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Abstract

Within the information systems field, reference models have been known for many years. A reference model is a conceptual framework and may be used as a blueprint for information systems development. Despite the relevance of reference model quality, little research has been undertaken on their systematical evaluation. In this paper, we propose an approach to evaluate reference models based on the Bunge-Wand-Weber ontology. We demonstrate that this application is possible and useful for model evaluation and several other areas. The main idea of our approach is the ontological normalization of a reference model. An ontological normalization is comparable with the normalization of a database schema but considers the structure of reality and not technical aspects. The ontological normalization of a reference model consists of four steps: (1) Developing a transformation mapping, (2) Identifying ontological modeling deficiencies, (3) Transforming the reference model, and (4) Assessing the results. Although our approach is based on sound theory, we argue that this approach is not inherently superior to other approaches of reference model evaluation.

Keywords: Reference modeling, conceptual modeling, information modeling, framework, multiperspective evaluation, quality, selection, IS development, ontology

Introduction

Within the information systems field, information modeling is an instrument to analyze, design, implement, and deploy information systems (Frank 1999; Mylopoulos 1998; Wand and Weber 2002). However, the modeling process is often time and resource consuming and faulty. The concept of reference modeling has been introduced as a way to improve and accelerate the modeling process (Mertins and Bernus 1998; Mišic and Zhao 2000; Scheer and Nüttgens 2000).

There is a great deal of terminological confusion in the modeling literature. For example, the term "model" is often used for different purposes. To avoid confusions, we use the following definitions: A *grammar* "provides a set of constructs and rules that show how to combine the constructs to model real-world domains"(Wand and Weber 2002, p. 364). In the remainder of this paper, we always refer to analysis grammars, e. g. the entity-relationship modeling grammar (ERM) or the Unified Modeling language (UML). And while *modeling method* "provides procedures by which a grammar can be used"(Wand and Weber 2002, p. 364), *scripts* are the product of the modeling process. "Each script is a statement in the language generated by the grammar"(Wand and Weber 2002, p. 364). A script is a representation of a real-world domain using a particular grammar. A *reference model* is a script representing a class of domains, e. g. a reference model for a financial service provider or a reference model for retail. It is a conceptual framework which could be used as the blueprint for information system development. Reference models are also called universal models, generic models, or model patterns. To use reference models, they must be adapted to the requirements of a specific enterprise. We refer to such an adapted model as an application model.

Several reference models are known in practice and research (Bernus et al. 1998, pp. 619-707; Fettke and Loos 2003a). Examples include Scheer's reference model for production planning and control system (Scheer 1994) and the reference models for electronic business applications described by (Mišic and Zhao 2003). Despite the obvious relevance of reference model quality, little research has been undertaken on their systematical evaluation. An evaluation of a reference model contains on the one hand

criteria regarding the application domain such as semantic correctness, relevance, and universal applicability, and, on the other hand, criteria regarding syntactical correctness, systematical structuring and robustness (Mišic and Zhao 2000). Results of known approaches to evaluate reference models and scripts show that an objective evaluation is problematic for several reasons (Schütte 1999), e. g. because a reference model can be used in various application areas such as software development or business process reengineering. These application areas have different quality requirements. However, it can be argued that because of their high theoretical and practical relevance it is necessary to evaluate reference models systematically: First, an evaluation makes it possible to assess the quality of the research outcome "reference model" that can be understood as a theory in the information systems field. Second, a comparative evaluation of reference models enables the identification of similarities between reference models. Such investigations can show new application areas of reference models. Third, an evaluation of reference models improves the understanding of the characteristics of reference models. Fourth, since no reference model is suitable for all situations, we need to know which reference model has to be chosen in which situation. Evaluation and comparison of reference models provides viable means to gather this information.

In this paper, we propose a new approach to evaluate reference models. It is based on the ontological evaluation of grammars introduced by (Wand and Weber 1993). Ontology is that branch of philosophy that "studies the most pervasive features of reality, such as real existence, change, time, causation, chance, life, mind, and society"(Bunge 2003, p. 201). This discipline provides a foundation for reference modeling, if the assumption is followed that reference models represent reality (Wand et al. 1995). So, our approach allows evaluation of reference models with respect to a sound theory.

