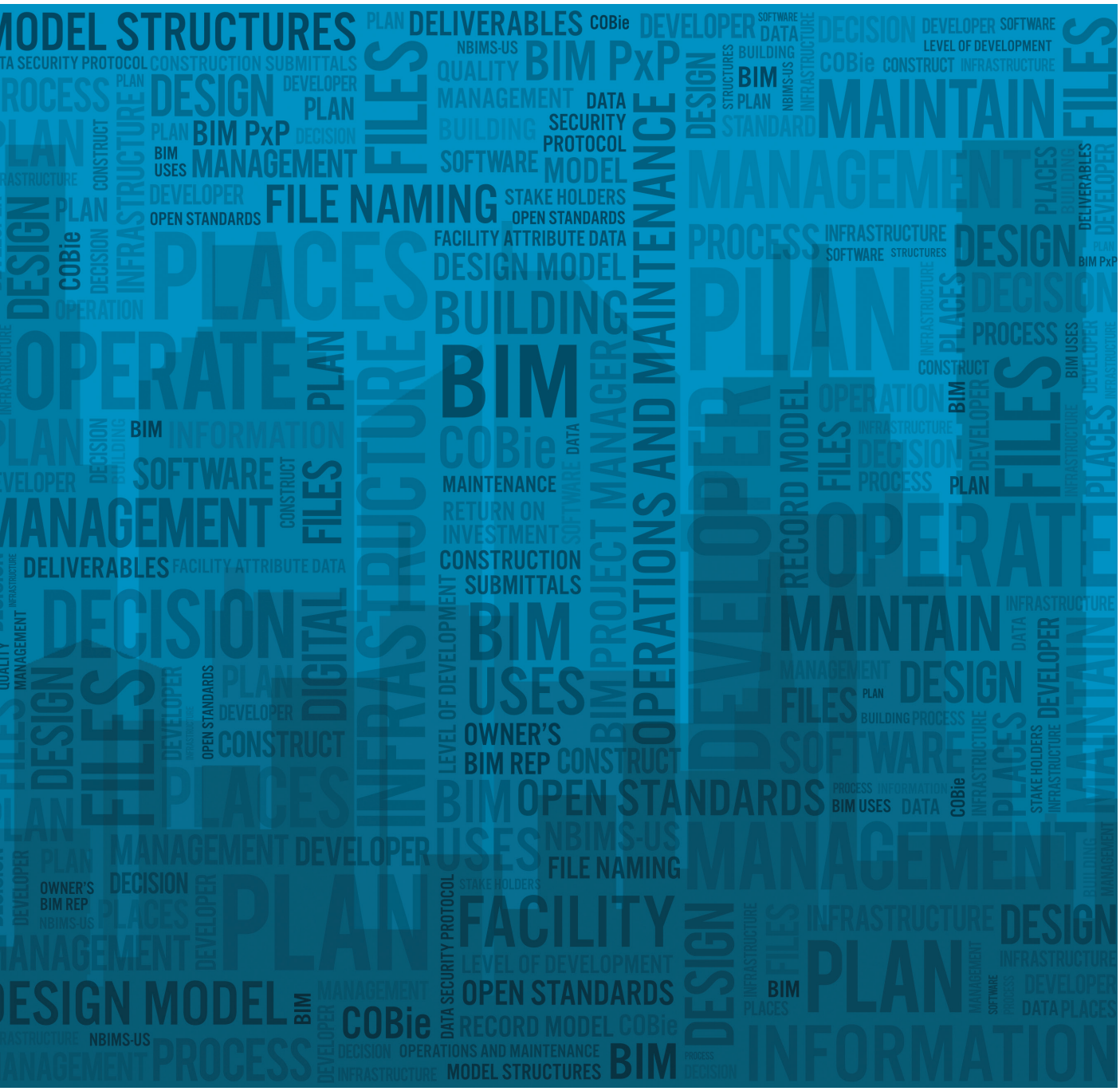
National Institute of
BUILDING SCIENCES

National BIM Guide for Owners



Disclaimer:

When using this Guide to develop contracts between stakeholders regarding the use of BIM to plan, design, construct, and operate buildings, the information herein should not be considered a substitute for legal, business, insurance or financial advice. Each stakeholder or party to a contract is strongly encouraged to seek the advice of attorneys, and business, insurance, and financial counselors and advisers, as each stakeholder deems appropriate, when drafting, reviewing, and negotiating all contracts and clauses including, but not limited to, all terms and conditions, contract and project management requirements, intellectual property rights, and the electronic storage and transfer of documents and data.

NATIONAL BIM GUIDE FOR OWNERS

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FOREWORD

Recent SmartMarket Reports by McGraw Hill Construction (now Dodge Data & Analytics) indicate the business value of Building Information Modeling (BIM) is increasing. *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings* (2007-2012) showed BIM adoption increasing from 17% in 2007 to 71% in 2012, with 62% of respondents among the industry perceiving a positive return on their investment in BIM. *The Business Value of BIM for Owners* (2014) identified 68% of U.S. Owners surveyed as either requiring or encouraging BIM for their projects.

The National Institute of Building Sciences is proud to introduce the *National Building Information Modeling Guide for Owners (NBGO)*, intended to outline for the building Owner how to develop and implement requirements for BIM application in internal policies and procedures as well as in contracts to plan, design, construct, and operate buildings.

As BIM adoption in the U.S. continues to rise, the Owner stands to benefit most, by implementing BIM as a tool to maximize a building's value throughout its lifecycle. BIM potentially facilitates better-informed Owner decision-making, design-intent communication, project coordination across various phases, enhanced project delivery schedule and budget management, post-construction asset and facility management, building automation and control, and many other benefits, including increased property resale values of the building, as well as leasing revenues.

We authored the *NBGO* to assist Owners in working with the other members of the building team to maximize the potential of BIM on their projects. We would welcome your comments and feedback as you put the *NBGO* to work for you.

Sincerely,

Henry L. Green, Hon. AIA

President

National Institute of Building Sciences

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EXECUTIVE SUMMARY

The intended audience for this Guide is the building Owner. The Guide defines an approach to creating and fulfilling Building Information Modeling (BIM) requirements for a typical project from the Owner's standpoint.

Merely requiring BIM on a project does not equate to success if the Owner's goals for the project are not clearly set and BIM requirements do not correlate to achieving those goals. BIM must be well planned and properly executed; not just BIM, but "BIM DONE RIGHT,"[1] aligning the right amount and types of resources to achieve the right results.

This Guide builds on the premise that BIM, in and of itself, is not the end but rather the means to a number of potentially valuable project delivery outcomes for the Owner. It offers a toolset addressing three broad areas the Owner should understand in order to direct the Project Team to BIM DONE RIGHT: process, infrastructure and standards, and execution.

The Process for using BIM effectively on a project begins with defining BIM requirements in the Owner's contracts with service providers (to plan, design, construct, and operate the building) and with other stakeholders based on the project delivery method (design-bid-build, design-build, IPD, etc.). Early on, a successful BIM process includes identifying the roles and responsibilities of key project stakeholders with respect to information modeling as well as creating a BIM Project Execution Plan (PxP), an outcome-driven BIM roadmap that details how the project will be completed. Process also includes managing the project for compliance with the PxP and contract requirements, including the project deliverables.

Infrastructure and standards acknowledges the high degree of human collaboration and software interoperability needed for successful project information modeling , particularly as the project moves from phase to phase. To achieve the necessary level of interactivity, the Owner must require all members of the Project BIM Team to adhere to a framework of standards and structures from the project's onset.

Execution encompasses creating a Project Execution Plan (PxP), a master plan for how information modeling will be done and managed, at the inception of a project. The PxP documents the Owner's and the Project BIM Team's mutual agreement on how, by whom, when, why, to what level, and for what project outcomes (called "BIM Uses") information modeling will be used.

While the Guide highlights the essential requirements for BIM, it also offers options for Owners who wish to go beyond minimum requirements. And finally, while the guide uses the term "building" generically, in keeping with the terminology of "Building Information Modeling," it is intended to apply to information modeling for the built environment; i.e., site elements and facilities as well as buildings.

1. INTRODUCTION

1.1 PURPOSE

The purpose of the National Building Information Modeling Guide for Owners (NBGO) is to outline for the building Owner how to develop and implement requirements for the application of Building Information Modeling (BIM) for internal policies and procedures, and explain how to include these requirements in contracts to plan, design, construct and operate buildings. This Guide uses the term "building" generically, in keeping with the terminology of "Building Information Modeling." It is intended to apply to information modeling for the built environment: site elements and facilities as well as buildings.

1.2 SCOPE

This Guide establishes recommendations for processes, standards, and deliverables for a BIM-enabled project that can be continually shared and agreed upon by the Owner and the rest of the Project BIM Team, which can include planners, constructors, facilities managers, and subcontractors, as well as designers.

1.3 USE

The recommendations in this Guide should be used by the Owner to create specific project requirements for BIM based on the project's unique and individual needs that can then be followed and implemented by the Project BIM Team to enhance facility value.

Many aspects of the building industry are discovering increased value in BIM. Owners, architects, engineers, contractors, subcontractors, and facility managers all have collective and individual interests for the project and their business continuity, respectively. BIM has the capacity to be used within each phase of a project – from conceptual, through final design, construction, and on to operations – with a variety of applications ranging from Clash Detection, Quantity Takeoff, Scheduling, FM operations, and many others. While each application or 'use' of BIM offers value in itself and any project participant engaging in these various 'uses' could state they are 'doing BIM'; the efforts won't likely yield optimal results without proper planning, coordination, and execution. It is the project team's activities in concert with the Owner's requirements that provide the greatest potential lifecycle value. This is "BIM Done Right" and helping Owners achieve this for their projects is the goal of this* Guide.

