8-2010

Effects of Semantic Quality in Business Process Modeling

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ABSTRACT

In contrast to the increasing meaning of business process management (BPM), there is a lack of knowledge about processes that impedes their analysis, implementation, and execution in business process management systems (BPMS). In this context, process modeling is an opportunity to capture process knowledge. Nevertheless, models are incomplete concerning semantic completeness. Therefore, ontologies as explicit and formal specification are used to enrich models semantically to achieve a high degree of semantic quality, model efficiency and effectiveness. But also ontology engineering needs models to describe the underlying discourse of universe. For this reason, it is the paper's goal to examine and compare the *Resource Event Agent Model* (REA) with respect to semantic quality, model effectiveness, and -efficiency in data modeling for ontologies. Moreover, the paper addresses the research question, if REA enables an effective modeling to reduce the precision deficit and complexity in BPM.

Keywords (Required)

Accounting Information Systems, Business Process Modeling.

INTRODUCTION

The use of business process management systems (BPMS) does not seem to be fully exploited, yet. This is surprising by realized total software revenues of about 1.7 billion USD (Hill et al. 2008). According to IDG (2009), only 46 per cent of the surveyed companies have measured a higher process performance by using BPMS. Global 360 points out that 32 percent of the BPMS users do not know the benefit of their business process management (BPM) project. Positively, Global 360 renounces an automated BPM execution, which is positively correlated with process improvement. Negatively, manual process-workarounds indicates an organizational efforts leading to a modeling overhead. Baeyens (2008) emphasizes a lack of knowledge concerning process analyses, technical implementation, and process execution within BPMS. In this context, process modeling is identified as a tool to gain process knowledge. It is the paper's goal to examine the meaning of an effective and efficient conceptual modeling in context of business process modeling and its impacts to BPM.

Companies cannot gain profit from BPM just as a managerial concept, they need both knowledge and computational capabilities to identify, analyze, simulate, and improve business processes. Nowadays, BPMS provide software tools that enable an automated process modeling, execution, and improvement. Although the adoption of BPMS has reached a high level, because the adaption, analyses, and reengineering of business processes is complex (Roser et al. 2008; Scheer et al. 2000). Therefore, process modeling is used to gain process knowledge, which is the basis to reduce uncertainty by capturing and controlling relevant process parameters. Such knowledge needs also modeling consistency between the business processes and organizational levels. But multiple modeling and execution standards (Hill et al. 2008; Ko et al. 2008) as well as the complexity of BPMS are the main obstacles for a holistic process knowledge, yet, which is a key factor to improve system usage (Hunton and Price 1994). Current approaches lead to an extensive modeling overhead. Even integrated approaches like ARIS (Scheer 2001) have drawbacks in context of effectiveness, efficacy and model integration. This leads to extensive rework when executing business processes, because functional requirements have to be translated into programming code. Due to these drawbacks, conceptual modeling is used to improve model integration and all-encompassing understanding (Mylopoulos & Zicardi 1992). In this context, Poels et al. (2004) have examined the use of the *Resource Event Agent* (REA) Model (McCarthy1982) with respect to conceptual model quality. According to Morris (1970), quality consists of categories addressing syntax, semantics, and pragmatism. Poels found out (based on the Method Evaluation Model (MEM) of Moody (2001)) that REA modeling might prove to be efficacy with respect to user comprehension. But models are not per se explicit. Therefore, model efficacy is improved by using ontologies to achieve model quality in context of BPMS implementation.

Reviewing the literature, there exist different semantic approaches addressing the improvement of semantic quality in modeling to close the gap between functional modeling and BPMS implementation (Heinrich et al. 2008; Hepp and Roman 2007; Thomas and Fellmann 2007; Roser et al. 2008). But they all renounce the perspective of model consistency and efficacy in context of analyzing capabilities within the value chain in order to improve process knowledge. Therefore, this paper contributes to the discussion of the REA model in comparison with non-REA models in respect of semantic quality in BPMS following the concepts of the *Framework for Quality and Conceptual Modeling* (Lindland et al. 1994). The REA model is analyzed according to model effectiveness, efficiency, and semantic quality, as well as the impact of model efficacy to BPM.

The course of the paper is as follows. Section 2 describes the universe of discourse and explains current drawbacks of BPM with respect of process knowledge, analyses, and BPMS execution. Section 3 explains the *Framework for Conceptual Modeling*, which justified the use of REA in BPM according to efficiency and pragmatism. Section 4 describes the research design. In Section 5, two modeling approaches are compared in context of efficiency, effectiveness, and efficacy. Moreover, it is shown, how REA is used to model and define business processes activities taking emphasize to process measurement parameters. Moreover, the meaning of REA in semantic BPM is presented in a SBPM framework to explain the influences of model quality to BPM execution.

