



NATSPEC National BIM Guide

Appendix C

BIM Use & Enabler Descriptions

October 2022



AS ISO 19650 Aligned

NATSPEC//
Construction
Information

NATSPEC National BIM Guide Appendix C – BIM Use & Enabler Descriptions

October 2022

Publisher: Construction Information Systems Limited ABN 20 117 574 606

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Acknowledgements

NATSPEC thanks the numerous individuals and organisations who contributed to the development of this document through material they provided and/or comments they made on drafts.

Comments

NATSPEC welcomes comments or suggestions for improvements to the *NATSPEC National BIM Guide* and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities.

NATSPEC also encourages users to share their experiences of applying it on projects with us.

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NATSPEC BIM Position Statement

NATSPEC believes that digital information, including 3D Modelling and Building Information Modelling will provide improved methods of design, construction and communication for the Australian construction industry. Further, NATSPEC supports open global systems. This will result in improved efficiency and quality. Visit the NATSPEC BIM Portal bim.natspec.org

TABLE OF CONTENTS

1	Introduction	1
1.1	Purpose	1
1.2	Scope	1
1.3	BIM use selection in the project planning process	1
1.4	BIM uses included in the Appendix	1
1.5	BIM use selection tools	3
2	BIM use descriptions	4
2.1	Existing conditions modelling	4
2.2	Cost management (5D modelling)	6
2.3	Phase planning (4D modelling)	8
2.4	Spatial programming	10
2.5	Site analysis	12
2.6	Design authoring	13
2.7	Design review	14
2.8	Structural analysis	16
2.9	Lighting analysis	17
2.10	Engineering analysis (mechanical, other)	18
2.11	Energy analysis	20
2.12	Sustainability analysis	21
2.13	Code validation	22
2.14	3D coordination	23
2.15	Construction documentation	24
2.16	Site utilisation planning	25
2.17	Construction system design (virtual mock-up)	26
2.18	Digital fabrication	27
2.19	3D control and planning (digital layout)	29
2.20	Record modelling	30
2.21	Digital twins	31
2.22	Asset management	34
2.23	Building maintenance management	36
2.24	Building systems performance analysis	37
2.25	Space management and tracking	38
2.26	Emergency response planning	39

3	BIM enablers/Enabled by BIM	40
3.1	Core enablers	41
3.2	ICT Enablers	41
3.3	Cultural enablers	42
3.4	Input enablers	43
3.5	Outputs enabled by BIM.....	44
4	References.....	46
5	Annex 1: Mapping between ABAF and NATSPEC BIM uses	47

Formatting conventions

In addition to the text formatting conventions used for Section headings, Clause titles, Table headings, etc, the Table below shows other text formats used in this document:

Text type	Example	Indicates
Italicised text	<i>Project BIM Brief</i>	Name of a specific document or standard.
Violet text	Data Reuse	Cross reference to a Section, Clause, Table, Diagram, etc
Blue text on blue fill	See the ABAB AIR Guide	References to relevant sources of information.
Blue underlined text	www.natspec.com.au	Hyperlink/weblink

In this document:

- ‘National BIM Guide’ or ‘Guide’ means the *NATSPEC National BIM Guide*.
- ‘Appendices’ means the Appendices of the *NATSPEC National BIM Guide*.
- ‘Appendix’ means this Appendix: *NATSPEC National BIM Guide Appendix C – BIM Use & Enabler Descriptions*.
- Numbering of Tables, Diagrams and Figures is derived from the Clause in which they appear.

1 INTRODUCTION

1.1 Purpose

This Appendix provides descriptions of BIM uses to assist clients, consultants, contractors and stakeholders to clarify their BIM requirements for projects in a nationally consistent manner.

It also includes brief descriptions of BIM enablers, i.e. technologies and processes that enhance BIM uses by providing data inputs to the modelling process or that leverage data from models. The BIM enabler descriptions include references to the BIM uses they complement.

1.2 Scope

The BIM uses and enablers described in the Appendix are primarily for building construction projects. However, many of the principles could be readily applied to horizontal infrastructure projects.

1.3 BIM use selection in the project planning process

Before selecting BIM uses, the appointing party should first clearly define their project goals and information requirements. Defining the overall goals for BIM implementation on a project from the start provides a framework for following decision-making and priority setting. Goals should be based on measurable performance criteria, e.g. reducing project duration, reducing reworks, improving



quality or safety. However, goals may also relate to aspirations beyond the project, e.g. as a means of extending the project team's BIM capabilities, or as a pilot for testing new working arrangements with BIM. Document requirements in the exchange information requirements (EIR) document.

The prospective lead appointed party may propose additional BIM uses or refinements to the BIM uses included in the invitation to tender they consider will benefit the project.

All of the above is an essential prerequisite for planning the BIM project execution process. The Pennsylvania State University *BIM Project Execution Planning Guide Version 3.0 (Penn State BPEPG)* describes a structured five-step procedure for developing a BIM Execution Plan (BEP) including a method for identifying appropriate model uses for a project. It includes supporting resources such as worksheets and templates.

1.4 BIM uses included in the Appendix

This Appendix has been designed to complement the *Penn State BPEPG*. Its BIM use descriptions are similar, and the information about each builds on that found in *Penn State BPEPG Appendices B and D*.

1.4.1 BIM uses across project phases

BIM can be used for many purposes across the project life cycle. The BIM use descriptions in this Appendix are listed roughly in the order they can be applied over the project life cycle. [Table 1.4.1](#) shows to which phases they generally apply.

NOTE: This is in reverse order to that found in the *Penn State BPEPG Appendices*.

Table 1.4.1 BIM uses across project phases

Ref	BIM use	Planning	Design	Construction	Operation
2.1	Existing conditions modelling				
2.2	Cost management (5D modelling)				
2.3	Phase planning (4D modelling)				
2.4	Spatial programming				
2.5	Site analysis				
2.6	Design authoring				
2.7	Design review				
2.8	Structural analysis				
2.9	Lighting analysis				
2.10	Engineering analysis (Mechanical, other)				
2.11	Energy analysis				
2.12	Sustainability analysis				
2.13	Code validation				
2.14	3D coordination				
2.15	Construction documentation				
2.16	Site utilisation planning				
2.17	Construction system design (virtual mock-up)				
2.18	Digital fabrication				
2.19	3D control and planning (digital layout)				
2.20	Record modelling				
2.21	Digital twins				
2.22	Asset management				
2.23	Building maintenance management				
2.24	Building system performance analysis				
2.25	Space management and tracking				
2.26	Emergency response planning				

1.4.2 About the BIM use descriptions

The BIM uses in this Appendix largely follow those described in *Appendix B* of the *Penn State BIM Project Execution Planning Guide Version 3 (Penn State BPEPG)*. Rather than duplicate all content, only the description is included. Other items such as the BIM use's potential value and resources required are not, but other items such as requirements definition have been added. It is recommended that the *Penn State BPEPG* is read in tandem with this Appendix – together they form a comprehensive resource.

