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Understanding the Impact of Business Functional Areas on the Theory of Multiple Grammar Selection

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Abstract

Theory of Multiple Grammar Selection (TMGS) is used to select the optimum combination of grammars when more than one grammar is needed to create conceptual models. However, as unnecessary grammars may also be selected into the optimum combination, overlap of the grammatical constructs can increase. Thus, the resulting conceptual model decreases its clarity and usefulness. One way of solving this issue is reducing the number of constructs in the reference ontology. Since ontological constructs have different importance levels in different domains the level of importance can be used as the basis for reducing number of constructs. This paper presents the result of a study we carried out to find how the importance levels of Bunge-Wand-Weber (BWW) ontology can be measured within a selected domain. As the information system domain of this study, we selected a specific business functional area namely, Sales & Distribution. Thus.the findings can be applied to any domain with similar characteristics to Sales & Distribution functional area.

Keywords

Conceptual modeling, BWW Ontology, TMGS, business functional areas

INTRODUCTION

The requirement analysis phase of the information system development lifecycle often uses conceptual modeling as a user requirements modeling method (Milton et al. 2010). The output of the conceptual modeling process: the conceptual model graphically represents the user's perception of the static (e.g., things and properties) and dynamic (e.g., events and processes) aspects in the phenomenon being analyzed. These conceptual models are created using conceptual modeling grammars. The theory of ontology has been proposed as a formal approach for evaluating any conceptual modeling grammar's ability to represent the real world phenomena (Wand and Weber 1990 a; Wand and Weber 1990 b). Ontology is a well-recognized discipline of philosophy that focuses on the nature of the real world (Chopra 2008). The ontology that is used to evaluate a grammar is known as the reference ontology. To date, the Bunge-Wand-Weber (BWW) ontology is the most widely used reference ontology (Heales 2000).

The BWW ontology has constructs that cover all the static and dynamic aspects of the world. However, every grammar developed to date represents only certain parts of the real world such as data (Spyns et al. 2002), process (Rajapakse 1996), or behavior (Renolen 2000). Thus, systems analysts tend to use combinations of different grammars to represent the complete real-world phenomena (Fettke 2009). The *Theory of Multiple Grammar Selection* (TMGS) (Green 1997) is the theory that is currently being used to select the most optimum combination of grammars.

TMGS motivates a prediction that a higher level of "ontological completeness" among a set of conceptual modeling grammars is associated with a higher likelihood that the grammars will be used together as a combination (Green 1997). The level of ontological completeness is measured in terms of the number of constructs in the reference ontology covered by the constructs in the modeling grammars. However, when the BWW ontology is selected as the reference ontology, representing the maximum number of ontological constructs sometimes leads to select unnecessary grammars in to the optimum combination. These unnecessary grammars increase the number of overlapping grammatical constructs among the selected combination. Overlapping constructs will cause unnecessary complexity and unclearness in the resulting conceptual models.

Several researchers (Burton-Jones and Weber 2011; Green et al. 2007; Rosemann et al. 2004a) state that BWW constructs have different importance levels in different domains. For example, Green et al. (2007) suggest that, for Enterprise System Interoperability (ESI) domain, the construct "Transformation" may receive higher importance level than the construct "History". Understanding the variation of the importance levels will help identify the unnecessary ontological constructs (referred as "ontological excess" hereafter) in the modeling domain. Therefore, the importance level of ontological constructs for the particular domain can be used to reduce the number of modeling grammars required to model the same.

Nonetheless, one can argue that, eliminating the unnecessary/excess grammars from the optimum combination is not necessary because, excess ontological constructs are not used in the resulting conceptual model. However, as in the example depicted in Figure 1, only four ontological constructs are required to model the sample domain. Nevertheless, when selecting multiple grammars one could select a set of grammars that covers all the ontological constructs. Thus, final set of grammars could have grammatical constructs that represent the same ontological constructs. As a result, the complexity of the resultant conceptual model is increased because one ontological construct can be represented by several grammatical constructs (ontological excess). Thus, final model may have some inconsistencies in terms of grammatical constructs because modeler may use different grammatical constructs for the same ontological construct appearing in two different places. Moreover, increased number of grammars in the combination would increase the number of diagrams created. If some of these diagrams represent unnecessary aspects of that particular phenomenon, the stakeholders would be confused when identifying the most related requirements. Imprecise requirement modeling will cause inaccuracy in the next stages of the system development process, resulting the whole projects being delayed, experienced cost overruns, or totally failed.