PROBLEM STATEMENT AND CONTRIBUTION

The research in this paper is part of a major research. The overall research goal is to decrease the complexity and to improve the cost-benefit ratio of BPMS usage. The need for this research is shown by various empirical findings. According to the studies of Global360 (2009) and Palmer (2007), process modeling and automation is a key driver for process improvement. Instead, many companies do not use the full scope of BPMS. BPM&O (2009) has identified the lack of knowledge that impedes system usage and automated execution. Reviewing the literature, we have identified several reasons: First, companies concentrate on operational modeling and manual workaround to execute business processes (ibid). Second, modeling requires model consistency between the different organizational levels, which is aggravated by multiple modeling and execution standards (Hill et al. 2008; Ko et al. 2008). For this reason, consistency is ensured with a high organizational and technical effort leading to a modeling overhead (Roser and Haberman 2008). Furthermore, the implementation of process models is ensured by engaging IT experts. But it is time consuming, expensive and impedes a deep knowledge about processes (Baeyens 2008; Link et al. 2008). Third, existing BPM solutions like ARIS (Scheer 2001) have drawbacks concerning expressiveness, the degree of formality and the linkage between different model level perspectives, i.e. operational control, management control, and strategic planning (Hepp & Roman 2007). Fourth, according to Poels et al. (2004) current conceptual models have drawbacks in semantic and pragmatic quality. Limited quality affects model efficacy (Morris 1970), which impedes process knowledge.

By using a theory driven approach based on the *Framework for Quality and Coneptual Modeling* (Lindland et al. 1994), this paper addresses the meaning of conceptual model quality and in BPM. Conceptual modeling is defined as a process. It reveals, analyzes, and describes entities of the domain subject, relationships between them, constraints, and their behavior. Its goal is to provide a formal description of a domain to understand and communicate with it (Mylopoulos & Zicardi 1992). Conceptual modeling is an important aspect to gain process knowledge by capturing, controlling, and analyzing relevant process parameters. To understand processes and their interdependencies according to the value chain, process knowledge indicates a differentiation between process logic and application logic (Mutschler and Reichert 2005). But many business process models do not contain enough semantics to describe process parameters and their contribution to the value chain. Although detailed process modeling in context of workflow management sounds promising (van der Aalst 2004), they concentrate on process tasks on a conceptual level (Georgakopoulos et al. 1995). They are restricted across companies and ignore the diagnosis component of BPM (Ko et al. 2009).

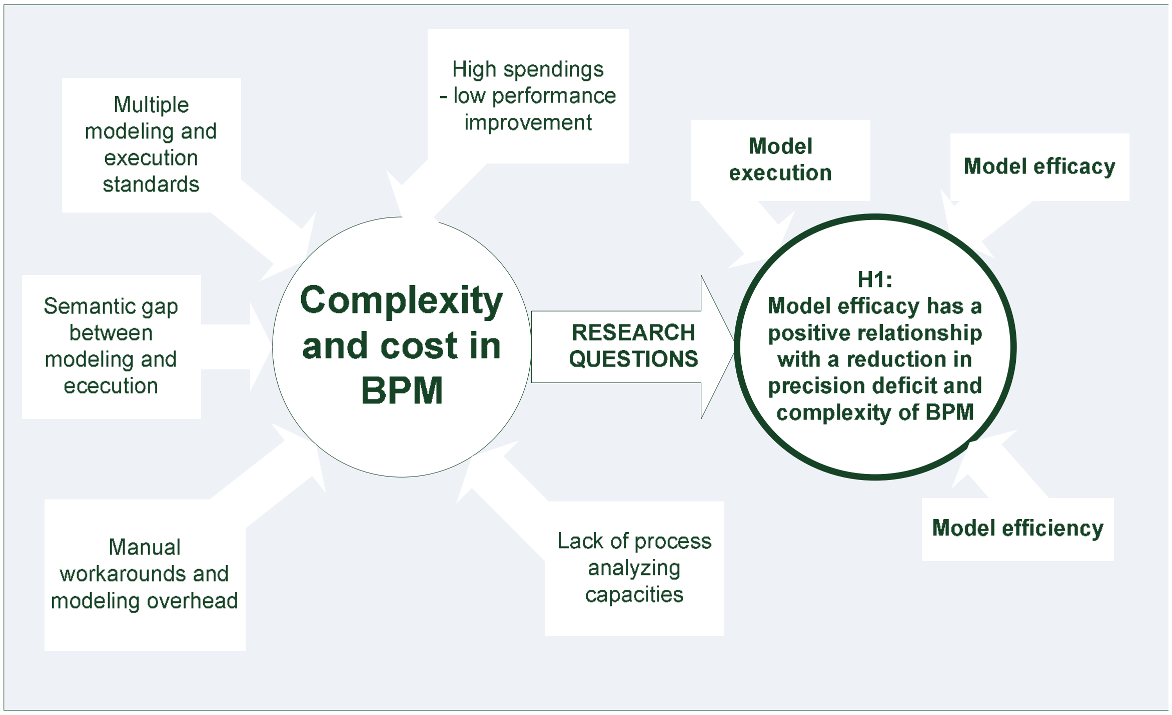

Figure 1: Overall Research

Due to these drawbacks, we examine the use of REA in its function as conceptual model and comparing it with non REA models with respect to semantic quality, model effectiveness, and -efficiency in data modeling for ontologies. By using the ontology engineering approach of Sheth (2003), the meaning of context information that decrease modeling overhead is examined. Therefore, the paper addresses the research question, if REA enables an effective modeling, reduce modeling overhead by providing semantic quality, and facilitate automated process execution within BPMS. REA is chosen because it is used as an abstraction as well as ontologic basis, which describes economic exchanges within an enterprise. REA distinguishes between the physical exchange of resources and their properties. This idea is not new, but rather it is derived from the Roman law (*ius civile*). REA consists of the three core entities, *Resources*, *Events*, and *Agents* to describe economic exchanges. Later, the *Commitment* and *Contract* entity are complemented. The entities can be composed to describe business processes and specify the fundamental laws of a business domain.