As the categorization of BIM uses is quite broad, some aspects inevitably overlap. Likewise, many BIM uses can represent parts of a continuum as models and data are progressively developed over the project life cycle, e.g. from design models to As-Built models to models for asset management. As a result, the scope of BIM uses selected needs to be further defined to reflect project-specific needs.

1.4.3 ABAF BIM Competency Framework for Australian Universities BIM use descriptions

This framework – developed by the Australian BIM Academic Forum (ABAF) – identifies competencies, in the form of intended learning outcomes, systematically mapped against a list of BIM uses.

There is significant overlap between the BIM uses described in this appendix and in the Framework because both have been influenced by the *Penn State BIM Project Execution Planning Guide*. **Annex 1** of this appendix includes a table that shows the relationship between the BIM uses described in each document.

Reference: *BIM Competency Framework for Australian Universities Version 1* Hosseini, M.R., Joske, W., Oraee, M Deakin University 2022. Available from <https://nla.gov.au/nla.obj-3024188324/view>

1.5 BIM use selection tools

In addition to the method described in the *Penn State BPEPG*, the tools described below can assist the selection of the most appropriate BIM uses to support project goals and the definition of the information delivery process that needs to be documented in the BIM Execution Plan.

1.5.1 SBEnrc BIM Value Tool

The Sustainable Built Environment National Research Centre (SBEnrc) BIM Value Tool can assist the selection of BIM uses which offer the most potential value for a project. See <https://bim.natspec.org/tools/bim-value-tool>



1.5.2 Scottish Futures Trust ROI BIM Tool

The Return on Investment (ROI) BIM tool estimates the benefits and the level of return that the adoption of BIM will bring to a project. The tool enables the **appointing party** to assess the benefits of adopting BIM against a predefined list of benefits. The tool provides both a quantitative and qualitative assessment that is reported on an easy-to-understand dashboard. See <https://bimroi.scottishfuturestrust.org.uk/>

2 BIM USE DESCRIPTIONS

NOTE: Reference is made to defining requirements for the following BIM uses in the exchange information requirements (EIR).

They can also be defined in the Project BIM Brief if this document is being used instead.

2.1 Existing conditions modelling

Description

A process in which a project team develops a 3D model of the existing conditions for a site, facilities on a site, or a specific area within a facility. This model can be developed using various methods, including laser scanning and conventional surveying techniques, depending on the information required and what is most suitable. Once the model is constructed it can be queried for information, whether it is for new construction, refurbishment, or a modernisation project.

Refer to Penn State BPEPG [Appendix B-21](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.2](#)

Commentary

- Clearly documenting existing structures and functions aids understanding of what is changing from the current state to the proposed design. It assists the planning of associated capital works and determining their costs.
- Uses of the existing conditions model include:
 - Identifying and quantifying the risks to an organisation associated with the asset's current condition, and determining and demonstrating the level of risk reduction provided by the proposed design.
 - Clearly developing, defining and communicating the investment justification case (business case) for proposed changes including return on investment.
 - Determining the optimum scope of works and capital investment.
 - Enabling remote progress measurement by means of camera-carrying drones and photogrammetry. This includes being able to quantify changes in volumes of excavations, filled areas and stockpiles.
 - Providing data for potentially enabling autonomous vehicles to carry out specific tasks such as digging. In this instance, the information required to specify the location and depth of an excavation would need to be defined.

Requirements definition

Consider the following items when defining EIR:

- Extent of area to be modelled, e.g.:
 - within property boundaries
 - site plus immediately adjoining buildings and features
 - a defined precinct beyond the site
- Model inclusions/exclusions, e.g.:
 - Existing structures, finishes, vegetation
 - Existing utilities: surface and/or subsurface
 - Subsurface features
 - Geotechnical conditions

- Level of model detail required, e.g.:
 - block forms only
 - detailed modelling
 - photorealistic modelling
- Model accuracy/tolerances/quality:
 - AS 5488-2013 *Classification of Subsurface Utility Information (SUI)* defines four quality levels for location and attribute information that can be used to specify the quality of modelling requirements for subsurface utilities. In some instances the accuracy levels in the standard will not be sufficient, e.g. accuracies of $\pm 10\text{mm}$ are required for z values for the grade of gravity sewerage pipes. The *SEQ Water Supply and Sewerage Design & Construction Code Asset Information Specification* addresses this in clause 2.1 Survey Tolerance and Confidence Levels.
- Surveying and modelling methods, e.g.:
 - Create 3D topographical surface from survey information
 - Integrate laser-scanned data about existing buildings and features
 - Integrate photogrammetry data about existing buildings and features
 - Integrate LIDAR data about subsurface features and utilities
- Proposed deliverables, e.g.:
 - 3D point cloud of existing buildings
 - Surface model of existing geometric elements
 - Parametric model; geometry only
 - Parametric model, including specified data about existing building components

Modelling requirements

- Incorporate a reference point defined relative to true north and AHD.
- Align site with GIS information, northing, easting, etc.
- Subdivide large sites into individual building sites, development phases, etc, as required to suit project requirements.

References

- *Architectural Survey Using 3D Imaging Data – Performance Specification USIBD 2014*
- *ASTM E57 3D file format* (Refer ASTM E2807)
- *BIM for Heritage: Developing a Historic Building Information Model* Historic England 2017
- *BIM Survey Specification and Reference Guide* Plowman Craven 2015
- *Client Guide to 3D Scanning and Data Capture* BIM Task Group 2013
- *COBIM Series 2: Modeling of the Starting Situation*
- *GSA BIM Guide Series: 03 – 3D Imaging*
- *Guidance for Implementing Data Capture and Modelling Techniques for Managing Heritage Assets: Vision for Heritage BIM (HBIM) – Research Report (Project 2.72)* SBEnrc 2021
- *National Guidelines for Digital Modelling* clause 3.1.1
- *SEQ Water Supply and Sewerage Design & Construction Code Asset Information Specification* South-East Queensland Water 2020. <http://www.seqcode.com.au/standards/>

2.2 Cost management (5D modelling)

This BIM use should be read in conjunction with the [ANZIQS BIM Best Practice Guidelines](#)

Description

A process in which BIM can be used to assist the generation of accurate quantity take-offs and cost estimates throughout the life cycle of a project, typically undertaken by a quantity surveyor or pre-contract estimator. This process enables the project team see the cost effects of their changes, during all phases of the project, which can help curb excessive budget overruns due to project modifications. This process can continue into post contract works where contractors and quantity surveyors (QS) use the model to support material ordering, contract variation costing, payment claim assessments and snagging/defects tracking.