--Johnny Fortune
BIM/IT Director, Bullock Tice Associates

* Tice, John, Bullock Tice Associates BIM DONE RIGHT, a BIM-enabled, client-focused delivery approach and strategy (2015). http://www.bulltice.com/

2. PROCESS

At the project's inception, the Owner establishes the intent and general requirements for the building. Collectively, these are known as the Owner's Project Requirements (OPR), and are defined by the National BIM Standard – United States® (NBIMS-US™) Version 3^2 (V3) as the 'Owner's written documentation of the functional requirements of the "facility" and the expectations of how it will be used and operated. They include project and design goals, budgets, limitations, schedules.' These requirements are transferred into the building's "basis of design," (BOD), used by the building's design team to define the approach and parameters for designing the building to meet the Owner's requirements. The data developed during design is then transferred by the design team into construction documents, which become the record of all the building's physical elements. As each building element's construction is completed, it is either accepted through traditional design team construction contract administration practices and/or commissioned by an independent Commissioning Authority that the final construction meets the OPR and that the functional performance of the element has been verified.

As the project moves from phase to phase, the information contained within the BIM grows in both quantity and specificity. The nature of BIM technology and the interoperability (ability to be exchanged and used) of the data contained within the BIM allow different Owners to use the BIM in multiple ways, depending on their specific needs. In addition to design and construction, BIM applications can include asset management, building automation and control, interdisciplinary coordination, scheduling, cost estimating, and integrated construction specifications.

Models generated during planning, design, construction, and operations continue to serve as information resources used to keep the building operating at optimal efficiency. When well planned and executed, the use of BIM may reduce the building life-cycle cost. Using BIM in concert with planning and team building, with its shared and continually updated information, also helps the team minimize conflicts, cuts down on repetition and duplication of tasks, and helps to optimize planning, design, construction, and operations.

The process for enabling BIM to be used effectively on a project should follow these steps:

1. Define minimum BIM requirements in the Owner's contracts with service providers (planning, design, construction, operations, etc.) and other stakeholders based on the project delivery method (design-bid-build, design-build, IPD, etc.).
2. Identify the roles and responsibilities of key project stakeholders with respect to information modeling.
3. Collaboratively create a BIM Project Execution Plan (PxP) with key project stakeholders.
4. Manage the project for compliance with the PxP and contract requirements, including Model and Data Deliverables, through periodic reviews.

Where the model(s) is to be used for design/documentation and then for construction, the BIM PxP should address model exchange procedures, i.e., how the model(s) can migrate between project phases effectively with minimum effort. First, the Project BIM Team members need to coordinate the BIM Uses they seek to leverage when they determine the model exchange procedures. For example,

model coordination would require a high degree of geometric accuracy for the design model. Once BIM Uses are identified, the team should decide who is developing which models, and when these models are exchanged. The BIM PxP should be used to organize responsibilities and modeling requirements.

2.1 DEFINE BIM REQUIREMENTS

BIM requirements are defined by the Owner's overall goals, business practices, and corporate culture and are shaped by the OPR. They are developed on a project-by-project basis, as the Project BIM Team selects BIM Uses to achieve these requirements. The Owner should provide any resources, such as feasibility studies and/or access to stakeholder interviews, for the BIM Project BIM Team to define Owner-related goals. Once the Owner's project BIM goals are defined, the Project BIM Team should also ensure that these BIM goals can be met with current technology practices and required team competencies. The project BIM goals should lead to the choice of BIM Uses and additional BIM requirements.

2.1.1 BIM Uses and Requirements

The Owner should at a minimum require the five Essential BIM Uses described in Section 4.2.2: Existing Conditions, Design Authoring, Design Review, three-dimensional (3D) Coordination, and Record Modeling. Project conditions may justify other Enhanced BIM Uses, as described in Section 4.2.3, or Owner-Related Uses, as described in Section 4.2.4. The Project BIM Team should develop the recommended BIM Uses for the project by leveraging resources provided in the National BIM Standard– United States® (NBIMS-US™) Version 3 (V3) along with other resources. NBIMS-US™ , developed by the National Institute of Building Sciences buildingSMART alliance®, contains core consensus-approved standards regarding the exchange of information and standard practices for implementing BIM on a project.

Once BIM Uses are defined, the Level of Development (LOD) requirements should be determined. There are Default LOD, Template LOD, and Custom LOD (see Section 3.6.4). An Owner can adopt a Default LOD that references established LOD requirements, such as the United States Army Corps of Engineers (USACE) Minimum Modeling Matrix (M3).[3] The Owner also can use existing templates to develop LOD requirements, such as the American Institute of Architects (AIA) G-202 Building Information Modeling Protocol.[4] It also is possible for Owners to develop a custom LOD matrix for their organization, but if they do so, they should adhere to the LOD spec definitions. Any of these three forms of LOD specification provides a means for Owners to develop contract requirements for models and data requirements.

2.1.2 Project Delivery Method

The choice of project delivery method for the project affects the way in which the BIM is developed and how information is exchanged. A design-build (DB) project may only have one Project BIM Manager, while a design-bid-build (D-B-B) project should have one BIM Manager for design and another one for construction. Similarly, the Owner should understand that the project delivery method will affect the level of responsibility that the Owner assumes for information management and

exchange between project phases. For example, in D-B-B, the Owner may be responsible for information exchange between design stakeholders and construction stakeholders. The project contracts should define responsibilities for the design and construction contracting entities, and, therefore, the Level of Development (LOD) and division of responsibilities. Information exchange across contracting parties also should be clearly defined and closely managed.

2.1.3 Intellectual Property.

Project deliverables should be clearly and completely defined in the Owner/designer and Owner/contractor agreements, especially if the PxP is developed after contracts have been executed. The intellectual property rights of the Owner should be clearly defined and validated in the PxP. The Owner should, at a minimum, have the right to use the project data defined as project deliverables in the BIM PxP. Project data should include the:

- Model files (BIM, CAD)
- Drawing files (CAD, electronic sheets such as PDFs, and/or plot files)
- Electronic manuals
- Tabular/textual information derived from BIM (e.g., spreadsheets)
- Reference files necessary to supplement other project data

Publicly funded projects are subject to the governing authority's acquisition requirements. Federally funded projects are governed per Federal Acquisition Regulation (FAR) Part 27, Patents, Data, and Copyrights.[5] Any exceptions to ownership rights should be clearly noted in the project contract(s), documented in the BIM PxP, and approved by the Project BIM Team. Ownership of project data is conveyed to the Owner at the time of project closeout. Owner reuse rights should be defined in the Owner/stakeholder contracts. The Project BIM Team should review this guide, the BIM PxP, and the project contract(s) to determine governing requirements and permissions and/or limitations for ownership, conveyance, and/or reuse of data. The project contract conditions and terms take precedence over this guide, and, as with all contract documents, it is advisable to seek the advice of legal counsel.

Commentary:

When using this Guide to develop contracts between stakeholders regarding the use of BIM to plan, design, construct and operate buildings, the information herein should not be considered a substitute for legal, business, insurance or financial advice. Contracts may have important legal, business, insurance and financial consequences. Each stakeholder or party to a contract is strongly encouraged to seek the advice of attorneys, and business, insurance, and financial counselors and advisers, as each stakeholder deems appropriate, when drafting, reviewing, and negotiating all contracts and clauses including, but not limited to, all terms and conditions, contract and project management requirements, intellectual property rights, and the electronic storage and transfer of documents and data.

2.1.4 Final Turnover Requirements

The Owner should consider the final deliverable requirements for project data. Owners should review their current information needs for operations and maintenance, and establish data requirements that support those needs. The Owner also should consider how BIM can support future facilities management and operations, and develop requirements that support future needs as well. At a minimum, major equipment should be described by facility attributes such as make, model, manufacturer, and serial number. Additional attributes include warranty information, parts lists, maintenance schedules, and manufacturer contact information.

2.2 TEAM ROLES AND RESPONSIBILITIES

2.2.1 Owner's BIM Representative(s)

Especially for larger and more complex projects, the Owner should designate an Owner's BIM Representative. The Owner's BIM Representative should have a clear understanding of BIM and the OPR. The Owner's BIM Representative should, at a minimum:

- Represent the Owner's requirements and be able to effectively communicate them to other stakeholders.
- Serve as the primary liaison between the Owner and the Project BIM Manager(s) for all BIM-related issues.
- Have oversight of BIM requirements in all project phases, from planning through the construction of the project, and at least the beginning of the operations phase.
- Receive, review, and approve BIM deliverables.

