The Egyptian Code for Building Information Modeling (BIM)

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LIST OF ABBREVIATIONS

AIM	Asset Information Model
AIR	Asset Information Requirement
BEP	BIM Execution Plan
BIM	Building Information Modeling
BMP	BIM Management Plan
CAD	Computer Aided Design
CDE	Common Data Environment
COBie	Construction Operations Building Information Exchange
EIR	Employer's Information Requirements
EOLIM	End-of-Life Information Model
LOD	Levels of Development and Levels of Detail
IFC	Industry Foundation Classes
IMP	Information Management Process
OIR	Organizational Information Requirement
PIM	Project Information Model
WIP	Work-in-Progress Area in the Common Data Environment

1. INTRODUCTION

In construction projects, the process of producing design information requires some improvements. The techniques for this improvement need some protocols and standards to standardize the whole process from the early beginning of the project and to facilitate working with an integrated design management mindset.

The construction industry nowadays requires the enhancement of several points in the planning and development since the use of papers, documents, and 2D drawings is not proficient any longer. This prompted the development of 3D advanced models that can be used to allow for better data management. This approach is known as Building Information Modeling (BIM).

BIM is changing how facilities are planned, designed, constructed, and operated. It has increased advanced development and innovations that will essentially change the construction industry and lead to the conveyance of an intelligent building environment. This changing innovation will enhance the profitability, the level of incorporation, and the coordinated effort over different levels in the development of projects. Since BIM is expected to develop and progress with time, the objective of this Code is to be used as a part of the business' endeavors to facilitate the use of BIM and to clarify the prerequisites for utilizing BIM at various projects' phases.

Through the use of computer-based simulations, BIM allows studying and validating the design and the construction plans of projects before their implementation. It is significantly more than a fundamental 3D model; it is a business approach that coordinates enormous amounts of project-related data. It moves clients far from the conventional "document-centric" approach, towards a "data-centric" approach which supports the lifecycle operation of the facility. It brings about a more powerful methodology for the stages of the design, estimation, scheduling, construction, and operation. In addition, BIM considers the combination of various developments over the different project stages such as project scheduling, automated quantity take-offs, automated material take-offs, and energy analysis, etc.

This BIM code is essentially a Best Practice that provides information needed to advance the knowledge and understanding of the Building Information Modeling (BIM) and the importance of its incorporation in the construction industry. It offers recommendations and guidance for achieving different levels of implementation of BIM in Egypt based on the current conditions of the construction industry. The Code discusses the main uses of BIM for the Integrated Delivery (ID) of projects, the key requirements for BIM implementation in construction projects, the workflow in BIM-based projects over the different project phases, and the basis for preparing BIM execution plans for projects. Also, it gives a brief overview on the implementation of BIM during the operational phase of projects.

2. SCOPE OF BIM CODE

The Egyptian BIM Code of Practice offers guidance and recommendations for the implementation of BIM in construction projects. This document is formed to improve the processes of design, construction, information exchange, and communication between projects' stakeholders.

Figure 1 shows the Project Information Model (PIM) and its development throughout the project lifecycle. As shown in the figure, the scope of this Code covers the design, construction, and operational phases of the project.

The information model is continuously developed whether through semantic or geometric data. This development needs to be carefully planned through BIM to acquire more confidence in the management and execution of the project.

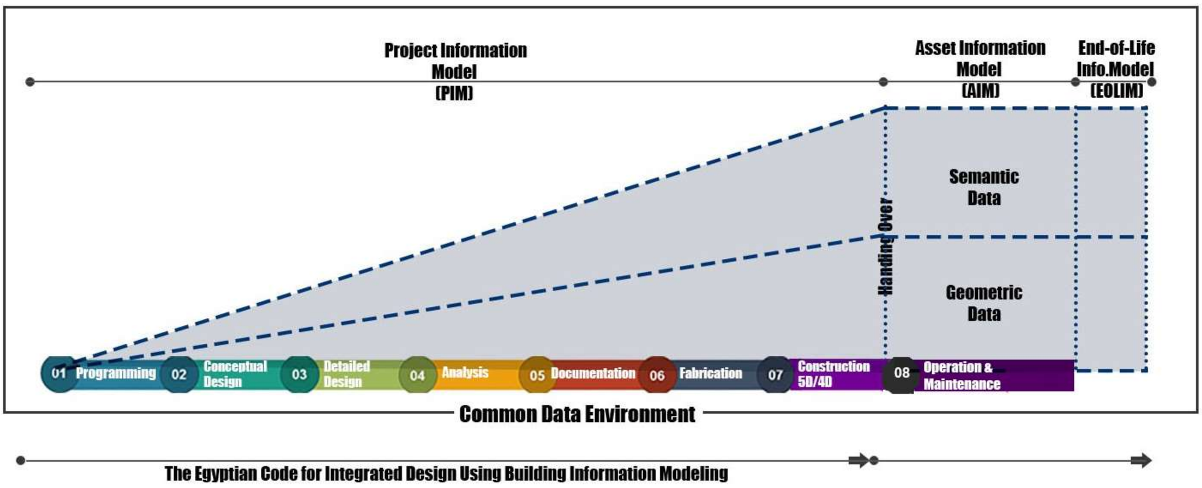


Figure 1: Project Information Delivery

3. INTEGRATED DELIVERY USING BIM

3.1. BIM OVERVIEW

The complexity of the construction industry requires a higher level of details. Therefore, exchanging design models for design and construction in the form of papers and 2D drawings is not efficient any more. This led to the development of 3D digital models to be used in the construction industry for presenting and exchanging project information between project parties. This approach is known as BIM (Building Information Modeling).

BIM is a digital presentation of the whole project details, functions and information from initiation till close-out stage. BIM is a combination of several applications that are used through every stage to help in information exchange, coordination and communication between the project parties, also it allows the analysis and visualization of the delivered models.

Implementing BIM enables the occurrence of a huge transformation in the construction industry especially in projects that involve a high level of details, special manufactured items, large number of stakeholders, and high quality of designs and required outcomes.

By using BIM, there is no need for re-collecting and formatting information, all designs can be analyzed and revised before construction. Outputs can be checked by the stakeholders to offer a greater understanding throughout the project, higher quality of designs and construction activities can be obtained, higher ability for sharing data can be achieved between project stakeholders which allows taking correct decisions. All of these features and more offer an opportunity of reducing the project time and cost overrun, helping the project teams to reach a better collaboration, and seeing the project and its details as a real model before construction.

BIM is a multi-dimensional model which is not limited to 2D or 3D only but it spreads on a larger scale to reach 7D. This allows the integration and efficient utilization of all project data.

3.2. BIM MATURITY LEVELS

Defining and sorting construction practices with respect to the BIM compliance have become widely adopted concepts with different levels of this adoption. The BIM adoption levels or the so-called BIM Maturity levels are pointed out in Figure 2. These levels form milestones that start from a limited or primitive collaborative environment (level 0) and progresses towards full collaboration. It can be noticed from the figure that it has no ‘clear’ end. This reflects how future enhancements in collaborative tools together with their effects on the construction sector are still unpredictable. Therefore, continuous update or evolution of new levels is expected.

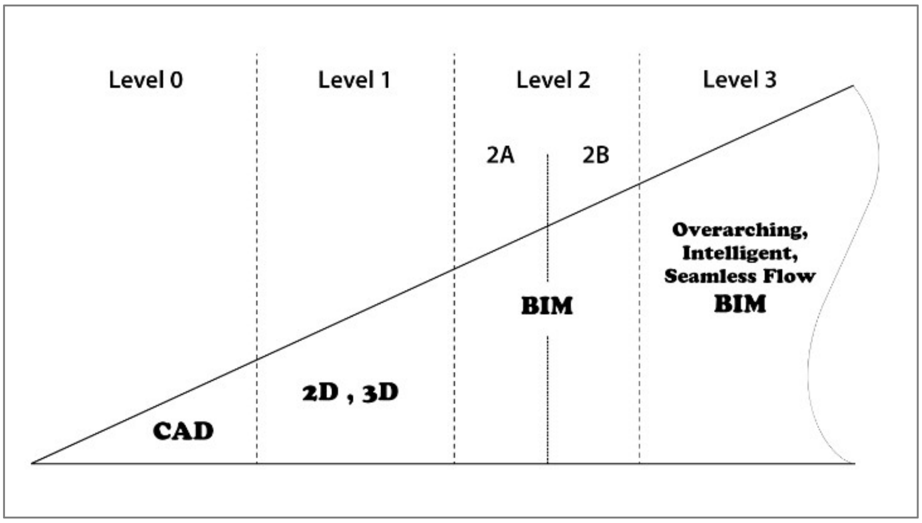


Figure 2: Adjusted BIM Maturity Levels for the Egyptian Construction Sector

Level 0 BIM:

This level supports no collaboration. In this stage, 2D CAD (Computer Aided Design tools) for drafting is adopted, but there is no incorporation of any BIM enabling software. Also, distribution of information is mainly via paper or electronic prints.

Level 1 BIM:

This level represents the current level for most organizations that are involved in the construction sector. In this level, the collaboration is more augmented within the internal departments of the organization itself and 3D CAD models are more common. However, these models are mainly used for conceptual work. The attachment of data representing different aspects of the project into the model is minimal and 2D drawings are mostly used for documentation of work and production of shop drawings.

Level 2 BIM:

This level is divided into two milestones; the first milestone witnesses an improved collaboration environment among a limited number of stakeholders and it can be referred to as level “2A”, while the other milestone represents an extended collaboration protocol among the main stakeholders in a project and it can be referred to as level “2B”.

The nature of the current collaboration environment does not necessitate the presence of a single shared model accessible to all stakeholders. It comprises the sharing of data through common file formats like IFC (Industry Foundation Classes) and COBie (Construction Operations Building Information Exchange). Therefore, each party is entitled to use any type of BIM software on the condition that it is interoperable with the formats agreed upon for information exchange purpose.