“BIM does not resolve quantity take-off related issues exhaustively and not all quantities needed during a project can be taken off from a BIM. The professional skill of a Quantity Surveyor or pre-contract Estimator is still needed for assessing the validity of the source data and source materials, ensuring the coverage of the take-off, proposing alternative solutions and analysing the results.”

Finland COBIM 2012, Series 7

Refer to Penn State BPEPG [Appendix B-18](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: [Appendix D, Figure D.3](#)

Commentary

- Clearly communicate that the QS is responsible for the cost estimate and the model is to be used as a support tool. It does not replace the traditional responsibilities of the QS.
- It is important that the level of information need for costing purposes at each stage of the project is clearly defined so all disciplines know what is expected of them, and what to expect from others.
- A master information delivery plan (MIDP) based on the level of information need of the QS will enable model-based quantification for costing purposes. It should list building elements plus the required model content for each based on AIQS and NZIQS standard methods of element measurement and/or classification systems. This is sometimes referred to as a Model Content Plan (MCP).
- For the maximum cost benefit to be realized from BIM, models need to be used by the prime/general contractor.
- Contractors using models will need limitations and a known model content gap analysis statements from the designers to support limitations of model use as a contract document.
- Best practice design modelling and interdisciplinary model coordination significantly reduces the cost and effort of contract administration, e.g. assessment of claims.

Requirements definition

Consider the following items when defining EIR:

- Contractual status of BIM: where BIM is not a contractual requirement, refer to *ANZIQS BIM Best Practice Guidelines* for guidance.
- Roles and responsibilities for modelling, quantity take off and costing.
- The scope of service, e.g.:
 - Quantity take-off only.
 - Cost estimation.

- Costing data linked to 4D BIM, i.e. a model linked to time or scheduling data to generate cash flow reports, etc.
- Reporting requirements, e.g.:
 - Number and timing of reports.
 - Reporting format including classification and level of detail.
- A specification of information to be provided to the QS including lead times to enable them to prepare reports by the required program milestones.

Modelling requirements

- Use agreed specialised model-based cost estimation applications.
- Model as you would physically construct the building, with greater emphasis in the later design phases i.e. columns modelled floor-to-floor. This does not extend to detailed breakdowns that may not be defined at design stage, e.g. slab pours. The procurement method is likely to determine when it is realistic to define this.
- Model elements should conform to the project's modelling standards for any elements and include agreed data to support the quantification process.
- Minimise the use of 'Generic Model' category objects, as they often do not contain useable object information.
- Use agreed standard-based object naming conventions/descriptions that can be readily understood.
- All modellers should use the agreed storey and room naming conventions included in the BEP.
- Exterior versus interior model objects: objects should be clearly identified by their naming and/or attributes so they be readily grouped for cost estimating and reporting.
- Assign the correct status and phasing properties to all model objects, e.g. Existing, Demolition, New Works.
- Add material and finish coding parameters or keynotes to objects when appropriate. For architectural objects, do this in a way that enables them to be reported through a schedule, or linked to a specification.
- Modellers should export project files with the ANZIQS Element and Trade Classification Systems included but leave the classification selection as 'unclassified' so the QS can make the correct selection.
- The quantity surveyor and other disciplines should agree what in-place or placeholder objects it is permissible to use at each design phase milestone. These items can be discussed in BIM coordination meetings.

Most of the above items are included in the *ANZIQS BIM Best Practice Guidelines*. Refer to it for more details.

References

- *AIQS Australian and New Zealand Standard Method of Measurement of Building Works (ANZSMM)*
- *AIQS Australian Cost Management Manual (ACMM) Volumes 1 and 2*
- *AIQS Book of Areas for Analysis and Comparison of Buildings*
- *ANZIQS BIM Best Practice Guidelines* <https://www.nziqs.co.nz/Resources-Tools/NZIQS-Resources/BIM-Best-Practice-Guidelines>
- buildingSMART IDM & MVD: http://www.blis-project.org/IAI-MVD/reporting/listMVDs_4.php?SRT=Name&MVD=GSA-004&DV=2
- *COBIM Series 7: Quantity Take-off*
- *National Guidelines for Digital Modelling clause 3.5*

2.3 Phase planning (4D modelling)

Description

A process in which a 4D model (3D models with the added dimension of time) is used to effectively plan the phased occupancy in a renovation, retrofit or addition, or to show the construction sequence and space requirements on a building site. 4D modelling is a powerful visualisation and communication tool that can give a project team, including the owner, a better understanding of project milestones and construction plans.

Refer to Penn State BPEPG [Appendix B-17](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: [Appendix D, Figure D.4](#)

Example: [Appendix E, Figure E.5](#)

Commentary

- If the contractor is expected to use design models for phase planning, specify this in the EIR.
- If not specified in the EIR, and the contractor proposes to use models for phase planning, provide details in the pre-appointment BIM Execution Plan.
- The work breakdown structure that drives construction phasing is unlikely to be defined in fine detail during the design stage. The procurement method is likely to determine the granularity of definition it is realistic to expect at each phase of the project.
- Modelling for phase planning enables:
 - Running scenarios for different construction sequences to determine the optimum approach.
 - Modelling changes in the construction schedule throughout all project phases to confirm whether progress will or can continue as intended.
 - Tracking progress against the baseline plan.
 - Monitoring completion against the contract program and potentially linking this to change, variation and progress claim assessment processes.

