About the Need for Semantically Enriched Reference Models

Completed Research Paper

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ABSTRACT
The concept of reference model has been discussed for years as a means for increasing the efficiency and effectiveness of conceptual modeling. But the necessity of support for understanding reference models is poorly understood. Most literature on reference modeling provides several configuration mechanisms and extensions of modeling languages, but the consequences of a constructivist understanding on reference modeling have been neglected so far. In this paper we focus on the constructivist characteristics of conceptual models in general and reference models in particular. We consolidate literature on constructivist model theory, quality frameworks for conceptual modeling and design rationale approaches. As a result of this study we propose a rationale management framework for reference modeling structured according to the four dimensions syntax, semantic, pragmatic and agreement. In this context we discuss the specific function of reference models within the modeling process and the consequences for its target oriented construction. The paper is concluded with an outlook on desired research for reference modeling theory.

Keywords
Reference Modeling, Model Rationale, Experience-Based Model Evolution, Model Quality.

INTRODUCTION
Conceptual models represent a perceived problem situation at hand and are commonly accepted means for organizing, managing and improving business processes (Davies, Green, Rosemann, Indulska and Gallo, 2006; Fettke, 2009). They are research subject within the information systems community since decades. A business process model is often the key means of communication within projects for business process reengineering or starting point for workflow management due to its ability to abstract from the complex object perceived and to describe it in an intuitive semiformal and formal manner, respectively.

But modeling projects are considered as labor intensive, time consuming and risky. Thus, the reuse of process model is one of the key issues in business process management research (van der Aalst2013). Reusable conceptual models, labeled as reference models, are proposed to increase the effectiveness and efficiency of model construction and to improve both the model quality and the problem solution (vom Brocke and Buddendick, 2006). Within academia this development is reflected by a constantly growing body of literature on adaptation techniques for reference modeling (e.g. Becker, Delfmann and Knackstedt, 2007; vom Brocke, 2007), suitable extensions of modeling grammars (e.g. Rosemann and van der Aalst, 2007) and the necessity for configuration management (e.g. Braun, Esswein, Gehlert and Weller, 2007; Thomas, 2008). But the actual benefits gained by usage of reference models do not come up to the expectations (Koch, Strecker and Frank, 2006). One reason might be an inadequate consideration of the constructivist modeling theory.

Assuming a constructivist paradigm for conceptual modeling, the participation of the model user in model construction is essential in order to discuss the appropriateness of the designed model for the intended model use and to ensure a proper model interpretation (e.g. Schuette and Rotthowe, 1998; more general Kujala, 2003). This is because a constructivist understanding of conceptual modeling assumes different worldviews of the stakeholders wherefore a discussion of alternative modeling solutions and their consequences among relevant stakeholders is essential (Krogstie, Lindland and Sindre, 1995).
But the claim for user participation could normally not be fulfilled within reference modeling due to the considerable time-lag between the construction and the use of the reference model. A personal communication between the model creator and the model user is unfeasible, thus the model solution implies lots of assumptions about the underlying objectives and the perceived phenomena. Only little research is done on issues concerning the impact of inherent assumptions on the understanding and interpretation of the reference model. We argue that this theoretical shortcoming causes the absence of reliable and applicable reference models supporting the model construction in a meaningful manner. The goal of the paper is to overcome this shortcoming in reference modeling approaches by discussing the consequences of a constructivist paradigm and deriving requirements on method engineering.

Before looking at the specific requirements of reference modeling, a common understanding of conceptual modeling must be gained first. For this reason we discuss the constructivist paradigm and common quality frameworks for conceptual models in the next section. Subsequently, the implications for a deliberate and target-oriented construction of reference models are derived. The paper is concluded by an outlook on future work.

BACKGROUND AND THEORY

In this section we give a brief overview on the fields of both constructivist paradigm and semiotics of conceptual modeling concluding with a four-dimension-concept of conceptual models. This idea will provide the basis for the discussion of types of information needed by readers of reference models for interpreting model statements in the intended way.