The division of Level 2 into two sub-levels is due to the nature of the construction sector in Egypt. Normally, the consultant (Owner's representative) is the first entity to adopt the current collaboration tools and to provide a reliable and integrated BIM model as an output of the design process. The contractor, engaged in the project, is expected to share the same information exchange protocols to communicate the changes occurring to the BIM model. In case the process extends to include all the relevant sub-contractors communicating through 3D CAD models and the model itself for each entity is not only used for visualization purposes, then that's the Level 2B BIM. However, if the model is used only for visualization by the contractor while other management procedures such as scheduling and cost estimation are done independently of the model then that's an incomplete Level 2 BIM which is denoted by Level '2A'.

Level 3 BIM:

This level represents the "Optimistic View" of collaboration among different construction stakeholders and throughout all the construction processes and disciplines. It is formulated by the presence of only one shared project that acts as a central hub. This project is accessible to all parties; thus, duplication or loss of information can be greatly eliminated. This environment is backed up by cyber security measures for protecting the 'cloud-based' data. It shall also require risk-sharing partnerships among all participants in the project. As such, a paperless project is extended till the execution of the project, where rugged tabs replace the conventional shop drawings.

4. BIM USES

BIM technology relies on three fundamental pillars, namely: Parametric object Modelling, Intelligent Modelling and Bi-directional Associativity.

***Parametric Object Modelling*:**

BIM applies constraints that are similar to the hierarchy in an object-oriented programming. Where a class of a parametric BIM object allows the occurrence of numerous 'instances' in the model. Each instance inherits the parameters of the what's called its belonging 'family' (the class it belongs to). Yet each instance has its own values for these parameters (called attributes). The structure of attributes remains the same for instances of the same family, while the values differ to distinguish the unique properties of each instance. These BIM objects may represent the physical building elements or other abstract elements like annotations or model lines. This concept which relies on the inheritance of attributes and methods in a hierarchical structure allows the building up of extensive taxonomies of objects with complex relations in an efficient manner. It's worth mentioning that any attribute that has a visual effect on the related BIM object, once modified or updated, transforms the visual shape of the BIM object immediately with respect to the change that was done and that's explained by the 'Intelligent modelling' concept.

***Intelligent Modelling*:**

Based on what was explained in "parametric object modelling", any change in one of the BIM instances is applied globally in all views and related documents. Unlike drafting CAD systems where lines and polygons representing one element are unconnected in each view, BIM objects, no matter any view, preserve their own properties. So, any change is applied to the BIM instance itself, independent of the view. Also, the structural hierarchy of BIM properties and attributes prohibits the duplication of a certain value and 'intelligently" detects any discrepancy in them.

***Bi-directional Associativity*:**

One of the key powers of BIM is what is called "Bi-directional Associativity". They are rules and expressions that govern the way the surroundings of a BIM instance respond when an action is applied to this instance. The strength of any BIM authoring tool is in the degree of intelligence in applying bi-directional associativity such that:

1. The least manual modifications are needed from the user.
2. The modifications applied to the surrounding BIM objects imitate the behavior of their real-world counterparts. For instance, when a wall is shifted, all BIM objects attached to this wall instance are expected to move with it.

These three pillars are the cornerstone in achieving the BIM uses that are described in below Sub-sections (Parametric Data, Time, Cost, Energy and Sustainability, and Facility Management). As such, BIM tools are superior in modelling building's form, function and linking the change in its behavior.

4.1. PARAMETRIC DATA

3D model can be created from the data given by the project stakeholders. This model enables them to understand the project clearly, to use the integrated information of the model, to determine their views and needs to update the model through the project lifecycle, and to identify and resolve construction problems before occurring on site. Clashes occur due to the incompatibility of drawings and designs of different disciplines, which are not discovered until construction begins causing great delays and conflicts on site. These problems are solved by BIM since these clashes can be detected and seen during design phase before the construction begins.

Further, the information extracted from the model helps in determining all aspects of prefabricated components to be assembled directly on site. As a result, more construction work can be performed offsite, cost efficiently, in factory-controlled conditions and to be efficiently installed afterwards.

4.2. TIME

The 3D model can help in site layout management where it contains temporary site components such as cranes, lorries, and other items. These components and visualization tools can be used in planning and monitoring the construction sequence as well as the on-site safety precautions as the project progresses. Schedule visualization can be performed by project stakeholders to be able to make sound decisions based on multiple sources of accurate real-time information. Within the BIM model a chart can be used to show the critical path and to visually show the dependency of some sequences on others. Visualization of different construction scenarios or the effect of design changes is enabled through the available BIM tools.

4.3. COST

Quantity Takeoff is performed using the accurate information included in the model. The contractors and quantity surveyors can easily and quickly estimate quantities and costs of materials, areas, and other needed information. They do not need to do this manually so no over-consumed time or estimation errors occur. Cost data is added to each element in the model so that rough estimate of materials' cost can be calculated automatically. This enables parties of the project, especially designers, to efficiently use value engineering.

4.4. ENERGY AND SUSTAINABILITY

A complete and accurate energy analysis can be performed in the project design phase where measurements and performances of the building during occupancy can be easily known from the model. This helps in reducing the energy consumption during operation phase.

4.5. FACILITY MANAGEMENT

The designer creates the model and during the construction phase, the model is updated till the release of 'As built model' which is submitted to the owner by the end of the project. The 'As built' model contains all specifications, operation and maintenance (O&M) manuals, and warranty information which are necessary for future maintenance. The advantage of this model is to reduce future problems during operation and maintenance phase.

During operation phase, the owner can take advantage of BIM, where sensors can record relevant data in this phase to be evaluated using BIM so it becomes easy to monitor building's life cycle costs and optimize its cost efficiency. Also, it enables the owner to evaluate the cost-effectiveness of any proposed updates.

5. MAIN REQUIREMENTS OF BIM IMPLEMENTATION

BIM enables project stakeholders to better collaborate and share the experience through the project phases. This can be achieved by making the BIM Model more accessible and actionable for the entire project team. Implementing this collaboration requires several aspects as explained in the below Sections (Common Data Environment, Interoperability, and Model Structure).

5.1. COMMON DATA ENVIRONMENT

For collaborative working and design, the Common Data Environment (CDE) core principles shall be applied. The CDE has four areas which are (work-in-progress, shared, published documentation, and archive). Figure 3 represents the four areas of the CDE which are detailed as follows:

Work-in-Progress (WIP):

During this stage, in house team of the same discipline share drafts, development concepts, non-verified design data.

Shared:

Upon the check, review and approval of design data according to pre-agreed standards (e.g., BS1192[1]) workflow, coordination between disciplines shall occur. Each discipline-shared model should be accessible to all other disciplines. Data sharing is scheduled and documented in the BIM Execution Plan (BEP) to allow all disciplines to be working on the latest data and information. In case of changes and modification to the shared information, a method shall be defined and agreed upon for communicating such changes.

Published Documentation:

Client approval and authorization of the shared information precedes the creation of the published documentation for use by all project participants. (As in BS1192 section 4.2.4 and PAS1192-2[2] section 9.2)

Archive:

All approved data shall be stored in the designated archive location for retrieval when needed.

[1] BS1192: Collaborative Production of Architectural, Engineering and Construction Information -Code of Practice published by the British Standard Institution (BSI). This code of practice sets out methods for managing the production, distribution, and quality of construction information.

[2] PAS1192: Publicly Available Specification. It is used for the information management in the delivery of construction projects using BIM. It is sponsored by the Construction Industry Council (CIC) and published by The British Standards Institution (BSI).

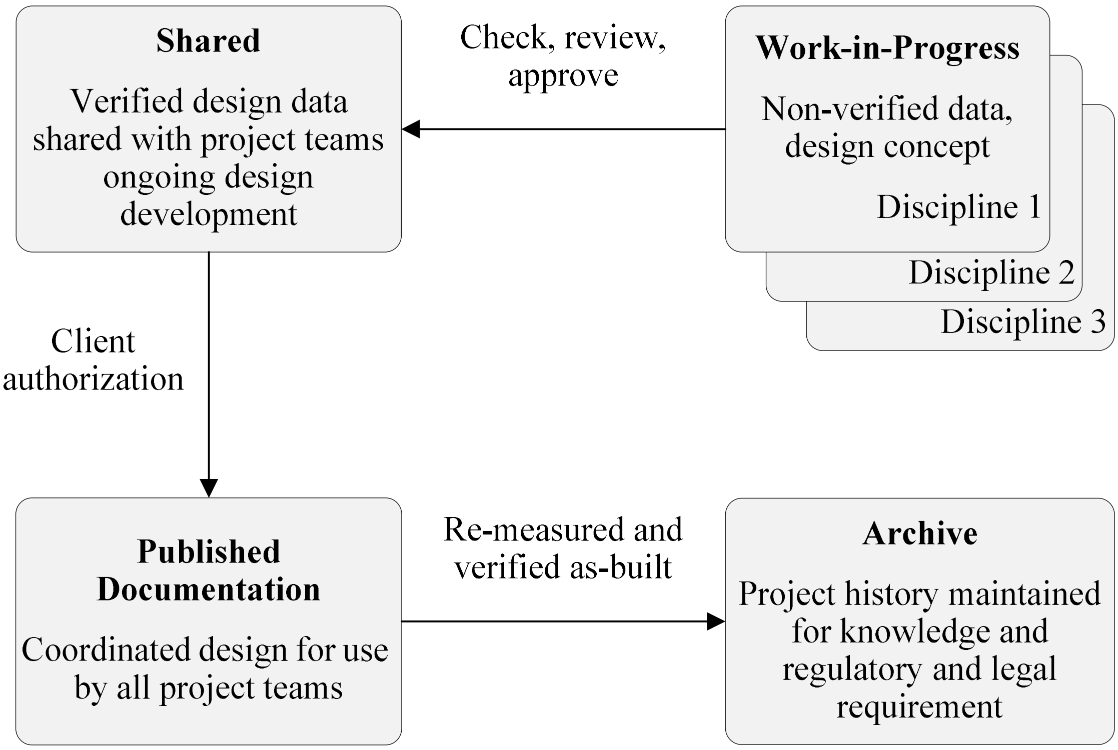


Figure 3: Structure of Common Data Environment (CDE)

5.2. INTEROPERABILITY

Interoperability between software packages is of fundamental significance for fruitful BIM working. Whether it yields 2D CAD for consequent drawing creation or yield 3D for perception or examination, the planning and strategies used to develop the BIM will decide its fruitful application inside other software packages.

