2016

Building Information Modelling (BIM) Guidelines Research

A REPORT PREPARED FOR THE 2016
SUSTAINABILITY SCHOLARS PROGRAM

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1. EXECUTIVE SUMMARY

The construction industry is experiencing several changes in its process due to its pursuit for delivering a better product at lower cost and higher predictability. One of the most recent distinguished advancements in this industry is the use of Building Information Modelling (BIM) to enhance several areas such as design, cost estimation, scheduling and facility management for new and renovation of a facility. Different from conventional tools, a BIM model consist of a database specific for construction projects with the ability to communicate its building components in a tridimensional (3D) form and store data of this objects such as geometry, cost, operation manuals, warranties and etc. Despite its documented success in several occasions, the use of BIM still raises several questions related to its implementation and use at a systematical level by institutions. In light of this, several institutions produce guidelines specific to BIM, known as BIM Guidelines, in order to communicate its expectations and requirements regarding the use of BIM on their projects.

In order to implement BIM at its construction and renovation projects, the University of Alberta through the Sustainability Scholar Program decided to conduct a review of several BIM guidelines from different institutions in North America in order to better address their own needs and investigate the progress of others in this area. The work was conducted by a graduate student and his mentors during the Summer of 2016 and consisted in three phases: (1) a Current Process Assessment was performed through interviews with major players at the University of Alberta (urban planning, construction, operation, maintenance and energy modelling) in order to better assess their current process and potential uses of BIM, (2) a comprehensive review of twelve guidelines from institutions with different backgrounds (third party, government and university organizations) followed by (3) recommendations for a future BIM guideline tailored for the University of Alberta capital and renovation projects and further implementation.

BIM aligns with the university's sustainability objectives by developing strategies in order to promote integration between all stakeholders involved in the design, construction and operation of a facility and should be used to reduce uncertainty during the design and construction stages by compiling all information from stakeholders in a systematic and structured manner. Moreover, BIM should be used by the university in order to reduce the operational cost of its facilities by linking all information with record drawings provided at project commissioning.

After reviewing the 12 guidelines, it is concluded that no single institution's BIM guidelines entirely suit the University of Alberta context and requirements. Hence, a BIM guideline based on the main findings of the analyzed documents for each stage of the building lifecycle (e.g. design, construction, operation, etc.) and knowledge about current operations and local context is recommended for the University of Alberta. In order to achieve success, this guideline should consult the local construction industry to address their current expertise on BIM and should include important documents such as a BIM Execution Plan and BIM Objective & Responsibility Matrix. The university should also put a considerable effort into preparing the BIM model to reduce the ongoing operational cost of its facilities since it is well known this is the main cost driver during a facility's life cycle and the university is the long-term owner-operator of its buildings.

2. INTRODUCTION

The use of Building Information Modelling (BIM has grown the interest of the construction industry in the past years due its capacity to increase productivity in several areas such as design, project coordination, construction and facility management. According to the Canada BIM Council (CanBIM) (2014), BIM is defined as a digital representation of the physical and functional characteristics of a facility built from elements and information pertinent to the model to be used as a shared knowledge resource for that facility along its life cycle. In Canada, its adoption grew 46% from 2009 to 2012 in a survey performed by McGraw-Hill Construction (2012) with national companies proving the growing interest in this area by local construction practitioners.

In order to implement and fully satisfy its requirements effectively, the University of Alberta Facilities and Operations department (F&O) is interested in beginning to incorporate BIM more thoroughly into the design, construction and operation of its buildings. To do so, F&O needs to develop a standard to reflect its intended use and how to proceed regarding the use of BIM on its projects across campus. This standard, referred to within this report as BIM Standard, shall consist of a document defining the use of this tool for consultants, general contractors and any professional involved with the operation & maintenance of the facility in order to clearly state the university's expectation, requirements and level of detail towards BIM. To this end, F&O has opened a position for a graduate student as part of the Sustainability Scholars Program during the summer of 2016 to perform a review on other institutions currently using BIM and compile recommendations for a future production and implementation of a BIM Standard for F&O.

BIM aligns with the university's sustainability objectives by developing strategies in order to promote integration between all stakeholders involved in the design, construction and operation of a facility. Wong and Zhou (2015) points BIM as a main driver of new ways to predict, manage and monitor construction projects and its environmental impact thus allowing a better and sustainable operation for the facility. By promoting this integration and process improvement, the successful development and adoption of BIM within F&O specifically aligns with the goal to "embed social, economic and environmental sustainability into the development and care of the university's indoor and outdoor spaces" as stated in the DRAFT 2016-2020 Sustainability Plan.

The project objectives are described below:

- Review existing BIM policies/ standards in North America and evaluate their similarities and differences
- Investigate critical policy elements and challenges encountered by other institutions regarding their policy
- Propose key policy elements for a University of Alberta BIM Standard covering both new and existing facilities
- Deliver a realistic BIM strategy that will inform implementation of BIM in the department.

3. METHODS

In discussion with the mentors of this project an overall plan was defined and divided into five steps. Figure 1 demonstrates the steps for F&O intentions and the scope of the Sustainability Scholar project (and this report) regarding the use of BIM on its projects. Firstly, a current process assessment through structured interviews was performed in order to assist the Sustainability Scholar to better assess and understand F&O's requirements towards the use of BIM in its process. Secondly, a structured review of existing BIM standards from other institutions was performed based on the findings of previous step to serve as a benchmark for F&O to propose its own standards in the future. Lastly, the Sustainability Scholar suggested recommendations for a future BIM Standard based on the previous two steps. These steps are described in more detail in the following sections of this report. The next two steps ((4) development of an F&O BIM Standard and (5) implementation and control of this standard) are to be performed in the future and are not part of this program nor this report.

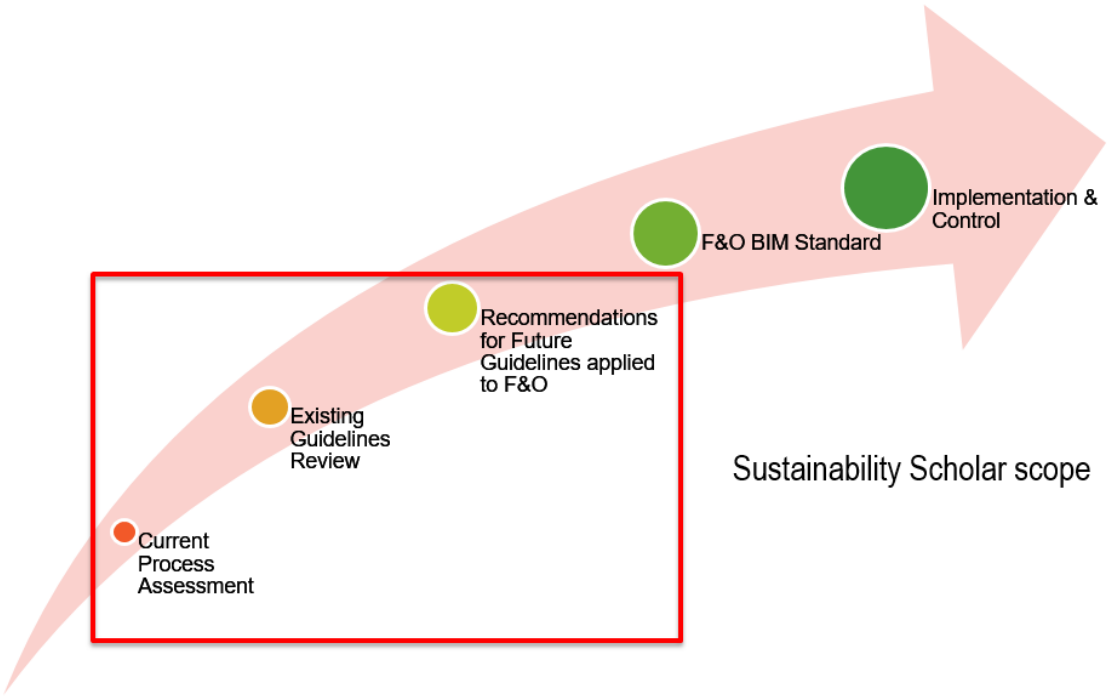

Figure 1 Steps and Sustainability Scholar scope for the implementation of BIM on F&O's projects

4. RESULTS

This section intends to discuss and demonstrate the findings of this project and it is divided in two parts: (1) Current Process Assessment depicts the expectations and questions regarding the implementation of BIM within F&O's context; (2) Existing Guidelines Review presents the findings of the analyzed guidelines from 12 (twelve) different institutions followed by a summary of the main findings and recommendations on the next section.

4.1. Current Process Assessment

In order to better address current needs and expectations of F&O towards the use of BIM, an assessment phase was performed with the five units that will use and will directly benefit from this tool. The main objective of this phase is to evaluate the current procedures of each unit and identify possible improvements by adopting BIM in their projects. Table 1 summarizes the assessed units and their main responsibilities under F&O umbrella.

Table 1 Analyzed units and its respective main roles

Unit	Main role
Office of the University Architect (OUA)	Design oversight on major capital projects and zoning within campus
Project Management Office (PMO)	Implementation of construction projects from concept through the completion of construction
Design and Technical Services (DTS)	Document management for building operations
Operations & Maintenance (OM)	Management of maintenance trades and daily operations
Energy Management & Sustainable Operations (EMSO)	Optimization of maintenance operations with a focus on energy management

As demonstrated in Table 1, the assessed units are responsible for managing a campus facility through the different stages of its life cycle. The interviews were scheduled with representatives of each unit between May 18th and 25th with a predetermined set of questions in order to address the proposed scope in an efficient manner. The questions are displayed below and a full script template of the questions performed in this section along with the detailed information from each unit are found in Appendix A of this document.

1. Brief description of unit's role
2. How many people are involved in the unit?
3. What is the current use of BIM in the unit?
4. Where could BIM be used in the unit?
5. Do you have any questions about BIM and its applicability?
6. What would the main bottlenecks in the unit be for BIM data processing according to the interviewee's opinion?
7. What are the current main bottlenecks in the unit according to interviewee's opinion?

These questions intended to capture the current practice and how to implement BIM in order to promote efficiency on each unit workflow in a practical manner. Questions 1 to 3 are related to each unit's scope and current use of BIM in their workflow. Questions 4 to 6 intends to prospect the use of BIM and any expected barrier to its implementation while the last question (7) is performed in order to capture any other possibility for the use of BIM that the interviewer may recognize if not mentioned previously during the interview. At the end of each interview, a flow chart was developed in order to better understand the current workflow of the unit and identify

opportunities to implement BIM within F&O's context. Figure 2 demonstrates an overview of the current process performed by all 5 (five) units and its interactions for the life cycle of a facility.

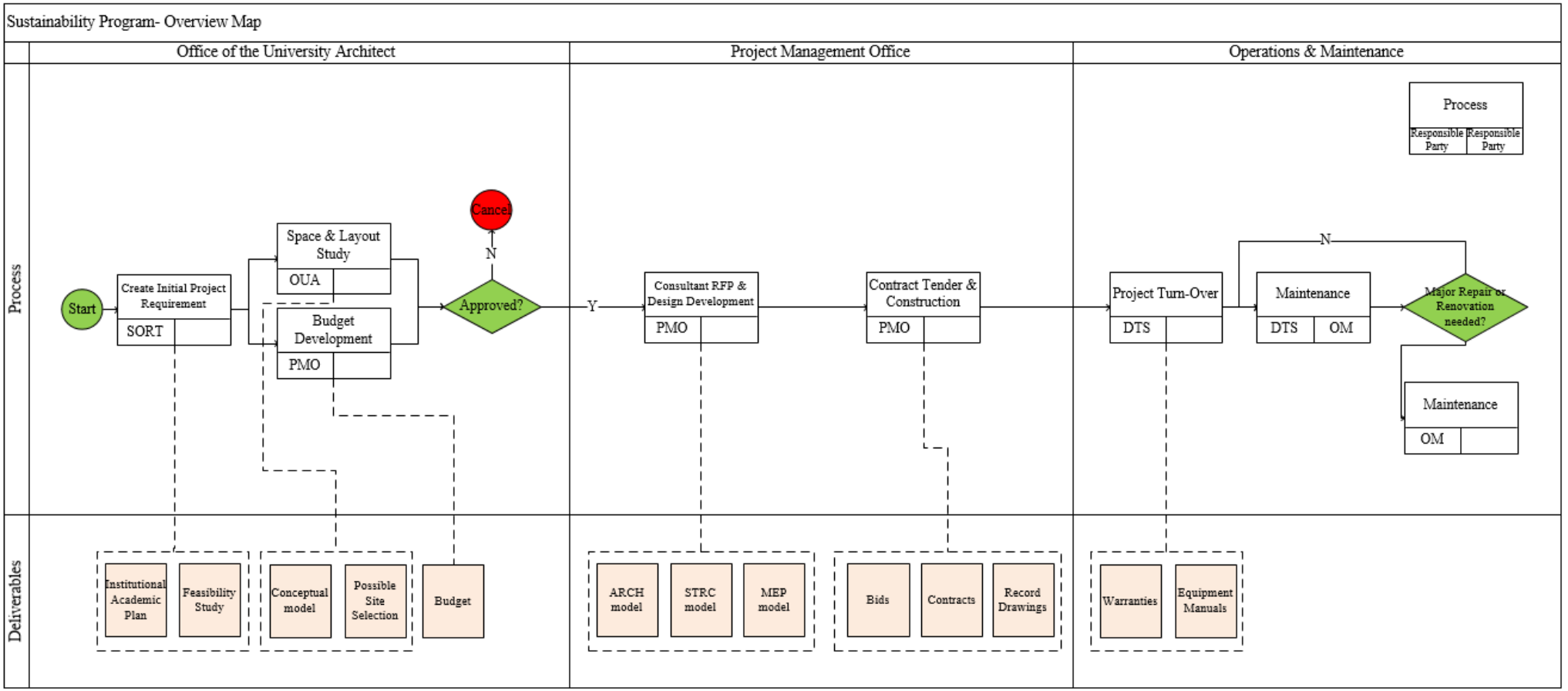

Figure 2 Overview map about current process in F&O.