The objective of this paper is to describe our evaluation approach of reference models and to give some examples of potential uses. In our analysis, we use the Bunge-Wand-Weber-model (BWW-model). The BWW-model is an ontological theory initially developed by (Bunge 1979; Bunge 1977) and adapted and extended by (Wand and Weber 1989; Wand and Weber 1995; Weber 1997). We use the BWW-model for two reasons: First, the model is well founded on mathematical concepts. Second, prior research on the evaluation of grammars (Evermann and Wand 2001b; Green and Rosemann 2000; Opdahl and Henderson-Sellers 2002; Weber and Zhang 1996) show promising results using this model.

The main contributions of this work are twofold:

(1) Provide a method for the evaluation of reference model founded in ontology, and
(2) Give insights to different application areas of the proposed method.

The remainder of the paper is structured as follows: Known approaches to the evaluation of reference models are outlined in section 2. Section 3 provides a brief recapitulation of the BWW-model. Our ontological approach to the evaluation of reference models is described in section 4. In section 5 some of its applications are sketched out. Finally, section 6 presents the conclusions and directions for further research.

Prior Research

Several types of research have already been undertaken to evaluate scripts in general or reference models in particular. To systemize approaches to model evaluation we use two main criteria (Fig. 1). On the one hand, regarding the research method it can be distinguished *analytical* and *empirical* evaluation approaches. Analytical approaches are based on logical conclusions, empirical approaches are based on experiences. On the other hand, it can be differentiated whether the quality criteria used by an evaluation approach is introduced *ad hoc* or *theory-driven*. Theory-driven quality criteria are derived from and founded on a specific theory, a so-called reference theory (Vessey et al. 2003). Whereas ad hoc quality criteria are just introduced for the purpose of the evaluation approach without referring to a specific reference theory. Because of space limitations, we cannot describe the framework in great detail. Instead, three important aspects are highlighted (for an in-depth discussion of the framework see (Fettke and Loos 2003b)):

(1) Known approaches to evaluate reference models are (Fettke and Loos 2003a; Mišic and Zhao 2000; Schütte 1998).[1] These approaches use a set of features to characterize, compare and evaluate reference model. The problem with these feature-based evaluation approaches is that the development and selection of a specific feature set is often a subjective

[1]This PhD thesis is written in German, an overview of this approach in English is given in (Schuette and Rotthowe 1998).

issue. Furthermore, the criteria used are often defined ambiguously. The strength of these approaches is that they are relatively easy to undertake.

(2) There are many more approaches to evaluate scripts in general. For reasons of abbreviation, just three more types of work are mentioned: (Siau 1999) uses theories of cognitive psychology for the evaluation of scripts. A paradigmatical evaluation of data modeling practice and research is given by (Hirschheim et al. 1995). (Prechelt et al. 2001) examine the quality of software patterns – that are comparable with reference models – by applying laboratory experiments.

(3) We argue that none of these perspectives is inherently superior to others. Instead, each perspective has its specific potentials and limitations. So, a reference model should be evaluated using different perspectives.

Note, although we recommend a multi-perspective evaluation of reference models, in this paper we just provide and describe a single evaluation perspective, namely the ontology based evaluation. We are unaware of work that uses ontology as a foundation for the evaluation of reference models. Compared to other evaluation perspectives, this new perspective has two main advantages:

- This evaluation perspectives is founded on a sound theory.
- The evaluation is not just based on formal evaluation criteria.

In the following, we give a more comprehensive understanding of the ontological evaluation perspective starting with an overview of the BWW-model.