Requirements definition

Consider the following items when defining EIR:

- How the model is to be linked to the project schedule.
- The extent and scale of construction elements included, e.g. primary structural and enclosure elements only, services, fit out elements, furniture, fixtures and equipment.
- For what purposes and audiences 4D BIM will be used, e.g.:
 - By design consultants to plan sequencing of renovation swing space or master planning for long-term build-out.
 - By design consultants to illustrate, interact, communicate, and get approval of the final design and spatial sequencing with the building occupants.
 - By the Contractor for construction schedule planning and communication with subcontractors, and to understand the impact of changes to the schedule.
 - By the Contractor to coordinate with the building users and the Facility Manager, where one has been appointed, on logistics that affect existing building operations or require shutdown of any affected facilities and utilities.
- How the animated phasing plan will address issues such as swing space during construction, parking interruptions, and re-routing of pedestrian/vehicular traffic, or any other construction work that could affect building operations.

Modelling requirements

- Model as you would physically construct the building, e.g. columns modelled floor-to-floor. This does not extend to detailed breakdowns that may not be defined at the design stage, e.g. slab pours. The procurement method is likely to determine when it is realistic to define this. Later changes to design models, e.g. splitting slabs into bays, can result in the loss of linked dimensions, etc.
- Use standard-based and logical object descriptions

References

- *COBIM Series 13: Use of Models in Construction*
- *GSA BIM Guide Series: 04 – 4D Phasing*
- *National Guidelines for Digital Modelling* clause 3.6

2.4 Spatial programming

Description

A process in which a spatial program is used to efficiently and accurately assess design performance regarding spatial requirements outlined by the appointing party. The developed BIM allows the project team to analyse space and understand the complexity of space standards and regulations. Critical decisions are made in this phase of design, and bring the most value to the project when needs and options are discussed with the appointing party and the best approach is analysed.

Refer to Penn State BPEPG [Appendix B-19](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.6](#)

Commentary

- Architectural programming software (APS), e.g. Affinity, Codebook, dRofus used to compile space (rooms, etc) and equipment requirements are useful aids to brief formulation and the creation of a Program for Design (PFD).
- APS also provide the project team with the ability to manage, track and report on spaces and equipment in the model during design and construction. This data can also be reused for facility management purposes.
- To be truly effective APS must be able to export and import data to and from the model.
- APS is a very effective information management tool, particularly for complex projects. However, it can represent a significant investment, both in terms of software license costs and the resources required to establish and maintain it.

Requirements definition

Consider the following items when defining EIR:

- The purpose/s for which floor area will be measured (program validation, leasing, floor space ratio, etc). This should be defined before modelling begins as it will determine the appropriate method/s of measurement.
- The standard method of measurement that is to be used for spaces, e.g. AIQS Book of Areas.
- The type of area calculation to be used, e.g.:
 - Gross Lettable Area – GLA – for industrial buildings, showrooms and freestanding supermarkets.
 - Net Lettable Area – NLA – which is used for office buildings and tenancies.
 - Gross Lettable Area Retail – GLA-R for retail tenancies in shopping centres, commercial buildings and retail strip shops.
- How spaces and elements/objects will be named and designated.
- The space classification system that will apply for analysis and reporting.
- Proposed deliverables, e.g.:
 - Room area summaries of design options which show how they compare to the brief.
 - Room data sheets including details of services, furniture, fixtures, equipment, finishes.
 - Room type and area summaries for facility management purposes.
- How space and element/object data will either be exported from the APS and imported into the BIM software's 'space' tool and 'elements' or 'objects' tools appropriate to the particular BIM software, or the data can be linked to a database external to the BIM software.
- How spaces and equipment will be derived from the model and validated against the PFD at each information delivery milestone.

References

- *AIQS Australian and New Zealand Standard Method of Measurement*
- *AIQS Book of Areas for Analysis and Comparison of Buildings*
- *COBIM Series 3: Architectural Design*
- *GSA BIM Guide Series: 02 – Spatial Program Validation*
- *National Guidelines for Digital Modelling clause 3.2 & Appendix 1.*
- Property Council of Australia (PCA) *Method of Measurement (of floor area)* formerly known as the Building Owners and Managers Association (BOMA) *Standard Method of Measurement*. Select the appropriate Method the building type, e.g. Office Buildings, Industrial Buildings, Multi-Unit Residential, Retail Properties, Mixed-Use Properties.

2.5 Site analysis

Description

A process in which BIM/GIS tools are used to evaluate properties in a given area to determine the most optimal site location for a future project. Collected site data is used to first select the site and then position buildings and related elements, based on other criteria. Collected site information and its analysis can be retained for the planning of future expansion and/or site works.

Refer to Penn State BPEPG [Appendix B-22](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.5](#)

Commentary

- Analysis can provide a clear understanding of the site and aid decision making on how to best utilise it for its intended purposes. Providing robust information about site profiles, ground conditions, hazards, etc and the like will help ensure that these aspects are considered in the design and their cost implications understood.

Requirements definition

Consider the following items when defining EIR:

- The scope of modelling, e.g.:
 - Inside and/or outside existing buildings.
 - Subsurface conditions and utilities.
 - Condition of existing buildings and structures.
 - Existing vegetation.
 - Town planning setbacks, building envelopes, etc.
 - Site gradients and drainage patterns.
 - Vehicle and pedestrian access and circulation patterns.
 - View corridors, privacy patterns (into and out of the site).
 - Solar access and shade patterns.
 - Climatic influences: wind patterns, etc.
 - Environmental considerations: noise and vibration sources, etc.
- Proposed deliverables, e.g.:
 - Site models and or maps showing design constraints and opportunities.

References

- *National Guidelines for Digital Modelling clause 3.2*

2.6 Design authoring

Description

A process in which design authoring, auditing and analysis software is used to develop a building information model based on the brief and performance criteria.

Design authoring tools are a first step towards BIM and connecting the 3D model to a powerful database of properties, quantities, methodologies, costs, and schedules.

Refer to Penn State BPEPG [Appendix B-20](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.7](#)
Example: [Appendix E, Figure E.2](#)

Commentary

- The level of information need or Level of Development (LOD) required for elements or systems at any given time throughout the project will depend on the procurement strategy used for the project. The deliverables and their timing will be different for Design, Bid, Build (DBB) than for Design and Construct (D&C) or Integrated Project Delivery (IPD).
- The NATSPEC BIM Properties Generator can be used to assign required properties including geometric, material and performance properties to building objects/elements such as walls, floors, roofs, doors, and windows.

Requirements definition

Consider the following items when defining EIR:

- The procurement strategy.
- The discipline models required.
- The scope of modelling in each discipline model.
- The Model Element Authors (MEA) responsible for each model element or system including when the responsibility for them is shared or transferred between MEA.
- The expected level of information need or LOD required for project elements or systems at each project stage. Document in a responsibility matrix or LOD Table.
- The drawings and schedules to be derived from the model.