Abbreviations:
OUA: Office of the University Architect;
PMO: Project Management Office;
OM: Operations and Maintenance
DTS: Design and Technical Services
ARCH: Architectural
STRC: Structural
MEP: Mechanical, Electrical and Plumbing

All units, with the exception of OM already use BIM tools on some projects as an efficient manner to communicate design intentions between consultants and university employees. This practice is driven by consultants and, after attending their agenda, the BIM model is discarded demonstrating a discontinuous and disconnected use of BIM in the department.

Table 2 Possible use of BIM in each unit

OUA	PMO	DTS	OM	EMSO
Conceptual model	Enhance communication	Tie information to assets (e.g. manuals, warranties, etc.)	Predictive maintenance	Use of BIM for energy modelling
Oversight of architectural drawings	Interference checking	Enhance communication	Process improvement	Life-cycle analysis
				Decision making

Table 2 demonstrates the possible application of BIM identified by each unit during this phase. From the displayed answers it can be observed two streams: some suggested that the BIM model could be used to enhance internal and external communication between stakeholders (units, consultants and trades) as demonstrated by OUA, PMO and DTS while others identified the chance to improve their process such as PMO for interference checking, tying information to assets by DTS, use of BIM for predictive maintenance (OM) and life-cycle analysis for EMSO. Table 3 presents the answers regarding questions and the applicability of BIM that interviewees had at the time of the interview. Table 3 demonstrates that all interviewed presented a cohesive knowledge about BIM, with specific questions regarding its applicability within its specific context. As presented below OUA, PMO and OM have questions regarding existing agreements and guidelines related to BIM in points such as who should own the model, what is the investment and the maturity of the local community in order to perform services related to BIM. Moreover, the impact on the existing workflow is also questioned by OUA, OM and EMSO as demonstrated in Table 3 below.

Table 3 Questions about BIM and its applicability

OUA	PMO	DTS	OM	EMSO
Interaction between currently used systems	Maturity of local community	None	Impact in current work flow	Flexibility towards custom solutions
Model ownership			Model ownership	
			Cost of a model	

Table 4 demonstrates the results from the sixth question of the interview regarding interviewee's perception of main bottlenecks for the implementation of BIM in F&O. OUA, PMO and OM demonstrated a relevant concern regarding training, time and funds to be invested during the implementation of BIM and its acceptance by the local design and construction community. DTS and EMSO highlights possible problems regarding information sharing done with BIM due to the current lack of procedures to do so while all units, except OUA, also points out the lack of definition in sensible areas regarding the project such as definition of the scope of work, which applications and hardware to use and the ownership of the BIM model. It is noted that the questions mentioned in Table 3 and uncertainties found in Table 4 can be cleared through a review of existing guidelines from similar institutions thus demonstrating their experiences and applying it to F&O's context.

Table 4 Main bottlenecks for implementing BIM

OUA	PMO	DTS	OM	EMSO
Resources (training and skill)	Model detail trough deliverables submittal	Information sharing through the model and stakeholders	Unclear definition regarding model ownership	Information sharing through the model and stakeholders
Resources (time and investment)	Definition of BIM's scope of work	Which software to use (open or closed architecture)	Which software to use and hardware capacity	
	Training for local community		Model detail trough deliverables submittal	
			Resources (training and skill)	

For the last question of the interview, all units indicated the lack of trained personnel and communication in their current process. It is noted that these questions are present through all units interviewed and are cornerstones for a successful implementation of BIM at the University of Alberta. In order to perform the BIM guidelines review in an efficient manner, a summary of the main questions to be addressed on the next stage is described below:

1. Information exchange through the model during its life cycle
2. Workflow change due the use of BIM
3. Which software to use (use of open or closed architecture application approach)
4. Ownership of the model
5. Financial investment incurred from BIM
6. Other institutions practices and experiences

4.2. BIM guidelines review

This section describes the findings from the BIM guidelines review performed in order to address F&O's requirements and expectations towards the use of BIM in their capital projects. The evaluated guidelines were selected based on the criteria developed on the Current Process Assessment presented on the previous section and a previous work which evaluates existing BIM guidelines in order to develop BIM guidelines for auto-codes and auto-checking (Leite and Wang, 2013). Table 5 depicts the final twelve guidelines studied during the program, their country of origin, release data, organization type, organization name and its application areas. Despite the scope of this work was limited to existing BIM guidelines in North America, an exception was made to AEC (UK) BIM Technology Protocol and Singapore BIM Guide due its significant work in this area and the local industry capacity to comply with what is required from these documents. This section is divided between four parts: (1) guidelines from third party, (2) government, (3) university organizations and a (4) summary of all guidelines. The first three parts present a brief explanation of each guideline followed by a quick summary at the end of each part. At the end of this section a summary of all guidelines is presented in order to address the questions raised in the Current Process Assessment. All information is briefly summarized in this report while detailed information is present at Appendix C of this document.

Table 5 Reviewed BIM guidelines

Name	Country	Release Date	Organization Type	Organization Name	Design	Construction	Operation	Energy Modeling	Procedures	Implementation	Legal	Interoperability
National BIM Standard - United StatesTM	US	July, 2015	Third party	buildingSMART alliance (bSa)	X	X	X	X		X		X
AEC (UK) BIM Technology Protocol	UK	June, 2015	Third party	AEC (UK) Intiative	X				X	X		X
AEC (CAN) BIM Technology Protocol	CA	September, 2014	Third party	CanBIM	X				X	X	X	X
Singapore BIM Guide	SG	August, 2013	Government	Singapore Government	X	X	X		X	X	X	X
New York City BIM Guidelines	US	July, 2012	Government	City of New York	X	X				X	X	X
GSFIC BIM Guide	US	March, 2013	Government	State of Georgia	X	X			X		X	X
State of Ohio BIM Protocol	US	July, 2011	Government	State of Ohio	X	X	X	X		X	X	X
Texas Facilities Commission Professional Architectural/ Engineering Guidelines	US	February, 2008	Government	State of Texas	X	X			X	X	X	X
USC BIM Guidelines	US	April, 2012	University	USC	X	X	X		X	X	X	X
Georgia Tech BIM Requirements & Guidelines	US	September, 2011	University	Georgia Tech	X	X	X	X	X	X	X	X
IU BIM Guidelines and Standards	US	July, 2015	University	IU	X	X		X	X	X	X	X
MIT CAD & BIM Guidelines	US	April, 2012	University	MIT	X	X					X	X

4.2.1. Third party guidelines

Third party institutions are constituted by stakeholders from various sectors of the industry and are intended to play an unbiased role by promoting a common ground to different points of view and proposed directions. Particularly for the scope of this study, the analyzed guidelines in this section have the highest reach and the common purpose to standardize BIM practices across their respective countries. In light of this, three guidelines are evaluated:

1. **AEC (UK) BIM Technology Protocol** intends to enhance the construction industry through BIM aligned to United Kingdom (UK) Government and International practices. More importantly this document is a key part of a big initiative in order to allow UK's government

into mandate all public sector procured construction projects to be delivered using BIM by 2016.

2. **National BIM Standard- United States™ (NBIM-US™)** is a combined effort from diverse stakeholders in the American construction industry with the main objective to standardize, facilitate and provide information to construction practitioner's interest to apply BIM at any stage of a facility. This document is considered the most influent guideline in North America and is destined to two distinct groups: (1) software developers & vendors and (2) construction practitioners willing to implement BIM at any level of the construction industry.
3. **AEC (CAN) BIM Technology Protocol** is a document that intents to communicate and standardize BIM practices in Canada. Based on the previously mentioned British guideline, the analyzed document develops a strong link with the Canadian construction industry practices and provides good insight regarding legal requirements and software selection specific to its country of influence.

AEC (UK) BIM Technology Protocol demonstrated a cohesive documentation for the implementation of BIM such as templates for contracting BIM services, defining the detail required from the BIM model (e.g. use of metrics such as Level of Detail (LOD) and Level of Information (LOI)) and clarification regarding attributions per hierarchical level during the implementation process. Table 6 demonstrates a Skill Matrix adapted from the mentioned document and certainly applicable for F&O's context in case of a future implementation. Moreover, AEC (UK) Initiative provides guidelines for every main software application in the market (e.g. Revit, ArchiCAD, Vectorworks, etc.) describing several procedures for implementation and better practices through the project.

Table 6 Skill Matrix (Adapted from AEC (UK) Initiative, 2015)

Role	Strategy							Management			Production	
	Corporate Objectives	Research	Process Workflow	Standards	Implementation	Training	Execution Plan	Model Audit	Model Coordination	Content Creation	Modelling	Drawings Production
BIM Management	X	X	X	X	X	X	X					
Coordination						X	X	X	X	X	X	
Modelling/ authoring										X	X	X

NBIM-US™ supports two areas relevant for the purpose of this study: (1) the creation of a unified "language" around the construction industry to enhance communication between stakeholders during a project while embedding this work in the BIM model and (2) the strong incentive towards the use of Industry Foundation Classes (IFC) for exchange of information in BIM models.

The first discussed area promotes the use of the OmniClass™ classification system in the BIM model in order to standardize the identification of building components through its life cycle (e.g. maintaining the same code on a mechanical equipment from its first appearance on mechanical schedules extracted from the consultants design up to its maintenance schedule and disposal during the operation of the facility). Furthermore, NBIM-US™ is collaborating on the development of a dictionary and library applied to the BIM model in order to standardize and enhance communication between stakeholders while designing, building and operating the facility. In another words, NBIM-US™ introduces tools to standardize classification and communication in the BIM model in order to avoid misinterpretations and rework among all stakeholders working on the project, this should be considered by F&O during the implementation of BIM since the models will be shared and modified by a significant number of stakeholders during its life cycle.

NBIM-US™ also strongly promotes the use of IFC in the construction industry. IFC consist in a neutral format file for exchange of information between different applications regardless of authoring software's system or company. In another words, the use of a neutral file format (IFC) ensures that construction practitioners are not bind to a specific software company and, consequently, a monopoly which one small group may dictate price and services to the entire construction industry. This a major discussion among BIM professionals and one of questions raised during Current Process Assessment performed on this study. In the opinion of the Sustainability Scholar, it is in F&O's best interest to adopt measures allowing the use of any BIM authoring software giving consultants and trades the freedom of choose their tools to perform their work. Thus the use of IFC becomes a key component for a future implementation and NBIM-US™ provides a significant body of knowledge for this purpose.

