A Model Use Ontology

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Abstract
Building Information Modeling (BIM) has been applied to many different processes throughout the lifecycle of facility projects. While planning for the adoption of BIM, the clear definition of Model Uses on a project is important. There have been a number of Model Use categorization systems documented within the industry, but there is a lack of consistent terminology used when discussing and defining the application of BIM to different project tasks. This paper outlines the process used to develop a Model Use Ontology which is structured around the core purpose for implementing BIM on project tasks. The methods performed to develop the Model Use Ontology included: 1) Defining Domain and Scope, 2) Acquiring Domain Knowledge, 3) Documenting Domain Terms, 4) Integrating Domain Terms, 5) Evaluating the Model Use Ontology, and 6) Documenting the Model Use Ontology. The Model Use Ontology classifies Model Uses primarily based on the purpose of implementing BIM; and secondarily based on characteristics of the Model Use. The Model Use Ontology includes five primary Model Use Purposes: 1) Gather, 2) Generate, 3) Analyze, 4) Communicate, and 5) Realize. After the Model Use Purpose is determined, an implementer can identify more detailed Model Use Characteristics such as facility elements, facility phases, author discipline, or level of development. Overall, the Model Use Ontology allows for better communication of the Model Uses being implemented throughout the life of a facility. The Model Use Ontology can be applied within procurement language; defining exact BIM requirements; and standardizing BIM processes and information exchanges.

Keywords: BIM, Ontology, Model, Modeling, Uses.

1 Introduction: The Need for a Model Use Ontology
Building Information Modeling (BIM) does not change the purpose, only the means by which that purpose is achieved. Currently, there is not a common language that exists for communicating the purposes of BIM implementation. The purpose of the Model Use Ontology is to establish a common language for communicating the objective of using a model. A Model Use (Use) is defined as a method of applying modeling during a facility's life-cycle to achieve a specific objective. The Model Use Ontology (the Ontology) provides a shared vocabulary that is applied to express the Model Uses, including the terms, concepts, properties, and relationships that exist.

The need for a model use ontology was identified during the development of the *BIM Project Execution Planning Guide* in 2009 (Computer Integrated Construction Research Program, 2010). When developing the *BIM Project Execution Planning Guide*, the research team documented 24 to 26 BIM Uses depending on the version). Examples of these Model Uses include Existing Conditions Modeling, Design Authoring, Design Reviews, 3D Coordination, Energy Analysis, and Record Modeling. In general, these Model Uses were organized by facility phase (plan, design, construct, and operate).

Organizing Model Uses by phase has many drawbacks. First, each Model Use does not reside within one single facility phase. Rather, most can be applied during any phase of the life-cycle of a facility. Second, the current structure has few levels, categories, or classes of Uses. Furthermore, the structure is not easily adaptable to changes such as adding new Uses. While the Guide made progress

towards standardizing a list of terms and definitions, the terms have not been accepted uniformly and groups implementing the Model Uses often customize the definitions to suit their needs.

These types of issues are not only found within the *BIM Project Execution Planning Guide,* but also other industry guides. Few publications employ a standard list of Uses. Of those publications that list the Uses, the lists vary greatly from one publication to the next. Moreover, even fewer publications categorize the uses into classes and class hierarchies. This lack of a standard list prevents project team members from clearly planning and communicating "what" they will achieve through the application of BIM on a facility. Therefore, there is a need to create an ontology that presents a standard list and definition of the Uses, and organizes the Uses in classes and a class hierarchy. While the Uses defined in the *BIM Project Execution Planning Guide* along with other guides moved the industry in the right direction, a more structured and specific categorization of Model Uses will enable project teams and organizations to develop more effective plans.

2 Methodology

The methodology implemented to develop the Model Use Ontology combines multiple methods defined in ontology literature. These methods include the Toronto Virtual Enterprise (TOVE) approach, the Enterprise Model Approach, the METHONTOLOGY approach, and the Integrated Definition for Ontology Description Capture Method (IDEF5) approach (Noy and McGuinness 2001; Uschold and King 1995). The steps implemented to develop the Model Use Ontology include:

1. Defining domain and scope of what is a Model Use
2. Acquiring knowledge through collection of Model Uses
3. Documenting domain terms by creating a list of Model Uses and terms
4. Integrating domain terms by creating initial Model Use Ontology
5. Evaluating (refining and validating) the Model Use Ontology
6. Documenting the Model Use Ontology so that it is understandable

Content analysis, focus group meetings, industry expert interviews, and surveys were applied to accomplish the goals of this research. Figure 1 displays an overview of the research steps.

