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INTEGRATING MULTI-PERSPECTIVE VIEWS INTO ONTOLOGICAL ANALYSIS

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Abstract

It is argued that contribution to the theory and practice of the analysis and design of information systems and services within organizational contexts requires the following steps. First, an underlying theoretical domain is needed. Second, the constructs of this domain have to be communicated using some commonly understood “language.” Third, these constructs have to be applied to purposes that are of interest to users, particularly business users. Finally, this application needs to take into consideration the constraints that users work under and, particularly in business, the need for cost effectiveness. It is claimed that the models developed by Bunge, Wand and Weber (BWW models), in particular the representation model, provide a good starting point for this theoretical foundation. In order to communicate the BWW models, an ER-based meta model for the BWW representation model is suggested. A common issue about some of the results with a number of the ontological analyses that have been done so far is the lack of relevance and cost effectiveness. This situation suggests that integrating perspectives into the process of ontological analysis would improve the usefulness of the results to users. Specifically, ensuring the relevance of the results to the different purposes of different users would improve the usefulness of the ontological analysis to users of modeling grammars. Accordingly, the application of a third dimension—the cost effectiveness dimension—to the analysis of modeling grammars using the BWW representation model is investigated. Specifically, the requirements of activity-based costing systems are analyzed as a first example of a perspective.

1. INTRODUCTION

The goal of this paper is to argue for a set of steps that will facilitate the advancement of theory and practice in the analysis and design of information systems and services within organizational contexts. First, an underlying theoretical domain is required. Second, the constructs of this domain need to be communicated using some commonly understood “language.” Third, the constructs of the theory have to be applied to purposes that are of interest to users, particularly business users. Finally, this application needs to take into consideration the fact that users in various situations work under constraints and, in particularly business, the need for cost effectiveness.

This paper unfolds in the following manner. First, we will explain why the Bunge, Wand and Weber (BWW) representation model might be considered a good starting point for a theoretical foundation to underlie the IS discipline. Also, the use of the BWW model to analyze and evaluate information systems analysis and design (ISAD) grammars to date is reviewed. Next, we explain briefly how a meta model of the BWW representation constructs can be developed and used to facilitate not only communication of the constructs but also the analysis of ISAD grammars using the BWW constructs. Then we extend the usefulness of the BWW analyses by introducing a third dimension—the cost effectiveness dimension—to the analyses. It is argued that the cost effectiveness dimension must be linked to the modeling purpose. Finally, we conclude by integrating this new dimension into the ontological analysis of the modeling grammar that supports activity-based costing systems.

2. A CANDIDATE THEORETICAL FOUNDATION AND HOW IT HAS BEEN APPLIED TO DATE

Without a theoretical foundation, one framework of factors, features, or facets is as justifiable as another for use in analyzing and evaluating ISAD grammars (Bansler and Bodker 1993; Batra et al. 1990; Colter 1984; Floyd 1986; Gorla et al. 1995; Karam and Casselman 1993; Seligmann et al. 1989). Wand and Weber (1989a, 1989b, 1990a, 1990b, 1991, 1993, 1995) have investigated the branch of philosophy known as ontology (or meta-physics) as a foundation for understanding the process in developing an information system. Ontology is a well-established theoretical domain within philosophy dealing with models of reality. Wand and Weber (1989b, 1990a, 1990b, 1993, 1995) and Weber (1997) have taken, and extended, an ontology presented by Bunge (1977) and applied it to the modeling of information systems.¹ Their fundamental premise is that any information systems analysis and design (ISAD) modeling grammar must be able to represent all things in the real world that might be of interest to users of information systems; otherwise, the resultant model is ontologically incomplete. If the model is incomplete, the analyst/designer will somehow have to augment the model(s) to ensure that the final computerized information system adequately reflects that portion of the real world it is intended to simulate. The Bunge-Wand-Weber (BWW) (1989b, 1990a, 1990b, 1993, 1995) models consist of the representation model, the state-tracking model, and the good decomposition model. This work focuses on the representation model. The representation model defines a set of constructs that, at this time, are thought by the researchers to be necessary and sufficient to describe the structure and behavior of the real world. Table 1 shows these constructs expressed in plain English.