For the following discussion on constructivist understanding of conceptual (reference) modeling and suitable quality frameworks, a primary description of the considered modeling process seems to be advisable. Figure 1 illustrates the construction and usage of a conceptual model. For constructing a conceptual model a modeling team negotiate perceived phenomena having regard to various objectives, individual knowledge and experiences, organizational guidelines and so on. Reference models pre-structure reoccurring problem situations and could support the achievement of agreement among model stakeholders. Thus, the conceptual model has not to be designed from scratch and the reference model contributes to reduce modeling efforts and to assure model quality, respectively.

For using a conceptual model, the model user has to interpret the model statements and to deduce adequate activities for real problem situations. Objectives and other underlying conditions are influencing this process in a similar way as they do in the construction process.

![Figure 1: The Constructivist Paradigm of Conceptual Modeling](image)

**About the Constructivist Paradigm of Conceptual Modeling**

Since the end of the 1990’s a construction-oriented understanding of the term conceptual model has been adopted within academia (Schuette and Rotthowe, 1998, pp. 242 et seq.). Schuette and Rotthowe defined a model "...as the result of a construct done by a modeler, who examines the elements of a system for a specific purpose [...] at a given point of time with
a specific language..." (Schuette and Rotthowe, 1998, pp. 243). Thus, the subjectivity and the structure-giving achievement are key factors of the modeling process. The modeling objectives and their weighting are determining for the nature of the conceptual model and have to be defined for every modeling process in a certain way. In the following we explicitly distinguish between mental models and conceptual model. The latter one are explicatized models represented in a specific modeling language whereas the former one are imaginary models constructed by one person out of the perceived and interpreted model object. The explication of the conceptual model is a prerequisite for its persistence and its subject-independent usage.

We already mentioned the distinction between the model creator and the model user within the modeling process. The model creator perceives and interprets the model object and constructs the conceptual model by means of a specific modeling language. Krogstie and Lindland and Sindre emphasize the individual perception of the world by defining it the local reality (Krogstie et al., 1995). On this account it is necessary to externalize stakeholders local realities and to discuss them for reaching a valid conceptual model. Therefore model statements are results of an agreement process among model creators and are valid only for a certain period of time. Subsequently the resulting conceptual model is read and interpreted by the model user for the situation at hand in the same manner. This distinction of stakeholder types and their impact on the resulting model statements are a vital problem for the development of reliable and applicable reference models.

Concluding, a conceptual model is:

- a representation of a perceived problem at hand,
- the result of a subjective construction performance,
- determined by modeling objectives,
- constructed for a specific user group,
- valid for a specific period of time,
- an artifact formulated in a conceptual modeling language.

**Semiotics of Conceptual Modeling**

As outlined in (Frank, 2006) various quality frameworks for conceptual models exist in academic literature. Due to missing empirical evidence for or against a certain quality framework, we decided to ground our research on conventional approaches basing on epistemological and linguistic theories.

The above-mentioned definition of the term conceptual model is starting point for a discussion of main issues influencing the quality of the resulting model. A conceptual model represents a perceived problem at hand and takes part in various communication processes. Due to its formalization in a conceptual modeling language it is a linguistic artifact and could be analyzed along the linguistic dimensions syntax, semantic and pragmatic. The following analysis is based on existing theoretic work about the semiotic of conceptual models which is grounded on a constructivist world view (e.g. Lindland, Sindre and Solvberg, 1994; Krogstie et al., 1995; Price and Shanks, 2004; Gehlert, 2007). The resulting framework for model quality determines the requirements for a target-oriented reference model.

At first sight a conceptual model is an artifact formulated in a conceptual modeling language. The first semiotic dimension, Syntax, is related to the applied modeling grammar. For defining modeling grammars current literature emphasizes the distinction between modeling constructs, its notation and rules of how to combine them (e.g. Höfferer, 2007). Modeling constructs represent types of perceivable phenomena like processes and objects. In this regard the structure-giving performance of the model creator is strongly affected and limited by the applied modeling grammar. The notation defines graphical symbols representing the modeling constructs. The definition of the modeling grammar is done within a metamodel. The overall goal of the syntactic dimension is syntactic correctness (Krogstie et al., 1995). To fulfill this goal the conceptual model has to be complete and consistent with the metamodel (Schuette and Rotthowe, 1998).