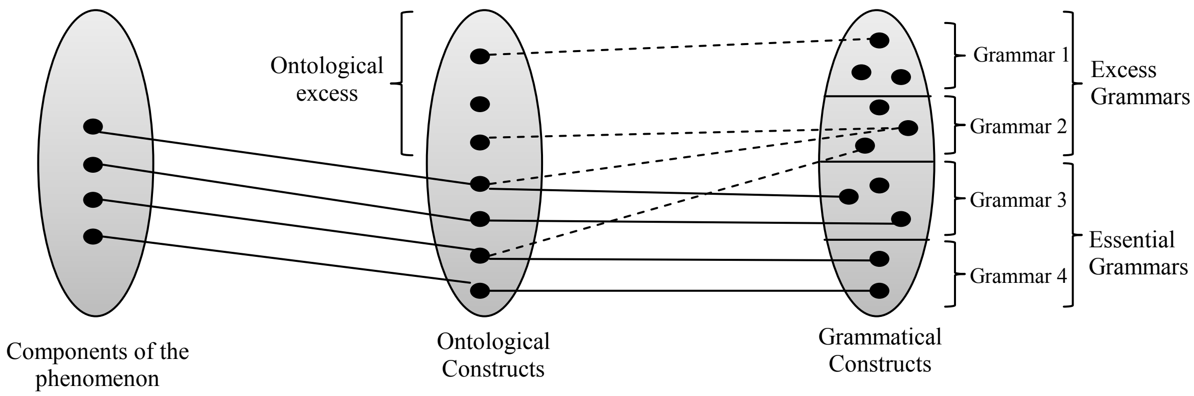

Figure 1: Preventing the ontological excess to optimize the grammar selection process

However, identifying the important ontological constructs according to the domain of interest still remains as an unresolved problem. As such, in this paper we present a preliminary study we carried out to find how the variation of the importance levels of BWW ontological constructs can be measured within the domain of interest. As the information system domain of this study, we selected a specific business functional area namely, Sales & Distribution. We have identified BWW constructs that are important for the functional area of interest. Moreover, we have also identified the characteristics of the Sales & Distribution functional area those motivated to select the particular set of the BWW constructs. Finally, we propose that the identified constructs can be used as the reference ontology for any other functional area with those similar characteristics.

The paper is structured as follows. First, we provide an introduction to the TMGS and BWW ontology. Then we review previous work related to this study. The next section explains the methodology we used for identifying the importance levels of ontological constructs. We then discuss the findings. Finally, we summarize the findings of this study, review the limitations of this work and outline future research.

THEORETICAL FOUNDATIONS

Theory of Multiple Grammar Selection (TMGS)

Green (1997) proposed a theory–the Theory of Multiple Grammar Selection (TMGS)–that predicts how stakeholders would select a combination of grammars to use from a set of alternative grammars. There are three objectives in TMGS that should be covered when multiple grammars are selected:

1. Maximum ontological completeness (MOC): The maximum number of ontological constructs in the reference ontology should be covered with the grammatical constructs available in the selected combination of grammars.
2. Minimum ontological overlap (MOO): The number of ontological constructs that are represented by more than one grammatical constructs should be minimized.
3. Rule of parsimony: The least number of grammars should be selected that can satisfy the MOC and MOO objectives.