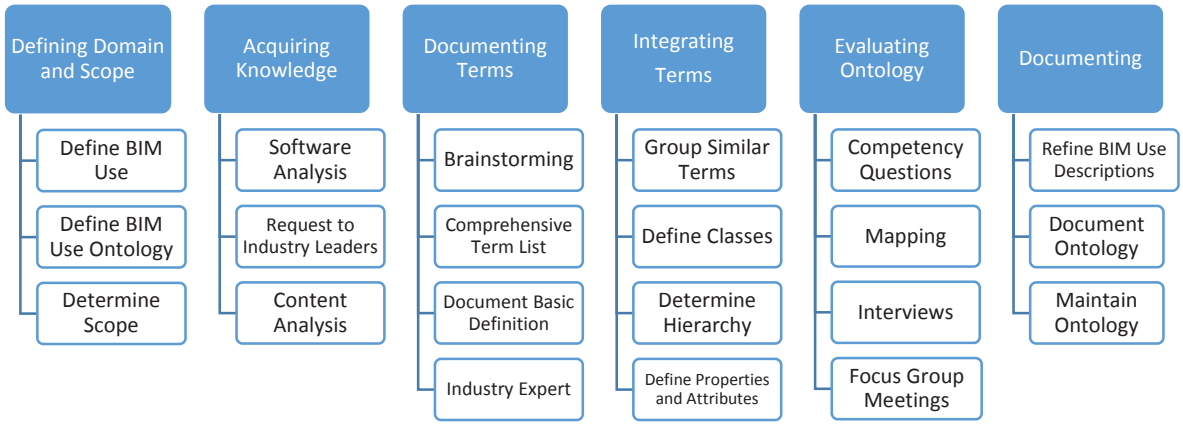

Figure 1: Methodology to Develop the Model Use Ontology

Over 550 terms were classified into an ontological structure to develop the Ontology. Prior to finalizing the Ontology, the structure was validated through competency questions, term mapping, industry interviews, and focus group meetings. The research methodology implemented to develop the Model Use Ontology was designed based on the following criteria: clarity, comprehensiveness, extendibility, minimal bias, and minimal ontological commitment.

3 The Model Use Ontology

The Model Use Ontology provides a shared vocabulary that is applied to model or express the Model Uses, including the type of objects or terms, concepts, properties, and relationships that exist (Kreider, 2013). A Model Use is defined as a method of applying modeling during a facility's life-cycle to achieve

a specific objective. The Model Use Ontology classifies the Model Uses primarily based on the purpose of implementing BIM on a facility or within an organization; and secondarily based on characteristics of the Model Use. These purposes and characteristics (see Figure 2) can be defined at varying levels depending on the level of specificity required for different applications of the Model Use Ontology.

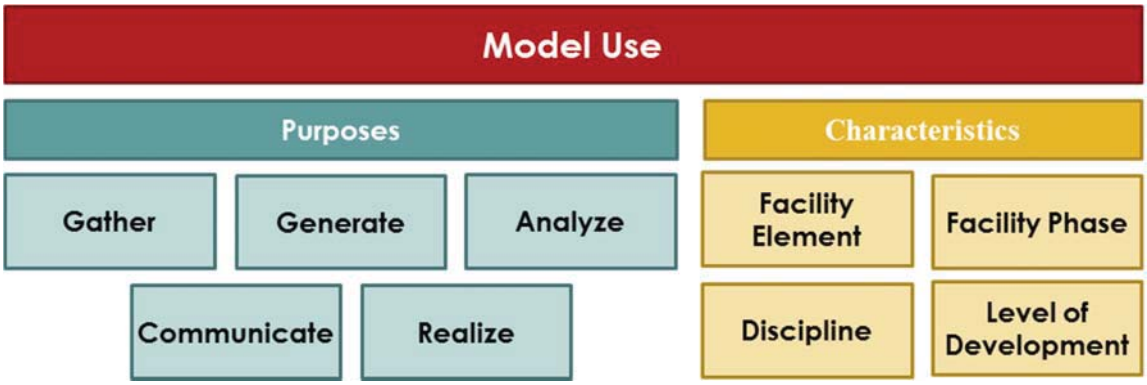

Figure 2: The Components of a Model Use

The Model Use Purpose communicates the primary objective of implementing the Model Use. The Model Use Purposes, shown in Figure 3, include five categories: gather, generate, analyze, communicate, and realize. Within these categories, there are numerous subcategories to further specify the purpose of the Model Use.