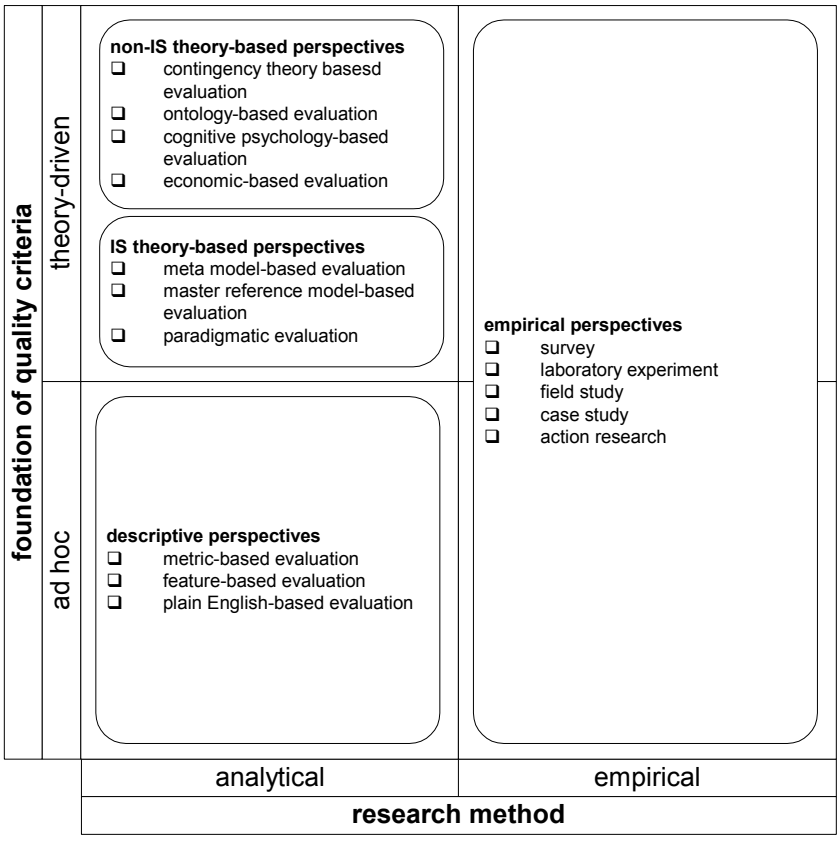

Figure 1. Framework for Multiperspective Evaluation of Reference Models

Overview of the Bunge-Wand-Weber Model

In this section we recapitulate some concepts of the BWW-model that are needed to understand the remainder of our analysis. This overview cannot replace the original work on the BWW-model (for references see section 1). The term "ontology" always refers to the ontology defined by the BWW-model. In the following, for reasons of clarity, each term of the vocabulary of the BWW-model is used with a BWW-prefix. Every BWW-term refers to a construct of the ontology.

The elementary construct of the ontology is a BWW-thing. The world is made up of substantial BWW-things. A BWW-thing, e. g. a person or a book, possesses BWW-properties, e. g. name, color, weight etc. A BWW-composite thing can be decomposed to a set of BWW-things, e. g. a production systems can be decomposed to several working places. There exist basic BWW-things that cannot be decomposed. Composite BWW-things possess BWW-emergent properties that are not possessed by any of its components, e. g. the throughput time of a production systems is a BWW-emergent property. A BWW-class is a set of things that possess a common property.

BWW-properties cannot be observed directly, instead BWW-attributes are representations of the BWW-properties of a BWW-thing as perceived by an observer. A BWW-attribute is a function that maps a BWW-thing on to a BWW-value at some point of time or other conditions. The set of BWW-attributes of a BWW-thing forms a BWW-functional schema. The BWW-state of a BWW-thing is represented by the vector of all BWW-values that are associated with the BWW-functional schema of this BWW-thing. An BWW-event is a change of the BWW-state of a BWW-thing, e. g. "manufacturing machine of a production system is repaired" is a BWW-event.

So far, the terms "ontology" and "construct of ontology" are introduced. Additionally, we use the terms "ontological model" and "construct of an ontological model". An "ontological model" is a set of constructs of an ontology that represents reality as perceived by an observer. The term "construct of an ontological model" refers to a specific construct of the ontology used in the ontological model.

Ontological Evaluation of Reference Models

This section introduces our approach to the ontological evaluation of reference models. The main idea of our approach is the ontological normalization of a reference model. An ontological normalization is comparable with the normalization of a database schema. The objective of both techniques is to represent the domain of interest in a normalized way by applying specific transformation patterns. Normalization of a database schema aims at eliminating problems of information representation and processing in database management systems (e. g. avoiding data redundancies, problems of lost update, dirty read etc.). In contrast, the ontological normalization aims to achieve a unified representation of facts represented by a reference model with respect to the structure of reality. Compared to other representations such as UML or ERM, an ontological representation of a reference model has the advantage that it is most general and not influenced by technical aspects. The ontological normalization of a reference model consists of four steps:

(1) Developing a transformation mapping (paragraph 4.1),
(2) Identifying ontological modeling deficiencies (paragraph 4.2),
(3) Transforming the reference model (paragraph 4.3), and
(4) Assessing the results (paragraph 4.4).