Domain ontologies as a *"formal, explicit specification of a shared conceptualization"* (Gruber 1993) are an instrument to describe functional aspects of business processes that are machine-readable. Ontologies provide a knowledge base and are used as an instrument to close the gap between functional process modeling and IT implementation (Thomas and Fellmann 2007; Hruby 2005; Markovic and Pereira 2007). But also ontology engineering is based on (conceptual) modeling to facilitate the understanding of the underlying discourse of universe. Fernández-Lopez et al. (1997) emphasize in their framework *METHONTOLOGY* the meaning of conceptual modeling. In this context, Gailly et al. (2008) evaluate conceptual modeling languages to represent formal representations in an ontology language. Concentrating on the drawbacks of BPMS implementation, the *Managing End-To-End OpeRations for Semantic Web Services* (METEOR-S) framework (Sheth 2003) provides a differentiation between data-, functional-, non-functional-, and execution semantics. Data semantics deals with the modeling of inputs and outputs of process parameters. Functional semantics defines the functional capabilities of process parameters, non-functional capture requirements like policies and agreement. The execution semantics focuses on the interaction of process parameters to execute a valid process flow. The differentiation is used to describe business processes in detail, defining terms, conditions, relations, and states (ibid). We concentrate on the data semantics that explains all constructs and their relations that are required for a process specification. It is the goal to compare the REA model with non-REA models as conceptual ones with respect of semantic quality following the concepts of the *Framework for Quality and Conceptual Modeling* (Lindland et al. 1994). It will be shown that semantic quality in data semantics improves model efficiency and –effectiveness in the functional semantics reducing the precision deficit in modeling. It leads to a better understanding and knowledge, which is expressed as model pragmatism (Moody 2001). Whereas Poels et al. (2004) analyze the REA model in conceptual accounting modeling; it is our contribution to examine the impacts of REA in context of BPM. Also Gailly and Poels (2007) has analyzed REA semantics as accounting ontology; we not only concentrate on accounting artifacts, but also on technical applications as shown in a case study.

RESEARCH BACKGROUND

As the evaluation of REA in AIS modeling, the evaluation of REA in context of BPMS implementation is based on the framework for quality and conceptual modeling (Lindland et al. 1994). It is deduced from the semiotic theory (Morris 1970) which defines four components called *sets*. The model *M* is the set of statements that has been represented. The language *L* is the set of statements that can be made according to the syntax. The domain *D* is the set of statements that would be correct and relevant for a problem of the discourse of universe. The interpretation *I* is the set of statements that the audience thinks the model contains. The concepts are linked with three quality aspects expressing linguistic concepts. First, *syntactic quality* describes the relationship between model and language with the goal of correctness. It can be described as $M \setminus L = \emptyset$, i.e. morphological errors and syntactic incompleteness lead to syntax errors. Second, *semantic quality* addresses the relationship between model and the domain. In this context, *validity* is described as $M \setminus D = \emptyset$, i.e. all statements made by the model are correct and relevant to the domain. *Completeness* means that all statements about the domain that are correct and relevant are defined as $D \setminus M = \emptyset$. Third, pragmatic quality describes the relationship between model and audience interpretation. It is defined as $M \setminus I_i = \emptyset$ & $I_i \setminus M = \emptyset$, i.e. there are no statements in the model that are not in the stakeholder's model interpretation, and vice versa.

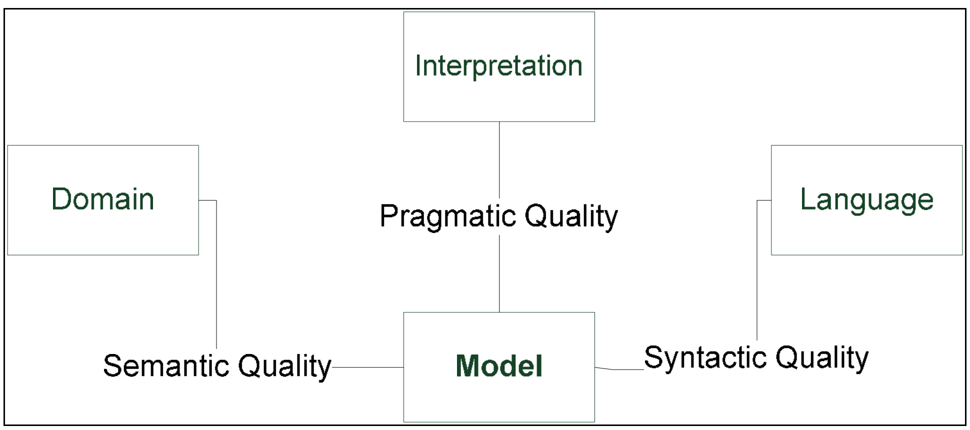

Figure 2: Framework for Quality and Conceptual Modeling (Lindland et al. 1994)

The three linguistic concepts are key drivers to improve understanding and knowledge about business processes. Poels et al. (2004) consider semantic and pragmatic quality in conceptual AIS modeling. Concerning these aspects, we also use the Method Evaluation Model (MEM) (Moody 2001) to proof REA as ontologic base for BPMS implementation in context of (actual) efficacy.