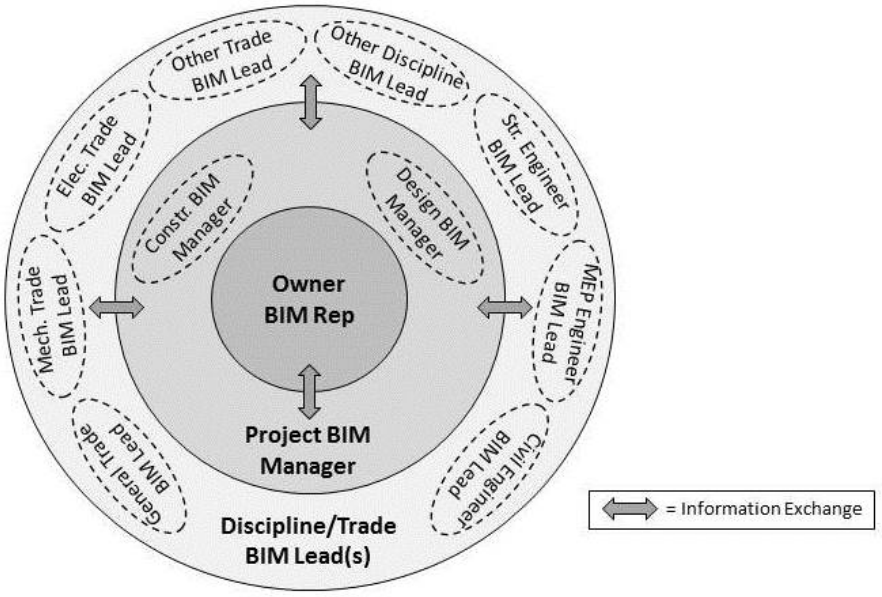

Figure 1. BIM Role and Responsibility Chart

2.2.2 Project BIM Manager Role

The project should have a designated Project BIM Manager. The Project BIM Manager role may be fulfilled by more than one person; for example, many projects have a lead design BIM Manager and a lead construction BIM Manager (see Figure 1). The Project BIM Manager should have sufficient BIM education and experience for the size and complexity of the project, as well as the relevant proficiency in the proposed BIM authoring and coordination software selected for use on the project. In the absence of an Owner's BIM Representative, the Project BIM Manager should serve as the main point of contact with the Project BIM Team for all BIM-related issues.

During each phase of a project, the Project BIM Manager at a minimum should:

- Lead the process of creating and updating the BIM PxP in accordance with the OPR.
- Verify compliance of the PxP deliverables.
- Coordinate all updates for individual models, specialized models, and databases.
- Administer Project Quality Management and Data Security Management.
- Develop, coordinate, publish, and verify necessary configurations required for integration of project data.
- Facilitate distribution of project data.
- Compile project data for review and coordination.
- Facilitate design review.
- Meet with relevant project stakeholders for review of turnover documents.
- Deliver model(s) and Facility Data to Owner for use in operations.

2.2.3 Discipline/Trade BIM Leads

Each discipline/trade should assign an individual to the role of BIM lead for the duration of the project. These individuals should have the relevant BIM experience required by the complexity of the project. The discipline/trade BIM lead maintains a continuous interface with the Project BIM Manager.

The responsibilities of the discipline/trade BIM leads for their respective discipline/trade include:

- Act as the lead BIM contact for the discipline/trade.
- Develop and manage exchange of models.
- Maintain and manage integrity of the model.
- Assume additional roles and responsibilities as defined to support the PxP and other contractual requirements.

2.2.4 Collaboration

The Project BIM Team should not rely on information exchange as the sole means of project communication; information exchange is not collaboration. The Project BIM Team should schedule regular BIM coordination meetings during which team members meet to discuss design and construction issues, using the model as a shared resource. The frequency of such interactions depends on the project's goals, BIM Uses, and Project BIM Team members' capabilities.

Through the BIM project planning process, the Project BIM Team should agree on how and in what ways the Project BIM Team members will collaborate using the BIM. All project stakeholders involved with modeling should develop and agree to a project-specific BIM PxP. This plan should include the requirements for information exchange among the parties, as well as for expected interactions with the model.

2.3 BIM PROJECT EXECUTION PLANNING

The BIM Project Execution Plan (PxP) is the central document for BIM implementation. This plan should be authored by the Project BIM Team collectively, and onboarding processes should be developed for Project BIM Team members who join the project after the initial plan has been developed. The steps of BIM PxP include:

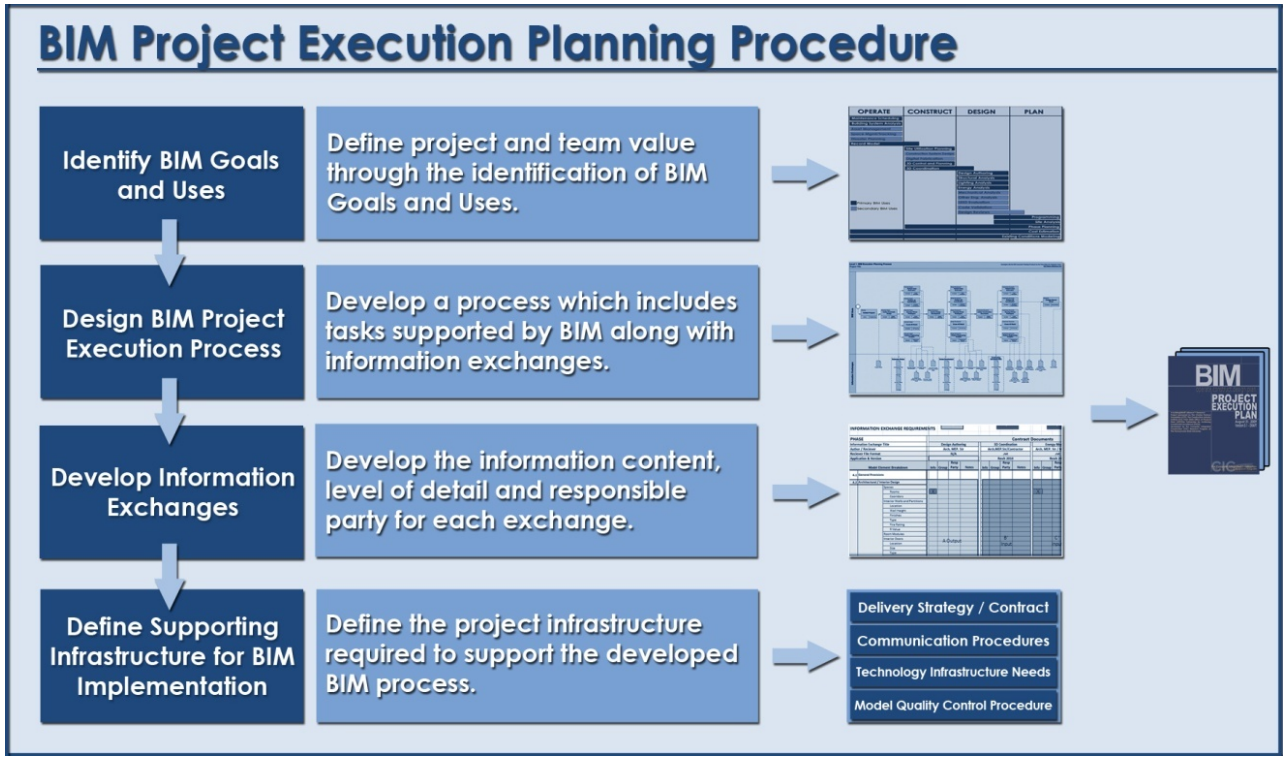

Figure 2. BIM Project Execution Planning Procedure[6]

The BIM PxP should contain all content necessary to document the process of implementing BIM on a project. Specific BIM PxP content requirements can be found in Section 4.1 of this document. Specifically, the team should develop plans and protocols to meet the OPR, including, as a minimum, file sharing and data security.

2.3.1 File Sharing Requirements

The file sharing requirements will vary depending on the project's BIM Uses. At a minimum, the PxP should include a description of the:

- File system(s) the team will use to exchange, merge, and visualize models
- Schedule for or frequency of model updates and clash detection checks
- Tools and process to be used for clash detection checking
- Process to be used to generate drawings from coordinated models

2.3.2 Data Security

Owners should apply their existing data security standards to BIM protocols. The Owner should consider the security risks in terms of the protection of data. The Owner may wish to consider including data restrictions procedures, such as check-out and check-in, as well as stipulating the degree of access control for project participants. The Owner should require the Project BIM Team to complete a Data Security Protocol that complies with data security requirements as defined below.

2.3.2.1 Data Security Protocol (DSP). As part of the PxP, the Project BIM Team should develop and submit a Data Security Protocol (DSP) to the Owner that outlines security protocols to be implemented for the project. The DSP should be approved by the Owner prior to commencing work. At a minimum, the DSP should address:

- User access rights and permissions, outlining the various roles and degrees of access to the data. Roles should correlate to those defined in this guide and the BIM PxP. The DSP also should identify any additional user access required.
- Data protection, documenting how the data will be protected from:
    - Accidental loss
    - File Corruption (malware, viruses)
    - Misuse/negligence
    - Unauthorized conveyance
    - Deliberate attack (internal or external)
- Data process and handling protocol procedures for:
    - Exchange: How and with what frequency data will be exchanged. The DSP should align with other requirements in the BIM PxP and provide more detail specific to data exchange.
    - Maintenance: Describe the maintenance plan for all data sources, transmission devices, and storage devices used for the project.
    - Backup: Describe in detail the backup scheme implemented by the Project BIM Team, including frequency and retention of backups.
    - Archiving: Describe the storage, retrieval, and retention system to be used by the Project BIM Team.