Developing a Transformation Mapping

Until now, various grammars are used to represent reference models. For instance, (Scheer 1994) uses the architecture of integrated information systems (ARIS) (Scheer 1998a; Scheer 1998b), (Hay 1996) employs some kind of an ERM, and (Fowler 1997) uses an object-oriented approach. In the first step of our method, it is necessary to develop a transformation mapping for the grammar used for representing the reference model. This transformation mapping allows to convert the constructs of the used grammar to the constructs of the BWW-model. The term "construct of an grammar" refers to a relationship type – when using the ERM – or a class – when using the UML. The first step is based on the method for the ontological evaluation of grammars proposed by (Wand and Weber 1993). The transformation mapping introduces an ontological meaning for each construct of the grammar used by the reference model. The explicitly ontological definition of the transformation mapping have a beneficial effect

on the objectivity of the evaluation. Without this definition it would be hard to criticize a conducted evaluation of a reference model.

The transformation mapping consists of two mathematical mappings: First, a representation mapping describes whether and how the constructs of the BWW-model are mapped onto the grammatical constructs. Second, the interpretation mapping describes whether and how the grammatical constructs are mapped onto the constructs of the BWW-model. With respect to both mappings, four ontological deficiencies can be distinguished (fig. 2):[2]

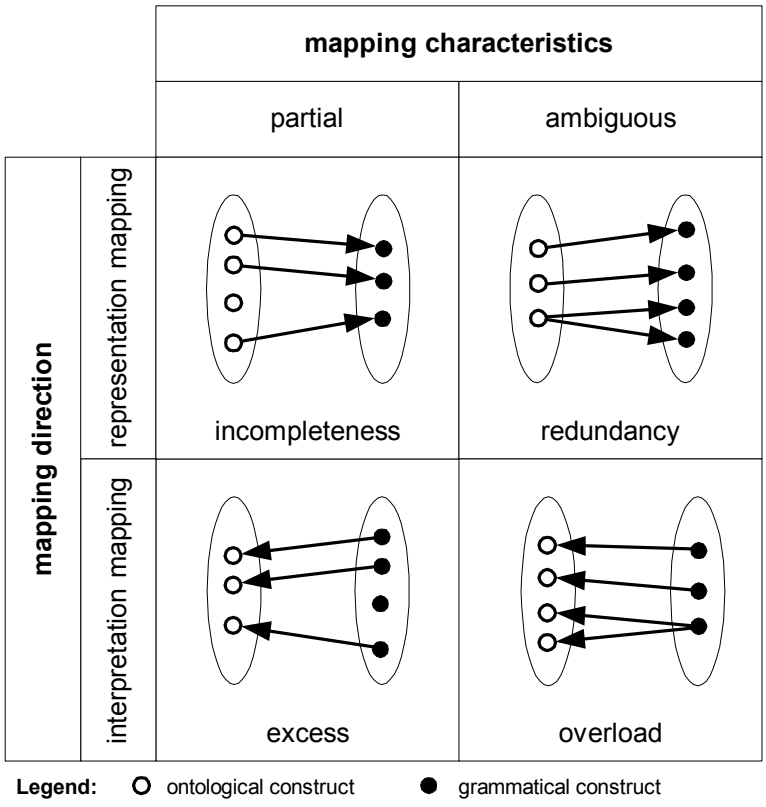

Figure 2. Ontological Deficiencies of a Grammar

- Incompleteness: Can each ontological construct be mapped on a construct of the grammar? A grammar is incomplete if the representation mapping is not defined in total. Otherwise a grammar is complete.
- Redundancy: Can each ontological construct be mapped on exactly one or on more than one grammatical constructs? A grammar is redundant if the representation mapping is ambiguous.
- Excess: Can each grammatical construct be mapped on an ontological construct? A grammatical construct is excessive if it can not be mapped on an ontological construct. A grammar is excessive if at least one of its constructs is excessive.
- Overload: Can each grammatical construct be mapped on exactly one or on more than one ontological constructs? A grammatical construct is overloaded if it can be mapped on more than one ontological construct. A grammar is overloaded if at least one of its constructs is overloaded.

[2]For systematical reasons, we introduce these terms in a slightly different manner as (Wand and Weber 1993).