MEM was developed to evaluate IS design methods concerning aspects of efficacy and adoption. Based on the *Technology Acceptance Model* (Davis 1989) and the *Methodological Pragmatism* (Rescher 1977), we focus on the validation of methodological knowledge. User acceptance is not considered, because our case study concentrates on actual effectiveness and efficiency and not on future believes. Therefore, this part of the research is theory-driven. Also Janisch (2009) emphasizes the meaning of effectiveness to improve the perceived quality by meeting user requirements within models. According to Moody (2001), efficiency is the extent to which a method reduces the effort required to perform a task. Effectiveness is described as the extent to which the method improves the quality. Efficacy combines the concepts of efficiency and effectiveness.

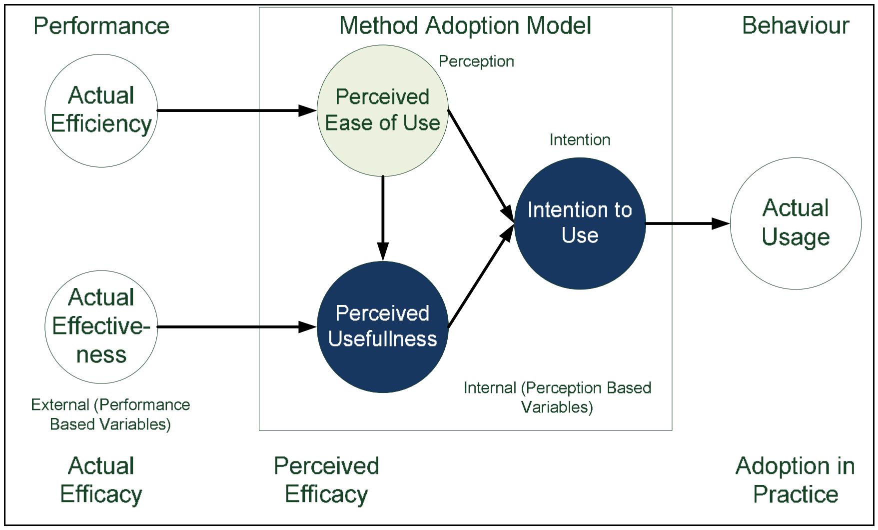

Figure 3: Method Evaluation Model (Moody 2001)

A case study is chosen to show the impact of REA in process knowledge improvement by providing a high level model quality in BPM. Yin (2003) describes a case study as an empirical inquiry *"…that investigates a contemporary phenomenon within its real-life context*" (Yin 2003). In context of MEM, the case study is not only an aid in defining research design, but also "*becomes the main vehicle for generalizing the results of the case study*" (ibid). Theorized analytical generalization reveals complex cause and effect chains to explain sophisticated phenomena. Using a case study, we can identify effective and efficacious factors in current process- and REA modeling. Statistical evaluation – as shown in Poels et al. (2004) – renounce complexity, in-depth analyses in semantic modeling, and examination of semantic quality in models.

RESEARCH DESIGN

The research design is based on a case study in the utility industry facing with the network access of distributed service operators. The design follows the guidelines of METEOR-S (Sheth 2003). It is chosen, because it is related to the complete lifecycle of semantic web processes, their interactions, and parameter annotations. Other frameworks, as the *METHONTOLOGY* (Fernández-Lopez et al. 1997), are only correlated to ontology engineering and do not consider BPMS implementation. The design of the case study is divided into five steps:

First, the case study starts with the explanation of grid service reliability, which is a quality key figure set by the national authority. Second, a BPMN diagram represents the process of network access. The base is the verbal description of the process owner. Its function is to show the semantic drawbacks of process models concerning process measurement and knowledge. Third, the ontology definition starts with modeling the conceptual models building the data semantics. The two models are compared in context of semantic quality. The models also based on the verbal description of the process owner. The non-REA model orientates on the principles of an entity-relationship (ER) diagram. Fourth, deduced from the conceptual model the functional semantics is created. It specifies the process by defining preconditions and effects, as well as input and output parameter that are deduced from the data semantics. This enables a direct comparison of actual model efficacy concentrating on model completeness and validity. Efficacy is measured by comparing the semantics with the parameters of the key figure. The more process measurement information a model contains, the more effective and efficacious is a model. Moreover, the meaning of context information is examined to enable facilitated process knowledge. Finally, we use the SBPM framework of Thomas and Fellmann (2007) to examine the implications of model actual efficacy concerning an improved modeling in BPMS.