References

- *COBIM Series 3: Architectural Design*
- *COBIM Series 4: MEP Design*
- *GSA BIM Guide Series: 07 – Building Elements*
- *National Guidelines for Digital Modelling* clause 3.2

2.7 Design review

Description

A process in which stakeholders view a 3D model and provide feedback to validate multiple design aspects. These aspects include previewing space aesthetics and layout in a virtual environment and setting criteria, such as layout, sightlines, lighting, security, ergonomics, acoustics, textures and colours, etc.

This BIM use can be undertaken with computer software only, or with special virtual mock-up facilities. Virtual mock-ups can be performed at various levels of detail depending on project needs. One example is the creation of a highly detailed model of a small portion of the building, such as a façade, to quickly analyse design alternatives and solve design and constructability issues.

Refer to Penn State BPEPG [Appendix B-12](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.8](#)

Commentary

- BIM provides the opportunity to create a virtual building and virtually test its functionality during design. It lets project stakeholders see realistic representations of proposed design solutions to assist their comprehension and decision making, enabling them to provide informed feedback to designers that contributes to design improvement before construction starts.
- Encourage designers to find efficiencies and uses for BIM that enhance communication with stakeholders.
- At a minimum, the model can be integrated into design reviews, review submittals, and 3D construction documentation views. Areas that would benefit from the use of 3D imagery and fly-throughs during the design process and during construction should be identified and noted in the BEP(s).
- It should be noted that even though the BIMs contain most of the source information needed for visualisation, they may require further refinement in specific animation and visualisation software to accomplish the intended results.
- During design, special consideration should be given to visualisations for occupant and maintenance issues.

Requirements definition

Consider the following items when defining EIR:

- Expected minimum number of reviews.
- Review context and the background of participants, e.g. will it be small group of internal stakeholders or a large public gathering of external stakeholders?
- Scope of modelling including:
 - Type of modelling: static, animated, immersive.
 - Level of detail: outline, photorealistic, etc
- Scope of visualization, e.g.:
 - Views of the building exterior.
 - Studies of overshadowing of adjoining properties at times nominated by the planning authority.
 - Views of the building interior.
- Visualisation techniques to be used, e.g.:
 - Basic visualisations generated directly from model authoring software.

- Enhanced visualisations for presentation purposes using photorealistic rendering software and photomontages of the proposed design in the context of the existing street or landscape.
- Simulated videos of the building, e.g. 'walk bys', 'fly overs', 'walk throughs', 'fly throughs'.
- Virtual reality or augmented reality for nominated individuals or groups.
- Functional analysis to be provided, e.g.:
 - Walking distances between major functional spaces.
 - Sightlines for supervision and security purposes.
 - Process areas where timing and volume may be problematic, e.g. areas used for queuing, waiting and delivery.
 - Supply, processing and distribution of materials.
 - Major building equipment clearance reservations for operation, repair, maintenance and replacement using graphics or animations.
 - Colour coding of floorplates for determining space function types, department locations, circulation zones and floor areas.

References

- *COBIM Series 8: Use of Models for Visualization*
- *National Guidelines for Digital Modelling* clause 3.2

2.8 Structural analysis

Description

A process in which analytical modelling software uses the BIM design model to determine the behaviour of a given structural system. Minimum required standards for structural design and analysis are used for optimisation. Based on this analysis, further development and refinement of the structural design takes place to create effective, efficient, and constructible structural systems. The development of this information is the basis for what will be passed on to the digital fabrication and construction system design phases.

This BIM use does not need to be implemented from the beginning of the design to be beneficial. Often, structural analysis is implemented at the connection design level to make fabrication quicker, more efficient and for better coordination during construction. This ties into construction system design. Examples include, but are not limited to, erection design, construction methodology, and staging. The application of this analysis tool allows for performance simulations that can significantly improve the design, performance, and safety of the facility over its life cycle.

Refer to Penn State BPEPG [Appendix B-15](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.10](#)

Commentary

- Other disciplines should provide the structural engineer with information that identifies:
 - The location and extent of all major building elements including required penetrations and set downs for finishes.
 - Loadbearing and non-loadbearing elements.
 - Loadings by all major plant and equipment.
 - High-load areas, e.g. for compactus units.

The level of information need for these items should be defined for each project phase or information delivery milestone.

Requirements definition

Consider the following items when defining EIR:

- Points at which structural analysis will occur, or its frequency.
- Data exchange formats required to facilitate analysis.
- Modelling expectations by the structural engineer.
- Information / data / metadata required by the structural engineer.

References

- *BIM & VDC for Structural Steel* American Institute of Steel Construction 2019
- *COBIM Series 5: Structural Design*
- *National Guidelines for Digital Modelling* clause 3.3

2.9 Lighting analysis

Description

Leveraging the model to perform a quantitative and aesthetic review of the lighting conditions within a space or on a surface or series of surfaces. This can include daylighting analysis or artificial lighting analysis. Also see [Energy analysis](#) for energetic aspects of lighting analysis.

Refer to Penn State BPEPG [Appendix B-14](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: Appendix D, [Figure D.11](#)

Commentary

- During Conceptual Design, Schematic Design and Design Development Phases, BIM can be used to develop and establish building performance and the basis of design in accordance with the appointing party's standards.
- Lighting analysis can include analysis of the following:
 - Daylighting and shading: Evaluation of options for window and skylight layouts, surface finishes, reflectors, light shelves and window shading to meet briefed requirements.
 - Artificial lighting: Evaluation of lighting layout options and lamp types and control systems to meet briefed requirements.
 - Emergency evacuation lighting: Design of layouts to comply with relevant codes and standards.
- To enable this, consider the interoperability of software tools proposed for the analysis of building envelope, orientation, daylighting, energy consumption, Building Management System (BMS), renewable energy strategies, life cycle cost analysis, and spatial requirements, etc with model authoring applications.
- As part of assessing the value of this BIM use for the project, the interoperability of proposed model authoring applications and engineering analysis applications should be checked and tested.

Requirements definition

Consider the following items when defining EIR:

- The type of engineering analysis required, e.g.: shading and/or overshading, natural lighting, artificial lighting, emergency evacuation lighting.
- How zones, spaces and building envelope surfaces need to be modelled to enable analysis by lighting analysis applications.
- The method for exchanging model data with lighting analysis applications, e.g.:
 - Direct linkage between applications via a plug-in or similar.
 - Through the export of data in file formats such as gbXML to an external lighting analysis application.
 - Following analysis, how the resultant data can be imported back into the model for consultants to check their work.
- Design review and reporting arrangements between disciplines.