The second semiotic dimension, Semantic, deals with the meaning of model statements, which should represent a perceived problem at hand. A model statement is characterized by domain expressions applied within the conceptual model and the combination of the modeling constructs (Pfeiffer and Niehaves, 2005). Semantic quality is characterized by the two goals feasible validity and feasible completeness (Lindland et al., 1994). Conceptual models, especially business process models, are enhanced increasingly by ontologies in order to formalize the meaning of terms used in domain expressions and to enable a computer supported analysis of model statements (e.g. Höfferer, 2007). In addition semantic verification rules are proposed for a built-in check of model element structure (Fellmann, Hogrebe, Thomas and Nuettgens, 2010). Benefits for model verification, model integration and model comparison are expected.
The third dimension, Pragmatics, is related to the model stakeholders and their interpretation of the conceptual model (Lindland et al., 1994). Referring to the opposing modeling activities (model construction and model use), analyses of pragmatic aspects have to be differentiated by types of stakeholders and model activities, respectively. Within model construction, model statements are formulated deliberately by considering the underlying modeling objectives and the requirements of the potential user group. However, the model user interprets the model statements according to his local reality. As pragmatic quality is crucial for the success of reference models, further research on how to deal with varying local realities is urgently required.

Besides the three linguistic dimensions, a fourth dimension, Agreement, could be identified (similar to the social quality aspect in Krogstie, 2012). This dimension addresses the subjective construction performance within conceptual modeling. The key issue of a constructivist attitude of mind is that model statements about perceived reality are subject to negotiation among model-stakeholders. How to reach and to support a meaningful agreement about model-statements are subjects of this dimension.

THE REFERENCE MODEL RATIONALE

We interpret the term reference model in a use-oriented way (Thomas, 2008) as reference models are specific conceptual models reused in different modeling situations by providing a generic solution (vom Brocke and Buddendick, 2006; Rosemann and van der Aalst, 2007). Our analysis focuses on deliberately constructed reference models supporting the conceptual model construction by providing specific configuration features like an extended reference modeling language (e.g. Rosemann and van der Aalst, 2007). To emphasize the different objectives guiding the conceptual modeling construction, vom Brocke distinguishes between design for reuse and design by reuse (vom Brocke and Buddendick, 2006). The latter one results in an arbitrary conceptual model whereas the former one results in a deliberately constructed reference model.

As we assume a constructivist paradigm for conceptual modeling in general, a constructivist paradigm is assumed for reference modeling too. But the majority of reference modeling approaches neglect the consequences of a constructivist modeling paradigm. The following analysis of shortcomings in reference modeling approaches bases on the four identified dimensions of conceptual modeling. Both the pragmatic dimension and the agreement dimension are of particular importance for reference modeling due to the fact that the model users are mostly unknown during the reference model construction. Therefore this aspect will be emphasized.

Analysis of Shortcomings in Actual Reference Modeling Techniques

The four dimensions of the above-mentioned quality framework will be analyzed in regard to reference modeling theories in order to reveal shortcomings of current approaches. Within the syntactic dimension research focuses on the extension of conceptual modeling grammars in order to capture potential configuration alternatives (e.g. Rosemann and van der Aalst, 2007). Beyond the assurance of the syntactic quality of the reference model itself, methods have to be developed to assure the syntactic quality of the derived conceptual model as well (Recker, Rosemann, van der Aalst and Mendling, 2006). No standard modeling language for configurable reference models exists.

The two modeling construction processes, design for reuse and design by reuse, are normally separated in time and space. So the reference model is imported into a problem-solving environment where the meaning or the formulation of domain expressions might differ. Approaches for capturing the meaning of model statements (semantic dimension) integrate ontologies and inference rules (e.g. Höfferer, 2007; Fellmann et al., 2010). These approaches are mainly theoretical principals and lack in widespread application.

A reference model is constructed for a recurring problem-solving situation. Therefore it abstracts from specific individual conditions and provides a generalized solution. But its design is still determined by underlying assumptions and objectives and prepared for a specific target user group (pragmatic dimension). The specific communication situation between the model creator and the model user requires novel modeling approaches for capturing pragmatic considerations and design decisions (agreement dimension).