Table 1. Ontological Constructs in the BWW Representation Model

Ontological Construct	Explanation
THING*	A thing is the elementary unit in the BWW ontological model. The real world is made up of things. Two or more things (composite or simple) can be associated into a composite thing.
PROPERTY*: IN GENERAL IN PARTICULAR HEREDITARY EMERGENT INTRINSIC NON-BINDING MUTUAL BINDING MUTUAL ATTRIBUTES	Things possess properties. A property is modeled via a function that maps the thing into some value. For example, the attribute “weight” represents a property that all humans possess. In this regard, weight is an attribute standing for a property in general . If we focus on the weight of a specific individual, however, we would be concerned with a property in particular . A property of a composite thing that belongs to a component thing is called an hereditary property. Otherwise it is called an emergent property. Some properties are inherent properties of individual things. Such properties are called intrinsic . Other properties are properties of pairs or many things. Such properties are called mutual . Non-binding mutual properties are those properties shared by two or more things that do not “make a difference” to the things involved; for example, order relations or equivalence relations. By contrast, binding mutual properties are those properties shared by two or more things that do “make a difference” to the things involved. Attributes are the names that we use to represent properties of things.
CLASS	A class is a set of things that can be defined via their possessing a single property.
KIND	A kind is a set of things that can be defined only via their possessing two or more common properties.
STATE*	The vector of values for all property functions of a thing is the state of the thing.
CONCEIVABLE STATE SPACE	The set of all states that the thing might ever assume is the conceivable state space of the thing.
STATE LAW: STABILITY CONDITION CORRECTIVE ACTION	A state law restricts the values of the properties of a thing to a subset that is deemed lawful because of natural laws or human laws. The stability condition specifies the states allowed by the state law. The corrective action specifies how the value of the property function must change to provide a state acceptable under the state law.
LAWFUL STATE SPACE	The lawful state space is the set of states of a thing that comply with the state laws of the thing. The lawful state space is usually a proper subset of the conceivable state space.
CONCEIVABLE EVENT SPACE	The event space of a thing is the set of all possible events that can occur in the thing.
TRANSFORMATION*	A transformation is a mapping from one state to another state.

¹In addition to the modeling of information systems, the usefulness of ontology as a theoretical foundation for knowledge representation (KR) and natural language processing (NLP) is a fervently debated topic at the present time in the artificial intelligence (AI) research community (e.g., Bateman 1995).

Ontological Construct	Explanation
LAWFUL TRANSFORMATION: STABILITY CONDITION CORRECTIVE ACTION	A lawful transformation defines which events in a thing are lawful. The stability condition specifies the states that are allowable under the transformation law. The corrective action specifies how the values of the property function(s) must change to provide a state acceptable under the transformation law.
LAWFUL EVENT SPACE	The lawful event space is the set of all events in a thing that are lawful.
HISTORY	The chronologically ordered states that a thing traverses in time are the history of the thing.
ACTS ON	A thing acts on another thing if its existence affects the history of the other thing.
COUPLING: BINDING MUTUAL PROPERTY	Two things are said to be coupled (or interact) if one thing acts on the other. Furthermore, those two things are said to share a binding mutual property (or relation); that is, they participate in a relation that “makes a difference” to the things.
SYSTEM	A set of things is a system if, for any bi-partitioning of the set, couplings exist among things in the two subsets.
SYSTEM COMPOSITION	The things in the system are its composition.
SYSTEM ENVIRONMENT	Things that are not in the system but interact with things in the system are called the environment of the system.
SYSTEM STRUCTURE	The set of couplings that exist among things within the system, and among things in the environment of the system and things in the system is called the structure.
SUBSYSTEM	A subsystem is a system whose composition and structure are subsets of the composition and structure of another system.
SYSTEM DECOMPOSITION	A decomposition of a system is a set of subsystems such that every component in the system is either one of the subsystems in the decomposition or is included in the composition of one of the subsystems in the decomposition.
LEVEL STRUCTURE	A level structure defines a partial order over the subsystems in a decomposition to show which subsystems are components of other subsystems or the system itself.
EXTERNAL EVENT	An external event is an event that arises in a thing, subsystem, or system by virtue of the action of some thing in the environment on the thing, subsystem, or system.
STABLE STATE*	A stable state is a state in which a thing, subsystem, or system will remain unless forced to change by virtue of the action of a thing in the environment (an external event).
UNSTABLE STATE	An unstable state is a state that will be changed into another state by virtue of the action of transformations in the system.
INTERNAL EVENT	An internal event is an event that arises in a thing, subsystem, or system by virtue of lawful transformations in the thing, subsystem, or system.
WELL-DEFINED EVENT	A well-defined event is an event in which the subsequent state can always be predicted given that the prior state is known.
POORLY-DEFINED EVENT	A poorly defined event is an event in which the subsequent state cannot be predicted given that the prior state is known.