CASE STUDY AND FINDINGS

The example process represents the grid access process that is necessary to calculate the grid service quality score Q_t that is part of the German price-cap-function (Bundesnetzagentur 2006).

$$Q_t = \varphi_{SAID} * q_{SAID} * (SAID_{REF} - SAID_{GRID,t}) + \varphi_{SAIF} * q_{SAIF} * (SAIF_{REF} - SAIF_{GRID,t})$$
$$+ \varphi_{ENS} * q_{ENS} * (ENS_{REF} - ENS_{GRID,t}) + \varphi_{VOLL} * q_{VOLL} * (VOLL_{REF} - VOLL_{GRID,t}).$$

Q_t represents the revenues in year t for the grid service quality. φ is a weighting factor and q is a monetary quality factor for *SAID*, *SAIF*, *ENS*, and *VOLL*. *REF* represents a reference for the quality factors, *GRID,t* is a key figure for the quality measurement. SAID is the *system average interruption*, whereas SAIF represents the *system average interruption frequency*. ENS is the *energy not supplied* and VOLL is the *volume of lost load*.

The next step represents the process of quality score measurement, which is done by the distributed service operator to specify grid fee and load profile. Based on various load profiles, transmission schedules are calculated and power is charged and discharged. Whereas the transmission process is running, various parameters have to be metered to calculate the quality figures. Typical BPMS uses BPMN diagrams to describe business processes, their activities, and sequences. But they are too unspecific to describe business processes in detail. Figure 4 describes the process and the used resources.

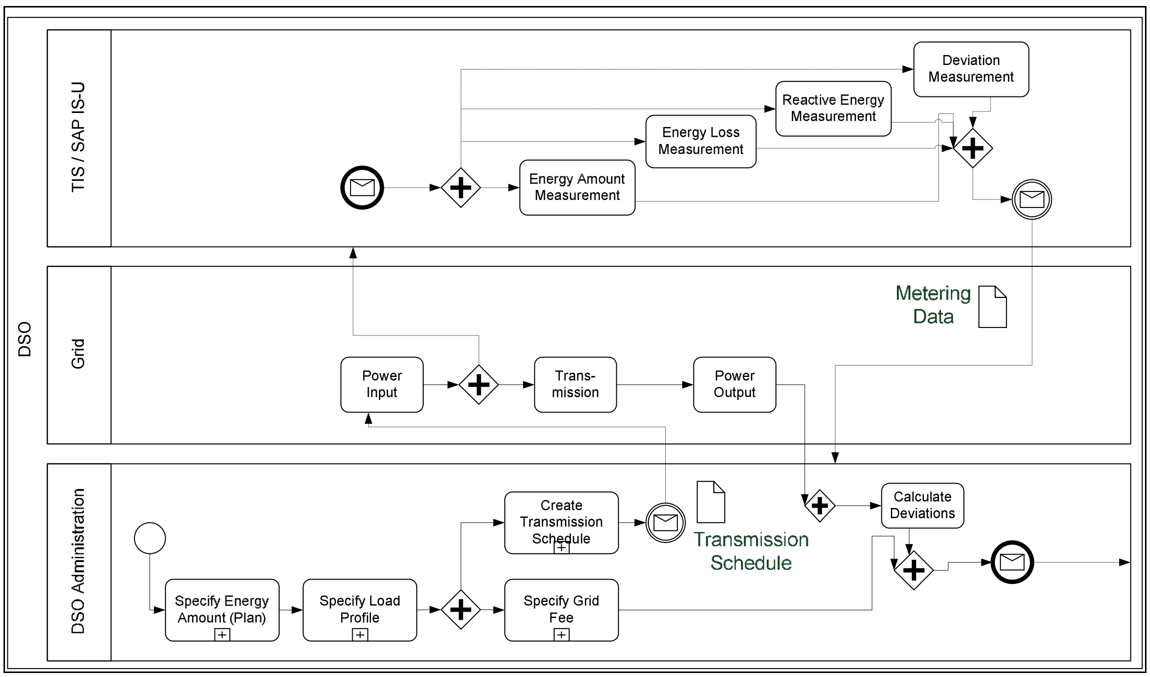

Figure 4: Concepts of the grid access process in REA

The third step constitutes the data semantics starting with the conceptual modeling of the ontologic level. Two models are compared. The first one represents the grid access process as REA model, the second one serves as ER-diagram. Notice, we concentrate on semantic quality, especially model completeness, to give context information for process knowledge improvement. Whereas a model cannot be complete, models and modeling languages differ in semantic completeness and validity (Morris 1970; Lindland et al. 1994).