We refer to the term "grammar" as "ontologically clear" if it is neither incomplete nor redundant. A grammatical construct is adequate if it is neither excessive nor overloaded, so that it is defined unambiguously with respect to the interpretation mapping. A grammar is adequate if each of its grammatical constructs is adequate.

The first evaluation step just refers to the used grammar and, therefore, is independent of the reference model being evaluated. This allows to carry out such evaluations in advance and to reuse the developed transformation mappings for ontological evaluations of various reference models. It is not the object of this paper to propose transformation mappings for known grammars and to identify their ontological deficiencies. Instead, we refer to the known approaches of ontological evaluations of grammars found in literature: (Wand et al. 1999) (ERM), (Weber and Zhang 1996) (Nijssen's Information Analysis Method (NIAM)), (Evermann and Wand 2001b; Evermann and Wand 2001a; Opdahl and Henderson-Sellers 2002) (UML) and (Green and Rosemann 2000) (ARIS).

Note, whether a grammar has ontological deficiencies is independent of the ontological evaluation of the constructs used in the reference model. In other words: The first evaluation step analyzes the used grammar in general. In the second step of the evaluation the used constructs of the reference model are analyzed with respect to the grammatical evaluation in particular.

Identifying Ontological Modeling Deficiencies

To prepare the ontological normalization of the reference model, all ontological deficiencies of the reference models have to be identified. This is the objective of the second step. The second step is based on the former constructed transformation mapping in general. It is possible that one ontological deficiency is resolvable in various ways or even not resolvable at all. Hence, it is useful to separate the identification of ontological modeling deficiencies from the transforming step of the reference model (the next step).

To identify the ontological deficiencies of the reference model all constructs of the reference model must be reviewed. Each construct of the reference model must be examined with respect to whether the construct is used correctly regarding the interpretation mapping. One of the following situations can arise:

- Adequacy: The grammatical construct is ontologically adequate. Nevertheless an ontological deficiency can emerge by applying the grammatical construct to build the reference model. Therefore it must be examined whether the construct of the reference model is used correctly with respect to the interpretation mapping. The construct of the reference model is used adequately if it is used correctly with respect to the interpretation mapping. Otherwise it should be marked as inadequate. For instance, a reference model consists of an entity-type "color". Furthermore, using the ERM, an entity-type should be mapped on a BWW-class regarding to an appropriate interpretation mapping. So, the entity-type "color" has to be mapped on a BWW-class. But this mapping we is inadequate because the entity-type "color" represents a BWW-property and not a BWW-class. So, the entity-type "color" is not used correctly with respect to the interpretation mapping.

- Excess: Construct excess is a modeling deficiency in general and needs a special handling in the transformation step. So, this construct should be marked as excessive in the reference model. Construct excess occurs if implementation specific aspects are represented in the reference model, e. g. the technical concepts of message passing or polymorphism cannot be represented with ontological constructs.

- Overload: Construct overload is a modeling deficiency in general and needs a special handling in the transformation step. So, this construct should be marked as overloaded in the reference model. For instance, using UML, an UML-object can represent a BWW-thing (UML-object "Mr. Miller" is an instance of the UML-class customer) or a BWW-Class (UML-objects "a-class journal", "b-class journal" etc. are instances of the UML-class "journal categories"). So, the construct UML-object is ontological overloaded.

The described identification step of modeling deficiencies relies on the interpretation mapping. In addition, the representation mapping supports an indirect means to identify modeling deficiencies. Based on the representation mapping it can be decided whether the used grammar is incomplete or redundant. An incomplete grammar leads to the trend that specific facts of reality cannot be adequately represented in the reference model. This deficiency appears in this way that a person who develops a model tends to represent facts that cannot represented ontologically adequate by grammatical constructs that are not adequate with respect to the interpretation mapping. This case will be illustrated by an example (Wand and Weber 1993, S. 227): BWW-events

cannot be represented by grammatical constructs of the ERM. So, persons applying the ERM grammar tends to represent BWW-events by using entity-types. This leads to the situation where entity-types are not used adequately with respect to the interpretation mapping.