2.4 MANAGING PROJECT REQUIREMENTS AND DELIVERABLES

2.4.1 Quality Planning

The entire Project BIM Team is responsible for quality control. However, the team should specify roles and responsibilities for model management and quality management for the project. The BIM PxP includes the management strategies for implementing BIM Uses and requirements. Quality

management processes should be used to ensure BIM is created for downstream uses of the model data.

The quality standards for the modeling activities should be discussed in detail at the early stages of the project. The following items should be developed by the Project BIM Team prior to the start of the modeling activities:

- A clearly defined Quality Assurance (QA) and Quality Control (QC) section within the BIM PxP
- A detailed QA approach for monitoring the modeling process
- A detailed QC approach to test the final deliverables for compliance with the quality standards

Each QA and QC activity should identify a Project BIM Team member specifically responsible for performing the task. The QA and QC approaches may also be incorporated into project contracts to ensure compliance.

2.4.2 Quality Assurance

Quality assurance procedures should be defined to ensure that the Project BIM Team members are performing the modeling process defined within the BIM PxP. The QA activities should also be consistent with the contract. Minimum QA activities should include:

- Definition and validation of testing or prototyping process to verify the model meets the minimum modeling requirements
- Validation of resource availability and capabilities to perform modeling activities
- Review of the information exchange definitions to assure that the deliverables are clearly defined and unambiguous

Additional QA activities may include:

- Periodic reviews of the modeling procedures to ensure that the activities being performed are consistent with the initial plan
- Documentation of the final modeling process for future reference by Project BIM Team members

2.4.3 Quality Control

Quality control tests should be defined to verify that the project deliverables comply with the project requirements. The Project BIM Manager should verify that all required deliverables are submitted and appropriately distributed as defined within the BIM PxP and any additional contractual agreements.

The following QC activities should be performed on all project data delivered to the Owner:

- Verification of the file or data exchange metadata as defined within the BIM PxP to include (as appropriate for the data exchange types):
    - Date of submission
    - File type (if file)
    - File name (if file)
    - Database access instructions (if there is database content)
    - General description of content

    - Data schema (organization) of the file, including version, date created, and date modified by buildingSMART International (as appropriate)
    - Description of the data exchange standard (if an open standard)
- Validation of the proper file type, naming convention, and appropriate software version
- Validation of final submitted model files (content) against the information exchange standard:
    - Manual validation of a specified sample of elements to verify that the information is properly structured and accurate. The sample size may vary based upon the level of criticality of the information element. The sampling procedure should be defined within the BIM PxP
    - Visual model inspection to review general model content
    - Inspection of the coordinate system to ensure that all model files have a common coordinate system
- Validation that model clashes have been resolved per the owners predefined minimum requirements and the criteria established within the BIM PxP.

The tests should be performed within an agreed-upon time before or after project milestones, as specified by the contract.

Additional QC activities may include:

- **Checks:** All Project BIM Team members should check the modeling content that they receive from other team members or the Owner to verify that the exchanges contain valid field entries and the proper information elements. Project BIM Team members should report any unusual information content.
- **Project Data Submission Log:** The Project BIM Team should develop and use a Project Data Submission Log, which includes model/modeling compliance issues and corrective actions. The Project BIM Manager should review the Project Data Submission Log, participate in collaborative team resolution, and provide direction when needed.

3. INFRASTRUCTURE AND STANDARDS

3.1 TECHNOLOGY INFRASTRUCTURE

For the purposes of this Guide*, infrastructure* is defined as the entire technology system used for a BIM project. It broadly encompasses BIM as the digital representation of the physical and functional characteristics of the built environment. The use of the term *platform* in this section applies to all project-relevant computing platforms (hardware and software), including but not limited to computers, servers, network devices, backup systems, and file-sharing systems, be they resident on a local network or web/cloud based. Computing platforms are part of an Owner's and other project stakeholders' technology infrastructure, along with networks and physical workspaces.

Computing platform generally and broadly applies to the computer hardware and operating systems (OS) on which computer programs or software are designed to run. The Owner should consider current hardware and OS, and software-specific application capabilities that exist within his/her own organization and the organization of other project stakeholders—as well as future hardware and OS capabilities that are preferred or can be anticipated. Infrastructure requirements should be considered for all project phases, from planning concept through what will be available during the facility management and operations phase of the project. For each project phase, the Owner should consider how information is created, stored, exchanged, secured, backed up or archived, and delivered, and whether each should be localized, cloud- or web-based, or a hybrid.

The Owner should require that any BIM-related work products be:

- Compatible with the Owner's computer platform requirements
- Capable of supporting current and legacy file formats
- Agnostic (i.e., designed to be compatible across most common OS, hardware or software systems), adaptable, and scalable with respect to potential future computing
- Able to support open, consensus standards to maximize future compatibility

Additionally, the Owner should consider requiring the Project BIM Team to use specific technology infrastructure to support the Owner's overarching business and project goals.

All technology infrastructure used for a project should be documented in the BIM PxP.

3.2 STANDARDS

3.2.1 Categories of Standards

The Owner should consider three broad categories of BIM standards: Organizational (internal) Standards, Primary Standards, and Reference Standards. Organizational Standards and Primary Standards for BIM (or appropriate portions of them) should be cited in the Owner's contract language with other stakeholders as the minimum acceptable standards when BIM is used and BIM deliverables are required. Merely citing the standard by name in a contract will not ensure that any use of BIM on a project or BIM deliverable required will meet an Owner's current and future needs.

Commentary:
Standards, as used in this guideline, are documents created to establish minimum levels of quality or achievement that are acceptable. Mandatory standards are those that have been formally adopted by a code agency or government entity (authority) such as municipalities, state or federal agencies, or departments. Voluntary standards are those non-mandatory standards used by Owners and other organizations and industries to set minimally acceptable standards of quality and achievement.

BIM is not a mandatory requirement in the United States. However, numerous countries around the world are beginning to write BIM requirements into their local and federal codes and statutes.

This section addresses the standards that Owners should reference when requiring BIM. These requirements include, but are not limited to, the Owner's internal policies, procedures, and requirements (Organizational Standards), as well as Primary and Referenced Standards. The Owner should include these standards in the OPR.

3.2.2 Standards in this Guide

The following standards should be used when applying this guide. Where the Owner already has Organizational Standards and OPRs or other agency-specific requirements that reference these standards or modify them, those standards should be used in conjunction with the guidance provided here. For dated references, only the edition cited applies. For undated references, the latest edition (including any amendments) applies.

The National BIM Standard– United States® (NBIMS-US™) Version 3 (V3), developed by the National Institute of Building Sciences buildingSMART alliance®, contains core consensus-approved standards regarding the exchange of information and standard practices for implementing BIM on a project. In addition to NBIMS-US™ V3, the buildingSMART International has developed multiple open information exchange standards. All information exchanges that require an open, standard format should comply with the information exchange standards approved within NBIMS-US™ V3 or approved by buildingSMART International. The current approved information exchange standards include:

- Construction to Operations Building information exchange (COBie) (NBIMS-US™ V3)
- Design to Spatial Program Validation (SPV) (NBIMS-US™ V3)
- Design to Quantity Takeoff for Cost Estimating (NBIMS-US™ V3)
- Design to Building Energy Analysis (BEA) (NBIMS-US® V3)
- Building Programming information exchange (BPie) (NBIMS-US™ V3)
- Electrical System information exchange (Sparkie) (NBIMS-US™ V3)
- Heating, Ventilation and Air Conditioning information exchange (HVACie) (NBIMS-US™ V3)
- Water System information exchange (WSie) (NBIMS-US™ V3)
- IFC 2x3 Coordination View (NBIMS-US™ V3) (http://www.buildingsmart-tech.org/downloads/view-definitions/coordination-view/sub-schema/CoordinationView_V20_EntityList_IFC2x3_Version16_Final.pdf)

These standards are available at no cost on the NBIM-US™ V3 website, https://www.nationalbimstandard.org [login required]

Approved by buildingSMART International but not yet included in NBIMS-US™ V3 are:

- IFC4 Reference View (buildingSMART International) www.buildingsmart-tech.org/specifications/ifc-view-definition/ifc4-reference-view[7]
- IFC4 Design Transfer View (buildingSMART International) http://www.buildingsmart-tech.org/specifications/ifc-view-definition/ifc4-design-transfer-view[8]

The NBIMS-US™ V3 also outlines a standard procedure for the development and documentation of a BIM PxP. (See NBIMS-US™ V3, Section 5.3: BIM Project Execution Planning Guide.) The Project BIM Team should follow this standard planning approach and document format.

NBIMS-US™ V3 also outlines by reference common information classifications defined within the OmniClass tables. When applicable, these information classification tables should be used to maintain standard information terminology and classifications.

In addition to NBIMS-US™-V3, there are other important standards that should be considered, including ISO 16739:2013,[9] which outlines the data schema for the Industry Foundation Classes, an open data schema for storing information regarding a building project. The United States National CAD Standard® (NCS) Version 6 (V6) should also be used to ensure that the final design documentation complies with standards.

These standards sometimes can cover similar subject areas. While areas of overlap or conflict should be identified in the BIM PxP, it is possible for inconsistencies between the documents to come to light during the project. In these instances, the Project BIM Manager should be notified immediately. In response, the Project BIM Manager should determine, in consultation with the Owner and other stakeholders, which document will take precedence or whether amendments are required.

Where an OPR is unique and its Organization Standards differ or are more stringent than the minimum requirements established by referencing the NBIMS-US™, the NBIMS-US™ and its referenced standards should be formally extended, modified, and supplemented by clear and specific language in the Owner's contracts with other stakeholders.