Before applying a reference model within a model construction process the creator of the individual conceptual model, i.e. the model user of the reference model, has to assess whether the problem at hand is similar to the problem represented by the reference model. In addition he has to assess whether the model statements are complete, relevant, representative and still valid. That kind of assessment demands information answering questions like 'who has constructed the model?', 'which model object has been perceived?' and 'whom and what reason the model has been constructed for?'. Approaches for
meaningful descriptions of recurring project situations are known in the research area of situational method engineering (e.g. Mirbel and Ralyté, 2006), but they are not adapted for reference modeling so far.

Due to the subjective perception and interpretation of real world problems, design decisions and their assessment (agreement dimension) play a key role for reusing conceptual models. The user of a reference model has to examine whether the decisions made within the model construction process are consistent to his knowledge. E.g. some possible modeling alternatives were disregarded, assessed differently or compared with unknown or obsolete modeling alternatives. The traceability of the construction process of a reference model (design for reuse) is a prerequisite for an informed decision for or against its application within a modeling situation at hand. In the research field of situational method engineering approaches for capturing the design rationale are adapted for similar problems (e.g. Rossi, Ramesh, Lyytinen and Tolvanen, 2004), but they are not adapted for reference modeling so far.

Summarizing, even the constructivist paradigm is commonly accepted within the research field of conceptual modeling, its consequences for reference modeling has been discussed insufficiently so far. The analysis of the four dimensions, syntax, semantic, pragmatic and agreement, revealed that efforts for improving syntactic and semantic quality of reference models increase. The development of extended reference modeling grammars and the integration of ontologies for standardizing the interpretation of model statements are latest level of knowledge. But the most challenging aspect of a constructivist paradigm in reference modeling, the agreement dimension, is neglected so far. On that account the following section deals with approaches for supporting the consensus finding during the construction process and a target-oriented documentation of relevant design decisions.

Derivations of Individual Models
In the following, we introduce the notion of design rationale as a promising approach for capturing design decisions relevant for the utilization and evolution of reference models. On the basis of relevant literature about design rationale and its

Figure 2: Roles of Conceptual Models and their Rationale Types

Experiences (Use Rationale)
adaptations (e.g. Dutoit, McCall, Mistrik and Paech, 2006; Rossi et al., 2004; Louridas and Loucopoulos, 2000; Regli, Hu, Atwood and Sun, 2000; Lee and Lai, 1991) we elaborate a proposal for integrating rationale information in reference models.

Similar to the distinction between construction rationale and use rationale in method engineering research (Rossi et al., 2004), the rationale captured in the design-for-reuse-process represents the reference model construction rationale whereas a part of the rationale captured in the design-by-reuse-process represents the reference model use rationale. The former one supports the understanding of the construction performance done by the reference model creator, which is essential for the usage and maintenance of reference models. The latter one is starting point for an evolutionary reference modeling due to the experience-based feedback information. Figure 2 depicts the roles a conceptual model can act as related to the associated modeling process. Within the design-for-reuse-context a reference model is constructed by generalizing specific problem situations and by providing a set of possible modeling solutions. Within the design-by-reuse-context an individual model could be derived from the reference model according to valid configuration operations (case a). Due to the generic nature of reference models reasonable modifications could occur to meet enterprise specific requirements (case b). The user of the reference model has to reflect the model statements and to assess their validity for the situation at hand. Additional information concerning crucial design decisions could support the construction of good individual models and the evolution of good reference models, respectively. For example the creator of individual model b) is not able to reconstruct a possible agreement to disregard the model element Z for cause. On the other side feedback information from model use are essential for an appropriate evolution of the (reference) model.

**Rationale Layers for Reference Modeling**

On the account of a literature review about argumentation-based approaches for representing design rationale, we elaborate a layer model for capturing and representing the rationale within reference modeling. The main ideas were adapted from the IBIS method (Kunz and Rittel, 1970) and the ISAL model (Liu, Liang, Kwong and Lee, 2010). Three types of elements were defined for representing the argumentation for a certain modeling solution. *Issues* represent questions to be deliberated during the modeling process and include objectives, motivations and requirements of designing a reference model and a conceptual model, respectively. Proposed modeling solutions were stated as *alternatives* responding to raised issues. Alternatives could be supported or objected by *arguments*, which comprise objectives, assumptions, experiences and anything influencing a decision for or against a certain modeling alternative.