Transforming the Reference Model

In the third step, the reference model will be transformed to an ontological model. The outcome of this step is an ontologically normalized reference model. More formally, an ontologically normalized reference model is a mapping from the constructs of the reference model to the constructs of an ontological model. While mapping a construct of the reference model on to an ontological construct, four cases can arise:

- Adequacy: The construct of the reference model is marked as adequate. It is possible to map this construct in a straightforward way onto a construct of the ontological model.
- Inadequacy: The construct of the reference model is marked as inadequate. It is necessary to interpret the representation in the reference model in a sensible manner. The result of this interpretation may be that it is possible to represent this construct by a specific construct of the ontological model.
- Excess: The construct of the reference model cannot be mapped onto a construct of the ontological model with respect to the interpretation mapping. Nevertheless it should be examined whether it is possible to represent this construct by a specific construct of the ontological model in particular.
- Overload: The construct of the reference model can be mapped onto several construct of the ontological model with respect to interpretation mapping. It is necessary to decide which interpretation mapping is preferable regarding to the interpretation of the representation in the reference model. The result of this decision may be that it is possible to represent this construct by exactly one construct of the ontological model.

The resolution of the ontological deficiencies of constructs should be guided by the intension of these constructs. This step relies on the interpretation of the subject performing the evaluation. The result of this transformation is an ontological model representing the reference model in an ontologically normalized way. The ontologically normalized model is assessed regarding different aspects in the next step.

Assessing the Results

In the last step, the reference model can be evaluated regarding the results of the three mentioned steps above:

(1) assessing the transformation mapping in general,
(2) assessing the ontological deficiencies of constructs in particular, and
(3) assessing the ontologically normalized reference model.

First, the transformation mapping can be assessed in general. Based on the representation and interpretation mappings it is possible to determine the ontological clarity and adequacy of the used grammar. This assessment gives an idea as to whether the used grammar is suitable to represent the facts of reality regarding to the intended application in general.

Second, the ontological deficiencies of constructs of the reference model can be assessed in particular. While the ontological deficiencies excess and overload have their roots in the definition of the grammar, the cause of an ontologically inadequate construct of the reference model is the specific application of a grammatical construct employed by the person who developed the model. Note, that an ontologically adequate construct of the reference model is not equivalent to a correct modeling (in a syntactical meaning). Instead, the high usage of inadequate constructs may be a sign of representing a lot of implementation aspects in the reference model.

Third, the ontologically normalized reference model can be assessed. In this case, two different evaluation aspects are reasonable:

(a) Isolated assessment: Different metrics can be used for an isolated assessment of the ontological model. Individual and comparative metrics can be distinguished. For reasons of brevity, we gives just two examples. First example: The number of BWW-things can be used to measure the size of the reference model (individual metric). Second example: The complexity of events can be defined as the number of BWW-events in relation to the number of theoretically possible

BWW-events represented in the reference model (comparative metric). The number of theoretically possible BWW-events can be calculated as the square of the number of BWW-states represented in the reference model. Formally:

$$complexity\ of\ events \underset{def}{=} \frac{number\ of\ BWW-events}{(number\ of\ BWW-states)^2}$$

(b) Comparative assessment: Comparative evaluations of reference models can be undertaken if further ontological models of the application domain are given. In this manner, it is possible to evaluate a reference model with respect to its completeness. Note, such an evaluation is possible only with respect to another ontological model.

Applications

Example

This section introduces an example ontological evaluation of a reference model. For reasons of brevity, we cannot describe a full and detailed evaluation, but point out several aspects primarily focusing on identifying ontological modeling deficiencies (evaluation step 2). The following example concerns a data model for the primary requirements management that is part of Scheer's reference model for production planning and control systems (Scheer 1994, p. 90-91) (cf. Fig. 3). Primary requirements are requirements figures for end products, independently salable intermediate products and spare parts.