References

- *COBIM Series 9: Use of Models in MEP Analyses*
- *GSA BIM Guide Series: 05 - Energy Performance*
- *National Guidelines for Digital Modelling clause 3.4 (energy, virtual testing & balancing, lighting, other engineering. analysis)*

2.10 Engineering analysis (mechanical, other)

Description

A process in which analysis software uses BIM to assess the performance of various system options to determine the most effective engineering solution based on the appointing party's performance requirements or design codes. Modelled performance data is first compared to physical commissioning results, providing the basis of material passed on to the owner and/or operator for building systems monitoring, or use in the building's operation (e.g. emergency evacuation planning, etc.). These analysis tools and performance simulations can significantly improve the design of the facility and its energy consumption during its life cycle.

Also see [Energy analysis](#) for energetic aspects of engineering analysis.

Refer to Penn State BPEPG [Appendix B-23](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: Appendix D, Figure D.9

Commentary

- BIM can be used for this purpose throughout the built asset's life cycle.
- To enable this, consider the interoperability of software tools proposed for the analysis of building envelope, orientation, daylighting, energy consumption, Building Management System (BMS), renewable energy strategies, life cycle cost analysis, and spatial requirements, etc with model authoring applications
- As part of assessing the value of this BIM use for the project, the interoperability of proposed model authoring applications and engineering analysis applications should be checked and tested.
- Virtual testing and balancing of the architectural model can be used to support sustainable building systems design and analysis. One method is to create a Space/Room schedule that shows calculated air flow vs actual air flow. See Figure 2.10 for an example. All air flows can be checked for load balance to the terminal box and all the way back to the air handling units.

Space Airflow Schedule				
Number	Name	Calculated Supply Airflow (L/s)	Actual Supply Airflow (L/s)	Airflow Delta (L/s)
System Type	Instruction	688	694	6
Supply Air	600x600 – 300x300 neck	SD 1-12-109	170	
Supply Air	600x600 – 300x300 neck	SD 1-12-110	212	
Supply Air	600x600 – 300x300 neck	SD 1-12-111	156	
Supply Air	600x600 – 300x300 neck	SD 1-12-112	156	
116	Conference	274	0	-274
117	Instruction	246	0	-246
118	Electrical	21	0	-21
119	Sprinkler Main	27	0	-27

Figure 2.10: Calculated vs actual airflow comparison

Other engineering analysis includes:

- Fire engineering: Design of passive and active fire control systems, e.g. sprinklers to comply with relevant codes and standards.
- Computational Fluid Dynamics: A tool that can be used to simulate the behaviour of fluids – usually air, wind, smoke – and how they interact with a building model. It is used to predict the

thermal and ventilation performance of proposed designs, the impact of a building on local air movement, e.g. at the base of a building, and for fire engineering purposes.

Requirements definition

Consider the following items when defining EIR:

- Type of engineering analysis required, e.g.:
 - Virtual testing and balancing of mechanical building services.
 - Fire engineering.
- Scope of each type of engineering analysis, e.g.:
 - Which systems are to be analysed.
 - The operational envelope applicable.
 - Performance criteria.
 - The range of alternative options to be considered.
- How zones, spaces and the building envelope need to be modelled to enable analysis by engineering analysis applications.
- Method for exchanging model data with the engineering analysis applications, e.g.:
 - Direct linkage between applications via a plug-in or similar.
 - Through the export of data in file formats such as gbXML to an external analysis application such as Trane/Trace or US Department of Energy (DOE) based analysis programs.
 - Following analysis, how the resultant data can be imported back into the model for consultants to check their work.
- Design review and reporting arrangements between disciplines.

References

- *COBIM Series 9: Use of Models in MEP Analyses*
- *Computational fluid dynamics in building design: An introduction (FB 69)* Chitty, R. and Chunli, C. BREPress
- *GSA BIM Guide Series: 05 - Energy Performance*
- *National Guidelines for Digital Modelling clause 3.4 (energy, virtual testing & balancing, lighting, other engineering. analysis)*

2.11 Energy analysis

Description

This is a process in which the energy performance of a building design is assessed by the application of one or more building energy simulation programs to a virtual model specifically modelled for this purpose. The core goal of this BIM use is to verify a proposed design's conformance with building energy standards and optimise it to reduce life cycle costs.

Refer to Penn State BPEPG [Appendix B-16](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
 Template: [Appendix D, Figure D.9](#)
 Example: [Appendix E, Figure E.4](#)

Commentary

- Similar to [Engineering analysis \(mechanical, other\)](#) and Lighting analysis but also as applicable to passive energy efficient solutions.

Requirements definition

Consider the following items when defining EIR:

- Scope of energy analysis, e.g.:
 - Passive design analysis: modelling the building to allow the use of specialist applications such as Computational Fluid Dynamics (CFD) software.
 - Mechanical systems analysis: See also [Engineering analysis \(Mechanical, other\)](#).
- Software to be used for analysis.
- How zones, spaces and the building envelope need to be modelled to enable analysis by energy analysis applications.
- LOD and quality of model elements required to perform an energy analysis appropriate for the phase and project decision making purposes.
- The method for exchanging model data with life cycle analysis applications, e.g.:
 - Direct linkage between applications via a plug-in or similar.
 - Through the export of data in file formats such as gbXML to an external analysis application such as Trane/Trace or US Department of Energy (DOE) based analysis programs.
 - Following analysis, how data will be imported back into the model for consultants to check their work.

References

- *COBIM Series 10: Energy Analysis*
- *GSA BIM Guide Series: 05 - Energy Performance*

2.12 Sustainability analysis

Description

A process in which a BIM project is evaluated based on Green Building Council Australia (GBCA) Green Star, NABERS or other sustainable criteria. BIM enables more sustainable practices to be adopted at all stages of a facility's life, including planning, design, construction, and operation.

The use of BIM technologies can enhance design decision making about sustainability based on key data. It enables the comparison of sustainability profiles of different design options, complex energy and material usage analysis, more efficient coordination of supply chains, and reduces the need for rework and subsequent wastage. Modelling sustainability in the planning and early design phases is more effective (ability to influence design) and efficient (inputs to cost and schedule decisions).