Source: Weber (1997) with minor modifications. * indicates a fundamental and core ontological construct.

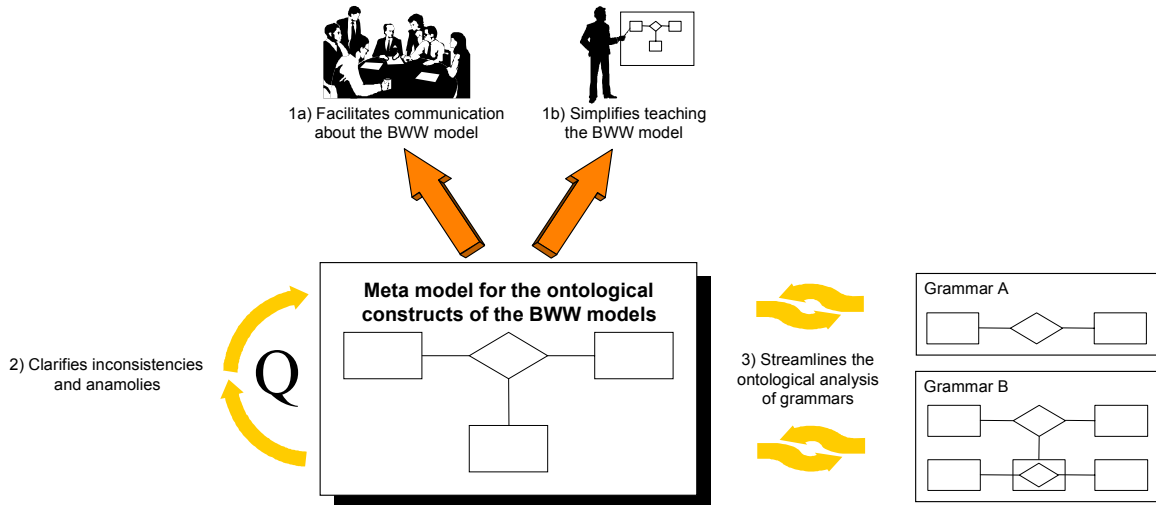
Table 2 summarizes how the BWW representation model has been applied to date (Green and Rosemann 2000). Moreover, it highlights how this current work-in-progress distinguishes itself by incorporating the type of user and the user’s purpose into the analytical process.

3. A META MODEL FOR THE BWW MODEL AND HOW IT CAN BE USED

We need to be able to communicate clearly and relatively easily the constructs of the BWW representation model. Wand and Weber (1990a) originally defined the constructs using a rigorous set-theoretic language. Even though in many subsequent works the researchers attempted to simplify and clarify the explanation of the constructs by defining them using plain English, the problem of *lack of understandability* has remained. To address the problem of understandability, we have developed a semi-formal description of the core Wand and Weber ontological constructs using a *meta model*. We have used a relatively well-known *meta language (an extended ER-approach)* (Chen 1976; Scheer 1998). An extract of the meta model that we designed for the BWW model can be found in Rosemann and Green (2000).

Table 2. Summary of Ontological Analyses

Study	Type of Grammar					Ontological Completeness	Empirical Testing	User Type	User's Purpose
	Traditional	Structured	Data-centered	O-O	Process				
Wand and Weber (1989b)		✓ (DFD)	✓ (E-R)			✓			
Wand and Weber (1995)			✓ (E-R)			✓			
Weber (1997)			✓			✓			
Sinha and Vessey (1995)			✓ (relational)	✓		✓	✓ (23 students only)		
Weber and Zhang (1996)			✓ (NIAM)			✓	✓ (10 interviews)		
Green (1997)	✓	✓	✓			✓	✓ (survey + interviews)		
Parsons and Wand (1997)				✓		✓			
Opdahl and Henderson-Sellers (1999)				✓ (OML)		✓			
Green and Rosemann (2000)					✓	✓			
This work					✓	✓		✓	✓

**Figure 1. Application Areas of a Meta Model for the BWW Ontological Constructs**

Through the BWW meta model, the current understanding of the ontological constructs and how they relate to each other can be explained relatively clearly. Furthermore, the need to structure precisely the relationships between the ontological constructs in the meta model facilitates the clarification of any inconsistencies and anomalies that might be present in the BWW models.