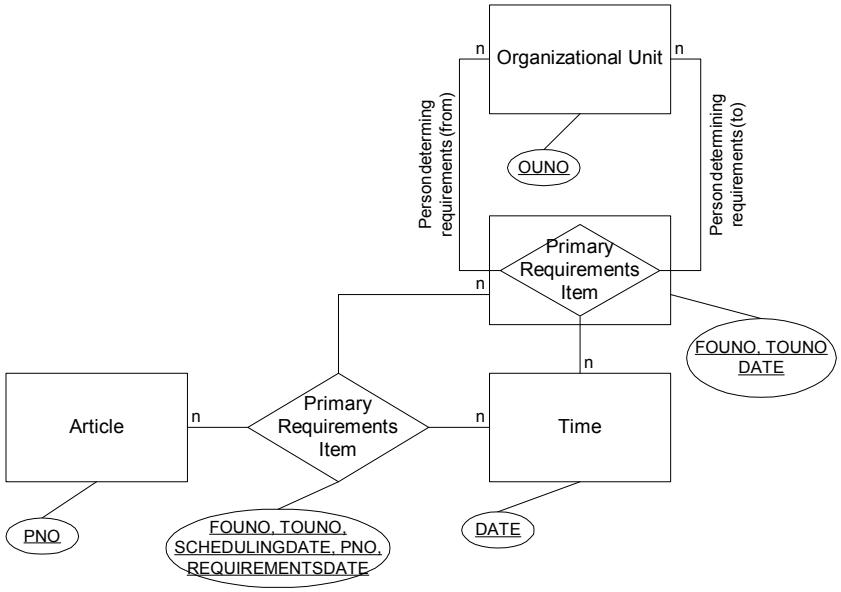

Figure 3. Reference Model to Determine Primary Requirements by Scheer (Scheer 1994, p. 91)

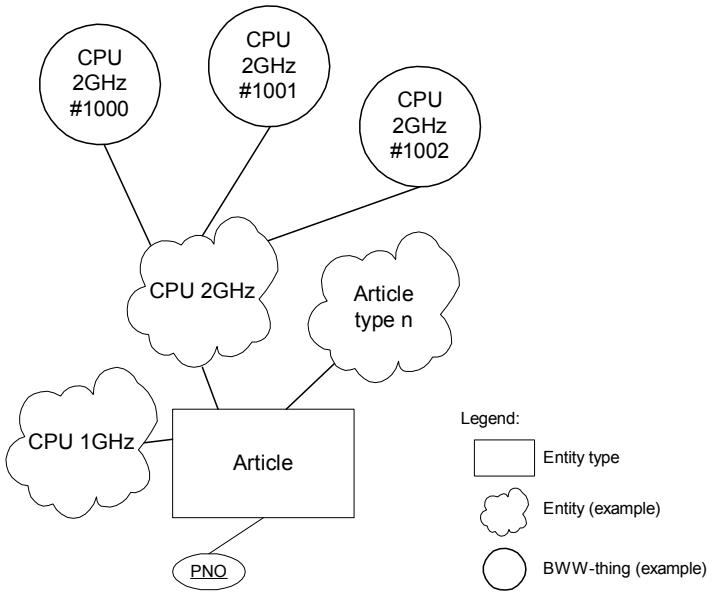

Figure 4. Possible ERM-Entities and Possible BWW-Things

First, we have to introduce a interpretation mapping. We propose to map an ERM-entity onto a BWW-thing (Wand et al. 1999, p. 506). But we do not follow to map a ERM-entity type onto a BWW-class as proposed by (Wand et al. 1999, p. 506). Instead we apply the interpretation mapping for UML-classes proposed by (Evermann and Wand 2001b, p. 359) to ERM-entity types. According to this argumentation, an ERM-entity type is mapped onto a BWW-functional schema. We do not discuss interpretation mappings for further constructs of the ERM.

According to the reference model, articles are identified by article numbers (attribute PNO). But note, these article numbers should not be confused with serial numbers etc: A serial number allow one to unambiguous identify a single, specific article, e. g. the CPU with the serial number 1000 that is bought by customer X. Instead, the entity type article describes a set of articles of a specific type. Possible entities of this type are e. g. "CPU 1GHz", "CPU 2GHz" etc. Figure 4 depicts the relationships between entity type article, possible entities and substantial articles. In other words: Entities of the entity type article cannot be interpreted as BWW-things, but as sets of BWW-things. Hence, entities of this entity type represents specific types of articles. These leads to several implications:

- The reference model implies that articles are discrete or at least made in discrete quantities. This assumption may be problematic in process industries (Hay 1996, p. 187).
- Specific articles may be grouped in types or classes. This assumption is not problematic in mass production, but may be problematic in customer-oriented, individual manufacturing.
- Specific articles do not hold specific attributes which must be represented in the information system (e. g. inventory place of a specific article).