3.2.3 Open Standards Format for Supporting Information

To ensure the life-cycle use of building information, information supporting common industry deliverables should be provided in open standards, along with their native file formats where applicable. The formats used should be specified in the BIM PxP and should include the following standards as appropriate:

- Industry Foundation Class (IFC), Model View Definition (MVD) formats. Three most commonly used model views are: Coordination View, COBie, and GSA Design to Spatial Program Validation[10].
- Additional open standard formats, such as gbXML[11].

For those contract deliverables whose open standard formats have not yet been finalized, the deliverable should be provided in a mutually agreed upon format that allows the reuse of building information outside the context of the proprietary BIM software.

3.3 SPACE AND GRAPHICAL STANDARDS

Commentary:
This section identifies standards and requirements for graphical output and/or paper printing.

3.3.1 Owner-Specified Guidelines and Standards

The Owner should specify any additional guidelines and standards for drawings and spaces. Rooms and spaces should adhere to the format as defined therein.[12]

3.3.2 Drawing

The United States National CAD Standard® (NCS) should be incorporated by reference. Graphical output from BIM should comply with the NCS per the clarifications outlined in its BIM Implementation Section. Sheet sets should be organized and numbered per the NCS. All annotation symbol requirements therein should be adhered to.

3.3.3 Sheet Layout

In addition to the sheet layout requirements in the NCS, all sheets should maintain a consistent size and orientation throughout the set. Title block borders should maintain the same positioning on each sheet to allow for overlay and appropriate printing of the extents of the sheet.

3.3.4 Areas/Rooms/Spaces

Identifying tags and schedules for areas, rooms, and spaces should comply with the NCS.

3.3.5 Digital Documentation and Archiving

Copies of all approved submittals and other documents normally provided in traditional paper-based formats should be provided Portable Document Format (PDF) format, or other open electronic document format. Documents authored directly by the Project BIM Team should be transformed to PDF to allow searching of the documents and selection of text within the document. Documents authored by others, but used by the Project BIM Team (such as manufacturer product data sheets), should be provided as PDFs made available by the manufacturer. If not available as PDFs from their authors, the documents should be scanned to create PDF documents. PDFs should comply with the following ISO Standards:

- ISO 19005-3 (2012): Document management—Electronic document file format for long-term preservation—Part 3: Use of ISO 32000-1 with support for embedded files (PDF/A-3).[13]
- ISO 32000-1 (2008): Document management—Portable document format—Part 1: PDF 1.7.[14]

PDFs of construction documents should comply with the *Guideline for Construction PDF Documents*[15] available from the Construction PDF Coalition. Additionally, the Construction PDF Coalition provides a web form for customizing the requirements on its website.

3.4 FILE STRUCTURE

Well-run BIM PxP and project data have well-defined project file naming and folder organization standards. The folder structure should be defined in the PxP. The project file sharing system should have the high level branches of the folder structure pre-populated in the system at the beginning of the project.

Since record documents will be distributed through the folder system, the project folder organization should align with the division of responsibilities of the stakeholders. It is beneficial to establish a file permission strategy on the shared folder system, where only appropriate organizations in the project have write permissions within their assigned folders, and the remainder of the team has read-only permission. At the highest level, the folder system should be controlled by the project administration.

File naming conventions similarly are needed to establish coherency of project documentation and simplify high level understanding of the file contents. The file naming system may identify a set of data fields to be contained in the file name. A typical file standard will establish a clear order on file name attributes with a reserved delimiter such as underscore (_) to identify the divisions between fields. The NCS provides a proposed naming convention for files, including standard contract documents https://www.nationalcadstandard.org/ncs6/

3.4.1 Owner-Specified Requirements

The project should comply with any Owner-specified platform requirements. The following sections are provided as examples for Owners who do not have predefined requirements. Regardless of the requirements used, the naming conventions should be consistent.

3.4.2 Folder Naming

Folder names should be numbered or alphabetized to control order. Folder names should be clear indicators as to what the folder contains (e.g., a folder for Models could be named *07_ Models*).

3.4.3 File Naming

File names should contain a discipline designator (such as “A” for Architectural) as defined in the NCS. Custom naming schema should be clearly documented in the BIM PxP.

- Sheet file names (regardless of file format, such as PDF) should comply with NCS, unless otherwise dictated or allowed by the Owner. At a minimum, they should include the sheet number (e.g., A-101.PDF)
- Model file names should contain discipline designator within the name, as outlined in the NCS (e.g., A-FP01.ext).

3.4.4 Component Naming Conventions

The naming conventions used for the following should be documented in the BIM PxP: e.g. Systems/Elements/Objects/Components/Parameters.

3.4.5 Submittal Package

All files should be organized and stored in an appropriately named folder as part of the submittal package. The submittal package should contain the deliverables as outlined in this document, the BIM PxP, and the project contract(s). The submittal package should also contain any support, source, reference, and/or linked files necessary to maintain file integrity.

3.4.6 File Sharing

The Owner should require that the team use a model sharing system. If the Owner does not designate a system, then the Project BIM Manager should provide a model sharing system for the sharing of individual and merged models. The model sharing system should consider:

- Project BIM Team access, including real-time access and synchronization of models
- Automated versioning of models
- Data security
- Maintenance and archiving of the previous model versions
- Permission-based access for each team member to upload their models

3.4.7 Data Transmittal Requirements

At a minimum, all transmitted data should include the following printed on the media or included as metadata as applicable per media type (i.e., CD/DVD would have printed labels, whereas model files would include metadata):

- Project title
- Project location
- Contract number
- Designer(s) of record and/or contactor(s) (general or sub)
- Classifications for the data (i.e., sensitive, classified, etc.)
- Contents of the transmittal, including date created, date modified, version, etc.
- Author and/or responsible individual
- Recipient(s)

Any additional information required by the Owner or identified in the BIM PxP should be included.

3.5 MODEL STRUCTURE

Model structure defines the highest level of decomposition (breakdown into component parts) of the digital model(s). Model structure should align with the Owner's Project Requirements (OPR) and selected BIM Uses, as defined in NBIMS™-V3 Section 5.9: The Uses of BIM.

If, for technological limitations or work share requirements, the model must be decomposed to a structure below a single building, then each model should be clearly denoted as a portion of a building,

and one composite model per building should be provided for each deliverable. Separate model files (i.e., discipline-specific or separated by level, etc.) are insufficient as a final deliverable. A holistic composite model is necessary, even if the composite model is only used as a container for links and/or references (i.e., a means of packaging all related files for delivery).

The model structure should be clearly defined in the BIM PxP.

3.6 MODEL REQUIREMENTS

The Owner should develop or adopt/adapt well-defined contract requirements to ensure the project model data requirements are met. The BIM Contract Requirements should address model requirements such as modeling responsibility, the modeling process, minimum model contents, Facility Data to be captured, and Level of Development (LOD). Because proper BIM planning at project inception is imperative to success and demands thorough understanding, it is recommended that the Owner procure the services of a specialized BIM consultant or identify one of the contracted parties to assist in identifying and defining the model/modeling requirements.

Alternatively, the Owner could consider following the example of successful Owner implementation of BIM requirements within NBIMS-US™ V3, Section 5.8: Practical BIM Contract Requirements, which outlines BIM Contract Requirements developed by the United States Army Corps of Engineers (USACE) to "ensure consistent and usable BIM project deliverables and BIM process. These BIM Contract Requirements consist of Contract Language, a Project Execution Plan (PxP) Template, and a Minimum Modeling Matrix (M3)."[16]

If the USACE M3 is adapted for use, it should reflect the Owner's particular requirements and objectives, specifically in the Instructions (Tab 2), Phasing (Tab 3), and Model Element LOD/Grade goals. Once the template is complete, the tables should be restricted to read-only for the project (unless project-specific variations are specifically desired and permitted in the contract).

It should be understood that with any BIM Contract Requirements—developed or adopted and adapted—there may be an information gap between what is required for the final BIM deliverables to the Owner and what is required for each team member to perform their required and/or recommended BIM Use. It is the responsibility of the individual members of the Project BIM Team to provide the information necessary for the project's selected BIM Uses.

Generally, BIM should include the necessary process and content to produce accurate construction documents (e.g., plans, elevations, sections, schedules, and integrated specifications) and Record Model project data (e.g., equipment, manufacturer, and model number).

3.6.1 Modeling Responsibility

Project stakeholders' modeling responsibilities should be clearly defined within the BIM PxP. Each model element should be assigned to a Model Element Author (MEA) and a corresponding LOD for the element clearly defined; consequently, each MEA is required to provide the elements at the LOD specified in the BIM PxP or a corresponding LOD worksheet. Each MEA is responsible for attaching any data or metadata to the model elements as required by the contract, BIM PxP, or as needed to facilitate the project's selected BIM Uses.

Model elements are most typically assigned to a MEA that also has the design or construction responsibility of the element. For example, a structural engineer or modeler is typically the MEA for structural slabs during the design phase. Models are typically divided by discipline or trade. As such, it is important that not only the MEA is identified for any given element but also the model in which the element is to reside. While there may be a duplication of some elements across multiple models, an MEA and LOD worksheet identifies the source responsible for the information and, therefore, that source is considered to be accurate and reliable.