5.2.1. Incoming Data Management

In general, for the correct application of interoperability the following guidelines shall be followed:

- A duplicate of received CAD/BIM information should be kept in its format in the project incoming subfolder.
- The appropriateness of received information might be affirmed before making it widely accessible through the project Shared area.
- Modifications of approaching CAD/BIM information need to be minimized. Only the person responsible for coordination shall have the right to perform modifications.

- Interoperability, for 3D data and information exchange, shall be achieved between BIM software using the international standard (e.g. buildingSMART[3]), such as the IFC[4] (Industry Foundation Classes) file format. The latest version is IFC 2x3.

5.2.2. Intended Use of BIM Model

Modeling is performed to the Level of Detail (LOD) required to create every discipline's plans and elevations precisely at the characterized scale, or to convey the Employer's Information Requirements (EIR) in the event that they exist.

5.2.3. BIM Exchange between Software Platforms

Preceding data exchange between various software platforms, the accompanying assignments shall be completed:

- Conduct BIM kick-off meeting.
- Consider limitations, and requirements of software/hardware system, these issues shall be settled to ensure that BIM data can be prepared appropriately for exchange. This should be recorded in the project BIM Execution Plan (BEP).
- 2D drawings from the BIM should be developed in a way that is consistent with CAD Standards and permits simple control of the information held inside the document (e.g. layering).
- Data exchange test shall be performed between different software/hardware systems to ensure data integrity.

5.3. BIM MODEL STRUCTURE

The Designer and the Designer’s Consultants shall use BIM authoring software to generate BIM models that include all the geometrical and physical characteristics, as well as the data needed to describe both the design and construction works of the Project in a collaborative environment. Working in a collaborative BIM-based environment is enabled through various methods such as working practices, team management in addition to the technological solutions presented in this document.

In general, the following practices should be followed:

[3] buildingSMART: It is a worldwide community founded in 1995 of industry participants and users with the intent to technically, politically, and financially support the use of BIM models and advanced digital technology in the construction industry. It helps facilitate the management of information through the development and adoption of open data standards
[4] IFC: A data model developed by buildingSMART specifying how information is to be exchanged to facilitate interoperability in the construction industry by allowing the exchange of data between different software applications.

- The model structure shall be taken into account and agreed upon by disciplines included in the modeling, internally or externally, and shall be documented in the BEP.
- Every single file shall not contain more than one building.
- Each model file shall contain data from only one discipline or project stakeholder. except for the cases where multiple disciplines of the building services converge.
- The Geometry of modelled Building Elements may be refined with respect to the actual details in real-world. The level of segregation is dependent on several variables, but it is essential to attain a workable version of the model on the available hardware.
- The ownership of model data and keeping track of it throughout the project lifecycle is a necessity. Thus, the model ownership in each phase, and even within each period in different phases, shall be defined. In addition, the process of "transfer of ownership" shall also be explicitly mentioned in the contract or its appendices (e.g. In the BIM model responsibility matrix).
- The existence of a central model in projects made up of multiple, discrete model files is essential. This model acts as a central hub for linking the different files of the project and detecting any discrepancies or coordination errors.

5.3.1. Project Folder Layout

The Project folder should consist of folders based on the disciplines, deliverables and a folder of Contract Documentation. The disciplines folders should be divided based on phases, zones, levels, and status, respectively. At the top-level folder, a "Families" folder contains any specialized families that are created or used in the BIMs.

5.3.2. Collaboration

The Owner may designate a web-based collaboration system for use by the Engineer. If the Owner does not designate a web-based collaboration system, then the Designer shall provide a web-based collaboration system for sharing individual and merged BIM files.

The web-based collaboration system shall provide:

- Real-time access of the Project Team which includes but is not limited to the Owner, Engineer, and other users as required by the Owner.
- Automated versioning of BIM files.
- Maintenance of the previous versions of BIM files.
- Access-controlled workspace or folders for each organization to upload its BIM files.

The web-based collaboration system shall be password-protected such that the Designer shall ensure that the collaboration system conforms to any Information Technology (IT) or security requirements set by the Owner. Also, the detailed protocols associated with the use of the web-based collaboration system shall be documented in the BEP.

5.3.3. Division of BIMs

Division of models enables multiple users to work on a model simultaneously. An agreed level of dividing the model (if any) shall be stated in the BEP, and the extents of these divided sub-models shall be properly referred to in other models.

The use of a container model to include all the divided models shall be encouraged and the agreed LOD of the container model (if any) must be stated in the BEP.

5.3.4. Referencing

The design team shall agree on a Coordinate System as stated in the BEP to geo-reference the site plans and building models. To obtain a coordinate from an AutoCAD DWG file submitted by other suppliers within Revit the following shall be done:

1. Link CAD file center-to-center.
2. Move and rotate the CAD file to the Revit building model without moving the Revit building model.
3. Obtain the coordinate from the CAD file then delete the link and notice the change in the shared coordinate.

A separate model shall be developed for each discipline involved in a project, whether internal or external. It is the responsibility of each discipline to prepare a model in compliance with the Volume Strategy. However, a discipline can reference another discipline's Shared model for coordination.

5.3.5. Operational Efficiency in Collaboration

In order to allow the cross-disciplinary work to be as efficient as possible and to reduce the waste of the design process (rework), an initial conceptual model shall be derived from each discipline to act as a starting point for other disciplines to start their work. This initial model shall be sufficiently detailed at this stage of development to help provide more suitable deliverables from various disciplines. The initial model shall be well referenced to allow on-going updating as the model evolves into the more detailed version.

A standard code for status should be included in the BEP to identify the level of details that an engineering discipline can design upon. This code shall differentiate between different issues of the model. Table 1 provides an example of the status code.

Table 1: Examples of Status Codes

Status	Status Code
Initial Model	M000
Work in Progress Model	M100

Model Issued for Coordination	M150
Model Issued for Review	M200
Model Issued for Approval	M250
Model Issued for Contractual Documentation	M300
Model Issued for Construction	M400
As-Built Model	M500

In the case of internal revisions, the model Status Code shall be incremented by changing the last digit e.g. M001 – Initial Model, rev.01. However, in the case of revisions made to reflect the latest inter-disciplinary review, the incremented digit shall be made in the tens digit e.g. M010 – Initial Model, ID rev.01.

The status of which major amount of (re-)work shall be made must be included in the BEP to prevent producing a large number of wasted design.

The model structure shall be agreed on by all disciplines and recorded in the BEP. The following guidelines shall be followed:

- Each building shall be modeled in a single separate file.
- Data contained in a model file shall reflect one discipline/ project stakeholder only. However, exceptions may apply where multiple disciplines converge is required.
- Further division of the geometry may be required to maintain model files remain workable on available hardware.
- Where multiple models are created to make up a single project, a central (container) model shall be created to link the various local files together for coordination and/or clash detection purposes.
- Resolution of any issues that may arise shall be done by users before saving the model.

5.3.6. Model Division within the Same Discipline

Division of a model allows various users to work in parallel on a model, consequently increasing efficiency and effectiveness on projects of any size. For proper model division, the following guidelines shall be followed:

- Appropriate model divisions shall be established and elements assigned, either individually or by category, location, task allocation…etc.
- Only the required models should be opened for a better hardware performance. It is better to use only the required models instead of opening or referencing them and turning off their display.
- Accidental or intentional misuse of data shall be avoided through proper management of access permissions and model ownership.

Table 2 shows an example of the model division in the architectural, structural, mechanical, and electrical disciplines.

Table 2: Model Division by Discipline

Discipline	Breaks in Design
Architectural	Floor by floor or groups of floors
Structural	Major geometry splits, such as beams, columns, slabs, east-wing or west-wing, or movement joints between sections
Mechanical	Construction joints such as podium and tower
Electrical	Work packages and phases of work

5.3.7. Inter-Disciplinary Referencing

Each separate discipline shall have its own model and shall be responsible for the contents of that model in compliance with the Volume Strategy. For coordination purposes, a discipline can reference another discipline's Shared model.

For successful coordination of activities, the guidelines stated below shall be followed:

- No deviation from the agreed project coordinates and direction of North shall take place without the permission stated in the Project BEP.
- Proper communication for the ownership of elements is determined through the project Model Responsibility Matrix. The BEP includes such matrix which defines the originator for each model and the intended Level of Model Development at each stage.
- In special cases, multiple disciplines may be incorporated in a single model, such as in cases when an equipment requires connection to various services.

5.4. LEVEL OF DEVELOPMENT

An agreed Level of Details (LOD) for each deliverable based on disciplines and status must be agreed upon and included in the BEP. The LOD should follow the following levels:

- ***LOD100 – Concept Design***
  - Symbolic place-holder that doesn't represent to scale or have any dimensional values but model elements might be graphically represented as symbols.
  - Most common with electrical symbols that rarely exist as a 3D object.
- ***LOD200 – Schematic Design***
  - Simple place-holder with minimal details.
  - General model with approximate quantities, size, shape, location, and orientation using basic dimensional representation.
- ***LOD300 – Detailed Design***
  - Generic model that sufficiently identifies the type and component materials.