Figure 1 outlines the areas where a meta model of the BWW ontological constructs can be applied usefully.

4. THE COST EFFECTIVENESS DIMENSION

The meta model attempts to overcome the problem of understandability of the BWW representation model constructs. Understandability is a prerequisite for the communication and use of this ontology. Using the easier-to-understand BWW meta model, we analyzed a popular business process modeling technique. Table 3 provides an extract of the results of the analysis of integrated process modeling—event-driven process chain (EPC) grammars—embedded in the Architecture of Integrated Information Systems (ARIS) technique (see Green and Rosemann 2000).

Every empty row in Table 3 indicates that even the entire ARIS approach incorporating five views is ontologically incomplete. That is, certain ontological constructs do not appear across any of the five views, *e.g.*, *conceivable state space*, *conceivable event space*, *lawful event space*.

Table 3 and previous ontological analyses raise the question: Is the BWW model mis-specified? In other words, does it include irrelevant constructs or is it missing important constructs such as goals or knowledge (Green and Rosemann 2000)?

In general, current ontological analyses focus on the selection of an adequate ontology and the evaluation of modeling grammars against that ontology. Ontological weaknesses are often interpreted as a weakness of the ontology or a weakness of the analyzed grammar. It might be, however, a *weakness of the comparison* as the ontology and the analyzed grammar do not fit. This situation can be explained by the highly interdisciplinary history of most ontologies (Guarino 1998) and it has motivated our extension of the process of ontological analysis by adding a dimension that expresses the relevance of the results.

Figure 2 describes the intention of this new dimension. Instead of an entire ontology, a more focused ontology derived through the identification of an appropriate subset and relevant specializations of the underlying ontology is taken for the ontological analyses. The main advantages of this kind of analysis are that the identified weaknesses are relevant weaknesses and that the focused ontology is based on a well-discussed ontology with philosophical foundations.

This use of the focused ontology in an analysis integrates the multi-perspective views of the *type of user* and his/her *relevant purpose*. The *purpose* describes the objectives of the modeling tasks and is used to focus the modeling process at an early stage. For example, many workflow management systems include their own approach to describing the work flows. They are designed for exactly one purpose: the design and support of the execution of work flows. Nevertheless, a traditional ontological analysis would identify weaknesses. Possibly, however, the developer of this particular workflow modeling language does not care about such weaknesses.

Besides the purpose, the *type of user* impacts the requirements of a situation. The user can be classified principally by role within a modeling project, role within the modeled domain, experience with modeling, and position in the organization.

Purpose and user together are the main factors of the modeling context. Together they form the *perspective* of the modeling situation and determine modeling requirements. If it is possible to describe the requirements of a specific purpose and anticipate the demands of a class of users, this information could be used to develop focused ontologies. Figure 3 extends Figure 1 by showing how *purpose* and *user* can be integrated to assist in developing new, ontologically based specific modeling grammars (see also Guarino 1998 and the idea of ontology-driven information systems).

The introduction into the analysis of the cost effectiveness dimension based on perspective (type of user and their purpose) is well grounded in business decision-making theory. The Finance-Economics paradigm of *rationality* tells us that decision makers are rational—they will make their decisions based on their perceptions of the (economic) costs and benefits of the situation. These costs and benefits are determined by the user (or at least the type of user) and their peculiar situation (purpose). For example, the same user may design different models for the same purpose in different contexts because of varying economic constraints. Examples of such constraints could be time and budget limitations on the project. Users will only “care” about the results of the ontological analyses if they are meaningful (*cost effective*) for them in their peculiar situations.