Figure 3: The Model Use Purposes

The Model Use Characteristics allow a user to further define the Model Use based on common facility and project attributes: facility element, facility phase, discipline, and level of development. By determining these factors, as shown in a particular Model Use can be focused toward a specific approach. Implementing characteristics allow the user to define a very specific instance of the Model Use for implementation for a specific facility at a specific time. Each implementation of Model Use will include the following items: a process, information, infrastructure, level of maturity, potential impacts, and references to support that specific approach. These characteristics are often shared between multiple Model Use Purposes.

4 Model Use Purposes and Objectives

The Model Use Ontology categorizes the Uses primarily by the purpose and objective of the Model Use. A Model Use Purpose is *the specific objective to be achieved when applying Building Information Modeling during a facility's life.* The purposes and objectives for implementing a Model Use, as shown in Table 1: Model Uses Purposes and Objectives, are divided into five categories and 18 subcategories.

Table 1: Model Uses Purposes and Objectives

Model Use Purpose			Model Use Objective	Synonyms
01	**Gather**		**to collect or organize facility information**	administer, collect, manage, acquire
	01	Capture	to represent or preserve the current status of the facility and facility elements	collect
	02	Quantify	to express or measure the amount of a facility element	quantity takeoff
	03	Monitor	to collect information regarding the performance of facility elements and systems	observe, measure
	04	Qualify	to characterize or identify facility elements' status	follow, track, identify
02	**Generate**		**to create or author information about the facility**	create, author, model
	01	Prescribe	to determine the need for and select specific facility elements	program, specify
	02	Arrange	to determine location and placement of facility elements	configure, lay out, locate, place
	03	Size	to determine the magnitude and scale of facility elements	scale, engineer
03	**Analyze**		**to examine elements of the facility to gain a better understanding of it**	examine, evaluate
	01	Coordinate	to ensure the efficiency and harmony of the relationship of facility elements	detect, avoid
	02	Forecast	to predict the future performance of the facility and facility elements	simulate, predict
	03	Validate	to check or prove accuracy of facility information and that is logical and reasonable	check, confirm
04	**Communicate**		**to present information about a facility in a method in which it can be shared or exchanged**	exchange
	01	Visualize	to form a realistic representation of a facility or facility elements	review
	02	Transform	to modify information and translate it to be received by another process	translate
	03	Draw	to make a symbolic representation of the facility and facility elements	draft, annotate, detail
	04	Document	to create a record of facility information including the information necessary to precisely specify facility elements	specify, submit, schedule, report
05	**Realize**		**to make or control a physical element using facility information**	implement, perform, execute
	01	Fabricate	to use facility information to manufacture the elements of a facility	manufacture
	02	Assemble	to use facility information to bring together the separate elements of a facility	prefabricate
	03	Control	to use facility information to physically manipulate the operation of executing equipment	manipulate
	04	Regulate	to use facility information to inform the operation of a facility element	direct

Each purpose is defined using the purpose term, an objective, synonyms, and a description (see Table 2).

Table 2: Model Use Defining Attributes

Attribute	Description
Term	A word or phrase used to describe a thing or to express a concept
Objective	The goal, aim or purpose for implementing a Model Use
Description	An account of the Model Use including all the relevant aspects, qualities, and properties
Synonyms	A word or phrase that means nearly the same as standardized Model Use Term. It may have had the same meaning but has since been superseded.