The considered modeling alternatives and their corresponding arguments are captured and documented within the argumentation layer, which represents the fourth dimension agreement. The three dimensions syntax, semantic and pragmatic determine the structure of the modeling solution layer. At this layer any information necessary for interpreting the reference model is provided. E.g. the meta-model for defining the modeling grammar and applied ontologies or inference rules are recorded. The artifact layer comprises the reference model itself and the conceptual model, respectively.

The layer-model for capturing the rationale of reference models is outlined in figure 3. It depicts exemplary discussions and design decisions within a (reference) modeling process. The reference model comprises an Exclusive-OR-connector to mark a configuration rule. The user of the reference model has to opt for one thread. As depicted the user selected the left thread. Beyond that the element Z was added to the model for objective reasons. The discussion for or against the modification of the model solution provided by the reference model is documented within the argumentation layer. All intentional made design decisions become traceable in this way. As a consequence, model users are able to assess whether the underlying assumptions and arguments are still valid for the situation at hand.

**DISCUSSION**

Literature on reusable conceptual models already claims additional information about the construction performance done by the model creator (e.g. Wolf, 2001; vom Brocke and Buddendick, 2006). They are necessary to understand the model statements in the intended way and to value the reference model for the modeling situation at hand. But only little work is done on how this kind of information should be documented and integrated in the reference model. The contribution of the proposed framework for successful reference modeling is threefold.

**Support for Model Interpretation**

Beyond information related to the metamodel or the appropriate ontology we demand information about project conditions, underlying arguments and assumptions and involved model creators including their domain and modeling knowledge. This kind of information is lost after finishing the model project. But it is crucial for model users to assess the model-construction-context and the validity of the model for the situation at hand. In addition these information are essential for the
maintenance and evolution of the (reference) model. Without understanding of the underlying assumptions and intended design decisions, the risk of violating substantial constraints is unpredictable.

Support for Model Configuration

The traceability of design decisions supports the derivation of individual models from reference models significantly. The recorded discussion about a particular design decision reveals disregarded alternatives and weighting of arguments. This information could affect the decision for or against a proposed alternative and could cause necessary modifications for the model situation at hand. Beyond that the configuration of an individual model could be supported by appropriate analyzing tools, which evaluate past modifications made during the derivation of various individual models.

Evolution of Reference Models

The rationale captured within the design-by-reuse-context poses a considerable information source for the maintenance and evolution of the reference model. It reveals obsolete or disregarded alternatives and arguments, respectively. The structure of
the model-solution-layer classifies the discussed issues according to the quality dimensions syntax, semantic and pragmatic. In this way an information overload could be avoided. The model creator gets only relevant information for the problem in question. E. g., he has not to deal with issues concerning the domain expressions when analyzing the suitability of configuration expressions.

CONCLUSION AND FUTURE WORK

Our presented research provides two main contributions. First, the proposed rationale management system for reference modeling supports both the argumentation-based construction of reference modeling and its comprehension due to the traceability of design decisions. The basic idea of our approach is grounded on the adaptation of the argumentation-based method IBIS and the quality framework for conceptual modeling. The four dimensions syntax, semantic, pragmatic and agreement span the scope of our rationale management for reference modeling. For considering the constructivist aspect of conceptual modeling we propose an argumentation layer representing the discussion of alternative modeling solutions during the construction process. The second contribution of our research is the consolidation of disparate literature on conceptual modeling, reference modeling and modeling quality. According to a four-dimension-framework we reveal shortcomings of actual reference modeling research, which should be object of future research.

Whereas issues of syntactical and semantic quality of conceptual models are object of research for decades, the impact of pragmatic design decisions is almost neglected, especially within reference modeling. Configuration mechanisms for cutting out certain modeling constructs or views are provided (Becker, Delfmann, Dreiling, Knackstedt and Kuropka, 2004), but only little insights about the impact of the organizational position and the experiences of the model reader are known. Empirical research could analyze which kind of influencing factors determine the room for interpretation or lead to significant misinterpretations. A characterization of typical stakeholder-groups and their requirements on reference modeling techniques would be useful too. In this way a target-group oriented construction of reference models and the development of aligned reference modeling languages could be supported.

REFERENCES