Table 3. Extract of the BWW Representation Model Analysis of Integrated Process Modeling

Ontological Construct	Process View	Data View	Function View	Organizational View	Output View
THING				User, department (instances)	Product catalogue, product model, bill of materials (instances)
PROPERTY: IN PARTICULAR IN GENERAL MUTUAL EMERGENT HEREDITARY ATTRIBUTES	Function Type Attribute type	 Attribute type	Function Type Attribute type	 Attribute type	
CLASS		Entity type		Organization type	Material Output/Input, Services
KIND		Specialization/ generalization (IS-A)	Specialization/ generalization (IS-A)	Organization type	Specialization/ generalization (IS-A)
STATE	Event type (only the state variables that trigger the function)				
CONCEIVABLE STATE SPACE					
STATE LAW	Function type → connector → Event type	Specialization/ generalization descriptors; [Min., max.] cardinalities	Specialization/ generalization descriptors		
LAWFUL STATE SPACE					
EVENT	Event type → Function type → Event type				
PROCESS	Process model Function type		Function type Process oriented function decomposition		
CONCEIVABLE EVENT SPACE					
TRANSFORMATION	Function type		Function type		
LAWFUL TRANSFORMATION	Event type → connector → Function type				
LAWFUL EVENT SPACE					
HISTORY					
ACTS ON					
COUPLING: BINDING MUTUAL PROPERTY		Relationship type (no symbol for relationship in grammar)			