4.1 Gather

Objective: to collect or cull facility information.
Synonyms: administer, collect, manage, and acquire.
Description: Models are often used to gather information about a facility at various phases during a facility's life. Whether that is to count the specific amount of an element or determine the current status of a facility element in order to properly manage that asset, the Model Use can greatly assist in this effort. This sub-purposes of Model Uses include: Qualifying, Monitoring, Capturing, and Quantify. In this primary purpose of Model Uses, the author is collecting, gathering, and organizing information about the facility. This purpose of Model Uses does not determine the meaning or make inferences about the meaning of the information gathered, rather it is solely focused on the collection and organization of the information. This is often the first step of a comprehensive series of BIM processes.

4.2 Generate

Objective: to create or author information about the facility.
Synonyms: create, author, and model.
Description: Within a facility's lifecycle, almost every discipline generates information about the facility. This purpose of Model Uses includes those where a model is used to create or author information about the facility. Generating includes prescribing, arranging, and sizing facility elements to various levels of development. Within the design phase, the design team will be the primary generators of information, while in the construction phase, the subcontractors will generate most of the information. Additionally, in the operations phase, that information could be generated by those maintaining the facility when they update or change that facility. Anytime new information is authored, modeled, or created, it is generated.

4.3 Analyze

Objective: to examine elements of the facility to gain a better understanding of it.
Synonyms: examine and evaluate.
Description: Elements of the facility often require further analysis to determine their viability for the facility. The analyzing purpose of Model Uses includes those uses in which a methodical examination of the facility elements is needed. The Uses of this purpose include coordinating, forecasting, and validating. It is in these Model Uses data is often taken from what was gathered or generated and put into the format into which it can be used for decision making.

4.4 Communicate

Objective: to present information about a facility in a method where it can be shared or exchanged.
Synonyms: exchange.

Description: One of the primary Model Uses is to communicate facility information. The communication purpose of BIM is intended to present information about a facility in a method which can be shared or exchanged. This is often the last step of many other processes when a visualization, transformation, drawing, or document is developed to communicate information from that process to the next user of the information. This is one of the most valuable Model Uses. It promotes and enhances communication and often reduces the time it takes to communicate. Additionally, communication of the data is often a byproduct of the processes to accomplish other Model Uses.

4.5 Realize

Objective: to make or control a physical element using facility information
Synonyms: implement, perform, and execute.
Description: Models are beginning to allow the industry to remove the direct input of human interaction to develop specific elements of the facility. The Model Uses within Realize includes those Use in which facility data (Model data) is used to make or control a physical element of the facility. This Model Use purpose gives the industry the ability to fabricate, assemble, control, and regulate elements of the facility. It is this ability that could eventually lead to the improved productivity of both construction and operations of facilities.

5 Model Use Characteristics

Model Use Characteristics are applied to more precisely define the Model Use beyond the purpose and objective alone. The characteristics to be defined, as shown in Table 3, include the facility element(s), facility phase(s), discipline(s), and level of development.

Table 3: Model Use Characteristics

Characteristics	Description
Facility Element	The system of the facility on which the Model Use will be implemented.
Facility Phase	The point in the facility's lifecycle at which the Model Use will be implemented.
Discipline	The party by whom the Model Use will be implemented.
Level of Development	The degree of reliability to which the Model Use will be implemented.

Adding these characteristics move the Model Use beyond answering "why" to a more distinct description which could be used in procurement efforts. Additionally, when planning, a team can communicate to all the stakeholders who, what, when, and to what degree the Model Use will be implemented. Depending on the facility's BIM utilization, it is possible to have multiple disciplines implement multiple Model Use purposes during multiple phases on multiple facility elements to multiple levels of development. For example, Coordination Analysis can be implemented during design and construction by the designer and contractor to a level of development 300 and 400. Therefore, creating two separate instances of a Model Use.

5.1 Facility Element

It is necessary to determine the facility elements upon which the Model Use(s) will be executed. Based on OmniClass Table 21: Elements (OCCS Development Committee Secretariat, 2012a) or other applicable element breakdown structures, the team can determine which facility elements are part of the Model Use. For example, the team may determine that it is only necessary to develop a schedule visualization of the substructure and superstructure and not the systems of the facility. The top level of this table include: 01) Substructure, 02) Shell, 03) Interiors, 04) Services, 05) Equipment and Furnishings, 06) Special Construction and Demolition, and 07) Sitework.