This comprehensive process requires early interaction between disciplines to capture their insights. This integration may require contractual integration in the planning phase. In addition to achieving sustainability goals, seeking GBCA certification requires submission of certain calculations, documentation and verification. Simulation, calculation and documentation can be performed within an integrative environment when the allocation of responsibilities is well defined.

Refer to Penn State BPEPG [Appendix B-11](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

[Penn State BPEPG Process Maps](#)

None

Commentary

- Sustainability analysis often overlaps energy analysis. Also see [Energy analysis, Engineering analysis \(mechanical, other\)](#) and [Lighting analysis](#).
- Life Cycle Analysis (LCA) – the systematic analysis of the potential environmental impacts of a built asset over its entire life cycle – entails considerably more quantification and analysis than for rating schemes such as Green Star and NABERS. It also requires the use of more sophisticated and complex software applications.
- As a minimum, analysis of design models should be able to confirm that it is possible to meet sustainability intentions and targets. It should also be possible to check As-Built models against planning and design models to confirm that sustainability intentions and targets have been met.
- All information including sustainability targets, assumptions, performance parameters, as-built and commissioning records should be retained in a form that enables operational performance to be checked against designed and commissioned performance for root cause analysis.

Requirements definition

Consider the following items when defining EIR:

- The type of sustainability analysis required, e.g. LCA, rating scheme-based.
- The rating scheme to be used to evaluate the model, e.g. Green Star Office.
- Properties required by the rating scheme to be assigned to model objects or linked to an external database for their management.
- How methods of measurement and scheduling will be aligned with those of the rating scheme.
- Additional items for LCA analysis:
 - The material codes required by the analysis software to be assigned to model objects.
 - Proposed internationally recognised assessment standards to be adopted.
 - The source of conformant LCA data about products and materials.
 - Protocols for the use of products and materials data.

References

- *National Guidelines for Digital Modelling clause 3.4*

2.13 Code validation

Description

A process in which code validation software is used to check model parameters against project-specific codes.

Refer to Penn State BPEPG [Appendix B-24](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)

None

Commentary

- Models can be checked for a design's compliance with current standards, codes and regulations by the use of purpose-made model checking software. This software has to be programmed with rulesets based on the standards and codes against which the model is to be checked.
- At present there are no publicly available standard rulesets based on the National Construction Code (NCC) or Australian Standards, so each organisation must author their own.
- Authoring rulesets requires specialist knowledge and skills. It also requires the on-going investment of resources in their maintenance to reflect any changes in standards and codes.
- While model checking software is generally used for checking the compliance of designs against codes and standards, it can also be used to check conformance with project standards and submission requirements, e.g. to check that data specified for an information delivery milestone has been included in a model, and in the correct format.
- Model checking software can be used to create compliance gap analysis reports of design options. On finalisation of the design it can provide a record of the relevant code and regulation compliance achieved and the extent to which they have been met or exceeded.
- Retaining a record of the code and regulation data applied enables future upgrade works to be checked for compliance against any updated standards and codes that may apply at the time.

Requirements definition

Consider the following items when defining EIR:

- The purpose-made model checking software to be used, e.g. Solibri configured for code checking.
- Specific codes, clauses or project standards against which the model is to be checked, including applicable standards.
- Reporting requirements, e.g. the timing, content and format of reports.
- Responsibilities and procedures for authoring rulesets, model checking and reporting.

References

- *e-submission common guideline for introduce BIM to building process – Technical Report No. TR1015* Masaki Muto buildingSMART International 2019
- *National Guidelines for Digital Modelling Appendix 1*

2.14 3D coordination

Description

A process used throughout the coordination process to determine conflicts of geometry within models that would result in problems on site. This process can be completed by using clash detection software to compile a federated model of discipline design models, which will automate the process of checking for conflicts. The goal of 3D coordination is to eliminate any major system conflicts prior to installation.

Refer to Penn State BPEPG [Appendix B-13](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: [Appendix D, Figure D.12](#)

Example: [Appendix E, Figure E.3](#)

Commentary

- Coordination is much more than just clash detection. A strategic approach to coordination begins in the early design phases by allowing adequate space for services and formulating an overall approach to the reticulation of all services. Buildability and access for servicing also need to be considered as part of this process.
- Regular communication between all parties is the key to successful coordination. Before a formal clash detection process is started, visual inspection of models can be used for general coordination. This includes coordination of single and multiple discipline models.
- Specialised applications known as Integrated Collaboration Platforms (ICP) for managing coordination issues in a formalized workflow are available. They enable a contextual view of an issue to be captured, named and assigned to other team members for resolution. The resolution of issues can be tracked and reported on to improve management and accountability.
- buildingSMART's BIM Collaboration Format (BCF) is an open standard that leverages IFC models for collaboration purposes, enabling collaboration between different proprietary software applications. BCF uses XML formatted data for exchanges. A web service-based (RESTful) API mode for BCF is also available as an alternative to a file-based workflow.

Requirements definition

Consider the following items when defining EIR:

- The party responsible for leading coordination, e.g. lead consultant, Architect, a third-party. Responsibilities may also be split or passed between parties, e.g. the lead consultant may lead the resolution of clashes between architectural and structural elements and then pass the responsibility for resolving clashes between services and other elements to the lead services consultant.
- The point at which coordination will commence, relative to the point at which task teams are expected to have produced information appropriate for coordination.
- The minimum number of formal 3D coordination reviews.
- Required workflows or processes.
- Consider whether self-clashes should be conducted by each discipline. In doing so, assess the project team's capacity to accommodate this.
- ICPs to be used for coordination.
- Reports to be provided, and their format.
- How set downs, recesses, voids, openings and penetrations in the building fabric necessary to accommodate and access services, equipment, fixtures and finishes are to be documented.

References

- *National Guidelines for Digital Modelling clause 3.6 & Appendix 1*

2.15 Construction documentation

Description

Using BIM to develop the documentation necessary to communicate the building design to construction personnel. This may include plans, elevations, sections, renderings, data schedules, 3D diagrams, or specifications.

Refer to Penn State BPEPG [Appendix B-10](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
None

Commentary

- The timing of the level of information need or Level of Development (LOD) required for elements(s) or systems(s) will depend on the procurement strategy used for the project, as the deliverables and their timing will be different for Design Bid Build (DBB) than for Design and Construct (D&C) or Integrated Project Delivery (IPD).
- The NATSPEC BIM Properties Generator can be used to define the required properties including geometric, material and performance properties for building objects/elements such as walls, floors, roofs, doors and windows before they are incorporated in the model.