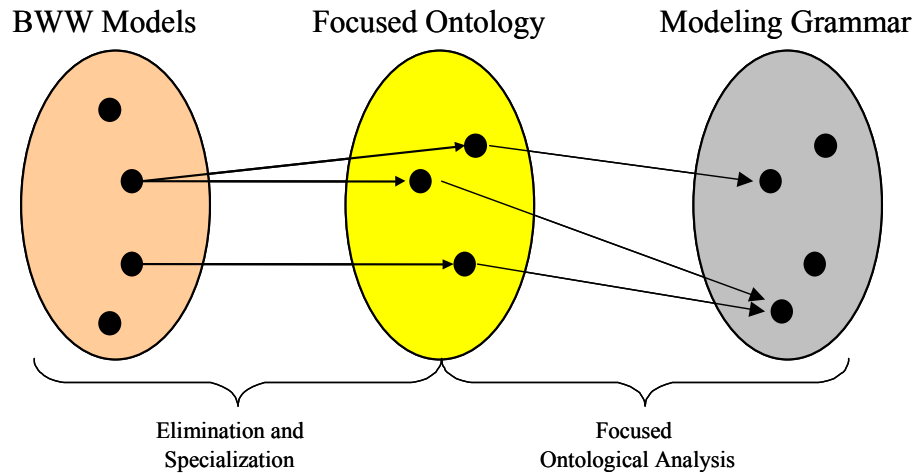


Figure 2. Extension of the Ontological Analysis

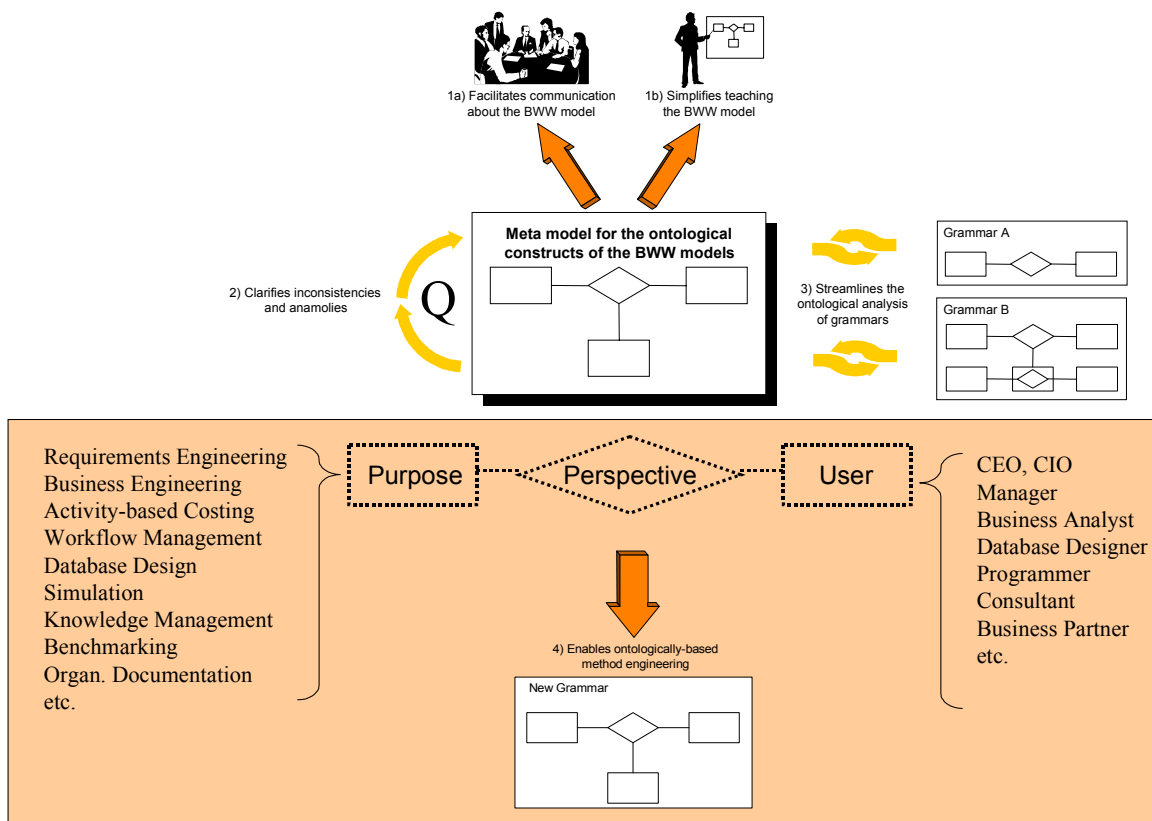


Figure 3. Ontologically Based Development of Specific IS Modeling Grammars

5. APPLYING THE COST EFFECTIVENESS DIMENSION TO ACTIVITY-BASED COSTING

In order to develop *more specific IS ontologies*, example purposes are required. Initially we selected one purpose with relatively precise requirements: activity-based costing (ABC). We selected the most widely used tertiary text on cost accounting worldwide (Horngren et al. 1996) as a reference for the identification of the mandatory constructs of the ABC purpose. Moreover, for this example, we did not incorporate the type of user. This approach is limited by the degree in which the Horngren reference describes activity-based costing without deficiencies. Moreover, we did not investigate whether the entire approach of activity-based costing is deficient. This analysis is beyond the scope of this paper and belongs to the discipline that developed activity-based costing.

Horngren et al. explain that firms use a costing system to accumulate and assign costs to products and services. Essentially, businesses can adopt a job costing system or a process costing system. ABC is not of itself a costing system; rather it is a refinement of either an existing job costing or process costing system. The fundamental costing constructs (grammar) pertinent to ABC need to be defined and mapped to the corresponding BWV constructs:

- *Cost object* is any THING (e.g., instance of product X) requiring a separate measurement of costs. Cost objects can also be a CLASS (e.g., product X) or a KIND (e.g., specialization, product X.1).
- *Direct costs of a cost object* are costs that can be traced as a PROPERTY to the cost object in an economically feasible way.
- *Indirect costs of a cost object* are costs that cannot be traced to the cost object in an economically feasible way. Accordingly, indirect costs are allocated to the cost object by using a cost allocation method and, therefore, represent a PROPERTY of the cost object.
- *Cost pool* is a grouping of individual cost items and, therefore, represents a PROPERTY of the CLASS of cost objects being represented in the pool. For example, if a firm operates out of a number of inner-city office buildings, it may choose to pool all of the individual office leasing costs into a single company-wide office leasing cost pool.
- *Cost allocation base* is the factor that has a cause-and-effect relationship with the indirect costs of a cost object. Again, it corresponds to a PROPERTY of the cost object CLASS or KIND.
- *Activity* is a lawful EVENT or TRANSFORMATION. A series of events over time represents a PROCESS.

Using these classical definitions of ABC provided by Horngren et al. (pp. 158-167) and the definitions of the BWV ontological constructs (Table 1), Table 4 provides a focused ontology for the ABC purpose.

A process model for the fundamental concepts of ABC involves as a minimum the ontological constructs of *thing*, *class*, *kind*, different types of *property*, *state*, *state law*, *transformation*, *lawful transformation*, *coupling*, and *process*. Our thesis is that unless a modeling grammar (e.g., event-driven process chains (EPC)) provides symbols to represent at least this set of ontological constructs, users interested in designing and implementing ABC systems will find the modeling grammar deficient and they will look for other compensatory methods.