  - Dimensions may be accurate or approximate.
  - Elements are defined with precise quantities, sizes, shapes, and locations.
- ***LOD350 – Construction Documentation***
  - Detailed model that shows how building elements interfere with each other and with various systems using graphics and written definitions.
  - Sufficient details available for producing shop drawings.
- ***LOD400 – Fabrication and Assembly***
  - Specific model that sufficiently identifies the type and component materials in addition to accurate quantities, sizes, shapes, locations, and orientations.
  - Marks the end of the design stages.
  - Suitable for procurement and cost analysis.
- ***LOD500 – As Built***
  - A precise model of constructed objects.
  - Includes any irregularities or changes during construction.
  - Elements are modeled as constructed providing actual and accurate sizes, shapes, locations, quantities, and orientations.
- ***LOD600 – Facility Management***
  - A precise model of constructed objects (LOD 500).
  - Facility management data added to the model for maintenance and operation requirements.

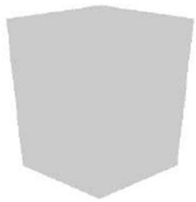
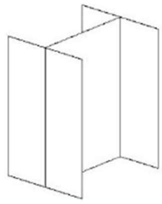
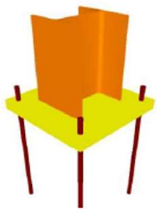
The LOD definitions ought to be viewed as least prerequisites, a component has advanced to a given LOD just when every one of the necessities expressed in the definition has been met. Likewise, it ought to be noticed that the prerequisites are aggregate; for a given component each LOD definition incorporates the necessities of all past LODs. This means that for a component to fit the bill for LOD 300 it must meet every one of the necessities for 200 and 100 and in addition those expressed in the LOD 300 definition.

Level of Development vs Level of Detail

The "Level of Detail" shows the extent by which the model geometry and features resembles the real-world building. Whereas, the "Level of Development" refers to the degree by which the semantic and geometric data attached to a BIM element has been thought through. It also represents the "development" of the model with respect to the amount of information presented in each of the project phases.

In essence, Level of Detail can be considered as an input to the BIM object, while Level of Development is reliable output. Table 3 provides a description of the different Levels of Development with an example for each level.

Table 3: Levels of Development

Level of Development	Description	Example
LOD 100	- This level presents a schematic or conceptual design model. - The Model Element is not presented in any of its forms. Instead, a symbol can denote its presence, or it can be logically inferred to be present in the model. Thus, the overall building model is in an abstract form.	
LOD 200	- This level presents a basic design model from the design development phase. - The main Model Elements are represented by graphical objects. The actual properties are attached in a coarse form. Properties like generic shape, basic quantities, and categorized types might be present in approximation. - Non-graphic information may also be attached to the Model Element.	
LOD 300	- This level presents the detailed design model for construction documentation. - The Model Element is represented graphically as a specific system, object, or assembly. This can be represented in terms of quantity, size, shape, location, and orientation. - Non-graphic information may also be attached to the Model Element.	
LOD 350	- The Model Element is represented graphically as a specific system, object, or assembly. This can be represented in terms of quantity, size, shape, orientation, and interfaces with other building systems. - Non-graphic information may also be attached to the Model Element.	

Level of Development	Description	Example
LOD 400	- This level presents the construction model showing the necessities of fabrication. - The Model Element is represented graphically as a specific system, object or assembly. This can be represented in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. - Non-graphic information may also be attached to the Model Element.	
LOD 500	- This level presents the record or as-built model. - The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. - Non-graphic information may also be attached to the Model Elements.	

5.5. DIGITAL FABRICATION

Digital fabrication is a process that ensures the direct flow of fabrication instructions and information from a digital design directly to the machines. The uses of digital fabrication in construction can be seen in the fabrication of metal sheets, ducts, pipe cutting, etc. Digital fabrication can also be used for creating prototypes of the building models for design intent reviews. Thus, digital fabrication ensures the integrity of information flow and thus waste streams are minimized throughout the manufacturing process.

5.6. DELIVERABLES

5.6.1. Hard Copy Deliverables

A hard copy of mechanical, electrical, architectural, structural, topographical and property line surveying drawings shall be provided using AutoCAD for each milestone or phase of the project.

5.6.2. Electronic Deliverables

For each phase or milestone of the project, BIM model must be submitted for it and all electronic files related to it. The data required from these deliverables is essentially a mature model that contains all the information needed for construction and final record drawings with all the coordination needed between all involved disciplines.

5.6.3. Final Deliverables

To fulfill the requirements of As-Built drawings and to ensure that BIMs are being updated, both the design team and construction team must cooperate together and coordinate with each other. The design team is the one responsible for the delivery of As-Built drawings.

5.6.4. Construction Record Documents

There must be a printed hard copy from the contract documents at the site as any deviation in the actual construction from the contract drawings must be highlighted in the contract drawings and resubmitted with the following requirements:

- Any existing utilities in the construction area are provided with their location and detailed description.
- Any change in the building from the contract drawings and the effect on the utilities provided with its new location and detailed description.
- All underground utilities and facilities provided with the location and detailed description.
- Updated grade or alignment of roads, structures, and utilities if any changes were made from the contract drawings.
- Updated elevations if changes were made in site grading from the contract drawings.
- All changes or modifications from the original design and from the final inspection. Even if the materials used have been changed not only the changes in design.

These deviations or changes must be continuously highlighted by the contractor during construction to keep them up to date. This operation must be conducted during the lifecycle of the construction and these documents must be available all the time for inspection.

6. WORKFLOW OVER PROJECT LIFECYCLE

This section shows how the integration in the design will be implemented in the different phases of the project over its lifecycle from the Pre-design phase to Post Occupancy phase.

BIM shall be used to create a framework for the different project participants in order to improve the coordination by creating all the design and construction deliverables as well as the data for installations using BIM models.

BIM models shall be provided throughout the different phases of the project with specific requirements that are different from one phase to the other as follows:

6.1. BIM MANAGEMENT PLAN

In this phase, a BIM Management Plan (BMP) shall be required in order to show how the project will be executed, monitored and controlled regarding the BIM, and also to assign the roles for the model creation before the project initiation.

The BMP shall be concerned with the design and construction activities, and it shall be continuously developed throughout the project lifecycle in order to ensure the timely completion of the project while satisfying other requirements as well.

6.1.1. Design BMP

The BIM manager in the Design Team shall prepare the BMP and submit it to the client for approval. The Design BMP shall mainly cover the following points:

- Plan for achieving the BIM requirements.
- Project schedule aligned with the development of BIM.
- The BIM software used by the team members in the various disciplines.
- Formats of the submitted files.
- Strategy for data transfer across disciplines and model sharing or exchange.
- The Level of Development of the model elements at each project phase.
- Strategy for including updates and changes that may occur during construction in the BIM final model.
- Strategy for energy model.

6.1.2. Construction BMP

The Contractor is required to submit a Construction BMP in which the Contractor shows the strategy for using the BIM technology in the construction activities. The Construction BMP shall mainly cover the following points:

- Strategy used by the Contractor to comply with the BIM requirements in the project.

- The BIM software that shall be used by the Contractor, subcontractors, and fabricators.
- The selected file formats and strategy for software compatibility.
- Strategy followed to ensure that all information from subcontractors is modelled.
- Strategy for digital fabrication.
- Proposed meetings for subcontractors that are integrated in the project schedule.

6.2. PROGRAMMING PHASE

The Programming phase of the project focuses on gathering information and setting the project team. In this phase there is often no BIM model yet, but the team starts analyzing the site's topography and surroundings as well as the climate data (e.g. prevailing wind, solar availability, potential use of natural ventilation, etc.). The data gathered in this phase is considered as an essential input for the design of the project so as to achieve the required goals.

6.3. CONCEPTUAL DESIGN PHASE

In the Conceptual or Pre-Design phase of the project, the owner sets the goals and identifies the needs for the project regarding space, components and the budget, while the Design Team analyzes the project requirements and the needed surrounding environment in order to choose the suitable location for the project. After choosing the location, a complete study shall be performed for the existing conditions and underground utilities, energy analysis, and surveying in addition to selecting the suitable planning tools to be used.

The work-flow in this phase shall require bringing together knowledgeable, diverse and specialized team members by holding several meetings and by setting effective communication pathways.

In the planning of the project execution, both the design and construction teams shall identify the deliverables of their teams as well as the different milestones of the project.

In this phase, several deliverables shall be required which are:

- Existing conditions model.
- Architectural massing model showing site arrangements and building geometries.
- Preliminary energy model.
- BIM Management plan.

6.4. SCHEMATIC DESIGN PHASE

In this phase, an initial design scheme is developed to define the general scope and conceptual design of the project showing the relationships between building components, and allowing the owner to verify that the architect has correctly interpreted the desired functional relationships between various activities.

The Design Team shall begin the design process using a BIM authored data file(s) in addition to using analysis tools, static images, and interactive 3D for better understanding the design concepts.

The Schematic Design Phase requires using a model with a Level of Development (LOD) 100 (Refer to the Level of Development).

In this phase, several deliverables shall be required which are:

- Architectural model
- Civil model
- Initial interference report
- Schematic energy model and analysis
- Projected energy cost report
- Square meter cost estimate
- Program and Space validation

6.5. DETAILED DESIGN PHASE

In this phase, the Design Team continues to build on the schematic design decisions giving a clear and coordinated description of all aspects of the design including Architectural, Mechanical, Plumbing, Electrical and Fire Protection Systems and providing a basis for preparing the construction documents.

At the end of this phase, the client should receive drafted to-scale drawings that show the project's site plan, floor plans, and exterior elevations. The design development drawings shall be used as the basis for the construction drawings and preliminary cost estimates. The Design Development Phase requires a model of a Level of Development (LOD) 200.

In this phase, several deliverables shall be required which are:

- Architectural model
- Civil model
- MEP model(s)
- Structural model
- Detailed energy model
- Specialty consultant model(s)
- Projected energy cost estimate
- Systems and energy cost estimate

6.6. ANALYSIS PHASE

This phase involves the analysis of the developed detailed design so as to check its alignment with the previously set goals, and to check the coordination between the different building systems.