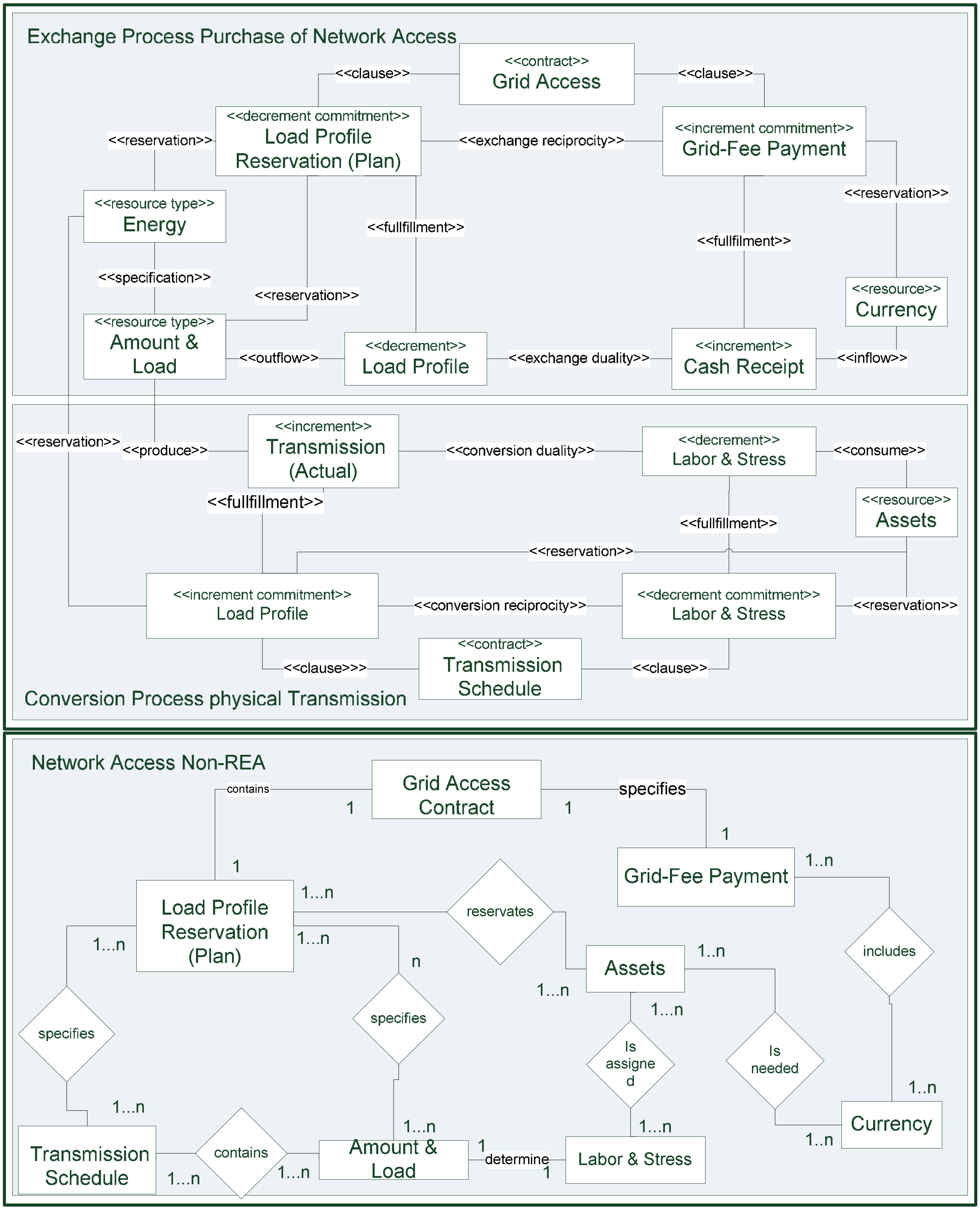

Figure 5: Concepts of the grid access process in REA and non-REA model

Comparing the REA and non-REA model with respect to semantic validity and completeness, REA takes strong emphasizes to the value chain. A company has to decrease value to some resources (decrement) in order to increase the value for other ones (increment). The model does not show how to maximize the value; it focuses on the meaning of each activity in terms of a cause-and-effect-chain, e.g. the transmission increases the load efficiency and causes stress and labor. All four key figures are instances of the resource *Amount&Load,* and produce the decrement *Labor&Stress* which have a decreasing impact to the resource *Assets* affecting the mechanics, the resistance load per unit length, and line protection releases. Moreover, context information is given by decrement and increment resources of reciprocal events. Value specific information in REA models combines technical and financial information.

This information is not existent within the non-REA model. Although the non-REA diagram represents the same objects, the relationships and their impacts to the quality scores is not obvious. Instead, only the context information between two neighboring objects is described. Furthermore, the context of the objects *Assets*, *Load*, and *Currency* is not clear. Finally, REA models posses a higher semantic completeness as non-REA ER-models because they contain more semantic information. Whereas this conclusion is not new (see Buder et al. 2009; Gailly et al. 2008, Poels et al. 2004), the next step shows effects of the conceptual model concerning context information.

The functional semantics define input- and output parameters for each process activity that are deduced from the data semantics. Furthermore, preconditions and effects are defined. Concerning the REA model, the input- and output parameters are instances of the resources, which are linked with decrement or increment events. The linkage in the conceptual model gives context information, if parameters and effects affect a decrement or increment. For this reason, REA provides context information in the conceptual model. Context has two different functions: First, it confines the data volume to improve data comparison. Second, it specifies and classifies data for analyses. The context information given in the conceptual model ensures that a conversion process (the transmission of power) is executed, if a *Grid Access* contract is assigned and a *Transmission Schedule* is calculated. Moreover, context information from the REA model explains which resources are decremented and incremented. According to $\mathbf{Q}_t$, the four quality scores are induced by the *Transmission* event and are the result of the decrement event *Labor&Stress*. They depend on the resource *Asset*, especially its instances number of transformers, grid-resistance, and transmission-distance.