The Bunge-Wand-Weber ontology

Among the available theories of ontology that have been proposed for information systems modeling, Bunge's ontology (Bunge 1977) defines a set of real-world constructs in a comprehensive manner (Wand 1989). Wand and Weber modified and extended the constructs in Bunge's ontology in order to apply it to the modeling of information systems(Wand and Weber 1990 a; Wand and Weber 1990 b). The resultant ontology is known as the Bunge-Wand-Weber (BWW) ontology (Green and Rosemann 1999). The BWW ontology consists of three models: the representation model, the state-tracking model, and the good-decomposition model. The representation model consists of high-level constructs that are needed to represent the structure and behavior of real-world phenomena. Table 1 shows these constructs in plain English. The state-tracking model discusses how the states of the instances in the real world are changing along the time and how to track those state changes. The good-decomposition model deals with how to break down real world phenomena into components so they can be better understood and represented in an information system. Our research work also focuses on the representation model.

Table 1: Ontological Constructs in the BWW Representation Model

Ontological Construct	Explanation
Thing*	The elementary unit in the BWW model. The real world is made up of things. Two or more things 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 modelled 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 a 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 set of things that can be defined via their possessing a single property.
State*	The vector of values for all property functions of a thing is the state of the thing.
Kind	A set of things that can be defined only via their possessing two or more common properties.
Conceivable State Space	The set of all states that the thing might ever assume.
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 an acceptable state.
Lawful State Space	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.
Transformation*	A mapping from one state to another state.

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 set of all events in a thing that is lawful.
History	The chronologically ordered states that a thing traverses in time.
Acts on	A thing acts on another thing if its existence affects the history of the other thing.
Coupling	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; 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.
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.
Subsystem	A system whose composition and structure are subsets of the composition and structure of another system.
System Decomposition	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 partial order over the subsystems in decomposition to show which subsystems are components of other subsystems or the system itself.
External Event	An event that arises in a thing, subsystem, or system by virtue of the action of something in the environment on the thing, subsystem, or system.
Stable State*	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.
Unstable State	State that change into another state by actions of transformations in the system.
Internal Event	An event that arises in a thing, subsystem, or system by virtue of lawful transformations in the thing, subsystem, or system.
Well-defined Event	An event in which the subsequent state can always be predicted.
Poorly-defined Event	An event in which the subsequent state cannot be predicted.

Source: (Weber 1997) with minor modifications.

* indicates a fundamental and core ontological construct.

RELATED RESEARCH

Researchers have used the BWW ontology for over thirty representation grammar analysis projects(Green and Rosemann 2004) such as measuring ontological completeness (Green 1997; Green and Rosemann 2000; Weber 1997; Weber and Zhang 1996), measuring ontological clarity (Davies et al. 2003; Green and Rosemann 2002), measuring ontological distance (Rosemann et al. 2004b), building BWW meta model(Rosemann et al. 2004a), building reference models(Fettke and Loose 2003) and comparison of different ontology (Davies et al. 2003). Table 2 summarizes several important BWW related ISAD analysis projects.

However, to date only three research studies have been published in relation to selecting a combination of grammars using BWW ontology. Green (1997) describes how the BWW ontology–in particular, the representation model– was used to analyse ISAD grammars implemented in an upper-case tool called Excelerator V.1.9. Green found that, from the grammars available in Excelerator, the users employed Logical Data Flow Diagrams in conjunction with Entity Relationship diagrams or Data Model Diagrams to cover static and dynamic real-world phenomena. Green et al. (2011) present an extension to the research study by Green (1997). Green et al. (2011) discuss the reasons for the users tend to combine various grammars available in Excelerator V.1.9. They found that the construct deficit in modelling grammar is the major reason.

Green et al. (2007) discuss the issues in a theoretical evaluation and comparison of Enterprise System Interoperability (ESI) standards using BWW ontology. These standards facilitate the integration of functions and data within organizations. They have evaluated four ESI standards: *ebXML BPSS*, *BPML*, *BPEL4WS*, and *WSCI*. They identified two sets of standards–ebXML BPSS and BPEL4WS, and ebXML BPSS and WSCI–that, when used together, provide the implementer with minimal overlap while maximizing the ontological completeness.

All the three research studies have treated the BWW ontological constructs as equally important in their evaluations. Accordingly, to date no research has involved in evaluating the usage of a subset of the BWW ontology in optimizing the multiple grammar selection process.