In this phase, several deliverables shall be required which are:

- Structural model analysis
- Mechanical analysis
- Detailed energy analysis
- Discipline interference reports
- Program and space validation
- Design analysis
- Lighting analysis

6.7. DOCUMENTATION PHASE

In this phase, the detailed construction documents will be developed showing the requirements for the construction.

The construction documents consist of Drawings and Specifications that are necessary for the Contractor in order to build the project as conceived by the owner and architect. All information needed to describe the "detailed design" shall be derived from the BIM models provided only, except for the Specifications. Moreover, the documentation of the models shall not occur outside the BIM Authoring software.

The Documentation Phase requires minimum LOD 350 with LOD 400 as needed and agreed upon.

In this phase, several deliverables shall be required which are:

- Architectural model
- Civil model
- MEP model(s)
- Structural model
- Specialty consultant model(s)
- Detailed energy model and analysis
- Pre-Bid interference reports
- Projected energy cost report
- Program and space validation
- Quantity cost estimate
- AutoCAD files

6.8. CONSTRUCTION PHASE

In the Construction phase, design models and/or drawings will be released to the Contractor for reference only, and the Contractor shall develop the model with further details for construction and fabrication with fully annotated drawings for/by the sub-contractors.

The Design and Construction Team shall work concurrently and shall hold coordination meetings to resolve design conflicts or coordination issues. The model(s) shall be updated, when required, by both the Design Team and Contractor in order to incorporate any changes agreed on. Also, as-built mark-ups shall be maintained on site by the Contractor(s) during construction.

In this phase, several deliverables shall be required which are:

- Concurrent As-Built models (Design and Construction teams)
- Discipline-specific coordination models
- Shop drawing models
- Fabrication models
- Scheduling and phasing models
- Collision reports

6.9. PROJECT CLOSE-OUT

At the Project close-out phase, the needed documentation will be collected for the efficient operation of the space or for the study and preparations of future projects. For this process to be completed, the following requirements shall be fulfilled:

- The consultant shall compare the detailed design against the final implementation (As-Built) according to the information provided by the Contractor.
- The Contractor develops the As-built model so that it can be used for the purposes of space management and building maintenance, or in case any modifications are to be made during occupancy.
- Operation and maintenance manuals are to be provided by the Contractor for the purpose of facility (asset) management.

6.10. OPERATIONAL PHASE

The transition between capital delivery phase and the operational phase is a critical process. The following sections provide a framework which the organizations shall follow. These provisions allow organizations and professionals to correctly manage the process of asset information exchange during the operational phase of an asset until demolition and disposal.

A detailed description of operational phase provisions is included in the following Section.

6.11. MODEL COORDINATION IN PROJECT PHASES

It is necessary for the project members to share and coordinate their models in order to resolve any potential conflicts and to avoid costly works and any possible delays at the construction stage. Thus, it is important to follow the recommended coordination flow for the project team throughout the different phases of the project lifecycle phases.

Table 4 lists the various roles of the project members at the different phases of the project, their interaction with the Employer and how the design model is developed and changed across the project life-cycle with a high level of coordination between team members.

For example, the role of the Contractor in the project early stages from the conceptualization to the detailed design phase shall occur in case the project is issued as design-build.

Table 4: Cross-disciplinary model coordination[5]

	Employer	Architect	Consulting Engineers	Contractor
Conceptual Design	Provides the project requirements related to the form, function, cost, and schedule	Designs a model showing the massing concepts and site considerations	Provide feedback on the performance goals and requirements for the building	Provides feedback on initial building cost, schedule, and constructability
Schematic Design	Provides further changes to the design requirements	Refines the design model with new inputs from Employer and consulting engineers	As the design model continues to develop, they provide schematic modeling, analysis, and system iterations	Reviews the design and provides feedback on cost schedule, and constructability

[5] Coordination Plan, retrieved from: *BIM Execution Plan* [Doc]. (2009). Indiana University-University Architect's Office.

Detailed Design	Reviews the design and provides a final approval of the project design and metrics	Continues to refine the design model, introduces consultant models and performs model coordination. Finalizes design model, tender documents and specifications, regulatory code compliance	Create discipline specific design model and analyses Finalize discipline specific design models, tender documents and specifications, code compliance	Creates construction model for simulation, coordination, estimates, and schedule Enhances construction model and performs final estimate and construction schedule, and manages bid estimate
Construction	Monitors construction and gives instructions for changes	Responds to construction RFI's, performs contract administration, and updates the design model with changes	Respond to construction RFI's and update discipline-specific design models, field conditions, and commissioning	Manages construction with subcontractors and suppliers, and makes changes to the design model
As-Built		Verifies the As-built model	Verify the As-built model	Prepares the As-built model
Facility (Asset) Management	Engages the architect and facilities group for handing over	Coordinates the exchange of information through the model to facilities group	Prepare documentation for handover	

Understanding the roles of the various stakeholders throughout the project phases depend to a great extent on the project requirements and conditions. As an example of some projects, the Architect and the Consulting Engineer can be formed as a single entity performing both roles.

7. Implementing Information Exchange in Operational Phase

The main purpose of this section is to set provisions for implementing information exchange and information management during asset operational phase. Applying such provisions shall be the responsibility of individuals/organizations operating and maintaining the asset. These provisions are for the use of individuals/organizations that are accountable to the operation, maintenance and strategic management of assets. Also, they could be used by individuals who are involved in transferring data from the Project Information Model (PIM) to the Asset Information Model (AIM) utilized by the organization and exchanging data throughout the asset's life.

These provisions specify the asset information management process during the operational phase in five ways as follows:

- It specifies how to develop an AIM to be used with existing enterprise systems to support the organizational information requirement (OIR).
- It covers the domain of recording information related to disposal, decommissioning or demolition of assets.
- It specifies data and information required by the AIM and illustrates their relationship to the PIM.
- It specifies the type and nature of data and information to be used in the information exchange and within the AIM.
- It enables revising the AIM as the asset changes, and providing criteria for AIM creation, validation, updating, maintaining, and monitoring.

7.1. Asset Information Management Process

The organization responsible for operating and/or maintaining such asset shall establish, document, implement, and maintain an Information Management Process (IMP) in compliance with the requirements of these provisions.

The IMP shall cover the life cycle of an asset starting from the handover after construction and delivery moving through operation, maintenance, minor and major works, and demolition.

The IMP shall operate in a manner that satisfies the OIR using the AIM and its linkage and inter-relations with other enterprise systems. The OIR generates the Asset Information Requirements (AIR). The AIR shall specify the AIM. The post created project information model PIM contributes to the creation of the AIM. The Asset information process-map is shown in Figure 4.

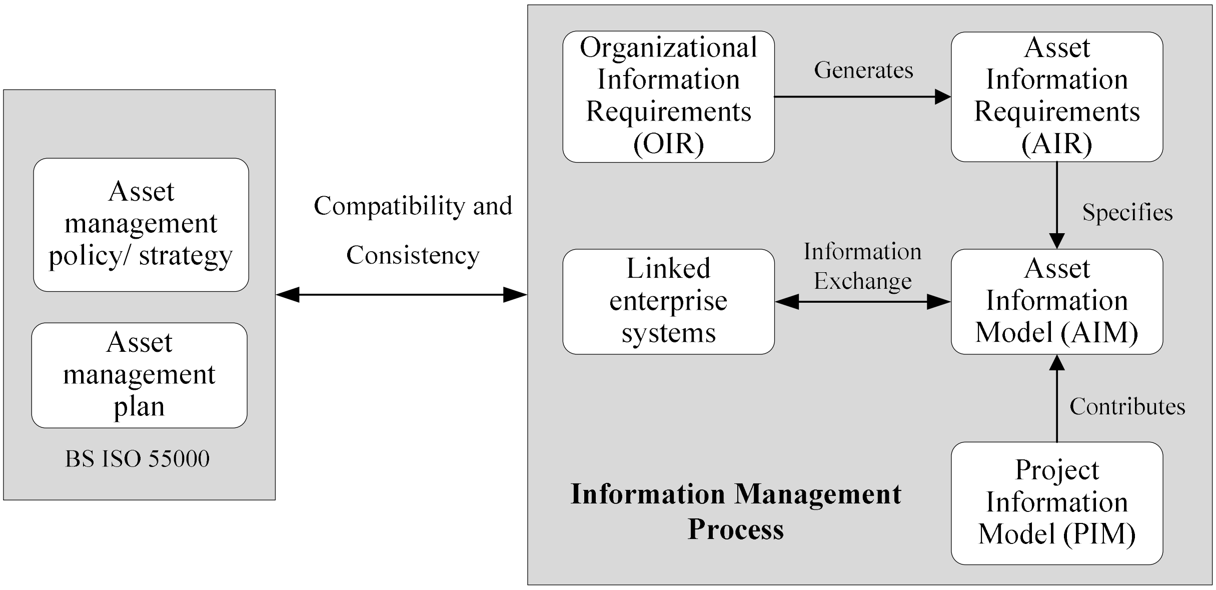


Figure 4: Information Management Process

It is recommended that the asset management policy, strategy, and plan be compatible with the requirements of BS ISO 55000[6].

7.2. REQUIREMENTS FOR ASSET INFORMATION MANAGEMENT PROCESS

During the operation phase, the following requirements should be achieved:

1. Establish an IMP to direct, control, and assure that asset information is managed effectively; the IMP shall be compatible and consistent with the asset management strategies and plans which may be developed through BS ISO 55000.
2. Establish the OIR to be compatible with the asset management activities as identified in the policy, strategy, and plan.
3. Define the AIR that shall be met so as to satisfy the OIR, and also define the information exchanges by which data and information are to be transferred to and from the AIM.
4. Define the mechanisms for checking the AIM validation with respect to creation, receiving, validating, verifying, storing, sharing, archiving, analyzing and reporting.
5. Define data and information exchange interfaces between the AIM and other information systems.
6. Define the mechanisms required for maintaining the AIM and checking its validity and quality so as to reflect the correct picture of the asset.