Table 4. Focused Ontological Constructs for ABC

ABC Construct	Focused Ontological Construct(s)
Cost object	Thing, class, or kind
Direct costs of a cost object	Property (in particular, in general, or binding mutual)
Indirect costs of a cost object	Property (emergent property of the process system)
Cost pool	Property (emergent property of a class)
Cost allocation base	Property (emergent property of a class)
Activity	Process, event, transformation, lawful transformation.

Moreover, users involved in designing and implementing ABC systems using EPCs will be indifferent to the analytical results that EPCs are ontologically deficient with regard to such ontological constructs from the original BWV model as *conceivable state space*, *lawful state space*, *conceivable event space*, *lawful event space*, *unstable states*, *history*, *poorly-defined events*, and the “system” constructs of *system*, *system composition*, *system environment*, *system structure*, *subsystem*, *system decomposition*, and *level structure*. From these deficiencies, it would appear that users of ABC are indifferent to capturing all of the potentially important business rules of the process(es) and to defining the scope and boundaries of the system (processes) being analyzed.

6. SUMMARY AND OUTLOOK

This paper has proposed a four-step process required for advancing the theory and practice in the analysis and design of information systems and services. We proposed the use of the BWV ontologically based models, in particular the representation model, as a candidate starting point for the theoretical domain. We explained that this model has been used to analyze and evaluate many different modeling grammars to date. While these analyses have highlighted some useful points for the development of those grammars, in many instances, users of the respective grammars have shown indifference to some of the highlighted shortcomings of their grammar. We propose that this indifference derives from the fact that users of modeling grammars use them for particular purposes. Accordingly, the user (or at least the class of user) and their purpose must be taken into account when performing the ontologically based analyses for the results to be useful. Therefore, we propose that a third dimension, the cost effectiveness dimension, needs to be added to the ontological analysis. To begin this work, we start with one well-known purpose, activity-based costing, to identify the subset of ontological constructs necessary to those purposes and for which any modeling grammar that is used to model this purpose must have representations.

Accordingly, we see the requirements for advancing the analysis and design of information systems/services within organizational contexts that we have presented in this paper guiding our future work. Table 5 shows how our work-in-progress will proceed to completion and how we feel the work supports these general requirements for advancing the IS discipline. Steps 1 to 3 have been completed thus far. Step 4 remains to complete the work.

Table 5. Requirements for Advancing Information Systems/Services and Their Application in Our Work

Step	General Requirement	Our Work
1.	Establishment of a theoretical starting point	Evaluated BWV Models.
2.	Adequate communication	ER-based meta model for the BWV models.
3.	Application to organizational contexts	Individualization of the BWV models and their application to activity-based costing in the first instance.
4.	Integration of existing constraints	Apply the focused ontology to a popular implementation of an ABC system <i>e.g.</i> , that module provided in SAP R/3. Then, evaluate the results of our individualized ontological model analysis with users of the selected ABC package.

References

- Bansler, J. P., and Bodker, K. “A Reappraisal of Structured Analysis: Design in an Organizational Context,” *ACM Transactions on Information Systems* (11:2), 1993, pp. 165-193.
- Bateman, J. A. “On the Relationship Between Ontology Construction and Natural Language: A Socio-semiotic View,” *International Journal of Human-Computer Studies* (43:5/6), 1995, pp. 929-944.
- Batra, D., Hoffer, J. A., and Bostrom, R. P. “Comparing Representations with Relational and EER Models,” *Communications of the ACM* (33:2), 1990, pp. 126-139.
- Bunge, M. *Treatise on Basic Philosophy, Volume 3: Ontology I: The Furniture of the World*, Boston: Reidel, 1977.
- Chen, P. P. S. “The Entity-Relationship Model—Toward a Unified View of Data,” *ACM Transactions on Database Systems* (1:1), 1976, pp. 9-36.
- Colter, M. A. “A Comparative Examination of Systems Analysis Techniques,” *MIS Quarterly*, March 1984, pp. 51-66.
- Floyd, C. “A Comparative Evaluation of System Development Methods,” in *Information Systems Design Methodologies: Improving the Practice*, T. William Olle, H. G. Sol, A. A. Verrijn-Stuart (eds.), Amsterdam: North-Holland, 1986, pp. 19-37.