3.6.2 Modeling Process

The project participants should fully implement industry- and software vendor-identified best practices and workflows for all aspects of modeling. These include, but are not limited to, using 3D geometry for representing physical characteristics of project and facility components and elements, using relevant object categories when possible, adding sufficient attribute information to elements, following proper naming conventions for all levels and types of data and metadata, and setting up shared resources and parameters to enable automatic display or extraction of model information to other formats (e.g., schedule or tabular formats).

Model elements should be used to produce representations shown in graphical legends and should match the graphical representations shown in other views and drawings. Model elements requiring a host or connection to some other component should be done within the same model whenever possible (e.g., a door is not freestanding but requires a wall as its host, so both door and wall should reside in the same model). Consideration should be given to how project phasing, display of content by other discipline/trade models, and workflows or features associated with specific software will be executed. The overall process utilized should be documented in the BIM PxP.

Modeling process requirements should not be overly prescriptive, but the general and minimum expectations should be established and responsibilities clearly defined as part of the BIM PxP.

Generally, the modeling process and responsibilities should include:

- Use of a standardized classification system organized according to NBIMS-US™ Section 2.5: OmniClass Table 21 Elements
- Use of IFC-compliant software (within one version of the latest certification available)
- Use of BIM software (within one release version of the latest available) that is capable of meeting the OPR per project-specific selected BIM Uses
- Use of the appropriate tool(s) within the BIM software selected to create or document the building element being represented
- The model(s) should remain current and represent design intent. The Project BIM Team should update the model(s) with any revisions as required to complete the work, or at a minimum, at each project milestone.

The Project BIM Team should document the choice of platform in the BIM PXP.

While the modeling process and corresponding models may vary per project, the following graphic is an example of typical model progression across project phases and could serve as an information flow map for an Owner implementing BIM requirements.

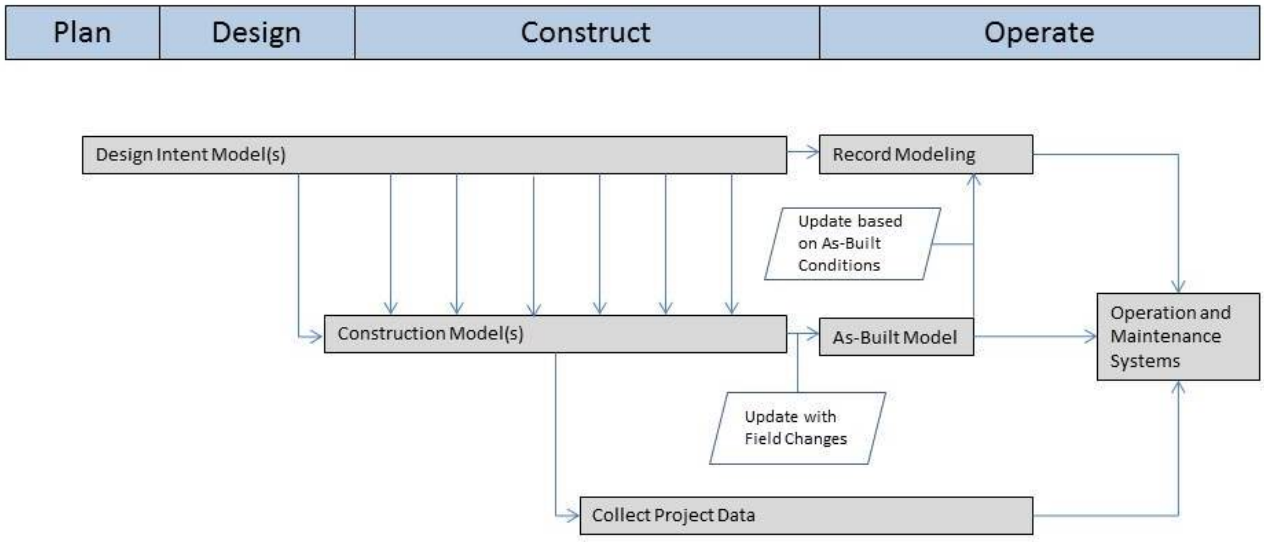

Figure 3. Lifecycle Model Requirements: A Sample Process

Project BIM Team members should use BIM application(s) and software(s) to develop and document the project. Design professionals should create the Design Intent Model(s) and use them to produce accurate construction documents. Construction professionals should use the Design Intent Model(s) and the construction documents as a starting point for developing the Model(s). Similarly as the Construction Model(s) are progressed during construction, they serve as the basis for Project Data (which oftentimes includes tabular or textual-based information). Also during construction, the various Construction Model(s) combine to develop an As-Built model that captures more-detailed construction conditions (e.g., trade-specific fabrication models). As the project progresses, the As-Built Model—along with the continual stream of project correspondence and information back to the Design professionals—facilitates the update of the Design Intent Model(s) into a Record Model. The construction model typically has highly detailed components that are not always an efficient source of information for operations and maintenance; hence the Record Model is developed from the Design Intent Model to provide a lightweight model. In general, the Record Model, along with the As-Built Model and Project Data, provides facilities management personnel with varying degrees of information in multiple formats to best support FM uses and activities.

3.6.3 Model Contents

Models and corresponding elements or sub-elements should be modeled at full scale (1:1) using actual (not nominal) dimensions. Models should include all content necessary to meet the requirements in the BIM PxP. Further content may be specified in the BIM LOD. General considerations for model content requirements include the following:

- Models should include all system components and connection points to utilities and/or components, whether site or building related. These components should include all information

parameters and annotations required to produce accurate drawings, details, schedules, and sheets.

- All Furniture, Fixtures, & Equipment (FFE) should be properly identified by make, model number, and building/department/room or space in which it resides.
- Clearance zones required for code compliance, access (such as needed for equipment, hatches, and panels), safety, maintenance, gauge reading, and other operations should be modeled.
- Any required layer of the systems, for example, insulation, double layered systems, or enclosures should be modeled.

3.6.4 Project Data

The Project BIM Team should develop Project Data for all elements that make up the model (e.g. doors, air handlers, electrical panels, etc.). This Project Data should include all material definitions and attributes that are necessary for the project planning, design, construction, and operations. All elements should be assigned the proper classification and category. All life safety and fire protection components and systems should be clearly identified as such. Minimum Project Data requirements should be identified in the BIM PxP.

3.6.5 Level of Development (LOD)

The Owner should define the desired LOD for BIM content that enables the project's specific organizational and project goals. The Owner may elect to reference an LOD standard holistically for all model content, or require a specific LOD per model or model element *and* by discipline, trade, and/or phase. When implementing an LOD, the Owner can use the default LOD, a template LOD, or develop a custom LOD. It should be understood that BIM cannot be successfully accomplished without some LOD defined for each model deliverable, which is typically recorded in a spreadsheet or worksheet. In general, the standard LOD definitions are defined in the BIMForum LOD Specification 2015, which is available as part of NBIMS-US™V3.[17]

Default LOD: If the Owner elects to reference an existing LOD without making modifications, use of the USACE Minimum Modeling Matrix (M3) is recommended, as it defines a minimum LOD of elements for a design model and a Record Model deliverable.

Template LOD: Several LOD templates are available to the Owner, but it is recommended that the Owner use a nationally recognized form. The Owner may adapt the USACE M3[18], use the AIA G-202 – 2013 document[19], or implement the Penn State University Model Element Matrix[20] or the PSU Project Execution Planning Guide.[21] Alternatively, the Owner may elect to use the worksheet provided with the BIMForum LOD Specification 2015 Model Element Matrix.

Custom LOD: Owners may elect to develop his/her own LOD Matrices identifying LOD and model element authors for models or model elements. Owners should adhere to the BIMForum LOD Specification 2015 definitions to avoid confusion among the Project BIM Team members.

At a minimum, BIM content should be developed to an adequate level to support:

- Establishment and communication of design intent

- Necessary content for construction documents
- Overall BIM requirements developed by the Owner
- Optional BIM requirements from this Guide chosen by the Owner
- Essential BIM Uses as identified in Section 4.2.2 of this document
- Enhanced BIM Uses that the Owner selects from Section 4.2.3 of this document
- Additional data and metadata necessary to achieve additional BIM Uses as documented in the BIM PxP

In summary, diligence should be given during project planning to select appropriate BIM Uses and develop a detailed BIM PxP, as these are the impetus for determining and assigning an adequate LOD.

4. EXECUTION

Commentary:
The BIM PxP should be developed to provide a master information/data management plan and assignment of roles and responsibilities for model creation and data integration at project initiation. The team members and Owner should jointly agree on how, when, why, to what level, and for which project outcomes BIM will be used.

In those projects where construction information is available during the design phase, the BIM PxP would address both design and construction activities. The BIM PxP should be considered a living document and should be continually developed and refined throughout the project development life cycle.

4.1 BIM Project Execution Plan (PxP)

BIM Project Execution Planning is "a process performed by a Project BIM Team to design the execution strategy for implementing BIM on the project. The final product of the execution planning process is a documented BIM Project Execution Plan (PxP)."[22] To maximize the effectiveness of BIM, the execution plan should be designed in the early stages of a project and focus on the decisions required to define the scope of BIM implementation on the project, identify process impacts of using BIM, define the team characteristics needed to achieve the modeling, and quantify the value proposition for the appropriate level of modeling at the various stages in the project life cycle.

4.1.1 Development of the BIM PxP

The BIM PxP, created early in the project, should be considered a living document that evolves throughout the project. The BIM PxP should be developed and refined by the Project BIM Team to document the collaborative process of how BIM will be executed throughout the project life cycle.