[6] BS ISO 55000: A guide published by the British Standards Institution (BSI) that defines concepts and terminologies needed for developing a long-term asset management system that incorporates corporate mission, values, objectives, policies, and stakeholder requirements.

7.2.1. Organization Information Requirement (OIR)

The organization shall determine and document the information requirement based on the asset management system in order to meet the organization function. The OIR shall be conveyed to in-house teams or external contractors through a task or project-specific AIR.

Determining the information requirement in an organization is a cyclic, iterative and flexible process which can be updated based on the organization needs and managerial functions. These updates shall be reflected on the AIR and consequently on the AIM. If the information available within the AIM is not suitable or sufficient to satisfy the OIR, then the organization shall amend the relevant AIR to obtain the necessary data and information.

7.2.2. Asset Information Requirement (AIR)

AIR shall be specified, based on OIR, as part of a contract or as an instruction to in-house work teams. In addition, AIR shall specify the required data and information to be captured and fed into the AIM.

7.2.3. Asset Information Model (AIM)

Any information that might be needed by the organization shall be drawn from the AIM. Each asset may have its own AIM or multiple assets may be grouped in one AIM according to organization preference. The AIM shall then serve the organization need during the operational phase. The (AIM) acts as the only source for approved and validated information related to the asset(s).

The AIM model shall include data and geometry including but not limited to ownership, history, specification, design and analysis of the original installation of the asset and any subsequent changes, 3D object-based model(s) of the environment and the location of the asset, spaces, data about performance, operation and maintenance manuals, expenditure, health and safety information. The AIM shall be created using various reliable resources such as:

- Surveys describing information and data of the physical asset.
- Exchange of data and information generated during the capital delivery phase.
- Exchange of data between AIM and enterprise systems.
- Existing PIM, after checking model validation and making sure that the PIM reflects the actual asset conditions.

Upon any update, the occurrence of any trigger related events, or receiving information from external sources, the AIM shall be authorized and accepted based on the information management process and then transferred to the Published part of CDE process (Refer to CDE).

7.3. DATA AND INFORMATION WITHIN AIM

Definitions of data and information within the AIM shall enable organizations to meet their OIR. These definitions shall enable assets of multiple occupants and/or multiple uses to be recorded and analyzed. Besides, AIM users could understand the engineering, commercial or other reasons for the specification or installation of each significant asset.

7.4. PROCESSES FOR MAINTAINING THE AIM

The organization shall maintain the AIM by performing the following activities:

- Assignment of roles and authorities to maintain, retain, retrieve, access to, and archive information and data.
- Data disposal, and unwanted information handling according to organization’s requirement and security and privacy requirement.
- Assurance activities, version control, integrity checks and validation checks, fitness for purpose with respect to AIR.
- Monitoring information exchange, quality of information, continuous update and verification to meet organizational needs.
- Requirements for the storage of information and data following integrity, security, and confidentiality requirements.
- Retrieval, distribution, and availability of information and data to designated parties according to agreed schedules or defined circumstances.
- Requirements for the archival of designated information and data, as in the case of retaining audit records and knowledge preservation.

7.5. DATA EXCHANGE BETWEEN AIM AND ENTERPRISE SYSTEMS

There shall be a two-way link between AIM and enterprise system in order to serve the OIR (see Figure 5). The interface shall send/receive authorized data and information to/from the enterprise systems.

The data and information exchange with the AIM shall be file-based and shall be implemented through exchanging information between the information provider as well as the organization responsible for maintaining the AIM. Information exchanges shall be carried out according to the requirements of the AIR as shown in Figure 5. In addition, the AIR shall define the structure, process, and content of information to be exchanged.

COBie may be the method of information exchange used. However, any procedure may be adopted for other applications which allows capturing and transferring of the information required at each exchange point, as well as facilitating its checking and validation.

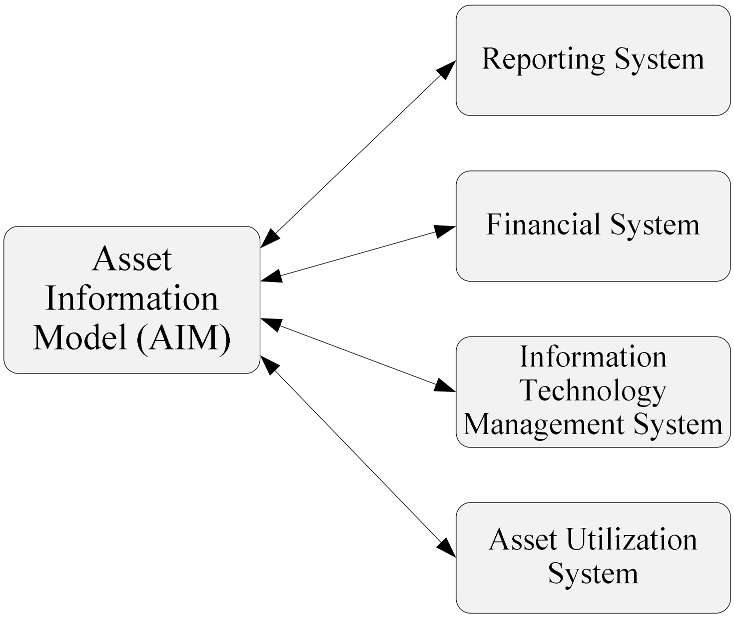


Figure 5: Relations between AIM and other systems

7.6. USE OF THE AIM

Existing/new AIM shall be identified/created at the inception of a trigger-related event and it shall be used as a repository for all the information related to the event works, as a means to access links to the information about the event works, e.g. to/from linked enterprise systems, as the means to receive information from other parties throughout the project stages, up to acceptance of the “as-built” PIM.

7.7. ROLES AND RESPONSIBILITIES

Roles and responsibilities shall be identified in the contract between owner and operator or maintainer, as discussed in the previous chapters.

8. BIM EXECUTION PLAN (BEP)

BIM Execution Plan (BEP) of a project is a document that is developed by the BIM manager before commencing design documentation to ensure that all parties are aware of the benefits of including BIM into the project work-flow.

This section provides guidelines on the content that should be included in the BEP to assist project teams in developing their BEP, and in understanding the purpose of implementing this plan on the projects. Also, it includes guidelines on a structured procedure to be followed and monitored by the project team to create a complete BEP to gain the maximum benefits of implementing BIM on projects.

8.1. BEP PURPOSE

BEP is a document that helps project team to identify and execute the roles BIM plays in various phases of the project. Properly built BEPs help keep project teams on track by outlining the overall vision and providing important details for the project teams to follow throughout the project. BEP should be developed at early stages of the project and monitored and updated throughout the project lifecycle.

BEP defines the scope of implementing BIM on the project, the information exchange process between parties, and the infrastructure needed to support the BIM implementation.

By developing BEP, project teams can achieve the following benefits:

- Enable a clear communication and understanding of the strategic goal for BIM implementation by all stakeholders.
- Help project team to collaborate on various phases of the project and prevent unnecessary tasks to gain the maximum benefit of executing BIM according to the needs of each project.
- Maintain the schedule of deliverables throughout the project to achieve the project benefits and reduce possible delays which ensures finishing on time and budget; because of BEPs focus and work on the most important details only.
- Add transparency to the process, as it makes the shared data available for all teams and stakeholders; it makes sure that all BIM shared data can be directly accessed by stakeholders and can be updated frequently.
- Describe the additional resources and training needed to implement BIM on project successfully.

8.2. BEP CONTENTS

The BIM execution plan should include the following categories; information for each category can vary according to the need of the project:

- ***Overview information:*** The reason for developing the project execution plan.
- ***Project Information:*** The critical information about the project such as project key facts, organizational chart, description, scope, phases, and critical schedule dates.
- ***Key Project Contacts:*** The contact information for the project personnel as reference information.
- ***Project Goals/BIM Objectives:*** The strategic goal, uses, and the scope of BIM in the project. It also includes information about the level of details needed, programming, and software platforms.
- ***Responsibility Matrix:*** The definition of the roles and responsibilities of the coordinator of the BIM execution process as well as the required staff to successfully develop and implement the plan through various stages of the project.
- ***BIM Information Exchange:*** The elements of the model and defines the level of details required to implement the BIM use in the project.
- ***Collaboration Procedures:*** The model management procedures such as file structure and permissions, and the schedule and agendas of the regular meetings.
- ***Model Quality Control Procedures:*** The procedures to ensure that the project participants successfully meet the defined requirements; these procedures should be monitored throughout the project stages.
- ***Technology Infrastructure Needs:*** The network infrastructure needed for the plan execution such as the hardware and software needed to successfully implement BIM in projects.
- ***Model Structure:*** The methods to ensure the model accuracy such as the file naming structure, coordinate system, measurement units, and how the information will be shared.
- ***Project Deliverables and Delivery Strategies:*** The project deliverables required by the owner and should also include the delivery strategy that will be used in the project.

8.3. BEP PROCEDURE

A four-step procedure is recommended to develop a detailed BEP. The procedures are designed to provide a structured process to be followed by owners, program managers, and early project participants to develop detailed, consistent plans for projects.

The four steps consist of identifying the BIM goals and uses on a project, designing the BIM execution process, developing information exchanges, and identifying the supporting infrastructure to successfully implement the plan. The four-step procedure is illustrated in Figure 6, and is discussed in details in this chapter.

