. Reference model for cloud computing usage at supply chain processes.

co-occurrences. Exemplary, we discuss some linkages. As one can see in Fig. 3, social interests in the stakeholder model have a quite high co-occurrence (0.261), when considering the intersection of CC and SCM research. Hence, CC does not only support economic interests but also social and environmental aspects. However, in terms of the process model, the sample literature obviously propagates a general process change (0.321) in aspects of CC and discusses the needed requirements (0.376). Yet, the interface configuration across SC partners, which is essential in practice, is mostly ignored by literature. In case of a structured and standardized SC, the linkage is not as complicated as is the case in a reciprocal, unstructured, or highly problematic SC with de-central responsibilities (Kumar and Dissel, 1996). Due to the researches' argumentation that CC is advantageous, especially for complex SC (Cegielski et al., 2012; Swafford et al., 2008), future research should focus much more CC details, such as interfaces, in order to provide practice with support. However, the overall

Table 4
Literature-based reference model sections.

Section	Description
Strategy model	This model is aligned with the triple bottom line concept. The model assumes that ecological and social responsibility can lead to long-term economic success (Carter and Rogers, 2008). Hence, it is proposed to integrate these three dimensions in the SC strategy (Elkington, 2004). The defined strategy consists of an action plan, measures, and targets for an adequate SC process adoption in order to satisfy related stakeholders.
Stakeholder model	This model involves internal and external stakeholders who may have diverse interests. They influence the company's strategy directly and indirectly. Major external stakeholders constitute standard setting bodies and governmental authorities (Marston et al., 2011). They encourage companies to initiate activities for a sustainable SCM. At the same time they define rules and preconditions for the usage of CC (Leimeister et al., 2010). Internal stakeholders such as shareholders, investors, and managers define the SC strategy, the goals, and their management support (Wu et al., 2013). Contrary, internal employees contribute to achieving the targets and goals through their efforts and commitment.
Organization model	This model determines the organizational units and roles that have to be established, included, or excluded for executing a business process (Cegielski et al., 2012). Here, not only internal employees have specific roles, resources, and access rights, but also the supply chain partners. When using CC services cross-company, an overall authorization concept has to be defined with the cloud provider.
Process model	This model addresses all business processes within the SC and has a central position in our RM. The quality and the speed of the processes are primarily depending on the efficiency of IT support (Cegielski et al., 2012; Steinfield et al., 2011). Processes are impacted by SC partners, both directly and indirectly (via the external stakeholder that affects the resulting strategy). Normally, a process can be structured into sub-processes and connection points between the sub-processes. Further, a business process consists of elements such as operators, functions, and events.
IT-architecture model	The nature of this model is to support business processes. In aspects of CC, much attention has to be paid to the interfaces and the configuration between the own organization, the SC partner and the CC provider (Benlian et al., 2010). In general, the architecture model determines data streams and systems that have to be used. Furthermore, the access types between hardware and software components should be justified as well as the specific modules of the single IT systems.
SC cooperation model	The overall SC success is strongly dependent on the interaction between the SC partners (Fremdt et al., 2013; Wu et al., 2013). This model contains the SC related chances and risks of CC implementations. The SC partners constitute a subset of the stakeholders. Kumar and Dissel (1996) point out that the success of SC co-operations is mainly determined by the behavior of the interacting employees. Managers can encourage employees to behave in a desired manner by assigning them responsibilities, roles, and IS such as CC. However, literature foresees three main advantages with CC usage: agility, collaboration, and knowledge sharing (cf. Section 5.2).
CC architecture model	This model shows the specific resources and features for supporting the IT-architecture. As there is no direct linkage to the process model, we want to underline the indirect influence of CC on SC processes. Moreover, this contains the CC service provider and the underlying service level agreements (Leimeister et al., 2010) that have to be controlled by the internal staff.
KPI model	Finally, this model contains the general (not SCM-specific) influence factors for CC implementation: costs, IT security, IT performance, IT flexibility. The KPI model is incumbent upon organizational roles. One possible method to operationalize these factors (and monitor CC) might be a balanced scorecard (BSC) as discussed by Lee et al. (2013). The KPIs contain criterions, scales, and target values.

co-occurrence picture indicates that our model has considered the relevant elements and significant linkages between these elements. (In order to hedge this statement, we analyzed all co-occurrences within the entire literature sample that show a value of above 0.050). Conversely, this means that the fitness of the overall model would have to be questioned if the RM led to low co-occurrences only.