Despite the quick advancement in United States and other countries, the Canadian construction industry has been delayed in using BIM. As example, the Sustainability Scholar could not find any BIM guideline in Canada for this study as note on Table 5 with case studies being applied in the country as isolated initiatives per project-basis. Aware of that, CanBIM took the decision to develop a parallel protocol based on the AEC (UK) Protocol with the intention initiate the work in Canada served upon existing mature standards already used in UK. In its second version, AEC (CAN) Protocol developed a strong document deeply involved with the Canadian market reflecting its conditions across the country. For the scope of this work, the "Legal Documents and Considerations" section of CanBIM's document is recommended since it provides a precedent in the country for sharing BIM information electronically and its possible implication towards the discussion regarding the ownership of the model in F&O BIM implementation.

AEC (CAN) BIM Protocol determines that a Terms of Usage letter shall be executed for exchange of electronic information in the BIM model. This term shall indicate the acknowledgement and acceptance that the BIM files may contain imperfect data such as omissions, conflicts or improper use of building components. Hence, the consultant shall not be liable or responsible for any damage incurred from the transmission of information to a third party. Also, CanBIM provides samples of disclaimers and model copyright specific for BIM models but, ultimately the decision on any matter is left upon the project's discretion.

After assessing the three guidelines from third party institutions, is concluded that those are significantly relevant for this study and F&O's intentions to implement BIM in its projects on an institutional and management level. All analyzed guidelines in this section present relevant stances on critical discussions around the implementation of BIM such as the use of open or closed architecture BIM authoring software and the ownership of the BIM model expressed by question 3 and 4 of the Current Process Assessment respectively. In the opinion of the Sustainability Scholar, these discussions are better addressed by these guidelines since those are result of a consensus between several stakeholders across its respective countries and not limited to specific cases unlike the remaining assessed guidelines. Despite their completeness, these guidelines are not suitable to address the remaining questions on the Current Process Assessment. This incurs from the fact these questions are more project-per-project oriented

which are not suitable for this section due to the broad range needed to be covered by third party institutions.

4.2.2. Government guidelines

For the scope of this work, government institutions shall be considered public funded establishments responsible for the planning and oversight of new construction or renovations within a determined jurisdiction. This study analyzed a total of five guidelines from governmental institutions (one national, three state and one municipal) intending to investigate how public facilities are using BIM to enhance their process and clarify some of the questions raised on the Current Process Assessment. The studied guidelines are described below:

1. **Singapore BIM Guide** is a document produced by a public-funded institution in conjunction with public and private organizations in order to improve business communication and the decision making process related to the national construction industry. Moreover, this document is an introductory document to a vast number of other publically available information demonstrating a high level of maturity in BIM and high sophistication of services such as the electronic submittal of BIM files to authorities in order to reduce significantly the processing time for permits and other documentation related to the intended construction.
2. **New York City BIM Guidelines** is intended to ensure uniformity in the use of BIM in all New York City Public Buildings projects and it provides good insights regarding the progression of the BIM model through the project's stages and procedures relevant to this work's scope.
3. **GSFIC BIM Guide** is the first document of a series developed by Georgia State Financing and Investment Commission (GSFIC) in order to inform the requirements in cases that BIM is requested as part of the bidding documents on a project in the state of Georgia. This document is limited for the design stage and is a good source of information about uses of BIM at this stage.
4. **State of Ohio Building Information Modeling Protocol** is a document intended to provide a benchmark for various stakeholders (consultants, builders, government agents, etc.) when working in public projects in the mentioned state. This guideline provides valuable information for procedures not dependent upon specific BIM authoring software

and methods to evaluate consultants' expertise towards BIM during the design bidding phase.

5. **Texas Facilities Commission Professional Architectural/ Engineering Guidelines** is the only document of this study not entirely focused on BIM but it consist of a comprehensive guideline to inform requirements and expectations for state-funded projects and/or renovations in the state of Texas. Due its high level of standardization in construction specifications, this document contributes as a source of templates and documentation for a future BIM implementation.

The Singapore BIM Guidelines is a comprehensive guideline and considered by the Sustainability Scholar as a great example of successful implementation of BIM as demonstrated by the vast and cohesive documentation available for construction practitioners. As a highlight for this report, information reflecting the progression of the model through the project stages and specific positions for BIM management will be presented as contribution to the overall work in order to assist clarifying questions 1 and 2 of the Current Process Assessment. Table 7 demonstrates an example of collaboration between different parties when using BIM through different stages of the project.

Table 7 Example of BIM Project Collaboration Map (Adapted from Building and Construction Authority, 2013)

	Owner representative	Architect	Consulting Engineer	General Contractor/ Quantity Surveyor
Conceptual Design	Provide requirements related to forms, function, cost and schedule	Initial design intent with model containing massing concepts and site considerations	Provide feedback on initial building performance and goals	Provide feedback on initial building cost, schedule and constructability*
Schematic Design	Design review and further design requirement refinement	Design refinement based on stakeholders input	Provide schematic modelling, analysis and system interactions as per Design model development	Provide design review and feedback regarding to building cost, schedule and constructability*
Detailed Design	Design review + final approval on project design and metrics	Finalize design based on coordination between other consultant's models and prepare documentation for tender and regulatory code compliance	Provide and update models as per coordination and provide require documentation for tenders and regulatory code compliance	Develop construction model for simulation, coordination, estimates, schedule while performing final estimate, constructional schedules, and manage bids.
Construction	Construction oversight and inputs regarding construction changes and issues	Respond to RFI's from construction, perform contract administration and update model with design changes	Respond to RFI's from construction, perform contract administration and update specific design models, field conditions and commissioning	Manage construction and inform of design changes
As-Built		Verify As-build model	Verify As-build model	Prepare As-built model
Facility Management	Engage architect and facility group of project turn-over	Coordination information exchange through model to Facilities Group	Prepare handover documentation	

*Applicable to Design-Build projects where General Contractor is appointed at the Conceptual Design Stage

As demonstrated in Table 7, the information workflow is not affected in overall by using BIM in a Design-Built project if compared with a similar project utilizing conventional tools. This indicates that the use of BIM is not a complete change in the industry, but an enhancement in current procedures that can be applied in a practical manner. Table 7 also indicates the creation of a construction BIM model based on design model and information from trades designed for construction operations by the General Contractor in place. This introduces a significant shift during the construction stage by allowing the General Contractor to combine all information and events occurred during construction in a systematical approach that can be properly stored and passed forward for facility management. The process of administrating all information and coordinate all trades from a facility's conceptual design stage up to its operation demands specialized training and abilities. Table 8 summarized the new roles and its respective responsibilities incurred from the use of BIM as per Singapore BIM Guidelines.

Table 8 Overview of Responsibilities of New BIM Roles (Adapted from Building and Construction Authority, 2013)

Role	Responsibilities in model management
Project BIM Manager*	– Implementation of BIM and all required documentation – BIM modelling quality control and oversight – Coordination of BIM models
BIM Coordinator for Consultant	– Create and update design models – Define discipline-specific BIM uses including analysis – Coordinate BIM models and its respective modelers – Coordinate with General Contractor and subtrades – Ensure modeling quality control
BIM Coordinator for General Contractor	– Coordinate with design consultants and subtrades – Study tender documents – Review design and fabrication models as drawings – Use BIM for coordination, sequencing, constructability, cost studies and field use – Create construction and as-built models – Ensure modeling quality control

*This role can be played by the lead consultant or BIM specialist appointed by the Owner representative or project manager

The information presented by Table 7 and 8 are highly relevant to this study since it portraits how the information is shared through the project's phases and changes in the workflow as a result of the use of BIM. This guideline is highly recommended for further reading in case of future implementation along with the remaining documentation publicly available on Building and Construction Authority's website. Yet, more information about the model progression and how information is exchanged through BIM is required for the scope of this work. The New York City BIM Guidelines is a comprehensive document with outstanding explanation about LOD, modelling process as which information must be modeled and progression of the model through the project stages.

Table 9 summarizes the deliverables incurred from the BIM model through the project stages. It is concluded that integration incurred from the BIM model is crucial for the success of the entire process as demonstrated on Table 9 which, at the Construction Documents stage, the model provides information in three fronts: (1) Design with final model and 3D coordination validation, (2) Project Management with cost estimations and (3) Sustainability with LEED reporting. Moreover, this guideline provides a good directive regarding what elements represent graphically in the model stating that "As a rule of thumb, any object that fits within a 6"x6"x6" cube should not be modeled" and every building component's level of detail required per each design stage.

Table 9 BIM deliverables per project stage (Adapted from New York City Department of Design + Construction, 2012)

Pre-Schematic	Schematic	Design Development	Construction Documents	Construction
– Existing Condition Model – Site Analysis – Space Program – Volumetric Model – Zoning and Orientation	– Preliminary Model – Sustainability LEED evaluation – Programing – Phase Planning – Square Footage Cost Estimate – Design Review – Preliminary 3D Coordination	– Design Model – Sustainability LEED analysis – Detailed Energy Analysis – System Cost Estimates – 3D Coordination Reporting – Program Validation	– Final Model – 3D Coordination Validation – Cost Estimation – Sustainability LEED Reporting	– Construction System Design – Phase Planning – Digital Fabrication – Record Modeling – Asset Management

The Georgia State Financing and Investment Commission (GSFIC) presents a BIM guideline oriented for the design stage while it is working in the subsequent stages. As contribution for this report, GSFIC BIM Guide provides valuable information regarding submittal procedures, specific preparation of model for Building Life Safety approval with certified state fire inspectors and which analysis are performed by GSFIC. As for models submittal, GSFIC states that all disciplines shall be separated in different files but connected to a central file liking all disciplines' models while all drawings must be extracted from the BIM model. These models shall remain updated and properly connected at all times through the entire project.

Moreover, this guideline presents a section specific for Building Life Safety components with detailed procedures of how to prepare the BIM model for submittal for certified fire inspectors, thus enhancing the process approval (and reducing waiting time) and promoting transparency for all parties involved. In an attempt to increase transparency, GSFIC also publishes their intended use and internal procedures when assessing the submitted BIM models and a good material for suggested procedures to be adopted by trades when working with the BIM model.

The State of Ohio developed their BIM guidelines with a similar intention of the past guidelines displayed on this report. As contribution for this report, the criteria selection for selecting a Design Team and the Contractual Provisions section are highlighted due their outstanding level of detail. According to the studied guideline a Request For Qualification (RFQ) is prepared containing BIM specific and owner's requirements, level of development intended, deliverables and owner intended use to the model. With possession of the RFQ, the Design Team must provide clarification of how the firm intends to manage the quality of construction documents and clarify responsibilities while demonstrating its expertise and BIM experience in previous projects. Firms are also encouraged to address how they will implement BIM in the specific project. This guideline also has a specific section for contractual provisions as mentioned previously which contains a useful set of legal definitions and provisions about key items when contracting BIM services such as document ownership and use, intellectual property and indemnity for use of electronic files, which are quite relevant for F&O's future BIM implementation.

Also is in F&O's interest, the standardization of process and construction documentation for an enhanced coordination of construction projects. Texas Facilities Commission Professional

Architectural/ Engineering Guidelines provides a comprehensive set of construction specifications with an unique level of standardization in their products (e.g. fourteen different types of suggested doors for all projects) reducing considerably the variability in different projects within Texas jurisdiction. Although this is not a result of using BIM, this guideline provides a cohesive material for the implementation of this work in the BIM model such as Autodesk Revit templates and settings adapted their predetermined sets. This demonstrates a good example to F&O since this practice will reduce considerably questions through the design and coordination process between F&O and consultants while adding transparency through the entire project.

In summary, government-based guidelines are highly relevant for the scope of this work with clarification to several questions raised on the Current Process Assessment such as the information exchange through the BIM model, workflow changes due the use of BIM, the use of open or closed architecture, ownership of the model while providing a portrait about how other institutions are performing in the implementation of BIM in their construction projects. However, their scope is often limited to the construction stage with other significant stages and activities such as operation and energy management are left in second plane. BIM guidelines applied to university facilities are necessary in order to clarify these questions since their scopes are more narrow (only educational facilities) and similar to F&O's context.

4.2.3. University guidelines

In agreement with his mentors, the Sustainability Scholar decided to investigate BIM guidelines produced by education institutions due the similar context that F&O is situated in. Four guidelines were found from universities in United States from public (one) and private (three) sectors as described below:

1. **University of Southern California (USC; private) Building Information Modeling Guidelines** is focused on new construction and major renovations based on Design-Bid-Build form of contract. In the Sustainability Scholar opinion, USC is the most advanced educational institution in regards to applying BIM tools in their projects and provides interesting insights in changes in the workflow brought by BIM, MEP coordination and use of the BIM model for the operation and maintenance phase of the facility.