RESEARCH METHODOLOGY

This study has used case study method as the research method because it facilitates the analysis of data collected from a sample size smaller than, for example, surveys (Gable 1994). The Sales & Distribution functional area of the case organization in Sri Lanka has been selected as the IS domain. Sales & Distribution was specifically selected as the case functional area because; it is one of the common functional areas in most of the industries worldwide. The Functional Requirement Specification (FRS) document of the Sales & Distribution process of that organization was evaluated using the BWW ontology representation model as the reference ontology, to map the components of each business process to the BWW constructs. A mapping technique that is commonly used for evaluating conceptual modelling grammars: *interpretation mapping* was used throughout this study. Interpretation mapping maps grammatical constructs with their corresponding ontological constructs.

This study was conducted in two stages; (1) interpretation mapping of the components of the business process to the BWW representation model, and (2) assigning the importance levels to each ontological construct and identifying the subset of the BWW ontology.

1. Interpretation mapping of the selected business process components

The case organization operates twenty-two sub-processes under the Sales and Distribution process. Some of those sub-processes were specific to that company, such as Product Exporting, Cash-on-delivery Sales, and Tender Sales process. Those specific sub-processes were ignored during this analysis in order to make the results common to most of the organizations. Accordingly selected set of sub-processes: Credit/cash ordering, Sales returns & after sales service, Incentive handling, Expenses handling, Tour itinerary handling, Quotation management, Sales planning, Payment follow-up & collection, Discounted credit note management, Distribution Requirement Planning and Direct order fulfilment were evaluated during this study. Two distinct steps were taken to arrive at the final results.

Step 1: Two researchers were involved in this mapping process. Both researches individually read the FRS document and mapped the components of each selected sub-processes to the BWW representation model constructs. Accordingly, two draft analysis results were generated for each sub-process.

Step 2: Then the two researches met to discuss and defend their interpretations. If any conflicts with each research's mappings were identified, further discussions were held to find the best interpretation. After several rounds of discussions the final results of the interpretation mapping for each sub-process were achieved. Table 3 shows a selected section of the final results because the complete result set is omitted for the sake of brevity. However the complete result set is available from the authors on request.

2. Assigning importance levels and identifying the constructs

We used "the frequency of use" as the criteria to measure the importance levels of the ontological constructs. Rosemann et al. (2004b) defines that the number of occurrences of a particular ontological construct is one way of identifying its significance. Two distinct steps were taken to calculate the frequency of use of each ontological construct.

Step 1: First, for each ontological construct, the frequency of use was calculated under each sub-process. Then, those values were combined to generate the frequency of use of each construct for overall Sales and Distribution process. For example, first, for the BWW construct "event", the frequency of use was calculated for each sub-process separately. Then these values were added together to calculate the usage frequency of "event" throughout the whole Sales and Distribution process.

Step 2: Based on the different levels of usage frequency, different importance levels were assigned to each ontological construct. Allocated importance levels were used to identify the subset of constructs of the BWW ontology required to model Sales and Distribution functional area.

Table 2: Section of the results obtained from the interpretation mapping

Ontological construct	Corresponding constructs in the Business process
Class of thing	Organization, Division, Item, Inventory, Customer, Distributor, Supplier, Staff
Stable state	Not used
Unstable state	Not used
External event	Sales return request, Loan return request, Quotation, Material loan request, Delivery note acknowledgement, Sales contract
Internal event	Sales order, Approval of loan request, Approval of return request, Purchase order approval, Sales order approval, Stock return note, Invoice
Well-defined event	Not used
Poorly-defined event	Not used
State law	
Stability condition	Minimum quantity of item in inventory, Reorder quantity of item in inventory, Minimum customer credit amount, Discountable order amount of an item, Discountable customer type
Corrective action	If item quantity is in minimum level, item is not approved as a loan item. If item quantity is in reorder level, item is ordered from the supplier. If customer credit amount is in or below minimum amount, credit purchases prohibited. If ordered amount according to discountable order amount allocate discounts. If customer is discountable customer allocate discounts
History	History of items promoted by sales rep in customer visits e.g.: promoted item, promotion date, item sales amount, etc.
Lawful event space	Reject loan item, Item order, approve credit customer, discount, discount customer allocation
System	Sales and distribution
System environment	Customer, Distributor, Supplier, Geographic area