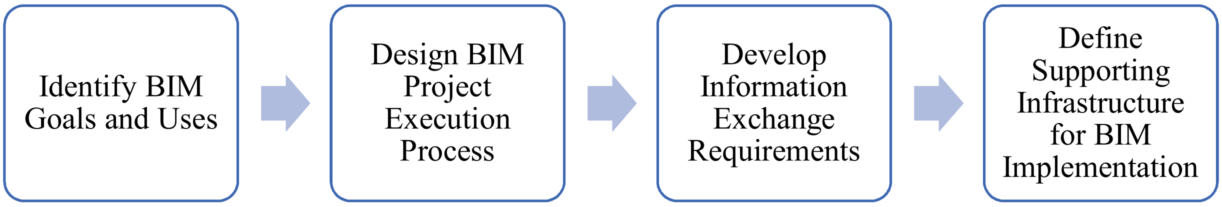


Figure 6: BIM Execution Plan Procedures

8.3.1. Identify BIM Goals and Uses

The first step of the four-step procedure presents the planning process in the BEP. It focuses on clearly defining the overall goals for the BIM implementation to express the potential value of BIM use on the project.

Identify BIM Goals:

It is important to define goals that will provide incentive for implementing BIM on the project. These goals should be measurable, specific to the project, and set from both a project and company perspectives so as to improve the success in the different project phases such as the planning, design, and construction, as well as the operational phase of the facility.

BIM goals could include items such as achieving higher productivity, reducing the schedule duration, reducing the cost of change orders, or facilitating the access to operational data for the facility. Goals may also advance the capabilities of the project team as the owner may need to facilitate information exchanges between design, construction and operations, or to increase the overall quality of the project. Quality goals include targeting more energy efficient design through energy modelling and analysis, or higher quality installed designs through detailed 3D coordination of systems.

Identify BIM uses:

Once the goals are defined, the project teams should identify the tasks they would like to perform using BIM. The process of identifying BIM uses should focus on the desired outcome of the project, therefore the project teams should identify the BIM uses associated with each phase of the project. It is important that each team considers all the potential uses and their relation with the project goals first, and then identify the responsible party for each BIM use. Also, each team should rate the capabilities of the involved parties to achieve the set potential uses.

For example, the organization needs to determine whether it has enough resources to implement this use, and whether the team has the know-how and enough experience to implement this use successfully. Then, the team should define the values and risks associated with each use, and finally, the team should determine whether or not to implement each BIM use.

8.3.2. Design the BIM Execution Process

After identifying each BIM use, the project teams should design and understand the implementation process for each use and for the whole project. Therefore, the teams should follow specific and structured procedures to successfully design the BIM project execution process.

In this step, the teams should develop process maps. The use of these process mapping techniques allows teams to design the BIM execution process effectively. This allows enables teamsto understand the overall BIM process, to define the various processes to be developed for each BIM use, and to identify the information exchange that will be shared between parties. These process maps serve as the basis for other implementation topics such as: Contract structure, BIM deliverables, and information technology infrastructure.

Level 1: Overview Map

The overview map shows the relationship between the BIM uses which will be used on the project, and the high-level information exchange that will be shared throughout the lifecycle of the project. Preparing the overview map can be done by the project team as follows:

- Identify the BIM uses for the project.
- Start the mapping process by adding the BIM uses that will be implemented in the project into the overview map.
- Order the uses according to the project sequence by identifying the phase for each BIM use and provide the team with the implementation sequence.
- Identify the responsible parties for each process by considering the team member which will be the best suited to complete the task. The identified party will be responsible for defining the process; the inputs and outputs, the process name, the name of the responsible party, the project phase in which it will be implemented.
- Determine the information exchanges required for each BIM use whether internal in a specific process or shared between processes and responsible parties. These exchanges could be done by sharing data file or the entry of information into a common database. All this information should be detailed in the level 2 maps.

Level 2: Detailed BIM Use Map

After developing the overview map, a detailed process map should be created for each BIM use. These process maps need to be customized according to each project because each project is unique. Accordingly, processes may need to be tailored to integrate specific supports for each project in order to successfully achieve the project and organizational goals.

A detailed BIM process map includes three categories as follows:

1. ***Reference Information:*** It includes the resources of information required to implement each BIM use.
2. ***The Process:*** The logical sequence of activities and the relationships between the BIM uses.
3. ***Information Exchange:*** The deliverables from one process which may be required as input for another process.

After creating the BIM overview map, the core of the BIM use shall be decomposed into a set of processes in a sequential order, then the project team shall define the dependency between these processes, by identifying the predecessor and successors of each process, the detailed process map shall be developed.

The detailed process map shall include the information exchanges for each process, responsible party and the resources of the information needed to implement BIM. A gateway can be used in the detailed process map to represent decisions, and quality control checks required before completion of BIM tasks.

Finally, the project team shall review and document these maps for future use in other projects; they may also use it to compare the actual process and the planned process.

8.3.3. Developing Information Exchange

The project team shall define the information exchanges between project processes to successfully implement BIM on projects, so the team should understand the information necessary for each BIM use to be able to define the input and output for every process and the deliverable of one process that could be used as input for another process.

Each item in an Information Exchange should have a party responsible for authoring the information. This party should complete the task with the highest level of efficiency and the team may use information exchange worksheet to complete this task.

An example for information exchange work-sheet is available in the appendices.

8.3.4. Define the Supporting Infrastructure for BIM Implementation

The final step in the four-step procedure to create BIM project execution plan is to define the supporting infrastructure required to implement BIM effectively, there are specific categories to support the BIM project execution process such as:

1. Project Information
2. Project Schedule
3. Terminologies/ Definitions
4. Key Project Contacts
5. BIM goals and Uses
6. Roles and responsibilities

7. BIM Process design
8. Collaboration Procedures
9. Electronic Communication
10. Project Deliverables
11. Quality Control
12. Model Naming

Information for each category can vary significantly according to the project needs; therefore it should be tailored to the project team for every project.

Project Information:

The information included in this section must be the most important ones only that will be reviewed throughout the life cycle of the project and can help others to understand it. This section may include the following items:

- Project owner
- Project name
- Project location and address
- Contract type and delivery method
- Brief project description
- Project numbers
- Project schedule/milestone
- Additional information (e.g. special project characteristics, method of payment, unique owner requirements)

Table 5 provides a sample of projects information which can be edited according to the project requirements and conditions.

Table 5: Sample of Project Information

Item	Description
Project name	
Project owner	
Project location and address	
Project numbers	
Brief project description	
Contract type	

Project Schedule

It includes BIM milestones, start and finish of each project phase, and the stakeholder responsible for each phase.

Table 6 provides a sample of the projects schedule-related information which can be edited according to the project requirements and conditions.

Table 6: Sample of Project Schedule-Related Information

Project Phase	Estimated Start	Estimated End	Responsible Stakeholders

Terminologies/Definitions:

This differs from project to another according to the terms that need to be defined and clarified.

e.g. BIM: Building information modeling, a digital representation of facilities function and characteristics.

Key Project Contacts:

Each party should assign at least one person as a representative to share his/her contact information among project stakeholders.

Table 7 provides an example of how to include key contact in BEP where BIM contact for each organization involved in the project should be listed below. Such information can be edited by addition or deduction according to the project requirements and conditions.

Table 7: Sample of Key Project Contacts Documentation

Discipline	Role	Organization	Name	Email	Phone	Time zone

BIM Goals:

In each project phase, state the BIM goals and BIM uses as per Tables 8 and 9 respectively. After defining BIM Goals, BIM uses which will be implemented are selected from the following table, by marking in front of each use. BIM uses ranking worksheet shall be produced according to project requirements and stakeholders.

Table 8: Sample of BIM Goals

Project Phase	Goal Description	BIM Uses

Table 9: Sample of BIM Uses[7]

X	Plan	X	Design	X	Construct	X	Operate
	Programming		Design Authoring		Site Utilization Planning		Building Maintenance Scheduling
	Site Analysis (3D Field Positioning & QC)		Design Reviews / Model Reviews		Construction System Design		Building System Analysis
	3D Safety and Logistics Planning		3D Coordination / Clash Detection		3D Coordination / Clash Detection		Asset Management
			Structural Analysis		Digital Fabrication		Space Management / Tracking
			Lighting Analysis		3D Control and Planning		Disaster Planning
			Energy Analysis		Record Modeling		Record Modeling
			Mechanical Analysis				
			Other Eng. Analysis				
			Sustainability (LEED) Evaluation				
			Code Validation				
	Phase Planning (4D Modeling)		Phase Planning (4D Modeling)		Phase Planning (4D Modeling)		Phase Planning (4D Modeling)
	5D Cost Estimation		5D Cost Estimation		5D Cost Estimation		5D Cost Estimation
	Existing Conditions Modeling		Existing Conditions Modeling		Existing Conditions Modeling		Existing Conditions Modeling
Legend: X = Confirmed Use; O = Potential Use							

Roles and Responsibilities:

For each BIM use, roles and responsibilities must be defined, which organization will implement it and the number of staff required to perform each use also the lead contact. Such roles and responsibilities are completed throughout the project lifecycle depending on which phase the project has reached and the available details and information.

Table 10: Sample of Organizations Roles and Responsibilities

BIM Use	Responsible person/organization	Number of Staff involved	Content	Lead contact

[7] BIM Uses, retrieved from: *BIM Project Execution Plan for Architects, Engineers, and Contractors* [Doc]. (2018). University of South Florida.

BIM Process Design:

Involves mapping the processes of BIM uses where it gives specific information exchanges for each activity, it includes an overview map of BIM uses [Level 1], detailed map for each use, and elements on each map [Level 2].

Collaboration procedures: Meetings

1. Project Meetings:

In this sub-section meetings are coordinated according to Table 11 where the type of meeting (e.g.: owner updates), meeting location, participants and project phase are stated.

Table 11: Sample of Project Meetings

Meeting Type	Phase	Frequency	Participants	Location

2. BIM Coordination Meetings:

In this sub-section meetings related to BIM activities (ex.: BEP coordination) are listed in the table below.