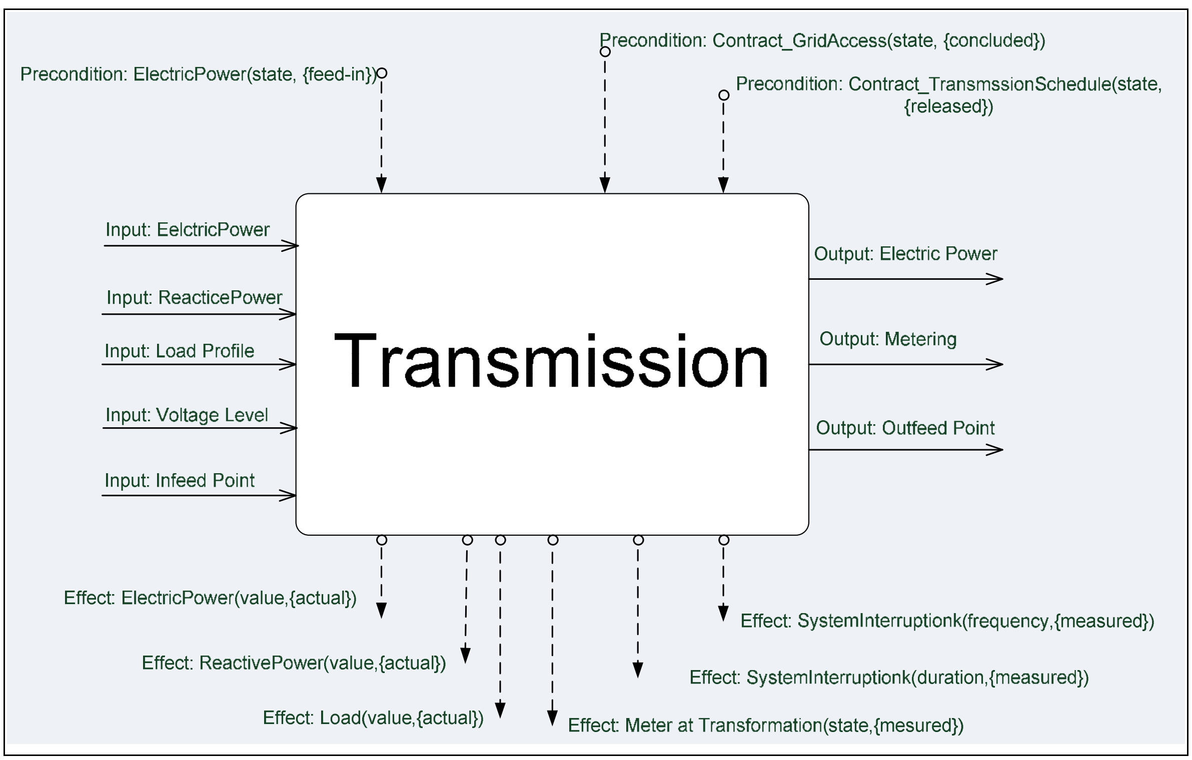

Figure 6: Functional Semantics deduced from REA diagram

The use of the non-REA model perhaps will lead to the same results, but they are not deduced from the conceptual model. They need different domain experts in conceptual modeling, definition of preconditions, and specification of process parameters. The context information is not within the conceptual model. The ER-model does not contain the value effects, e.g. if electric power is an instance of *Labor&Stress* or *Amount&Load*. Therefore, the functional semantics is not deduced one-to-one from the data semantics and does not contain value specific description of parameters.

In conclusion, REA improves the semantic quality and therefore is more effective as an ER-diagram in conceptual modeling. By providing context-information focusing on value activities, REA has a higher semantic completeness and therefore a higher semantic quality. In the functional semantics, the parameters are directly deduced from the REA data model representing input- and output parameters. Context information misses in the non-REA model and either additional domain experts or further process models are necessary. Objects and relations in the REA model improve the definition of process parameters, conditions, and effects without the assistance of domain experts, which increases model efficiency (see Buder et al. 2009; Heinrich et al. 2008). Therefore, REA provides a higher actual efficacy according to MEM.

Finally, the impact of a higher efficacy is shown with respect to an improved modeling using the SBPM framework of Thomas and Fellmann (2007). It differentiates between model-level, meta-model-level, and ontology-level. Model elements are linked with an ontology representing elements of the process-language or present the domain. A link is called semantic annotation, which enables machine-readability of additional information. Focusing on actual model efficacy, a high semantic quality decreases the scope of interpretation and increases the deduction of relations that are not explicit in the model. The model-level represents the intuitive process representation. The process activities are linked with the meta-level, which describes the semantic equivalence between model element and domain instance. Context information that is not part of the process model is defined with a relationship of a higher semantic specificity. Therefore, model elements can linked with one or more meta-level elements. The more semantic information a domain ontology provides, the more details are defined within the meta-level, the more effective is a process model. But building the ontology starts with conceptual modeling. The described formal and explicit annotation links the domain ontology with the process model, which is described as precise modeling. It reduces modeling overhead by describing a business process and enriches them with semantic information.