RESULTS

Table 3 shows, the importance levels/ratings assigned to each BWW ontological construct based on the frequency of usage among the whole Sales and Distribution processes. Most frequently used constructs (more than 30 times throughout the FRS) were assigned value 3. Ontological constructs that are not widely used (within 0-30 times throughout the FRS) but are important to the business process were assigned value 2. Ontological constructs that are not widely used (within 0-30 times throughout the FRS) and have a limited significance to the business process were assigned value 1 whereas unused ontological constructs were assigned value 0.

Table 4 shows the summary of this analysis: the total number of ontological constructs that acquired by each four types of importance levels.

Table 3: Rating of BWW ontological constructs based on the frequency of use

BWW ontological construct	Importance level assigned
Thing	0
Class of things	3

BWW ontological construct	Importance level assigned
Poorly-defined event	0
Conceivable event space	2

Property in general	0
Property in particular	0
Intrinsic property	3
Mutual property	3
Hereditary property	0
Emergent property	2
Kind	3
State	3
Stable state	0
Unstable state	0
Conceivable state space	3
Event	3
External event	3
Internal event	3
Well-defined event	0

State law	3
Lawful state space	2
Lawful event space	2
Transformation	3
Lawful transformation	3
History	1
Acts on	0
Coupling	0
System	3
System environment	3
System composition	3
System structure	3
Subsystem	3
System decomposition	0
Level structure	3

Table 4: Total number of ontological constructs acquired by each type of rating

Rate	Total number of ontological constructs
Rate 0	11
Rate 1	01
Rate2	04
Rate3	18

Table 3 shows that, each construct of the BWW ontology has different usage frequencies within the functional area been modelled and thus, receives various importance levels. Table 4 shows that, a considerable number of ontological constructs has not been used within the evaluated Sales and Distribution business process. Eleven ontological constructs out of thirty-four BWW ontological constructs (32.35%) have not been used (were assigned rate 0). Considerably less percentage of ontological constructs has rate 1 and rate 2- 2.94% and 11.76% respectively. The number of ontological constructs that is not frequency used by the evaluated functional area was significantly less. Eighteen ontological constructs (52.9%) were frequently used, so acquired rate 3. Only about 50% of the whole set of BWW ontological constructs were frequently used. Accordingly, as a preliminary conclusion we can say that, various importance levels can be assigned to the ontological constructs based on their frequency of use within the domain of interest.

- Extracting the subset based on the allocated ratings

The set of ontological constructs that has been assigned rate 3 is very important to the conceptual modelling process because, they represent the most frequent components of the phenomenon been modelled. Even though the ontological constructs that has acquired rate 2 represent a set of less frequently used components, they have a widespread effect on the phenomenon been modelled and thus are also very important to the conceptual modelling process. Ontological constructs that has been assigned rate 1 are not very important to the conceptual modelling process because, those constructs represents the process components that are not frequently used as well as have less effect in the phenomenon been modelled. Ontological constructs that have acquired rate 0 can be considered as not important for the conceptual modelling process, because these constructs does not have any corresponding component in the analysed phenomenon. As such, the set of ontological constructs that have achieved rate 3 and rate 2 are the constructs that should be essentially represented by the selected conceptual modelling grammars. Representing the ontological constructs that have achieved rate 1 may rely on the availability of grammatical constructs in the grammars that are selected to represent ontological constructs having rate 3 and rate 2. The ontological constructs that have achieved rate 0 can be completely ignored and thus can be categorized as ontological excess.

According to these interpretations, the BWW ontological constructs that have been assigned rate1, 2 and 3 were considered as the subset that is important to the phenomenon been evaluated. Among this subset, the constructs with rate 1 can be mentioned as optional ontological constructs. This subset can be considered as the reference ontology for the evaluated business process. Following is the extracted set of constructs.