The initial version of the BIM PxP should be developed by the Project BIM Manager, assisted by the Owner and the Project BIM Team (as referenced in NBIMS-US™ V3, Section 5.4), to detail the BIM requirements for the project. It should be submitted for approval to the Owner.

The BIM PxP should be refined by the entire Project BIM Team as design progresses. If a contractor is not procured for preconstruction services, the design team and Owner should develop the collaborative BIM PxP and coordinate with the contractor when the contractor is procured.

The BIM PxP should be reviewed and coordinated with the entire Project BIM Team prior to construction and submitted to the Owner for final approval. The BIM PxP should be reviewed with specialty contractors prior to execution of their contracts. Any revisions to the BIM PxP should be submitted to the Owner for final approval.

The Project BIM Team should use the PxP template in the NBIMS-US™ V3, Section 5.4: BIM PxP Content, which identifies the minimum BIM requirements to develop an acceptable BIM PxP. The PxP should specify how different versions of the model will be stored and retrieved as the project progresses.

4.2 BIM Uses

Commentary:
BIM Uses can be broadly categorized into authoring tools, auditing tools, and analytic tools. Some applications are designed or written to address a single task. Other uses are written to perform multiple tasks and are often referred to as "integrated software tools." The BIM Uses listed below can be either single-task applications or be part of integrated software tools.

BIM Uses focused on single tasks should be interoperable with the other BIM Uses used on a project. "Interoperability" is the ability of diverse systems and organizations to work together (inter-operate). Interoperability can be used in a technical systems engineering sense, or in a broader sense, including social, political, and organizational factors that affect system-to-system performance.

Interoperable BIM Uses are software programs designed to use the inputs and outputs of other BIM applications to perform the task and generate the output that the BIM Use being applied was designed to perform. Interoperable software reduces the amount of time required to manually exchange information and input it into single-task software. It also minimizes the risk of data transfer errors often caused by manual information exchange methods.

4.2.1 BIM Use Definition

A BIM Use is a method of applying Building Information Modeling during a facility's life cycle to achieve one or more specific objectives. [23] The nature of BIM technology allows different Owners to use the model in multiple ways, depending on their projects' specific needs. As the project moves from phase to phase, the information contained within the BIM grows in both quantity and specificity.

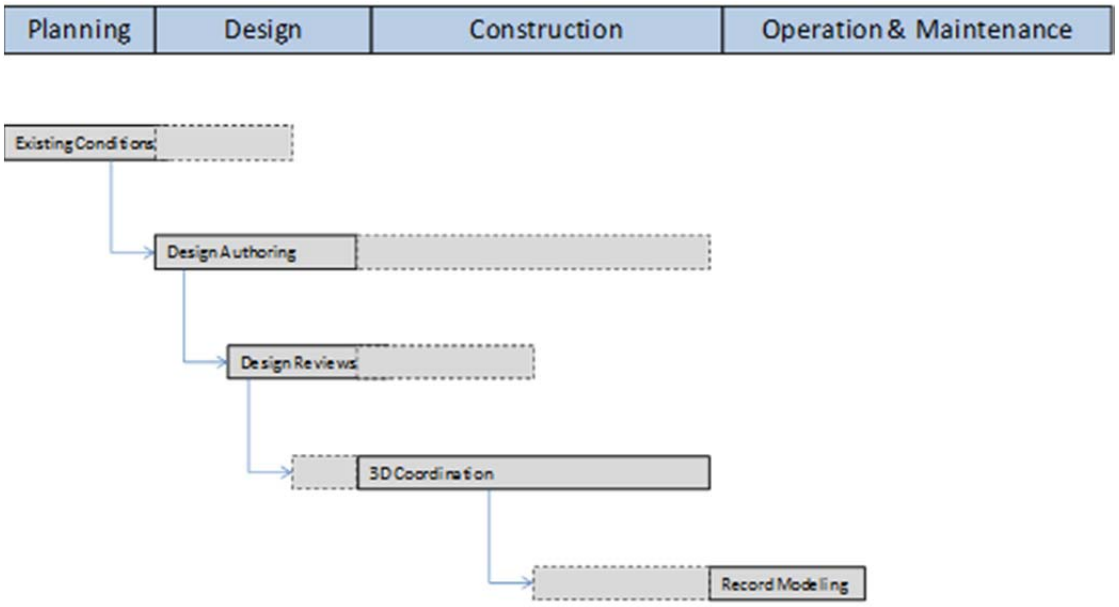

Figure 4. Minimum BIM Example

BIM Uses are characterized in this Guide as Essential BIM Uses, Enhanced BIM Uses, and Owner-Related Uses of BIM. The brief definitions below have been extracted and enhanced from the BIM Project Execution Planning Guide and the BIM Planning Guide for Facility Owners. BIM Uses should be considered and aligned with project goals, selected based on added value to the Owner, and clearly documented in the BIM PxP. This guide uses the term "building" generically, in keeping with the terminology of "Building Information Modeling." It is intended to apply to information modeling for the built environment: site elements and facilities as well as buildings.

4.2.2 Essential BIM Uses

The following BIM Uses should be applied on all projects:

- **Existing Conditions:** A process in which the Project BIM Team develops a model (geometry and information) of the existing conditions for a site, facilities on a site, or a specific area within a facility. This model can be developed in multiple ways, depending on what is desired and what is most efficient. Once the model is developed, it can be queried for information and can be modified.

- **Design Authoring:** A process in which software is used to develop a BIM of the design. Design authoring tools are a first step toward implementing BIM, and the key is integrating the geometric representation of elements in the model with element properties. Construction drawings should be produced from and remain consistent with the models.

- **Design Review:** A quality management process in which a model is used to allow stakeholders to verify whether the design meets the OPR and to visualize criteria such as layout, sightlines, lighting, security, ergonomics, acoustics, textures and colors, etc. Virtual mock-up can be done in high detail, even on a part of the building, such as the façade, to quickly analyze design alternatives and solve design and constructability issues. If properly executed, these reviews can resolve design issues.

- **Coordination:** A process in which model elements can be organized and coordinated, and clash detection software can be used to identify conflicts between model elements within the BIM.

- **Record Modeling:** A process in which a model contains an accurate depiction of the physical and functional conditions and environment of a facility and its assets at a point in time. With the continuous updating and improvement of the Record Model and the capability to store more information, the model contains a true depiction of space with a link to information, such as serial codes, warranties, and maintenance history of all the components in the building. Eventually, the Record Model also contains information linking pre-build requirements to as-built conditions. This allows the Owner to monitor the project relative to the OPR.

4.2.3 Enhanced BIM Uses

- **Cost Estimating:** A process in which a model can be used to generate an accurate quantity take-off and cost estimate early in the design process and provide cost effects of additions and

modifications, with the potential to save time and money and avoid budget overruns. This process also allows designers to see the cost effects of design modifications in a timely manner.[24]

- **Phase and 4D Planning:** A process in which a four-dimensional (4D) model (a model with the added dimension of time) is used to effectively plan the phased occupancy in a renovation, or to show the construction sequence and space requirements for laydown areas and temporary construction on a building site. 4D modeling is a powerful visualization and communication tool that can give a Project BIM Team a better understanding of project milestones and construction plans. (See also Construction Systems Design).

- **Site Analysis – Development:** A process in which BIM and GIS tools are used to evaluate properties in a given area to determine the most optimal site location for a future project. The site data collected is used to first select the site and then position the building based on the OPR.

- **Site Utilization – For Construction:** (See Phase and 4D Planning).

- **Digital Fabrication:** A process that uses machine technology to prefabricate objects directly from a model. The model is used as input into manufacturing and fabrication equipment for production of components, systems, and assemblies.

- **3D Location and Layout:** A process that utilizes a model to lay out the building assemblies and produce lift drawings, which are the two-dimensional (2D)/three-dimensional (3D) component drawings used by forepersons during site construction.

- **Engineering Analysis:** The integrated and/or interoperable tools that allow the use of the physical and material properties of project elements, assemblies, and systems within the model for engineering analysis, simulation, and documentation. Examples include structural engineering, energy analysis, daylighting, HVAC, plumbing, fire protection, life safety, and electrical systems design and documentation.

- **Sustainability Analysis:** The integrated and/or interoperable tools that allow the use of the physical and material properties of building elements, assemblies, and systems within the model for developing sustainable design elements. Examples include documenting sustainable features and attributes and documenting sustainable features for compliance with building rating systems.

- **Codes and Standards Compliance**: A process in which validation software is used to check the model parameters against applicable codes and standards. Code and standard validation is currently in its infant stage of development within the United States and is not in widespread use. However, as model checking tools continue to develop code and standard compliance software with more codes and standards, validation should become more prevalent within the

design industry. Examples may include building code compliance, energy code compliance, accessibility compliance, etc.

- **Construction Systems Design:** A process to design and analyze the contemporary systems (e.g. formwork, glazing, tie-backs, etc.).

4.2.4 Owner-Related BIM Uses

- **Asset Management:** A process in which project data is linked to a Record Model to aid in the maintenance and operation of a facility and its assets. These assets, consisting of the physical building, systems, surrounding environment, and equipment, must be maintained, upgraded, and operated at an efficiency that will satisfy both the Owner and users in the most cost-effective manner.