5.5. Practical model application and evaluation

After having derived the RM from research literature, we exemplarily applied the model and evaluated it by adopting a multi-method approach (Knackstedt et al., 2009) in order to comply with the already mentioned need for such an approach (Marston et al., 2011). In a participative case study (Baskerville, 1997) at an international automotive supplier (TIER1), we applied the model to real life. From the RM user perspective, the authors and the case companyś representatives found no other RM that addresses the company's underlying key issue (RMR4). Therefore, the selection process in terms of the conceptual process model (cf. Fig. 2) was completed without any iteration.

The case company intends to switch its electronic data interface (EDI) procurement process into a cloud based procurement process, where not only the case company and its supplier (TIER2) should participate, but also the supplier TIER3. This offers the advantage of having procurement orders available at a central place and in real time. Hence, compared to EDI, the supplier TIER3 obtains the needed information earlier and can therefore set up his physical production and logistics processes in time, which consequently helps the supplier TIER1 to increase his business performance. In order to improve the understanding of these cross-company linkages and to make them transparent, the case company set out a simulation. Therefore, the generic RM was translated into a project-specific information model (RMR5). Herein, we specified the information relevant to the SC such as bill of material and order frequencies on the one hand, and information relevant to CC such as service costs, responsibilities, and interfaces on the other.

The project-specific model was implemented with the help of the software ADOit by BOC GmbH (RMR5). This software is widely used at companies in various branches. The software platform provides various model types that can be used for projecting organizational and IT-structures as well as processes and measures. By first draft prototyping, we implemented the sub-models of the reference model and considered the specific information of the case company. In ADOit, an interrelation between two elements can be applied as a reference (cf. Fig. 2 in the appendix for more details on ADOit). With the help of experts from science and from the case company, we refined and improved this model gradually. Furthermore, we conducted four expert interviews with professionals from a SC software provider, in order to test the validity of the theoretical RM and the applied information model. The first empirical results indicate that financial benefits will by far compensate for the incurred cloud usage costs (RMR9), while having higher security risks. However, real business applications are compellingly needed in order to increase the suitability of the specific model and generalize the model findings. This will be conducted by the case company in the next step.

6. Conclusion

6.1. Implications

Reference information models constitute a suitable basis for creating company- or project-specific information models. However, in the light of the great amount of RMs that have been developed in the past, there is a danger of arbitrariness during the development and evaluation phases of these RMs. Even RMs published in scientific and practical outlets suffer from a low level of comprehensive documentation, which is indicted by our analysis (cf. Section 3). And compared to other research disciplines such as medicine, IS still tends to design models encapsulated from each other by often neglecting already existing research (Vom Brocke et al., 2014). Having considered service-oriented RMs only, in our analysis we indicate that the vast amount of papers, in which newly developed RMs are presented, do not document their respective development procedures accordingly. Furthermore, the authors of such RMs often do not distinguish between construction and application processes, which can prevent the models from being used. This makes it hard to accept such models as real theoretical references. Therefore, with this paper we provide ***10 subsequent requirements*** for reference modeling. These specific requirements are derived from general design science requirements and augmented by the ***findings of seven well-documented RMs***. In contrast to prior works on reference model processing and method engineering, our approach has a higher preexisting knowledge regard, in particular by RMR2 (document review) and RMR8 (knowledge-based evaluation), which may increase the degree of universality and recommendation of future RMs. As mentioned before, both phases will gain even more relevance when founding the RM on a broad and qualitative preexisting body of knowledge. Moreover, we propose a comprehensive ***conceptual process model*** for the overall development and evaluation of RMs. This model includes the determined RM requirements and connects every RM event to the both underlying roles, namely developer and user. Hence, we provide an adequate overall framework for the methodologically and scientifically founded development and evaluation of RMs and postulate to more strongly anchor future RMs in related work. Thus, this framework may be seen as a valuable extension of the present body of knowledge by combining already existing approaches from design science, reference modeling, and particularly document analysis.