- Class of thing
- Kind
- Intrinsic property
- Mutual property
- Emergent property
- State
- Event
- Internal event
- External event
- Conceivable state space
- Conceivable event space
- State law
- Lawful state space
- Lawful event space
- Transformation
- Lawful transformation
- History*
- System
- System environment
- System composition
- System structure
- Subsystem
- Level structure

* Optional ontological constructs

DISCUSSION

It was found that only twenty-three ontological constructs of BWW ontology are required to model the functional area of interest. It is 67.6% of the whole set of BWW ontological constructs, namely less than ¾ of the general BWW ontology. Therefore, if a combination of modelling grammars provides constructs to represent at least this subset of ontological constructs, such combination of grammars can be considered as the optimum combination of grammars for modelling Sales and Distribution functional area.

As such , although the selected optimum combination of grammars could not represent the BWW ontological constructs such as, thing, property in particular, hereditary property, stable state, unstable state, well-defined and poorly defined event, acts on, coupling and system decomposition, the conceptual modellers will not find the combination as ontological deficient.

Following characteristics of the user requirements of the Sales & Distribution functional area were identified as the motivations to select this subset of the BWW constructs. Accordingly, any other domain that has the same characteristics in its user requirements can use this subset of the BWW ontology as the reference ontology.

- Need to represent classes of things except each individual thing
- Need to defining the composites things within the system
- Need to model the subtypes of systems and sub-parts of systems
- Need to capture all of the potentially important business rules of the process (es)
- Need to defining the scope and boundaries of the system (processes)

CONCLUSIONS AND FUTURE WORK

This paper presented a study conducted to evaluate how the importance level of BWW onto logical constructs differs based on the functional area being modelled and how those importance levels can be measured. This study is a starting point that contributes to our broader research objective: developing a general framework to identify how the importance levels of the BWW ontological constructs vary in any domain of interest. We selected the Sales and Distribution as the case functional area. The results show that, within the selected business process, the frequency of use of each BWW ontological construct is different. Thus based on the frequency of use different importance levels were allocated to the BWW ontological constructs. Accordingly, a subset of the BWW ontology has been extracted. This subset can assist to,

- Reduce the unnecessary complexity of the conceptual model. When the number of grammars in the optimum combination is less, overlap of the ontological constructs will be reduced because one ontological construct will not be represented by more than one grammatical constructs.
- Increase the completeness of the conceptual model. Green (1997) states that the combination of grammars that can represent a maximum number of ontological constructs should be selected as the optimum combination. However, there is no guarantee that the selected grammars can cover all the important ontological constructs of a phenomenon of interest. In our approach since the subset

contains only the important ontological constructs for the particular domain, the possibility of not representing the important ontological constructs will be avoided. Thus, the completeness of the resulting conceptual model will be increased.

Moreover, we have identified the characteristics of the Sales & Distribution functional area those motivated to select the particular subset of the BWW constructs. We propose that the identified subset can be used as the reference ontology for modeling the systems in any other functional area with those similar characteristics.

While we have made every effort to increase the validity of our analysis, i.e., using two independent data analysis, limitations in the work remain. Most notably, the meanings of some of the terms and components of the business processes analysed were not very much familiar. Moreover, the analysis was limited to the Sales & Distribution functional area of one organisation. If more than one organisation was evaluated, the rating of the BWW ontological constructs would have been more precise. Additionally, if an industry processional group in addition to the two researchers was used to select the sales and distribution sub-processes, much needed rigor in research could be improved.

Our research has two main implications for future research. First, the process of extracting a subset of BWW ontology can be further enhanced, i.e., evaluating the effect of "conceptual modelling context factors" on priority level of ontological constructs. Conceptual modelling context is defined as the domain in which the conceptual modelling practice is applied. Wand and Weber (2002) have stated three critical factors in the context that affect the conceptual modelling process: individual difference factors (e.g., different levels of stakeholder experiences), task factors (e.g., different objectives of the information system) and social agenda factors (e.g., organization's standards and rules). These factors may also have an effect on the importance level of BWW ontological constructs. Second, the identified subsets of the BWW ontology can be further specialized to the related type of information system's objective. In some circumstances, components of the particular system objective could not be exactly mapped with the ontological constructs and thus there could be conflicts in selecting the optimum combination of grammars.

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