2. **Georgia Tech (private) BIM Requirements & Guidelines for Architects, Engineers and Contractors** provides several documentation for BIM implementation, building turnover and its operation.
3. **Indiana University (public) BIM Guidelines & Standards for Architects, Engineers, and Contractors** provides comprehensive information regarding the use of BIM in energy modeling in order to speed the decision making process in a practical manner.
4. **Massachusetts Institute of Technology (MIT; private) CAD & BIM Guidelines** is a document that its part regarding to BIM is still in progress but contributes with good templates to be consulted when preparing the documentation required for a future BIM implementation.

USC has employed a comprehensive documentation and effort regarding their BIM guidelines while demonstrating experience reflected in the level of detail employed in their directives while implementing and managing the BIM model. Although limited to only Design-Bid-Build, this guideline provides valuable information about the expected workflow when using BIM, coordination of mechanical, electrical and plumbing building components and integration of BIM model with existing software application for the operation and maintenance of a facility. Moreover, USC request as part of their bidding documents key components for the use of BIM such as BIM Facilitators/ Engineers from both the Design Team and General Contractors, a computer with all updated models at anyone's disposal on-site and a room with suitable equipment for coordination of the BIM model by the General Contractor. These requests, demonstrate a high level of commitment and acknowledgment from the institution that using BIM results in significant savings for the institution. Hence, all appendices of this guideline are recommended for further reading for future implementation by F&O.

The BIM guidelines from Georgia Tech presents a detailed document for presenting their requirements for using BIM in their projects. A detailed explanation about the deliverables and validation of data through the design and construction stages is presented targeting different areas such as design, construction, energy management and operation of a facility. This document also presents a specific section for the facility turnover and special procedures for maintenance of equipment and building components such as the exportation of all deliverables to a data format specific for building maintenance.

Indiana University provides a BIM guideline that comprehends the entire life cycle of a facility compliant with several other guidelines of the area. As a major contribution of this work, the analyzed document presents detailed procedures and requirements for extracting information on energy management efficiently in order to better access the decision making process towards different solutions towards the project. Table 10 summarizes the main requirements for the energy model through the different design stages it is required.

Table 10 Main requirements for energy model through design stages (Adapted from Georgia Tech, 2011)

Conceptual Design	Schematic Design	Design Development
– .GBXml export file – Elements shall be modelled as p. 8 of the document – Frenestation shall be calculated – Must inform early design decisions with reference to building envelope, lighting, domestic water and HVAC systems with "percent better" or "percent worse" scenarios – Spreadsheet with design interactions and comparisons	– Same format to be used in a DOE2 based software – Elements shall be modelled as p. 9 of the document – Information present on p.10 of the document shall be incorporated in the model – Design refinement – Results must include Annual and monthly energy usage by components	– Energy model shall contain enough information for any additional submission (e.g. LEED EA Credit 1 calculations if the project if applying for a LEED Certification) – Energy Conservation Measures (ECMs) shall be included in the model – This model should be a baseline for future comparisons. After one year of occupancy, actual building performance shall be compared with this model

The Massachusetts Institute of Technology (MIT) CAD & BIM Guidelines is a document that is still in progress with little to add to this work when compared with the previous studied guidelines. However, this guideline provides a good source of templates which can be used as reference when producing the documentation required for the implementation of BIM by F&O.

After careful analysis of university guidelines, it is concluded that these guidelines are the most specific and recommended to be used as reference by F&O when performing its own BIM guideline. This result is expected since these institutions perform similar activities as F&O performs under the University of Alberta umbrella. Also, it was noted that, with the exception of

MIT, all universities adopted COBIe to store information regarding the operation and maintenance of their facilities with a great effort to make the BIM model extract the required information automatically. This activity is highly recommended by the Sustainability Scholar.

4.2.4. Summary of all guidelines

This section presents a summary of all analyzed guidelines, important findings regarding the raised questions at the Current Process Assessment and relevant information to each stage of the facility life cycle. The structure of this section will follow the questions performed on the Current Process Assessment in an attempt to clarify what was unclear by the working units at F&O.

Information exchange through the model during its life cycle

Several guidelines have contributed to clarify this question with structures and the required model detail per submission phase. Government and University guidelines provided more clarity to this question since these institutions need to inform consultants and general contractors their requirements through the entire project. The suggested guidelines to better clarify the information exchange through the BIM model are from USC, New York City and State of Ohio institutions and should be used as a benchmark by F&O when preparing their BIM guidelines.

Workflow change due the use of BIM

After the analysis of the guidelines, it is noted that BIM will not reinvent significantly methods to develop, coordinate, built and operate facilities. BIM performs is a major key in enhancing several existing process by allowing construction practitioners to process information more rapidly and perform important decisions towards the project performance more accurately. However, USC, New York City and Singapore's guidelines have indicated specific full-time positions for managing the BIM model and the process derived from it (e.g. BIM Facilitator/ Engineer, BIM Trade Coordinator, etc.). F&O should become aware of these positions and evaluate if it should require these professionals from its consultants and general contractor for their projects.

Which software to use (use of open or closed architecture application approach)

All guidelines contributed to clarify this question. Figure 2 depicts the recommended work platforms informed by all guidelines when working on their respective projects. IFC, although is also considered an open architecture format, it is distinguished in Figure 2 since it was specifically asked as deliverable format. Requiring a specific file format, incurs depending on one software company and possibly reducing competitiveness from consultants and/or general contractors when providing services to the University of Alberta.

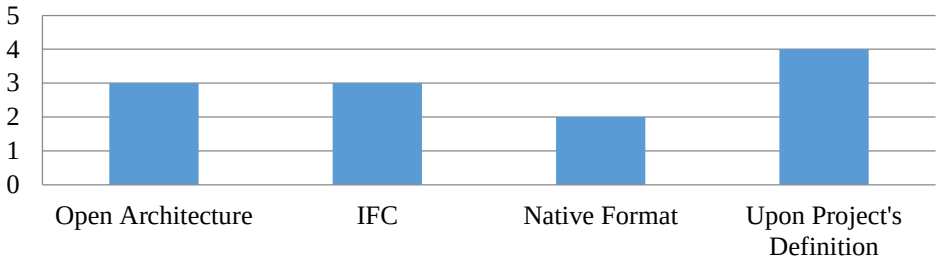

Figure 3 Summary of recommended work platforms required by guidelines

An intriguing finding from study is that, although most of guidelines encourage the use of open file formats to conduce the project coordination, several institutions required specific file formats for its submittals. The Sustainability Scholar believes this is incurred due the fact these institution have obtained specific licenses and personnel training for specific software. In order to overcome this possible barrier, F&O shall evaluate a claim from Texas Facilities Guideline when, in case of using different software that there are not used, the consultant may provide the software license and training in order to use any software in the specific project. Figure 3 demonstrates the deliverable formats required by the analyzed institutions. It is clear that Autodesk products are preferable by the analyzed institutions along with the requirement for COBIe at the Operation & Maintenance stage. This occurs due the dominance of these products in the North American market. In light of possible inconsistencies or problems incurred from not using native file format, further reading in Singapore's guidelines and extra documentation is recommended since they dispose of specific documentation for each main commercial BIM authoring software available.

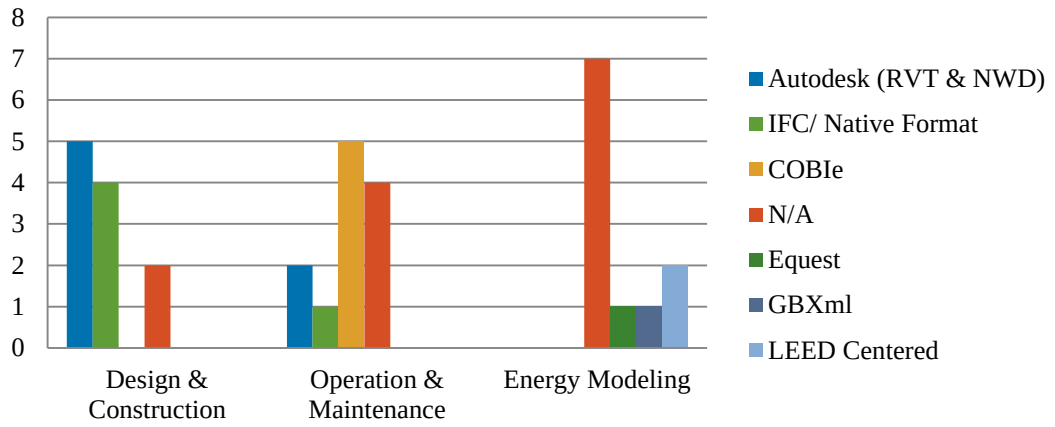

Figure 4 Deliverables format required by analyzed institutions

Ownership of the model

A clarification regarding the ownership of the model is a key component for a successful implementation of BIM in any institution. Figure 4 summarizes the analyzed institutions stances regarding this subject. It is noted that institutions with a wider range do not take a clear stance regarding this subject probably because of the high variability of projects under their scope. Most institutions required fully ownership of the model and any document related to it, opening a precedent to F&O to do the same. For more information about this matter, CanBIM and Ohio's guideline is recommended for further reading.

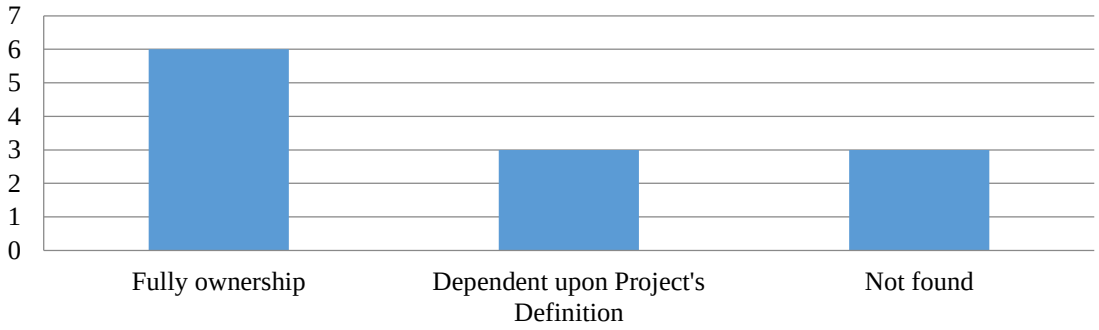

Figure 5 Analyzed institution's stance regarding the ownership of the model

Financial investment incurred from BIM

The financial investment incurred from BIM is also a cornerstone for a successful implementation of BIM. This question is divided in two parts: (1) when a project becomes

feasible to implement BIM as oppose to conventional tools and (2) how much other institutions are investing for BIM services. The Sustainability Scholar found initial values for construction and renovation projects when BIM should be used. The State of Ohio recommends using on BIM for projects on the value of $4M or greater while Georgia Tech and Indiana University recommends using it starting from $5M. In order to clarify the compensation incurred from BIM, Table 11 demonstrates the cost incurred from the use of BIM tools and services in consultants fees gathered from Singapore and Ohio's BIM guidelines. As depicted in Table 11, these institutions don't intend to pay any premium for the use of BIM in their projects, but frontload a portion of consultant's fee to the initial stages of design due the additional effort required from BIM tools at this point.

Table 11 Cost incurred from the use of BIM in total consultant fee (Adapted from Adapted from Building and Construction Authority, 2013 and Ohio General Services Division, 2011)

Project Stage	% change from the use of BIM the project	
	Singapore	Ohio
Preliminary Design	+2.5%	0%
Schematic Design	0%	+5%
Design Development	+2.5%	+5%
Construction Documents	0%	-10%
Bid and Award	0%	0%
Construction Administration	-5%	0%
Contract Closeout	0%	0%
Percentage change in total fees	**0%**	**0%**

Other institutions practices and experiences

After performing a comprehensive review on twelve guidelines from different institutions, it is concluded that University of Alberta is behind all these institutions including universities. In the Sustainability Scholar opinion, the two more advance institutions are Building and Construction Authority in Singapore and USC hence a complete review of their guidelines by F&O is recommended due their experience with BIM. Furthermore, an additional reading of NBIM-US^{TM} guideline and appendices is also recommended due its completeness and influence in the North American market.