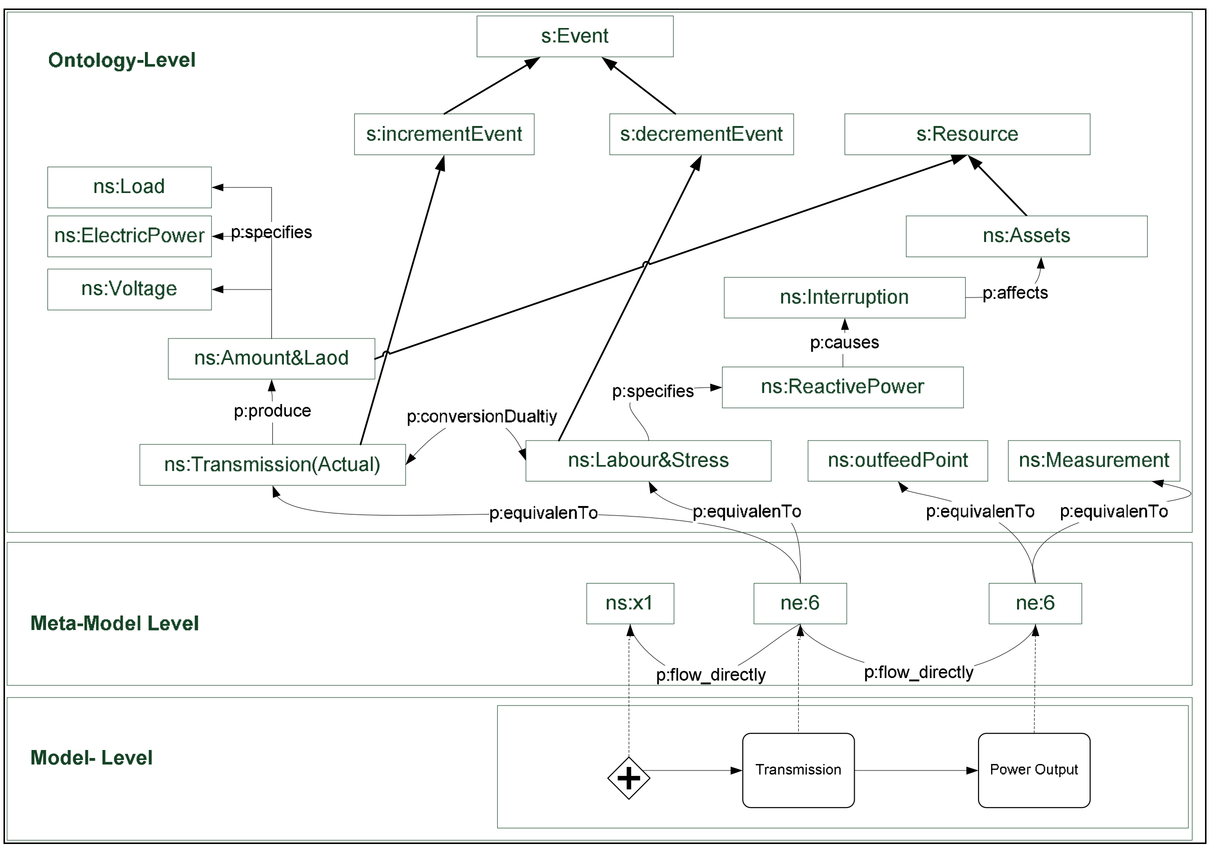

Figure 7: SBPM Approach according to Thomas and Fellmann (2007)

Concerning the hypothesis H1 (shown in Figure 1), the use of REA in conceptual ontology modeling improves the actual efficacy, especially semantic quality. It reduces the precision deficit giving context information within the model. Context information improves the functional semantics to annotate process activities at the model-level. Furthermore, a high degree of semantic completeness facilitates the engineering of domain ontologies that are the basis for a semantic annotation. The semantic annotation is the base to reduce the precision deficit in current process models and an enabler in BPM execution. For these reasons, value chain information in modeling improves knowledge gaining. Moreover, the complexity of current process modeling is facilitated using REA as a general pattern to describe the conversion and exchange of economic resources.

CONCLUSION

Caused by a lack of knowledge in business process analysis, implementation and execution in BPMS, the paper has examined the meaning and implications of process modeling. Using the ontology engineering approach of Sheth (2003), it is shown in a case study, how context information in conceptual data modeling improves the knowledge gaining and facilitates a semantic enrichment of process models using ontologies. To reach a high level of model efficacy, the REA model is compared with typical ER-models that are used in the conceptual, data-semantics-modeling. By giving context information, REA provides a higher degree of semantic completeness that is the base for building the domain ontology of a certain task. The higher the semantic quality of a domain model, the higher the semantic quality of the domain ontology. A high degree of semantic quality ensures an improved modeling in SBPM. SBPM is used to annotate process models semantically. The annotation ensures an automated execution and decrease the modeling overhead (Hepp and Roman 2007; Thomas and Fellmann 2007). Moreover, it enables an accurate modeling by linking ontology elements with the model activities. According to the hypothesis, a high model efficacy in data modeling impacts the semantic quality of a domain ontology and reduces the modeling overhead by annotating the process model elements semantically. Nevertheless, there are some limitations of the case study: The study only examines the actual efficacy and renounce the perceived efficacy of process models in BPM. But the presented results are an input for a further empirical examination. Moreover, the examination of the perceived efficacy gives information of cost-benefit analysis especially of REA modeling in SBPM. In conclusion, the study show the meaning of semantic quality, and efficacy in context of process modeling and its implications for an improved knowledge gaining, precise, and machine-readable modeling in BPM.

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