- **Disaster Planning and Management:** A process in which emergency responders have access to critical building information in the form of a model and information system. The BIM provides critical building information to the responders to improve the efficiency of the response and minimize the safety risks. The dynamic (real time) building information could be provided by building automation systems (BAS), life safety (fire alarm and fire protection), and security systems, while the static building information, such as geometry, floor plans, points of egress and access, and equipment schematics, reside in a model. These systems are integrated and made interoperable so that emergency responders can link to an overall system. The BIM—coupled with the BAS, life safety, and security systems—clearly displays where the emergency is located within the building, possible routes to the area, and any potentially hazardous locations within the building.

- **Space Management:** A process in which BIM is used to effectively distribute, manage, and track appropriate spaces and related resources within a facility. A model allows the facility management team to analyze the existing use of the space and effectively apply transition planning management towards any applicable changes. Maintenance scheduling is a process in which the functionality of the building structure (walls, floors, roof, etc.). and equipment serving the building (mechanical, electrical, plumbing, etc.) are maintained over the operational life of a facility.

4.3 Model Deliverables

The project execution plan should clearly define the deliverables that are to be transmitted to the owner at the completion of construction. These deliverables may include a design intent model in both native and open standard format; a construction model; and operations and maintenance data (see Figure 3). The model content for each of these deliverables should be clearly defined within the contract documents for each responsible party, as well as in the BIM PxP. The following sections provide a description of each deliverable.

Design Intent Model: The Model(s) from the design team that captures the intended design. This model is used for project BIM Use execution, digital design mock-ups, decision support, and coordination. The approved model is a contract document for submission to the Owner and for construction handover.

Construction Model: The Model(s) based on criteria that relates the facility's fabrication and construction. These models are developed from the Design Intent Model during construction coordination. The files are typically combined using a cross-platform 3D model viewing software to accommodate subcontractor file formats and a higher LOD. This new information is reviewed by the design team for approval.

As-Built Model: The Model(s) capturing conditions at the completion of construction. It should be initially based upon the Design Intent Model and increasingly incorporates project information as construction progresses.

Record Model: The Model(s) prepared for operations and maintenance. Typically the Design Intent Model is used as a baseline and then is updated to incorporate all the changes during construction. This is intended to be a "lightweight model" with enough detail to enable facilities management operations without overly detailed elements. This model may also include laser scan data. The Record Model will contain accurate attribute data on major equipment and systems for facilities management documented in the BIM PxP. The Record Model typically is updated by the designer from information provided by the contractor (e.g., digital mark-ups, photography, and laser scans). It may be used during commissioning or updated to reflect commissioning data.

Operations and Maintenance Data: This deliverable includes asset inventory with asset name, classification, and location. Owners should consider operations and maintenance data deliverables to include attributes such as make, model, and serial number of key components. Construction Operations Building information exchange (COBie), is an example of facilities data exchange (as referenced in NBIMS-US™ V3, Section 4.2.)

The Project BIM Team should provide deliverables in compliance with the phases described in the BIM PxP. At each phase, the Project BIM Team should provide a written report confirming that consistency checks, as identified in the Quality Management section of the BIM PxP, have been completed. This report should be discussed as part of the review process and should address any identified interferences and constructability issues.

The Project BIM Team should provide the Owner with the following, as identified in the BIM PxP:

- Updated BIM PxP
- 2-D drawing deliverables printed directly from the model in PDF format. Documents are to be stamped and signed in traditional practice to comply with the Owner Design and Construction Standard and local permitting requests.
- Construction Model(s) per discipline

- A 3-D interactive review format of the model in the latest version of software, as required in the BIM PxP. The file format for reviews can change between submittals.
- Construction Submittals. All construction submittals, requests for interpretation (RFIs), and change order requests (CORs) should make use of the model for clear interpretations.
- Record model(s)
- A report generated from the model of all assets and attributes
- A report verifying the model/modeling compliance with Owner Project Data exchange requirements
- A report verifying the accuracy of the delivered model elements and asset attributes
- An interference (clash detection) check report
- A list of all submitted files. The list should include a description, directory, and file name for each file submitted. Identify files that have been produced from the submitted model and Project Data.

The BIM PxP should define additional model deliverables for the project. Deliverable deadlines should be aligned with project milestones, for example:

- Schematic Design
- Detailed Design
- Construction Documents
- Bid/Procure
- Contract
- Notice to Proceed
- Construction
- Substantial Completion
- Commissioning
- Final Inspection
- Occupancy/Operations and Maintenance
- 10-Month Warranty Review

5. GLOSSARY

(Please note that references to "model" and any related requirements refer to individual models, such as a particular discipline/trade model, as well as to composite or federated models.)

As-Built Model: The model(s) capturing conditions at the completion of construction. It should be initially based upon the Design Intent Model and increasingly incorporates information as construction progresses.

Attributes: descriptors that represent the characteristics of elements (e.g., name, length, weight, price, manufacturer, model, warranty information, etc.)

BIM Element Matrix: A structure that defines the elements to be modeled for each phase of the design and construction process.

BIM Project Execution Plan (PxP): A plan that defines how BIM will be implemented throughout the project life cycle.

BIM Use: A method of applying Building Information Modeling during a facility's life-cycle to achieve one or more specific objectives, as defined by Kreider, R., and Messner, J. I. *The Uses of BIM* (2013). Pennsylvania State University, University Park, PA. http://bim.psu.edu

Building Information Model (BIM)/Model, as defined in the National BIM Standard – United States® Version 3: The digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onwards."

Construction Model: The model(s) based on criteria that relates the facility's construction.

Construction Operations Building information exchange (COBie), as defined in the National BIM Standard – United States® Version 3: The format for the exchange of information about building assets such as equipment, products, materials, and spaces.

Data Security Protocol (DSP): A definition of the security requirements for data to be implemented for the project and incorporated into the BIM PxP.

Design Intent Model: The model(s) from the design team that captures the intended design.

Industry Foundation Class (IFC): The Industry Foundation Class (IFC) is a data standard (specification) maintained by buildingSMART International and accepted as ISO Standard 16739. It is intended to allow the exchange of building and construction industry data between software applications. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors.

Level of Development (LOD) (as defined the BimForum website, November 2015): The degree to which the element's geometry and attached information have been thought through—the degree to which Project BIM Team members may rely on the information when using the model.

Model: See Building Information Model.

Model Element: A portion of the model(s) representing a major component, assembly, or construction entity (part) which, in itself or in combination with other parts, fulfills a predominating function of a construction entity.

Model Element Author (MEA): The party responsible for creating or updating any given model element.

Model View Definition (MVD): An IFC View Definition, or Model View Definition, MVD, defines a subset of the IFC schema that is needed to satisfy one or many exchange requirements of the building industry. The method used and propagated by buildingSMART to define such Exchange Requirements is the Information Delivery Manual, IDM (also ISO/DIS 29481). An IFC Model View Definition defines a legal subset of the IFC Schema (being complete) and provides implementation guidance (or implementation agreements) for the IFC concepts (classes, attributes, relationships, property sets, quantity definitions, etc.) used within this subset.

OmniClass™: A classification system for the construction industry.

Owner: Person or entity that represents and controls financial interests of a property, building, or development.

Owner's Performance Requirements (OPR): The Owner's written documentation of the functional requirements of the building and expectations of how it will be used and operated. They include project and design goals, budgets, limitations, and schedules.

Organizational Standards: Standards unique to every Owner and include the Owner's written policies, procedures, and processes. The Owner is encouraged, when creating any Organizational Standards that will be used as part of the contract language, PxPs, and OPRs, to document them in writing, especially when it comes to expected outcomes and deliverables.

Primary Standards: Standards written typically by local, national, and international organizations and industry groups by consent or consensus that establish minimum levels of performance and quality and are used for comparative evaluation and verification of compliance. Primary Standards are often adopted by an agency, organization, industry, or government body.

Project Data: Project data is the written and graphical information used to plan, design, construct and operate the building. It should include Model files (BIM, CAD); drawing files (CAD, electronic sheets such as PDFs, and/or plot files);electronic manuals; tabular/textual information derived from BIM (e.g., spreadsheets); and reference files necessary to supplement other project data.

Project Life Cycle: The full development of a building project from conception to demolition, including four phases (Planning, Design, Construction, and Operations).

Project Quality Management: a subset of project management that includes the actions required to ensure that the project will satisfy the needs for which it was undertaken. It consists of quality planning, quality assurance, and quality control.

Project BIM Team: typical members include the Owner, architect, engineers, contractors, subcontractors, and other stakeholders. The Project BIM Team members can vary by phase; stakeholders or participants will be introduced to and leave the Project BIM Team as the project progresses through its life cycle.

Record Model: The model(s) prepared for Operations and Maintenance. Typically the Design Intent Model is used as a baseline and then is updated to incorporate all the changes during construction. This is intended to be a lightweight model with enough detail to enable facilities management operations without overly detailed elements.

Reference Standards: Standards included by reference in Organizational Standards, Primary Standards, and Contract Documents and carry the full force and effect of their requirements as if their entire text had been replicated in full where referenced. Care should be taken when including Reference Standards in an Organizational Standard, Primary Standard, or Contract Document to be specific whether compliance with the entire Reference Standard is required or whether only compliance with certain portions of the Reference Standard is required. Reference Standards not only reduce a primary document's size, but also improve a primary document’s usefulness and effectiveness by relying on other standards-development organizations with better-suited expertise on particular subjects.

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