5. CONCLUSIONS AND RECOMMMENDATIONS

This study has analyzed twelve BIM guidelines categorized in three groups of interest (third party, government and university) under the criteria determined during the Current Process Assessment in collaboration with the different units that will utilize BIM on daily-basis at the Facilities and Operation department at the University of Alberta. It can be concluded this study has brought significant knowledge of current applications of BIM by different institutions as of clarifying several questions around its implementation at University of Alberta construction projects. It is also concluded that BIM is aligned the university's sustainability objectives by developing strategies in order to promote integration between all stakeholders involved in the design, construction and operation of a facility. Based on the work performed during this program, the advantages of using BIM in F&O are described by phases below:

- Design & Planning
  - Reduce the uncertainty in estimations by providing cohesive and structured information available to all stakeholders regarding the scopes of work, cost data and possible inconsistencies on designs.
  - Enhance the decision making process for building systems and envelope by connecting energy models to cost databases and other pertaining information thus providing a cohesive assessment regarding the available design options
- Construction & Tender
  - Improve the coordination process by integrating models provided by consultants and trades while accessing possible interferences on-site and reducing uncertainty on-site
  - Support for claims and change orders by reducing miscommunication and using the model as "live record" of progress and changes during tender and construction.
- Operation & Maintenance
  - Avoid rework and miscommunication while storing and updating documentation related to maintenance (warranties, manuals, purchase orders, etc.)
  - Use of BIM as interface for predictive maintenance models in order to reduce the operational cost of a facility

Moreover, the Sustainability Scholar suggest that the Facilities and Operation department at the University of Alberta should pursue implementing BIM at its capital projects, operations, maintenance and renovations. Should this proceed, four recommendations are displayed below:

- In possession of this report and its appendices, the University of Alberta should hire a professional proficient with BIM tools and project coordination to write BIM guidelines specific for F&O's context, implement them and perform the coordination of BIM data on F&O's projects following the example of other institutions.
- F&O should also consult the local construction industry in order to address their current expertise on BIM, streamline its intentions towards BIM and develop strategies in order to achieve the intended results for on-campus construction projects.
- As demonstrates by other institutions, some key documents should form part of the future guideline, these are:
  - **BIM Execution Plan:** It consists of a document demonstrating which tools, responsible personnel and strategies are employed by the Design Team and/or General Contractor in regards to BIM tools
  - **BIM Objective & Responsibility Matrix:** Document intended to define level of detail of BIM objectives per design stages and responsible personnel to model it
- The operational stage of a facility represents the major portion the cost in its life cycle. Hence, the future BIM guidelines should also be focused on the use of the BIM model in order to reduce the operational cost of the facility since the University of Alberta builds and operates all of its buildings.

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APPENDIX A: Complete questionnaires from interviewed units

UNIVERSITY OF ALBERTA

Sustainability Program

Date: May 18th, 2016

BIM Project

Interview Script

1. Present myself
2. Present the program and provide a little overview on BIM (important to set the context for the discussion as they may or may not be using BIM data or may consider that this is only a Revit model; suggest also informing them as part of this that you are speaking to others in different areas of F&O that could use BIM in the future - e.g. they should focus on their unit for this conversation)
3. Use the following form:

Department: Planning and Project Delivery (Office of University Architect)
Brief description of the department's role: - Design oversight on major capital projects - Develop guidelines or follow existing as per LRDP (legal requirement of PS Act) and coordinate those with the City of Edmonton - Overspace management
How many people are involved in the department: 6-10
Current use of BIM in the department: Conceptual model (on Revit)
Where BIM could be used in the department: - Use of conceptual model by consultants (currently the conceptual model is not passed over to no one) - Oversight of architectural changes proposed by third parties through design and construction phases
Questions about BIM and its applicability: - Possible interaction between BIM model used by PPD and AIM - B/c of F&O increased level going towards AIM, what is AIM doing, what standards are they looking at? What are they anticipating? - Struggles in the private sector - who owns the model, whose standards are being used
Three main bottlenecks in department for BIM data processing according to the interviewee's opinion: - Resources (education and skill) - Actually see BIM as a bottleneck breaker - few people could potentially do things quicker, but requires education and skill - need more people to have that skill - Time & money

Three main bottlenecks in department according to interviewee's opinion: - Resource (in terms of people - budget cuts and attrition) - Time & money
Flow chart in separate paper. Must contain: i. Logical sequence of work ii. Required input from other parties iii. Deliverables according to sequence iv. Tools utilized per stage v. Criteria used on each stage

4. Allow the interviewee to ask any other question

None

Notes:

None

Interview Script

1. Present myself
2. Present the program and provide a little overview on BIM (important to set the context for the discussion as they may or may not be using BIM data or may consider that this is only a Revit model; suggest also informing them as part of this that you are speaking to others in different areas of F&O that could use BIM in the future - e.g. they should focus on their unit for this conversation)
3. Use the following form:

Department: Project Management Office
Brief description of the department's role: - Implementation of construction projects from concept through the completion of the construction
How many people are involved in the department: 15-20
Current use of BIM in the department: Consultant desire to use a BIM model (consultant driven to communicate their ideas) Requirement for delivery is in CAD format
Where BIM could be used in the department: - Communication between clients (university, trades, general clients, etc.) - Reduce clashes and improve on-site coordination
Questions about BIM and its applicability: - Is there a maturity on this construction community to work towards BIM?
Three main bottlenecks in department for BIM data processing according to the interviewee's opinion: - Lack of understanding of what should be asked - What to do with what was asked - How to influence change in what we are asking
Three main bottlenecks in department according to interviewee's opinion: - Resources (bad timing between quantity of projects versus quantity of people available) - Bureaucracy (tender and contract awarding by others) - RFI's processing

Flow chart in separate paper. Must contain:

i. Logical sequence of work
ii. Required input from other parties
iii. Deliverables according to sequence
iv. Tools utilized per stage
v. Criteria used on each stage

4. Allow the interviewee to ask any other question

None

Notes:

None

Interview Script

1. Present myself
2. Present the program and provide a little overview on BIM (important to set the context for the discussion as they may or may not be using BIM data or may consider that this is only a Revit model; suggest also informing them as part of this that you are speaking to others in different areas of F&O that could use BIM in the future - e.g. they should focus on their unit for this conversation)
3. Use the following form:

Department: Design and Technical Services

Brief description of the department's role:
– Small design team (electrical and mechanical drawings) together with architectural drawings provided by the Architect's office
– Technical services for trades
  – Facilities, physical hazardous materials and safety codes
  – Technical documents management of buildings (using Meridian)
  – Allows for excavation permits

How many people are involved in the department: 13
Current use of BIM in the department: - Using aspects of BIM: Meridian (manage documents) + AIM (user of service by monitoring some equipment's) - Currently using 2 dimensional drawings
Where BIM could be used in the department: - Tie assets information between manuals, documentation (Meridian) + controls in AIM + BIM model (e.g. click on a valve and retrieve information regarding manuals, certification, inspection, etc) - 3D would enhance communication with non-traded personnel - Using BIM on small projects wouldn't be as effective due the small complexity involved
Questions about BIM and its applicability: - None
Three main bottlenecks in department for BIM data processing according to the interviewee's opinion: - Getting information through various systems (current system: physical documentation on turn-over such as cd, usb and the department has to validate in order to enter into the systems)

- What systems (e.g. AIM, Meridian, etc.) to use in order to retrieve information using BIM as interface. Not finding information on systems and having to retrieve this information physically may occur up to 10 times a month
Three main bottlenecks in department according to interviewee's opinion: - Communication through the entire project - Resources (people) - Getting all information to do all the work (don't own all the information)
Flow chart in separate paper. Must contain: (Tony to send this) i. Logical sequence of work ii. Required input from other parties iii. Deliverables according to sequence iv. Tools utilized per stage v. Criteria used on each stage

4. Allow the interviewee to ask any other question

None

Notes:

- Meridian: stores 2D + all documentation regarding equipments (overall manuals for the building)
- AIM: track people, jobs, space mgmt

Not finding information about existing equipment: 10 times a month

Interview Script

1. Present myself
2. Present the program and provide a little overview on BIM (important to set the context for the discussion as they may or may not be using BIM data or may consider that this is only a Revit model; suggest also informing them as part of this that you are speaking to others in different areas of F&O that could use BIM in the future - e.g. they should focus on their dept for this conversation)
3. Use the following form:

Department: Operations & Maintenance (Building Infrastructure)

Brief description of the department's role:
- Trades units: Provides maintenance and renovations-- elec, mech, arch trades
- Project coordination group: up to .2-3 m renovation projects (project management on a lower level)
  - Smaller, specific, or more general, or very small
  - Work with trades often, can also contract out
- Technology department: Capital & Operations (AIM) (space management, work amangement, asset management, maintenance tracking). Not custodial

How many people are involved in the department: 200 + contractors (probably another 200)
Current use of BIM in the department: None
Where BIM could be used in the department: - Predictive maintenance - If the 200 tradespeople have the tech and can access the info that would save labour costs and long term maintenance costs - Could go hand in hand with IPD, best-value, etc. - Training people - there is some knowledge (e.g. Of AutoCAD, construction drawings) - think reading the model would likely work, but training for getting people technically up to speed to really operate a model

Questions about BIM and its applicability:
- Are there any institutions that have done this? Case study?
  - How did they get buy in from architects?
  - How does it work?
  - How does the cost of the model fit? who pays? How does it work with capital cost??

Three main bottlenecks in department for BIM data processing according to the interviewee's opinion: - Resources (training people) - Technology (tools and hardware) - Convincing higher admin keep BIM in when it comes to value engineering and going beyond architectural details - mechanical info, finishes - Incompleteness of BIM - challenge bringing the high level design down to the O&M details - Ownership of model - university needs to own the model - Education of contractor community
Three main bottlenecks in department according to interviewee's opinion: - Higher cost is labor - Lack of communication between Capital and Maintenance regarding concern on the project - Thinking on the short term on construction projects - Education and understanding from design through to O&M Capital builds, but doesn't operate - skewed rewards - on time and on budget doesn't mean it's high quality - Starting to see the shift, but how do we educate the design community, both internal and external to the university, about the long-term O&M impacts of their design - How to get long-term mindset - Separate operating budgets and priorities
Flow chart in separate paper. Must contain: (Tony to send this) i. Logical sequence of work ii. Required input from other parties iii. Deliverables according to sequence iv. Tools utilized per stage v. Criteria used on each stage

4. Allow the interviewee to ask any other question
   - How does ownership of current drawings work? University would need to own the BIM model

Notes:

- BIM seems well suited for the university
- BIM should be concentrated on O&M because design community interest is only until end of construction
- O&M is a necessary cost for the mission of the university
- O&M often gets thought of too late in the game during building design process

UNIVERSITY OF ALBERTA

Sustainability Program

Date: May 25th, 2016

BIM Project

Interview Script

1. Present myself
2. Present the program and provide a little overview on BIM (important to set the context for the discussion as they may or may not be using BIM data or may consider that this is only a Revit model; suggest also informing them as part of this that you are speaking to others in different areas of F&O that could use BIM in the future - e.g. they should focus on their dept for this conversation)
3. Use the following form:

Department: Energy Management & Sustainable Operations
Brief description of the department's role: - Optimize operations (energy, water, waste, etc) - Energy management is responsible for bigger savings and funds the other programs
How many people are involved in the department: 4
Current use of BIM in the department: - Started 4-5 years ago driven by possible saving claims in projects regarding the use of alternative equipments. First project was Li Ka Shing building - Modeling from exterior to interior (building envelope) - Energy models outsourced to 3D Energy (Sherwood Park-based consulting company) using Revit and IES - Rough manual energy modelling using real data from utilities use
Where BIM could be used in the department: - Work not being currently performed on small projects, but could be if other units could also use the model and pay partial price for it - If we had BIM models already built, ability to make initial rough estimates and project decisions would be enhanced - Easier to look at life cycle costs and make decisions
Questions about BIM and its applicability: - How fast is to adapt traditional tools for specific cases?
Three main bottlenecks in department for BIM data processing according to the interviewee's opinion: - None, all modelling is outsourced
Three main bottlenecks in department according to interviewee's opinion: - Resource (few people for many projects)

Flow chart in separate paper. Must contain:

i. Logical sequence of work
ii. Required input from other parties
iii. Deliverables according to sequence
iv. Tools utilized per stage
v. Criteria used on each stage

4. Allow the interviewee to ask any other question

Notes:

1- Life cycle assessment not done in capital projects

2- Different budgets for construction and operations

APPENDIX B: Complete BIM guideline review from institutions

UNIVERSITY OF ALBERTA

Sustainability Program
BIM Project

BIM Guidelines & Standards

Institution name: National Institute of Building Sciences buidlingSMART alliance®
Institution Type: Third-party
Relevant initial notes: • Most relevant BIM guideline in North America • It takes the entire cycle of the building into consideration • Two specific audiences: (1) Software developers and vendors; and (2) Implementers working in any area of the construction industry
Prior guidelines relevant to this document: • ISO 16739, Industry Foundation Class 2X3- February 2006 • World Wide Web Consortium Extensible Markup Language Specification and Validation- Firth Edition • OmniClass™ Tables • International Framework for Dictionaries (IFD)/ buildingSMART Data Dictionary- May 2012 • BIM Collaboration Format (BCF)- Version 1.0 • LOD Specification- August 2013 • United States National CAD Standard (NCS)- V5
Interoperability: Heavy supporter of IFC
Deliverable formats: N/A
Ownership of the model: Not found
Relevant extra documentation: • ISO 12006-3, Framework for Object-oriented Information Exchange
Interesting insights: • Tetralogy process domains (see p. 4 of Scope document) • Proposes OmniClass™ in order to classify all BIM elements and "unify" a language around the BIM model through the life-cycle of the project • Tentative of creating a dictionary and library for building elements to enhance the workflow and communication around the BIM model, see p. 9-15 of Reference Standards-IFD Library/BSDD document for more information • "A BIM Use is defined as a method of applying Building Information Modeling during a facility's lifecycle to achieve one or more specific objectives." • Good set of definitions around BIM and its uses • Good guidelines for contractual arrangements

PROJECT PHASES
Pre-Design (Conception): N/A
Schematic Design: N/A
Design Development (Detailing): N/A
Construction Documentation: N/A
Bidding: N/A
Construction: N/A
Project Turn-Over: • All manuals and record documentation shall follow COBIe • Specific section for information hand-over
Operation: • Special section for facility management • Initial planning procedure shall include: (1) Strategic Planning, (2) Implementation Planning and (3) Procurement Planning • Good guidelines for applying BIM for facility management
Energy Modelling: • Specific appendix for BIM-based energy analysis • Building Energy Analysis (BEA) is an open IFC-based BIM information exchange to allow owners and designers to evaluate building energy performance through the design process by using BIM • BEA information exchange allows data pertinent to energy modelling to be added to the BIM model • Possibility for quality assurance of the program • Delivered package for certification test program: o IFC BIM file o Certification test results' summary report o Certification test results' detailed reports

BIM Guidelines & Standards

Institution name: AEC (UK) Initiative
Institution Type: Third-party
Relevant initial notes: • Maximize efficiency of industry through adopting a consistent BIM strategy aligned to UK Government and International practices • Objective to ensure BIM files are structured correctly to current practice standards
Prior guidelines relevant to this document: • AEC (UK) Layer Naming v3.0 2011 • BS1192:2007 Collaborative production of architectural, engineering and construction information • BS8541-1:2012 Library objects for architecture, engineering and construction. Identification and classification • BS8541-2:2011 Library objects for architecture, engineering and construction. Recommended 2D symbols of building elements for use in building information modelling • CIC BIM Protocol • CIC Outline Scope of Services for the Role of Information Management 2013 CPIx Protocols • PAS1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling • RIBA Plan of Work 2013 • Uniclass 2015
Interoperability: Specific BIM guidelines per authoring software (e.g. Revit, ArchiCAD, VectorWorks, etc.)
Deliverable formats: N/A
Ownership of the model: Dependent upon project.
Relevant extra documentation: Specific BIM guidelines per authoring software (e.g. Revit, ArchiCAD, VectorWorks, etc.)
Interesting insights: • Interesting union between LOD (Level Of Development) and LOI (Level Of Information) • Sub-division of models is recommended in order to avoid files to become too big and/or slow • Check p.12 of document for Skill Matrix • Check CPIc post-contract BIM Execution Plan template • Guidelines around workflow regarding BIM (kick-off meetings, review, etc) • Investigate AEC(UK)BIM Technology Protocol Model Validation Checklist mentioned on

p.19 of the document • "Data exchange protocol between different software/ hardware systems shall be verified through sample testing to ensure data integrity is maintained • Check p.23 of the document for example of model structure • Different classification for BIM models
PROJECT PHASES
Pre-Design (Conception): N/A
Schematic Design: N/A
Design Development (Detailing): N/A
Construction Documentation: N/A
Bidding: N/A
Construction: N/A
Project Turn-Over: N/A
Operation: N/A
Energy Modelling: N/A

BIM Guidelines & Standards

Institution name: Canadian BIM Council (CanBIM)
Institution Type: Third-party
Relevant initial notes: • Protocol based on AEC (UK) Protocol • Later, it has developed a strong link with the Canadian market
Prior guidelines relevant to this document: • UK (AEC) Protocol
Interoperability: "As a guiding principle, keep models in their native authoring formats to help maintain model integrity, reduce data loss, and reduce rework. Interoperability relies heavily on the project BxP and helps facilitate data transfers."
Deliverable formats: "Technological infrastructure needs should be tabled in the BxP, outlining the software and version to be employed by each discipline to achieve BIM deliverables (e.g. Design Authoring, Design Analysis, and Construction Coordination). Any incompatibility issues should be resolved prior to commencement of any modelling activities." In summary, dependent upon BxP
Ownership of the model: Dependent upon project
Relevant extra documentation: • AEC (CAN) BIM Protocol for Revit v2 (September, 2014)
Interesting insights: • "A BIM Execution Plan (BxP) is a living, collaborative document used to communicate the overall vision and procedures for BIM implementation to project stakeholders. Developed at the early stages of a project, the BxP should continually grow and be updated according to changing project requirements." • "The content of this information exchange should be documented in an information exchange worksheet or modelling matrix, detailing who will be responsible for which model element and the Level of Development (LOD) that will be required at defined project milestones." • Mention to quality check of the model

PROJECT PHASES
Pre-Design (Conception): • Guidelines for location and site coordination • Guidelines for linkage of different models and disciplines • Guidelines for folder structures and file naming • Guidelines for appropriate line weights, text and etc.
Schematic Design: N/A
Design Development (Detailing): N/A
Construction Documentation: N/A
Bidding: N/A
Construction: N/A
Project Turn-Over: N/A
Operation: N/A
Energy Modelling: N/A

BIM Guidelines & Standards

Institution name: Building and Construction Authority 2013 (Singapore)
Institution Type: Government
Relevant initial notes: • This document has the intent to outline the possible deliverables, processes and personnel involved regarding the use of BIM in Singapore's construction industry • This document also intends to depict the roles and responsibilities when using BIM in a construction project
Prior guidelines relevant to this document: • Level of Development (LOD) Specification (BIM Forum)
Interoperability: "To ensure the life-cycle use of building information, information supporting common industry deliverables shall be provided in existing open standards, where available. For those contract deliverables whose open standard formats have not yet been finalized, the deliverable shall be provided in a mutually agreed format which allows the re-use of building information outside the context of the proprietary BIM software. The format could be any of the prevailing open standards, such as the International Foundation Class (IFC) standard, where available. The formats used should be specified in the BIM Execution Plan."
Deliverable formats: • Native file or open sources as per client choice
Ownership of the model: The model's author does not convey any ownership right to the model as it is any subsequent author's or model user to use, modify and transmit the model for its limited scope their inherited to. The Employer may specify for ownership at initial agreement. (p. 12 for clarification)
Relevant extra documentation: • BIM Particular Conditions Version 2 • BIM Essential Guide For BIM Execution Plan • The VA BIM Object/ Element Matrix Manual Release 1.0 (in folder) • Regulatory submissions guideline: https://www.corenet.gov.sg/general/building-information-modeling-(bim)-e-submission.aspx

Interesting insights:

- According to the document, typical BIM deliverables includes models for cost estimation, clash detection, shop drawing, fabrication models, and data for facility management besides the traditional 3D model for design. Check p. 5 for more information.
- Check p. 7 of this document for a good example of element's progression through the project
- Check p.8-10 of this document for a good example of BIM deliverable's through the project
- Definition of model author/user at the BIM Matrix
- Model user should use the model for reference only where, in case of inconsistency, the model user shall inform the author to perform modifications.
- Check p.13 of this document for BIM fees and compensations.
- Check p.14 for other BIM services available
- BIM Modelling and Collaboration Procedures is a good Chapter for education
- Check p. 18 for a good example of BIM Collaboration Map
- Use of electronic signature is considered a good resource to validate a coordination model
- Check p. 21 for see "transition" to BIM process in Singapore
- The BIM manager is responsible to establish a quality assurance plan in the BIM deliverables and mention it on the BIM Execution Plan
- Check p. 25-26 for BIM Professionals and its responsibilities
- *All Appendices are really worth checking in more detail in case O&M decides to start its own BIM guideline*

PROJECT PHASES

Pre-Design (Conception):

- Building masses and other forms of data indicating geometry, orientation and position are expected at this stage

Schematic Design:

- Generalized building and system components with approximate geometry, orientation, position and quantities are expected at this stage. May include non-geometric properties.

Design Development (Detailing):

- A detailed version of the previous model including accurate geometry, orientation, position and quantities are expected at this stage. Non-geometric properties should be included.
- During the coordination process each party owns a discipline- specific model and it is responsible to modify its model as per discussed during the process

Construction Documentation:

- A detailed version of the previous model including accurate geometry, orientation, position and quantities are expected at this stage. Non-geometric properties should be included.

Bidding:

- A detailed version of the previous model including accurate geometry, orientation, position and quantities are expected at this stage. Non-geometric properties should be included.

Construction:

- 3D elements can be modeled with complete fabrication assembly details where applicable or useful during the construction stage. Otherwise, it shall be represented in 2D drawings contained in the BIM model.

Project Turn-Over: N/A • BIM elements shall be similar to the level of detailed in the design stage but updated with the changes from the construction stage
Operation: • Building element is modelled as construction and is connected to documentation regarding O&M
Energy Modelling: N/A

BIM Guidelines & Standards

Institution name: New York City Department of Design + Construction
Institution Type: Government
Relevant initial notes: • The document is intended to ensure uniformity in the use of BIM for all New York City Public Buildings projects • The goal is to improve design, management, construction and delivery of superior public facilities
Prior guidelines relevant to this document: • Uniformat classification • Omniclass
Interoperability: It does not require any specific commercial software. Please refer to p.8 of the document to see acceptable BIM applications
Deliverable formats: Autodesk products
Ownership of the model: "DDC holds ownership of the BIMs including all inventions, ideas, designs, and methods contained within the model. This includes, but is not limited to; the content submitted as part of the BIMs itself. DDC holds ownership of all the contents within the models from project conception (pre-schematic design) all the way to completion (construction)"
Relevant extra documentation: N/A
Interesting insights: • There is a special care in regard to the project delivery method in regards to manage the BIM model • Check p. 9 of the document for special section regarding the BIM Manager • Check p. 10 of the document for special section regarding Discipline Trade BIM Coordinator • BIM Execution Plan to be delivered within 30 days of project award and registration • Document has good explanation about potential uses and LOD • Compliant with Uniformat classification and Omniclass. • *"As a rule of thumb, any object that fits within a 6"x6"x6" cube should not be modeled"* (REALLY GOOD ONE) • Appendix named "Object Requirements" is a good example of objects progression through the design process • Directions for object naming

PROJECT PHASES
Pre-Design (Conception): • LOD 100 • Volumetric model • Site analysis • Space program • Zoning and orientation
Schematic Design: • LOD 200 • Preliminary model • LEED evaluation • Phase planning • Preliminary cost estimation (square foot based) • Design review • Preliminary 3D coordination
Design Development (Detailing): • LOD 300 • Design authoring model • Detailed energy analysis • LEED evaluation • System-based cost estimates • Program validation • 3D coordination report
Construction Documentation: • LOD 400 • Final models • Cost estimation • LEED report
Bidding: • Model must be identical to every documentation produced in bid documents • Model may be distributed for informational purposes only
Construction: • Construction system design • Phase planning • Digital fabrication • Scheduling
Project Turn-Over: • Record modelling • Asset management
Operation:
Energy Modelling: o LEED-centered analysis