- Gorla, N. Pu, H.-C., and Rom, W. O. "Evaluation of Process Tools in Systems Analysis," *Information and Software Technology* (37:2), 1995, pp. 119-126.
- Green, P. F. "Use of Information Systems Analysis and Design (ISAD) Grammars in Combination in Upper CASE Tools—An Ontological Evaluation," in *Proceedings of the Second CAiSE/IFIP8.1 International Workshop on the Evaluation of Modeling Methods in Systems Analysis and Design (EMMSAD'97)*, Barcelona, Spain, 1997, pp. 1-12.
- Green, P. F., and Rosemann, M. "Integrated Process Modeling: An Ontological Evaluation," *Information Systems* (25:2), 2000, pp. 73-87.
- Guarino, N. "Formal Ontology in Information Systems," in *Proceedings of Formal Ontology in Information Systems (FOIS 98)*, Amsterdam: IOS Press, 1998.
- Horngren, C. T., Foster, G., Datar, S. M., Black, T., and Grey, P. *Cost Accounting in Australia: A Managerial Emphasis*, Sydney: Prentice Hall, 1996.
- Karam, G. M., and Casselman, R. S. "A Cataloging Framework for Software Development Methods," *IEEE Computer*, February 1993, pp. 34-46.
- Opdahl, A. L., and Henderson-Sellers, B. "Grounding the OML Metamodel in Ontology," Working Paper, University of Queensland, Brisbane, 1999, pp. 1-59.
- Parsons, J., and Wand, Y. "Using Objects in Systems Analysis," *Communications of the ACM* (40:12), 1997, pp. 104-110.
- Rosemann, M., and Green, P. F. "Enhancing the Process of Ontological Analysis—The 'Who Cares' Dimension," in *Proceedings of the Information Systems Foundations Workshop - Ontology, Semiotics and Practice*, C. N. C. Dampney (ed.), Macquarie University, Sydney: Lighthouse Press, 2000, pp. 39-54.
- Scheer, A.-W. *Business Process Engineering: Reference Models for Industrial Enterprises* (2nd ed.), Berlin: Springer, Heidelberg, 1998.
- Seligmann, P. S., Wijers, G. M., and Sol, H. G. "Analyzing the Structure of IS Methodologies: An Alternative Approach," in *Proceedings of First Dutch Conference on Information Systems*, R. Maes (ed.), November 1989, pp. 1-28.
- Sinha, A. P., and Vessey, I. "End-user Data Modeling: An Ontological Evaluation of Relational and Object-oriented Schema Diagrams," Working Paper, Indiana University, Bloomington, 1995.
- Wand, Y., and Weber, R. "A Model of Control and Audit Procedure Change in Evolving Data Processing Systems," *The Accounting Review* (LXIV:1), 1989a, pp. 87-107.
- Wand, Y., and Weber, R. "An Ontological Evaluation of Systems Analysis and Design Methods," in *Information System Concepts: An In-depth Analysis*, E. D. Falkenberg and P. Lindgreen (eds.), Amsterdam: North-Holland, 1989b, pp. 79-107.
- Wand, Y., and Weber, R. "An Ontological Model of an Information System," *IEEE Transactions on Software Engineering* (16:11), 1990a, pp. 1281-1291.
- Wand, Y., and Weber, R. "Mario Bunge's Ontology as a Formal Foundation for Information Systems Concepts," in *Studies on Mario Bunge's Treatise*, P. Weingartner and G. J. W. Dorn (eds.), Atlanta: Rodopi, 1990b, pp. 123-149.
- Wand, Y., and Weber, R. "A Unified Model of Software and Data Decomposition," in *Proceedings of the Twelfth International Conference on Information Systems*, J. I. DeGross, I. Benbasat, G. DeSanctis and C. M. Beath (eds.), New York, 1991, pp. 101-110.
- Wand, Y., and Weber, R. "On the Ontological Expressiveness of Information Systems Analysis and Design Grammars," *Journal of Information Systems* (3:4), 1993, pp. 217-237.
- Wand, Y., and Weber, R. "On the Deep Structure of Information Systems," *Information Systems Journal* (5:5), 1995, pp. 203-223.
- Weber, R. *Ontological Foundations of Information Systems*, Coopers & Lybrand Accounting Research Methodology, Monograph No. 4, Melbourne, 1997.
- Weber, R., and Zhang, Y. "An Analytical Evaluation of NIAM's Grammar for Conceptual Schema Diagrams," *Information Systems Journal* (6:2), 1996, pp. 147-170.