As to RMR8b (metric-based evaluation), we propose a completely new approach, namely to ***combine semi-formal languages with co-occurrences***. This approach increases the degree of objectivity and brings new, mostly hidden features to the reference modeling paradigm. For instance, it may be of help in finding gaps in scientific literature: if, for example, co-occurrences are relatively low although there obviously are important interrelations, and beyond this, the approach provides an additional evaluation step. Hence, (i) interrelations may be weighted by co-occurrences, (ii) the model sections may be questioned when showing only low co-occurrences, and (iii) the underlying document sample may be questioned when showing relatively low co-occurrences. Especially the third point may constitute an indicator for the fulfillment of RMR2 (qualitative document verification), when there is the same base for the qualitative and quantitative document analysis. Finally, we ***applied the conceptual process model exemplary*** and developed a RM for CC in inter-company SC processes. We consciously decided not to discuss all underlying development and evaluation phases in detail as this would have gone beyond the scope of this paper. Moreover, apart from the involvement of scientific literature, also the integration of the state-of-the-art in practice may constitute a valuable basis for future research. Nevertheless, we deem it important to show the applicability and usability of our conceptual process model.

6.2. Limitations

Since this paper combines domain knowledge from design science and reference modeling as well as from document analyses, it is obvious that the general limitations of these domains are valid for this paper as well. For instance, design science research suffers from subjectivity and bears the risk of developing well-created theoretical artifacts that are useless in real organizational environments (Hevner et al., 2004). Contrary, qualitative document analysis is about investigating approaches and solutions from the past, which means that their contents may be outdated or ineffective for analyzing present and future challenges. Additionally, quantitative content analyses indeed provide a high degree of objectivity as the computation runs in a predefined way, the interpretation of the results, however, does not allow for absolute conclusions. Furthermore, the significance of the single units of the underlying document base (e.g., scientific and practice papers, transcripts) is hard to determine, often leading to equal weighting of all selected documents. However, we believe that a stronger linkage between the mentioned domains reduces the degree of weakness and improves the quality of future RMs. Moreover, the requirements of RMs may vary dramatically from model to model, which means that the determined RMR as well as the conceptual process model can be seen as a valuable starting point that might need adjustments to specific requirements (e.g., adding/deleting RMRs, extending/reducing process steps). Further, there is no doubt that some preexisting RMs such as ITIL or SCOR contribute valuable guidance, which represent *best practice* for some real-life cases. However, providing best practice is not our main concern, which can be stated as a limitation. Our approach rather aims to serve as a guidance in the development and evaluation of *common practice* RMs, namely by more firmly integrating the RM in preexisting knowledge and by analyzing similarities of related work.

6.3. Future work

We propose a metric-based theoretical evaluation of RMs, which enhances clarification and transparency, while providing more objectivity. To the best of our knowledge, this theoretical phase is new and therefore, it has not yet been sufficiently explored in information modeling, which may motivate future research. Hence, it is possible to include various valuable sources for RMs, such as practical literature, social networks, and transcribed expert interviews, which could provide more actual and relevant data to the information model (in order to mitigate the limitations of classic document analyses). Valuing the effectiveness of these sources may constitute a fruitful research approach. Further, the gathering of data from various sources will meet the often stated requirement of more triangulation in IS research (e.g., Loos et al., 2011; Venkatesh et al., 2013). Moreover, the approach can be extended by considering conceptual wording trees, ontologies, synonym data bases (e.g., WordNet), n-grams etc., which can further increase the data quality.

Switching to the empirical evaluation process, future work may investigate more properly how to involve objective measures and scientific methodologies, which are still scarce in this phase. Besides from economic measures, we found no relevant key performance indicators for the fit of the underlying RM. Towards this end, the conclusion from the specific information model to the reference model is widely unexplored.

In general, it has to be investigated whether our overall proposed conceptual process model stimulates research to develop future RMs in a more scientific and preexisting knowledge-oriented way instead of using intuitive approaches. And furthermore, it has to be found out whether the conceptual process model in itself leads to better outcomes than those RMs that have been developed more arbitrarily.

Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jss.2015.09.029.

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