5.2 Facility Phase

The planning team should determine during which facility phase they will be implementing the Model Use. The facility phase designation often results in multiple Model Uses and multiple disciplines. For example, the design team may be responsible for coordination analysis during the design phase and the construction team may be responsible for the coordination analysis during the construction phase. If project team does not have phase predetermined, it is suggest that the team use OmniClass Table 31: Phases (OCCS Development Committee Secretariat, 2012) to designate phases: The current phases within this table include: 10) Inception Phase, 20) Conceptualization Phase, 30) Criteria Definition Phase, 40) Design Phase, 50) Coordination Phase, 60) Implementation Phase, 70) Handover Phase, 80) Operations Phase, 90) Closure Phase.

5.3 Discipline

The discipline is also synonymous with the responsible party for the Model Use. OmniClass Table 33: Disciplines (OCCS Development Committee Secretariat, 2012c) presents standard disciplines. These disciplines could also correspond with the various project roles. At a top level, the disciplines currently in this table include planning, design, investigation, project management, construction, facility use, and support. While the primary discipline may be identified, this does not preclude other disciplines from being responsible for part of a Model Use. Additionally it is possible to have multiple disciplines responsible for a Model Use. This would then make for separate Model Uses.

5.4 Level of Development

For each of the Model Uses, the level of development should be identified in order to maximize the benefit from the Model Use. The Level of Development describes the level of reliability to which a Model Element is developed (BIMForum, 2015). The current level of development can be defined within a range from LOD 100 to LOD 500.

6 Conclusions: Application of Model Use Ontology

The Model Use Ontology provides the fundamental terminology and organizational structure for the purposes for which a model is implemented throughout the life-cycle of a facility. The Model Use Ontology was developed through the evaluation of over 550 terms. The critical feature of the ontology is the focus on the purpose, rather than facility phase or element. The Model Use Ontology is valuable for BIM Planning for both projects and organizations. The Model Use Ontology can be applied within procurement language to define exact requirements of various parties. The Model Use Ontology can also be applied to standardize process and information exchange terminology. This standardization is critical to the U.S. National BIM Standard (buildingSMART alliance, 2007). Overall, the Model Uses allow for better communication of the purposes for implementing modeling throughout the life of a facility.

Outside of BIM, the Model Use Ontology can be applied to understand the flow of information throughout the life-cycle of a facility. The pattern of gather, generate, analyze, communicate, and realize repeats itself over and over again in the activities performed by project teams. If not using BIM, but "traditional" processes, the principles discussed in this paper still apply because BIM does not change the fundamental purposes for which methods are applied. A goal of this research is that the Architectural, Engineering, Construction, and Owner (AECO) Industry no longer refers to this technology and processes as BIM, but rather simply as ways to improve the life-cycle of the facility. Because when this occurs, BIM will truly become normalized and standardized throughout the industry.

References

BIMForum. (2015). "Level of Development Specification: April 2015 Draft for Public Comment" AIA / AGC. www.bimforum.org/lod

buildingSMART alliance. (2007). *United States National Building Information Modeling Standard: Version 1 - Part 1: Overview, Principles, and Methodologies*. National Institute of Building Sciences, Washington D.C., USA.

Computer Integrated Construction Research Program. (2010). *BIM Project Execution Planning Guide - Version 2.0*. The Pennsylvania State University, University Park, PA, USA.

Kreider, Ralph G. (2013). *An Ontology of the Uses of Building Information Modeling*. The Pennsylvania State University, University Park, PA, USA.

Noy, N. F., and McGuinness, D. L. (2001). *Ontology Development 101: A Guide to Creating Your First Ontology*. Technical Report, Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.

OCCS Development Committee Secretariat. (2012a). "OmniClass Table 21 - Elements." www.omniclass.org. Alexandria, VA, USA.

OCCS Development Committee Secretariat. (2012b). "OmniClass: Table 33 - Disciplines." www.omniclass.org. Alexandria, VA, USA.

OCCS Development Committee Secretariat. (2012c). "OmniClass Table 31 - Phases." www.omniclass.org. Alexandria, VA, USA.

Uschold, M., and King, M. (1995). "Towards a Methodology for Building Ontologies." *Workshop on Basic Ontological Issues in Knowledge Sharing*.