BIM Guidelines & Standards

Institution name: Georgia State Financing and Investment Commission
Institution Type: Government
Relevant initial notes: • Document based for Design stage only • BIM deliverable does not replace traditional deliverables • BIM model shall be interpreted as an assisting tool to aid the Owner to review design submissions
Prior guidelines relevant to this document:
Interoperability: To Design Team's discretion
Deliverable formats: • A single BIM file in IFC 2x2 format (preferred) or IFC 2x format • BIM file(s) in native format Owner acknowledges present issues regarding compliance between IFC files and its native files. Therefore, a list with all issues contained in the file shall be submitted along with the model.
Ownership of the model: Owner has the ownership of the model and can make it available for the use of any agency as may see fit.
Relevant extra documentation: N/A
Interesting insights: • More versions to come • BIM models submitted with Change Orders shall contain all items included in the scope which were specifically modelled for that document and delivered to the required level of completeness. Elements contained in the model which are not related to the Change Order could be lesser detailed. • Specific section for Building Life Section Components (Section 2) • Specific section for BIM model hand-out (Section 3) • Good Appendices for "education"

PROJECT PHASES
Pre-Design (Conception): • Model(s) shall include material information relating gross floor area of prime building space and building systems. Other information such as site limitations, soil information, cost limitations and etc. do not need to be modelled.
Schematic Design: • "Site lighting requirements (ASTM E 1804-02 section 8.2.1.7) do not need to be modeled. Also specifications outline (ASTM E 1804-02 section 8.2.2.2) and mechanical/electrical/plumbing systems outline (ASTM E 1804-02 section 8.2.2.4)."
Design Development (Detailing): • Project specifications such as selected manufacturers and acceptable manufacturers do not need to be modelled.
Construction Documentation: • Shall include all specifications
Bidding: N/A
Construction: N/A
Project Turn-Over: N/A
Operation: N/A
Energy Modelling: N/A

BIM Guidelines & Standards

Institution name: State of Ohio Building Information Modeling Protocol
Institution Type: Government
Relevant initial notes: This document is intended for all projects with state funded worth of 4M or more Immediate goals: • Establish a common methodology to communicate Owner's expectations regarding level of detail and types of data • Establish minimum modelling requirements to provide immediate value to Owners Short term goals: • Standardize and refine Owner- specific requirement for all projects • Determine optimum implementation of BIM applications • Maximize integration between building components Midterm goals: • Increase minimum BIM requirements in light of usage from the industry • Increase level of detail in alignment with the current needs
Prior guidelines relevant to this document: N/A
Interoperability: Open architecture applications are encouraged while BIM authoring software shall comply with the latest IFC version certified by buildingSMART alliance. The Design Team shall provide reviewing tools (readers) that support collaborative design and construction work.
Deliverable formats: "While a specific BIM authoring software is not required by the protocol, all members of the design team shall provide models and data in the format necessary to support the model level of detail required for the project. A specific deliverable file format, if required for a specific project, will be described in the request for professional services and bidding documents for that project. Deliverable requirements are as specified in the SAO Manual and the Deliverables section of this protocol document."
Ownership of the model: "Drawings, Specifications, and other documents prepared by, or with the cooperation of, the A/E or any Consultant pursuant to this Agreement, including the Electronic Files used to create them, are, from the moment of creation, the property of the Owner, whether or not the Project for which they are prepared is commenced or completed, and the Owner alone owns every right, title, and interest therein."

Relevant extra documentation:
N/A

Interesting insights:

- Unless noted otherwise, the Architect is responsible to manage the model through the design and construction phases while construction personnel shall use the model as their discretion
- Process used to evaluate Design Team's BIM performance:
    - RFQ will be handed over by the Owner defining requirements, level of development, deliverables and Owner's intent to use the model after construction
    - The evaluation process is focused on Design Team's experience in implementing and managing the BIM models
    - Evaluation must also be focused on Design Team's ability to perform the work, manage the quality of construction documents and clarify the responsibilities through the entire process
    - The Design Team is encouraged to address how they will implement BIM in the specific project, level of personnel training and it's understanding of the BIM process
- Check p.11 of the document to see fee compensations
- "Cost of purchasing BIM authoring software and training will not be compensated by the Owner…"
- Check p. 14-16 of the document for model progression

PROJECT PHASES

Pre-Design (Conception):

- BIM Execution Plan (30 days after contract execution)
- Feasibility models
- Database of program/ spaces
- Massing
- Relationship/ functions
- Responsibility Matrix
- Data organization outline
- Restatement of Owner Requirements
- AIA E202 Refinements

Schematic Design:

- BIM Execution Plan update
- Architectural model based on approved conceptual model
- Complimentary disciplines as required by Owner
- Interference report

Design Development (Detailing):

- Architectural, Structural, MEP, Civil models and any other system as per required
- Detailed interference report
- Code review model if available

Construction Documentation:

- Same as Design Development Stage
- Quantity reports as required

Bidding:

- Models produced at this stage shall comply with the intended requirements on Construction section
- Check p. 14-16 of the document for model progression

Construction:

- Models shall support and confirm the program requirements of the project
- Models shall be sufficient to illustrate construction intends and spatial relationship of occupied spaces in a tridimensional illustration if required.
- Models shall support coordination purposes such as detecting interferences through software utilized by Design Team and/or General Contractor or anyone as selected by the Owner
- Models shall support the fabrication models delivered by Subtrades
- Check p. 14-16 of the document for model progression

Project Turn-Over:

- Record models updates with field changes and as-built conditions
- All models separated by disciplines
- Code review model if available
- Quantity reports as required
- No energy model or interference report

Operation:

- This section varies from project and the Owner specific requirements. Some examples are described below:
    - Model shall be development with the intend to assist Owner in reviewing future renovations and system requirements for the project
    - Integration with energy management systems and controls
    - Support facility management systems

Energy Modelling:

- Preliminary energy model shall be delivered at Schematic Design stage and may be outside of existing BIM model
- Energy model values shall be delivered in the Design Development and Construction Documentation stages
- BIM model shall be delivered to, at least, a minimum level of development to assure compliance with State of Ohio requirements for energy modelling and LEED certification if required.

BIM Guidelines & Standards

Institution name: Texas Facilities Commission
Institution Type: Government
Relevant initial notes: • The document is applied to all projects awarded by Texas Facilities Commission after the publication date of the same document • Document has the intent to identify Owner's preferred procedures, systems and materials • Document is not primarily focused on BIM • "BIM software may be used in lieu of CADD for any project" • *High level of standardization between projects (e.g. wall partitions, doors, etc.) translated to the BIM model*
Prior guidelines relevant to this document: N/A
Interoperability: • Focused on Autodesk products
Deliverable formats: • Focused on Autodesk products • Native format only
Ownership of the model: Not found
Relevant extra documentation: • AIA Document C106-2007

Interesting insights:
• Design Team must provide training in BIM authoring software as required by Owner
• Two types of model:
  ○ Unique model (more robust, ensuring all information compiled at one place)
  ○ Multiple models (maximizes workflow efficiency)
• Owner to provide template to Design Team in order to facilitate compliance with Owner's design standards
• Document dictates steps of "how-to" proceed with the BIM model day-to-day operations (e.g. p. 56 of the document)
• Revit view settings on p. 57-58 of the document
• Check p.59-70 for standardization of various items

PROJECT PHASES
Pre-Design (Conception): N/A
Schematic Design: N/A
Design Development (Detailing): N/A
Construction Documentation: N/A
Bidding: N/A
Construction: N/A
Project Turn-Over: N/A
Operation: N/A
Energy Modelling: N/A

BIM Guidelines & Standards

Institution name: University of Southern California (USC)
Institution Type: University
Relevant initial notes: • Guideline focused on the use of BIM for new projects, major renovations or other projects as required at USC campus based on *Design-Bid-Build* form of contract • Use of BIM to reduce schedule and construction cost while establishing a collaborative environment
Prior guidelines relevant to this document: • Indiana University BIM Guidelines • NBIMs
Interoperability: To Design Team and General Contractor's discretion
Deliverable formats: • RVT and NWD • Civil and structural engineers may opt to use Civil 3D and Tekla, respectively • Schedules shall be extracted directly from BIM model automatically • Specialty disciplines shall be provided in a different Revit model • Construction models in native format *and* RVT • Check p.7 and 10 for COBIe deliverables
Ownership of the model: Not found
Relevant extra documentation: All appendices of this document are extremely relevant to this project
Interesting insights: • Architect and General Contractor BIM Execution Plan as part of bid documents • Check p. 8 for BIM workflow • The design consultant must have a fully dedicated BIM Facilitator/ Engineer. See p. 9-10 to check his responsibilities. • The Design Team shall coordinate the quality and level of detail required at each step accordingly with USC's requirements • Good appendices to be consulted furthermore • This guideline has a good section for MEP modeling

PROJECT PHASES
Pre-Design (Conception): • Architects must set spatial coordinates at the beginning of the project and geo-referenced to a permanent campus monument • Check Table on p.12 for deliverables
Schematic Design: • The choice of BIM applications is left to Design Team discretion's • Survey file must be delivered in 3D format • All existing conditions shall be modeled as previously discussed • Check p.13 for required architectural elements at this phase • LOD 100 or level mentioned in BIM Execution Plan • Assignable, non-assignable and gross areas shall be extracted from the BIM model at this stage for Program and Space Validation • Check p.14 for COBIe deliverables at this phase • Document the use of EcoDomus, an Revit plug-in, as alternative to extract information from BIM • Interference checks and visual walks are expected at this stage
Design Development (Detailing): • Check Appendix A for required minimum model elements • LOD 200 or level mentioned in BIM Execution Plan • Check p.15 for COBIe deliverables at this phase • Construction and constructability analysis are to be continued as per Appendix F of this document
Construction Documentation: • Check Appendix A for required minimum model elements • Refinement of existent elements delivered on previous stages • LOD 300 or level mentioned in BIM Execution Plan • Program and Space Validation shall be reconfirmed at this phase • Design Team shall use interoperable applications with the BIM model in order to refine load calculations, daylight, natural ventilation, acoustics, code issues and design issues in addition to existent Revit warnings it may exist. • Check p.16 for COBIe deliverables at this phase
Bidding: • BIM models shall be available for tender leaving at the General Contractor's criteria to distribute the models as its deemed necessary to Subcontractor's. • BIM models are to provide clarification and design intent leaving any other purpose such as cost estimation at bidder's risk • The General Contractor shall submit a BIM Execution Plan compliant with existent from Design Team • Collaboration between "BIM teams" from the Design Team and General Contractor is encouraged. • The Design Team will continue updating the models as per modifications in the design • "The MEP Engineers will not be uploading changes to the MEPF models but will be updating their MEPF design models immediately following the subcontractor sign off of a given floor

on a floor by floor basis."
- The Design Team shall publish a monthly bulletin summarizing all questions and changes to the model
- USC provides a mash-up model to MEP trades in order to demonstrate its expectations towards the BIM model and depict the difference between a design and fabrication model

Construction:

- USC will provide comments upon General Contract's BIM Execution Plan
- General Contractor must have a dedicated BIM Facilitator/ Engineer with at least 3 years of MEP coordination experience. Check p. 18-19 to view his responsibilities
- Check p.19 for COBIe deliverables at this phase
- Information for construction shall be extracted directly from the BIM model
- It is the General Contractor's responsibility to distribute specific models for trades in the appropriate file format
- Subcontractors are responsible to update their models periodically and not at the end of the project. General Contractor is responsible to ensure this process
- BIM models are shared on project's collaboration platform
- General Contractor is responsible to integrate all consolidated 3D models (.NWF and .NWD format) per floor, running automated interference checks and viewpoints of identified issues
- MEP modelers shall provide clash free models from structural components
- All 3D detailers and associated foreman shall attend regularly scheduled meetings and interactive coordination process organized by the General Contractor
- General Contractor must provide a BIM coordination room for 3D coordination meetings
- The General Contractor is responsible to report BIM model to site personnel and provide a dedicated workstation with the most updated Navisworks files available for anyone on-site
- Check p. 21-22 for 3D models requirements at this stage

Project Turn-Over:

N/A

Operation:

- EcoDomus is used by the university to associate COBIe information with 3D elements

Energy Modelling:

N/A

BIM Guidelines & Standards

Institution name: Georgia Tech (GT)
Institution Type: University
Relevant initial notes: • Required for all construction (new and renovation) $5M worth or greater. $2.5M or greater are encouraged but not required. • "The intent of these requirements is to create a prescriptive framework with which BIM enabled teams will coordinate with Georgia Tech, the Board of Regents, the Georgia State Finance & Investment Commission, and other applicable groups. This document will allow all stakeholders to weigh the importance of each requirement on a per-project basis."
Prior guidelines relevant to this document: • AIA Document E202-2008 or current version • GIS GA State Plane West, NAD83 (1991) • GT Yellow Book • National CAD Standard • National BIM Standard • Postsecondary Facilities Inventory and Classification Manual (FICM)
Interoperability: "GT has adopted open architecture for data exchange. The Project Team may use any BIM software capable of delivering the necessary requirements during the design and construction process but is encouraged to use products based on or using open architecture for greatest interoperability between consultants and GT."
Deliverable formats: • RVT, NWD and DWG (for 3D Civil) for drawings and COBIe for operations. Any further format must be coordinated through the BIM Execution Plan. • In support to COBIe, information must be delivered as per GT BIM template • EQuest file is required for Energy Modelling • IFC file format
Ownership of the model: "GT has ownership of and to all CAD files, BIM Models, and Facility Data developed for the Project. GT may make use of this data following any deliverable."
Relevant extra documentation: N/A
Interesting insights: • Specific BIM template • See p.4-5 of the document for expected BIM proficiencies from GT • Use of BIM Execution Plan

- Check Data Validation diagram on p. 6 of the document
- Check Model Quality section on p. 7-9 of the document
- Check deliverables table on p. 10-11 of the document
- Guidelines for saving files and file conversion

PROJECT PHASES

Pre-Design (Conception):

- Check table on p.12 of the document
- Graphic or data information is expected to be exported from the BIM model at this stage
- Early target cost, schedule and program information is encouraged to be integrated with the BIM model at this stage
- Surveys and underground utilities must be delivered in 3D format

Schematic Design:

- Check diagram on p.15 of the document
- Any method or software is allowed since information is provided graphically or alphanumerically in the models. Design team is expected to provide static images and interactive 3D to describe proposed design.
- Takeoffs shall be extracted from BIM model at this stage and converted to spreadsheets
- Check p. 17-18 for expected deliverables on Program and Space Validation at this stage
- The Design Team shall submit information related to COBIe in IFC and spreadsheet format. Check p. 20 for expected deliverable

Design Development (Detailing):

- Check diagram on p.20 of the document
- Modelled elements from all disciplines, at its minimum, shall comply with GT Yellow Book
- Interference reports extracted from the BIM model is expected at this stage along with its solved solutions
- Design Team is expected to continue tracking cost information in format of spreadsheets
- Check p. 20 for expected information related to COBIe

Construction Documentation:

- Check diagram on p. 21 of the document
- Submittal together Pre-Bid Interference Reports at 95% of Construction Documents
- Quantity takeoffs are shall be extracted from BIM model and converted to spreadsheets in order to support comparative cost analysis
- Check p. 22 for expected information related to COBIe

Bidding:

- Check diagram on p. 23 of the document
- Model shall be updated with any documentation such as addendums, accepted alternatives and/or value enhancement proposals
- Contractors shall review and comply with BIM Execution Plan and the document at this stage up to the end of the project

Construction:

- Check diagram on p. 24 of the document
- Design intent model shall be updated periodically, published in .NWD format and posted to the project site
- Check p.24-25 of the document for expected deliverables
- BIM models, named as *Construction Models*, shall be provided by contractors and includes

fabrication models, coordination models and shop drawings in .NWD, 3D.DWF and DWG format
- Construction models shall be compliant with the BIM Execution Plan and AIA 202 document
- Check p. 25-26 for expected information related to COBIe
- Check p.26-27 for more information regarding Coordination Meetings
- "The Contractor is to use approved collision detection software as defined in section 3.1.1.5 for interference reporting. Interferences reports from the qualified clash detection software should be published weekly to the GT project site in a standard XML, HTML, or Text format as created by NavisWorks."
- Check p. 31-32 for model correctness guidelines

Project Turn-Over:
- Check diagram on p. 28 of the document
- Record drawing must be delivered within 30 days' notice to process
- Deliverables for turn-over in COBIe format shall include, but not limited to:
    - Verification of the design solution against the Program for Design
    - Scheduled building equipment/ component lists
    - Construction submittal register requirements
    - Identification of installed equipment and all tagger building products
    - Close-out deliverables
- "The Project Team shall submit a plan to the Owner for review that outlines the process for concurrent asbuilt documentation. Concurrency is mandated. Methods for recording as-built information are left to the discretion of the Project Team. The Designer owns, understands, and can make changes to the design models and understand the impact of those changes while the Contractor is the best entity to record all changes, convey them to the Design Team, and verify that the new models and documents reflect as-built conditions."
- Specific RVT file saving procedure on p.30
- See p.30 for O&M Manuals turnover

Operation:
- Every deliverable during design and construction phases must be exported to COBIe format
- Use of OmniClass for categorization
- Check COBIe Data Roles and Responsabilities on p. 34

Energy Modelling:
- Pre-Design
    - Carries the purpose to narrow down design options in order to achieve pre-defined targets and goals
    - Check list on p. 13 of possible items for energy targets
    - Check item 5.1.3.3 for modeled items at this stage
    - Compliance with LEED
    - .gbXML format
    - Cost comparisons are encouraged during at this stage using building perimeter, square foot zone cost per type, exterior envelope area, construction type, used materials and etc.
    - "Percent better" or "percent worse" scenario kind of analysis for multiple simulations
    - Design team shall model all existing conditions as per discussed with GT
- Schematic Design

- Purpose is to measure the performance of proposed design against programmatic criteria
- Check p.16 to review element which shall be modeled at this stage
- It shall be built upon previous model
- Model shall be fit for other calculations such as LEED EA Credit 1
- Shall be modelled for building occupation. This model shall be compared with actual data gathered one year after building occupancy
- "GT has developed a Smart M&V (measurement and verification) Plan to evaluate the real energy savings based on correcting the LEED submitted model to the actual constructed and operations for the one year of operations."
- Additional to the energy model, the Design Team shall include the Energy Conservation Measures document which evaluates control strategies and additional components for energy savings
- "The Design Team shall submit to GT, in spreadsheet format, the list of design iterations and comparisons of the design iterations. The spreadsheet should include columns for Peak Monthly Load, Peak Yearly Load, Total Yearly Load, and Total Yearly Energy Use by Source Type."
- Check p.17 for expected results from at this stage

- Construction Documentation
  - Design Team is encouraged to continue pursuing energy analysis on project
  - Energy Information Model is a milestone at this phase

BIM Guidelines & Standards

Institution name: Indiana University
Institution Type: University
Relevant initial notes: • Required on new and renovation projects with 5M or greater worth or any project that involves a portion that has been already delivered with a BIM requirement • Future goal to have all projects in BIM
Prior guidelines relevant to this document: • GSA 2007 National 3D-4D BIM Program • U.S Army Corps of Engineers 2006 BIM Road Map • NBIMS National BIM Standard (v3/ 2007) • COBIe (v9/2007) • Triton College BIM Standards Model 2005-2009 • State of Wisconsin Dept. of Administration BIM Guidelines and Standards 2009
Interoperability: "Indiana University has adopted open architecture for data exchange. The Design Team is encouraged to use products based on or using open architecture for greatest interoperability between consultants and Indiana University."
Deliverable formats: • Autodesk Revit • Autodesk Navisworks • .GBXml format • 3D DWF format
Ownership of the model: "Indiana University has ownership of all CAD files, BIM Models, and Facility Data developed for the Project. Indiana University may make use of this data following any deliverable."
Relevant extra documentation: • IU BIM Proficiency Matrix • IU BIM Execution Plan Template • Construction Operations Building Information Exchange (COBIe) • IU Revit CAD import lineweights file • Indiana University Deliverables Requirements for Construction Documents and As-Built & Record Documents

Interesting insights:

- Design Team Deliverable Schedule and Milestones on p. 9
- The Design Team shall submit a BIM Execution Plan (template available) as part of the final bid documents that must identify all consultants, roles and responsibilities for the project. The Owner shall evaluate the consultant's experience using BIM from this document.

PROJECT PHASES

Pre-Design (Conception):

- The Design Team is encouraged to use BIM software in order to capture early cost, schedule and program information during this phase
- All survey in electronic format with a minimum of: 3D topographic information, paving, retaining walls and as per existing guidelines
- Design team shall model all existing conditions and extra areas relevant to the project agreed beforehand

Schematic Design:

- The Design Team shall use a BIM software at this phase with all information needed to describe the project included and derived from the BIM model.
- Provide spreadsheet for comparative square foot cost analysis extracted from the model as part of the deliverables at this stage
- Assignable and Gross Areas shall be developed automatically from the model for **Program and Space Validation**
- Collision Report shall be extracted from the model and classified as per p.11 of the document

Design Development (Detailing):

- Parametric links shall be maintained between models for automatic generation of all plans, sections, elevations, custom details, schedules and 3D views
- Architectural, Structural and MEP models shall provide elements as per p. 12-16
- Submittal for **Program and Space Validation** shall be reconfirmed at this stage
- Square foot and system information shall be extracted from the model and presented in spreadsheets for cost analysis

Construction Documentation:

- All "execution documents" shall be included and derived from the models only. Specifications are not required to be linked with the model
- Submittal for **Program and Space Validation** shall be reconfirmed at this stage
- Submit Pre-Bid Collision Report at 95% of construction documents
- Square quantity takeoff information extracted from the BIM shall exported to spreadsheets and submitted as part of design solutions and justifications
- COBIe information shall be extracted and presented as per p. 19 of the document

Bidding:

- Model to be updated with all addendums, accepted alternates and/or value enhancement proposals
- Contractors shall review and follow all documentation regarding BIM including, but not limited to, the BIM Executional Plan presented by the consultant for this project
- Contractors shall submit IU BIM Proficiency Matrix and be evaluated by the Owner about his experience with BIM

Construction:

- Design Team is expected to maintain and updated models during construction and published in Naviswork format (version 5)
- Milestones and deliverables as per p. 20
- Contractor shall review BIM Execution Plan with Design Team and Owner
- Models shall include fabrication models, coordination models and shop drawings referred as Construction Models
- Elements shall reflect exact geometry, material properties and performance data
- Models shall be delivered in both Naviswork and 3D DWF format.
- COBIe information shall be submitted as per p.21 of the document
- Methods for record as-built information are left to the discretion of the Contractor
- Collision Reports must be submitted as per p. 22

Project Turn-Over:

- Commissioning data shall be recorded and/or linked with the model.
- Contractor is responsible to coordinate and integrate all information into the BIM model
- Design Team is responsible to update their models with the Contractor's recorded changes and shall republish all record documents in paper, .dwg and .pdf formats and submit the full Revit models.
- Contractor shall submit record documents as per Owner's guidelines
- Contractor shall submit O&M manuals as per Owner's guidelines

Operation:

N/A

Energy Modelling:

- Conceptual Design
    - .GBXml export file
    - Elements shall be modelled as p. 8 of the document
    - Fenestration shall be calculated
    - Must inform early design decisions with reference to building envelope, lighting, domestic water and HVAC systems with "percent better" or "percent worse" scenarios
    - Spreadsheet with design interactions and comparisons
- Schematic Design
    - Same format to be used in a DOE2 based software
    - Elements shall be modelled as p. 9 of the document
    - Information present on p.10 of the document shall be incorporated in the model
    - Design refinement
    - Results must include annual and monthly energy usage by components
- Design Development
    - Energy model shall contain enough information for any additional submission (e.g. LEED EA Credit 1 calculations if the project if applying for a LEED Certification)
    - This model should be a baseline for future comparisons. After one year of occupancy, actual building performance shall be compared with this model
    - Energy Conservation Measures (ECMs) shall be included in the model

BIM Guidelines & Standards

Institution name: Massachusetts Institute of Technology (MIT)
Institution Type: University
Relevant initial notes: Guideline focused to promote the development of compliance between new drawings (CAD and BIM) and record files to MIT's archive.
Prior guidelines relevant to this document: Documents from buildingSMART alliance
Interoperability: IFC compliant models are highly recommended
Deliverable formats: Revolves around Autodesk products. All deliverable formats must be informed in the *BIM Execution Plan*
Ownership of the model: Not found
Relevant extra documentation: • MIT BIM Execution Plan
Interesting insights: • Use of Q/A checklist to evaluate deliverables. Template available • Any design team not familiar with MIT's deliverable requirements or its facility information system *must* meet jointly with MIT's representative for discussion *prior* the delivery of any document • MIT BIM Execution Plan is a good document to be used as template
PROJECT PHASES
Pre-Design (Conception): No relevant information
Schematic Design: No relevant information
Design Development (Detailing): No relevant information
Construction Documentation: No relevant information
Bidding: No relevant information
Construction: No relevant information
Project Turn-Over: No relevant information

Operation: No relevant information
Energy Modelling: No relevant information