Possible entities of the entity type "Organizational Unit" are sales planning or production planning. One possible ontological interpretation of this situation is, that these entities represent a specific BWW-thing of a specific enterprise. For instance, the organizational unit "production planning" of a specific enterprise may consists of a set of employees, specific machines and other substantial working resources. If this interpretation is agreed upon, then the user of the reference model have to define which things of the enterprise refer to specific entities of this type during the application of the reference model. On the other hand, it can be argued, that these entities do not have a factual reference, but have just a formal character. The ontological ambiguity of the reference model cannot be resolved here in general, but it has important methodological consequences in particular: Following the first interpretation, it is possible to conduct empirical investigations ("Does the organizational unit 'production planning' consist of machine X, employee Y etc.?"). These verifications are senseless if the second interpretation is followed.

Possible entities of the entity type „Time" are date stamps which can represent both concrete dates such as "2003-05-20" or specific periods (period 1, period 2 etc.). The entities are not BWW-things. Instead, temporal aspects address a different ontological category. We argue that Scheer's conceptualization of time is caused by the fact that the ERM grammar does not provide sufficient concepts to represent temporal aspects explicitly. Hence, it may be problematic.

Note, that the previously discussed aspects should not be misinterpreted in the sense that the reference model is not correct in a specific manner. Instead, an ontological evaluation should lead the modeler's attention to implicit implications of the reference model, so the comprehension of the reference model can be increased.

Further Potential Applications

The proposed method can be used for the ontological evaluation of reference models. Furthermore, it may also be used for evaluating application models in general. For reasons of economic efficiency, we believe this application area is limited because an ontological evaluation is expensive. Instead, we see more applications in the following areas:

- Model comparison: Two or more reference models can be compared based on their ontologically normalized models. The compared reference models can be represented with the same grammar. In addition, the application of the proposed model allows to compare reference models that are represented with *different* grammars. Result of a comparison will be that the compared models are equivalent, complementary or in conflict. Furthermore, it is possible to introduce a measure of distance that defines the similarity of two models based on ontological constructs. Such a distance measure allows definition of ontological identity of models.

- Representation of reference models in model repositories: A reference model library is a software library (Mili et al. 1998) containing several reference model for reuse. Today's modeling tools such as the ARIS toolset (Davis 2000) use grammatical constructs or some kind of key words to represent models in a library. We propose that the constructs of an ontologically normalized reference model can be used for representing reference models. The advantage of this design is the equivalent representation of reference models independent of the used grammar.

- Selection of an appropriate reference model: There is a lack of systematical approaches for selecting an appropriate reference model for application. We propose that a user can describe key characteristics of a reference model using the BWW-model. For instance, a user is looking for a reference model comprising the BWW-event "customer placed an order". With this information all ontologically normalized reference models can be analyzed. In a second step, all relevant reference model can be further evaluated.

Conclusions and Further Work

Within the information systems field, reference models have been known for many years. Despite the relevance of model quality, little research has been done on their systematical evaluation. In this paper, we presented an ontological approach to evaluate reference models. Our approach allows the evaluation of reference models based on a sound theory, namely the ontology proposed by the BWW-model. We cannot answer the question why the BWW-model was chosen from an theoretical viewpoint. Instead, our arguments are pragmatic: The BWW-model is well formalized and has been successfully used in several studies which employed both analytical and empirical research methods (for references see section 1).

Furthermore, we point out that an ontological evaluation is not inherently superior to other evaluation approaches. This approach seems to be expensive and implies that the reference model is represented in a (semi-)formal grammar. In addition, there are other evaluation criteria that are not addressed by an ontological evaluation. For instance, from a teach- and learn-oriented point of view, facts about enterprises represented in reference models should be understandable, or, from an enterprise-oriented point of view, the purchase and usage of a reference model should make the development of enterprise systems more efficient. Instead an ontological evaluation focuses on criteria such as completeness, precision, and consistency. So, we think that reference models should be evaluated from different perspectives.

We see several areas for further research: First, our method should be applied to evaluate known reference models to examine and guarantee their quality. Second, our approach is based on the BWW-model. Further investigations should examine the usefulness of other ontological models. Third, in this paper we only outline some application areas of an ontological evaluation.

These and further areas should be examined in more detail. Fourth, ontological evaluations of reference models should be complemented with evaluation from other perspectives. To conclude, we think that the mentioned work provides a better understanding of reference model quality and insights that lead, in the long-term, to a theory of enterprise-modeling.

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