Table 12: Sample of BIM Coordination Meetings

Meeting Type	Phase	Frequency	Participants	Location

3. BIM Coordination schedule:

The deliverables for each project phase should be stated together with the deadline for each deliverable. A sample for the schedule format that can be used is shown in Table 13 and can be modified according to the project requirements and condition.

Table 13: Sample of BIM Coordination Schedule

Project Phase	
Deliverable	
Date	

Electronic communication:

1. Software Requirement:

Information about the software used for each BIM use and each discipline should be listed as shown in Table 14.

Table 14: Sample of Software Requirement Schedule

BIM use	Discipline	Software used	Version

2. Information Exchange Schedule:

Stating schedule for the exchange of information between project teams and it should be analyzed in project's early stages to avoid any errors or data loss throughout the project life cycle. Information that shall be included can be stated as per Table 15.

Table 15: Sample of Schedule for Documenting Information Exchange

Information Exchange	File Sender	File Receiver	One-Time or Frequency	Due Date or Start Date
Authoring – 3D Coordination	Architectural / Structural	FTP Post – Coordination Lead	Weekly	[Date]

3. File Storage:

An electronic storage location needs to be identified to provide a workspace for regular transferring of files. This location should store both archive and current files. After the BIM kick-off meeting is held, matrix shall be completed as described in the sample provided in Table 16 which gives an example of the information that needs to be filled.

Table 16: Sample of File Storage Documentation

File Location	File Path /Directory	File Type	Password Protect	File Maintainer	Updated
FTP site ftp://ftp.***.***/***	Root Project Folder /Arch /Mech	.rvt	Yes/no ********	State the name	Weekly

Project Deliverables:

In the following tables, the deliverables for design and construction that are required in the contract must be stated. In case extra deliverables are required, team members may share or state them below.

1. Design Deliverables:

Table 17: Sample of Schedule for Documenting Design Deliverables

Phase	Submission Requirements	Format
Pre-design		
Schematic Design		
Design Development		
Construction Documents		
100% Construction Documents		
Construction		
Record Documents		

2. Construction Deliverables:

Table 18: Sample of Schedule for Documenting Construction Deliverables

Type	Submission Requirements	Format
Coordination Models – MEP, Structural, Exterior Skin		
As-Built Model - Final		

Quality Control:

Quality Control (QC) of deliverables must be accomplished at each major BIM activity such as design reviews, coordination meetings or milestones. Each BIM model coordinator in all BIM teams of all disciplines shall check the model quality, level of detail, accuracy, and updates before exchanging information with project parties and ensure that all deliverables are applicable and comply with this handbook.

Quality checks are stated in Table 19.

Table 19: Sample of Quality Checks

Checks	Definition	Responsible Party	Software Program(s)	Frequency
Visual Check	Ensure there are no unintended model components and that the design intent has been followed.			
Interference Check	Detect programs in the model where there are any clashes between building components including hard and soft clashes.			
Standards Check	Ensure that the BIM modeling standards have been followed.			
Element Validation	Ensure that the dataset has no undefined or incorrectly defined elements			

QC checks:

Hierarchy of Systems Coordination:

In case of clash or interference occurrence with other system/model, Architect/Engineer (A/E) shall agree on a hierarchy resolution sequence for resolutions with the agreement of project team. For example, the list may be stated as below:

1. Structure.
2. Architecture. Etc.

Model:

1. Model File Naming:

The project team shall define the naming conventions for the models in accordance with the following format:

Table 20: Sample of Model File Naming

Format	[Project Number][-][Discipline Code][-][Software Version Designator][-][Reference Date]
Example	123456-A-R14-140627.RVT

The software version designator may be in the following list where team members shall agree upon the used software:

Table 21: Sample of Documenting the Software Version

R13	Autodesk Revit 2013	**R14**	Autodesk Revit 2014
R15	Autodesk Revit 2015	**R16**	Autodesk Revit 2016

The discipline code for both model and sheet files are listed in Table 22:

Table 22: Sample for Documenting the Discipline Codes

Discipline	Designator	Description	Discipline	Designator	Description
General	**G-**	**All General**	**Landscape**	**L-**	**All Landscape**
	GI	General Information		LD	Landscape Demolition
	GC	General Contract		LG	Landscape Grading
	GR	General Resource		LI	Landscape Irrigation
Survey/ Mapping	**V-**	**All Survey/Mapping**		LL	Landscape Lighting
	VA	Aerial Survey		LP	Landscape Planting
	VF	Field Survey		LR	Landscape Relocation
	VH	Hydrographic Survey		LS	Landscape Site
	VI	Digital Survey	**Structural**	**S-**	**All Structural**
	VU	Combined Utilities		SD	Structural Demolition
Geotechnical Civil	**B-**	**All Geotechnical**		SS	Structural Site
	C-	**All Civil**		SB	Structural Substructure
	CB	Civil Beach Renourishment		SF	Structural Framing
	CD	Civil Demolition		SR	Structural Reinforcement
	CE	Civil Ecosystem Restoration		ST	Superstructure
	CF	Civil Flood Control		SC	Structural Components
Geotechnical	CG	Civil Grading	**Architectural**	**A-**	**All Architectural**
Civil	CI	Civil Improvements		AS	Architectural Site
	CN	Civil Navigation		AD	Architectural Demolition
	CO	Civil Operation and Maintenance		AE	Architectural Elements
	CP	Civil Paving		AI	Architectural

					Interiors
	CH	Civil Shore Protection		AF	Architectural Finishes
	CR	Civil Recreation		AG	Architectural Graphics
	CS	Civil Site	**Interiors**	**I-**	**All Interiors**
	CX	Civil Security		ID	Interior Demolition
	CT	Civil Transportation		IN	Interior Design
	CU	Civil Utilities		IF	Interior Furnishings
				IG	Interior Graphics
			Fire Protection	**F-**	**All Fire Protection**
				FA	Fire Detection and Alarm
				FX	Fire Suppression
			Utilities	**U-**	**All Other Utilities**
			Civil Works	**W-**	

Discipline	Designator	Description	Discipline	Designator	Description
Equipment	**Q-**	**All Equipment**	Mechanical	MH	Mechanical HVAC
	QA	Athletic Equipment		MP	Mechanical Piping
	QB	Bank Equipment		MI	Mechanical Instrumentation
	QC	Dry Cleaning Equipment		MY	Mechanical Hydraulic Systems
	QD	Detention Equipment	**Electrical**	**E-**	**All Electrical**
	QE	Educational Equipment		EA	Electrical Airfield Lighting and Navaids
	QF	Food Service Equipment		ES	Electrical Site
	QH	Hospital Equipment		EC	Electrical Cathodic Protection
	QL	Laboratory Equipment		EG	Electrical Grounding
	QM	Maintenance Equipment		ED	Electrical Demolition
	QP	Parking Lot Equipment		EP	Electrical Interior Power
	QR	Retail Equipment		EL	Electrical Interior Lighting
	QS	Site Equipment		EI	Electrical Instrumentation
	QT	Theatrical Equipment		EY	Electrical Interior Auxiliary Systems
	QV	Video/Photographic Equipment		ET	Electrical Telecommunications
	QY	Security Equipment	**Telecommunications**	**T-**	**All Telecommunications**
Plumbing	**P-**	**All Plumbing**		TD	Telecommunications Demolition
	PS	Plumbing Site		TA	Audio Visual
	PD	Plumbing Demolition		TC	Clock and Program
	PP	Plumbing Piping		TI	Intercom
	PQ	Plumbing Equipment		TM	Monitoring
	PL	Plumbing		TN	Data Networks
Process	**D-**	**All Process**		TS	SCADA
	DS	Process Site		TT	Telephone
	DD	Process Demolition		TY	Security
	DL	Process Liquids	**Resource**	**R-**	**All Resource**
	DG	Process Gases		RC	Resource Civil
	DP	Process Piping		RS	Resource Structural

	DQ	Process Equipment		RA	Resource Architectural
	DE	Process Electrical		RM	Resource Mechanical
	DI	Process Instrumentation		RE	Resource Electrical
Mechanical	**M-**	**All Mechanical**	**Other Disciplines**	**X**	
	MS	Mechanical Site	**Contractor/Shop Dwg**	**Z**	
	MD	Mechanical Demolition	**Operations**	**O**	

2. Sheet Naming View:

Naming conventions for sheet views generated in the model shall be in accordance with the format illustrated in Table 23:

Table 23: Sample of Sheet Naming Conventions

Format	[Project Number] Space [Discipline Designator] Space [Sheet Sequence Number] Space [-] Space [Sheet Title]
Example	11456 A0101 – First Floor Plan

The sheet sequence number shall consist of four numerical characters utilizing the list shown in Table 24 or as agreed by the project team:

Table 24: Sample of Sheet Sequence Numbering

0000	General (Symbols, Legends, Notes)	**0500**	Details
0100	Plans (including Reflected Ceiling Plans)	**0600**	Schedules and Diagrams
0200	Elevations	**0700**	Elevators and Stairs (plans, details, sections) or User Defined (non-architecture)
0300	Sections	**0800**	Enlarged Restroom Plans and Interior Elevations or User Defined (non-architecture)
0400	Enlarged Views (plans, sections, elevations)	**0900**	Interior Details, Partition Types, Window Types

The files generated by the CM and trade contractors during the coordination process should follow naming conventions similar to those described in the model file naming and the sheet file naming sections.

GLOSSARY

- ***Asset**:* Item, thing, or entity that has potential or actual value to an organization.
- ***Asset information model (AIM)**:* Data and information that relate to assets to a level required to support an organization's asset management system.
- ***Asset information requirements (AIR):*** Data and information requirements of the organization in relation to the asset(s) for which it is responsible.
- ***Asset management**:* The coordinated activity of an organization to realize value from assets
- ***Project information model (PIM)**:* Information model developed during the design and construction phase of a project.
- ***Information Management Process (IMP):*** Process to manage information related to the operational phase of an asset.