Requirements definition

Consider the following items when defining EIR:

- The discipline models required.
- The scope of modelling in each.
- The level of information need or LOD required for project elements at each stage included in the responsibility matrix, LOD Table, etc, along with the Model Element Author for each.
- The drawings and schedules to be derived from the model.

References

- *COBIM Series 3: Architectural Design*
- *COBIM Series 4: MEP Design*
- *GSA BIM Guide Series: 07 – Building Elements*
- *National Guidelines for Digital Modelling clause 3.2*

2.16 Site utilisation planning

Description

A process in which BIM is used to graphically represent both permanent and temporary facilities on site during multiple phases of the construction process. It may also be linked with the construction program to convey space and sequencing requirements. Additional information incorporated

in the model can include labour resources, materials with associated deliveries, and equipment location. Because the 3D model components can be directly linked to the program, site management functions, such as visualised planning, short-term re-planning and resource analysis, can be analysed over different spatial and temporal data.

Refer to Penn State BPEPG [Appendix B-9](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: Appendix D, [Figure D.13](#)

Commentary

- The model can be used to plan engineered lifts, i.e. the lifting of large or heavy building components and assemblies into place.
- Lift plan models can be created through collaboration between the structural engineer and experienced site personnel such as the lift supervisor, and used to communicate the lift plan to those involved in its execution.
- A 3D model communicates the plan clearly to site personnel who may not be proficient in English or in reading 2D plans or written instructions.
- Lift plan models should address the following:
 - Location of cranes, hoists, rigging, etc.
 - Location of lifting team members.
 - Pick up and set down areas.
 - Lifting paths and load rotations.
 - Boom angles.
 - Crane boom and load clearances between other cranes, building elements, obstructions and hazards (power lines, etc).
- Also see [Construction system design \(virtual mock-up\)](#) for the use of BIM for work health and safety management.

Requirements definition

Consider the following items when defining EIR:

- How 4D BIM will be used to model permanent and temporary on-site facilities, equipment and material locations and movements, including deliveries for planning purposes and to communicate on-site activities to site personnel and building occupants.
- How the model will be used to plan engineered lifts.
- How the model will be used to communicate the lift plan to those involved in its execution.

References

- *COBIM Series 13: Use of Models in Construction*
- *National Guidelines for Digital Modelling* clause 3.6

2.17 Construction system design (virtual mock-up)

Description

A process in which 3D system design software is used to design and analyse the construction of complex building systems, e.g. form work, glazing, tie-backs, in order to improve constructability/buildability, maintainability and health and safety.

Refer to Penn State BPEPG [Appendix B-8](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
None

Commentary

- Virtual mock ups can help reduce risks and excessive contingency allowances. System design information shared with cost planners can improve budget and price accuracy. If shared with subcontractors for quoting purposes, it can avoid lengthy exclusions lists and/or price variations.
- Mock ups and modelled work methodologies including relevant details, assumptions, materials and equipment should be retained to assist assessment of any claims that may arise.

Requirements definition

Consider the following items when defining EIR:

- How complex building systems such as formwork and scaffolding will be modelled to improve planning, construction productivity and safety.
- How the model will be used to improve constructability and erection times through the design of modular construction components suitable for off-site construction.
- The safety in design legislation and standards that apply to the project.
- How the model will be used to model, analyse and report on work health and safety issues, and communicate them to the relevant parties.
- The specific requirements applicable to individual elements of the design.

References

- *Health and safety management using building information modelling: Phase Two Report* NSW Government Centre for Work Health and Safety
<https://www.centreforwhs.nsw.gov.au/Projects/completed-projects/building-information-modelling-for-whs-management>
- *National Guidelines for Digital Modelling* clause 3.6
- *Using Building Information Modelling (BIM) for Smarter and Safer Scaffolding Construction* (Project 3.27 Industry Report) SBenrc 2016 <https://sbenrc.com.au/research-programs/3-27-using-building-information-modelling-bim-for-smarter-and-safer-scaffolding-construction/>

2.18 Digital fabrication

Description

A process using digitised information to facilitate the fabrication of construction materials or assemblies. Some uses of digital fabrication can be seen in sheet metal fabrication, structural steel fabrication, pipe cutting, prototyping for design intent reviews, etc. The process helps ensure the downstream phase of manufacturing is clear and there is sufficient information to fabricate with minimal waste. An information model could also be used to create fabricated parts that form a final assembly and facilitate Design for Manufacture and Assembly (DfMA).

Refer to Penn State BPEPG [Appendix B-7](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

Penn State BPEPG [Process Maps](#)
None

Commentary

- A collaborative approach can ensure that the knowledge and associated efficiencies of the fabricator are embedded in construction models.
- There are two main aspects to digital fabrication:
 - Computer Aided Design/Computer Aided Manufacturing (CAD/CAM): The process in which digital information from a model is used to direct machines such as cutters, drills, lathes, 3D printers and milling, punching and folding machines that would otherwise be controlled by human operators.
 - Facilitating prefabrication: The accuracy of modelling made possible by BIM software makes prefabrication and modular offsite construction more viable than in the past. The individual components of assemblies can be fabricated with greater confidence that they will fit together as intended. This helps realise the benefits of these approaches.
- The products of these processes can include individual components such as steelwork or precast columns, beams and slabs, ductwork, roof assemblies and facades, through to preassembled service risers and runs, toilet PODS, bathroom PODS and complete plantrooms.
- The Monash University Handbook for the Design of Modular Structures makes numerous references to the place of BIM in the design and manufacturing of modular structures but does not provide specific guidance on modelling.
- Minimise high polycount / complex elements.
- If using BIM tools such as Revit, model components as systems.

Requirements definition

Consider the following items when defining EIR:

- Which construction trades have the capability to provide 3D fabrication models, e.g.:
 - Structural steelwork.
 - Mechanical system ductwork.
 - MEP subcontractors (incorporating vendor models if available).
 - Curtain walling.
 - Building envelope systems: rain screens, pre-cast panels, glazing systems, etc.
 - Any other subcontractors able to generate additional fabrication models.
- The purposes of fabrication models, e.g. as part of the shop drawing review process, as a deliverable (e.g. As Built). Different formats may be required for each.
- Measures including testing to ensure the interoperability of model authoring applications and digital fabrication tools which are often highly specialised.
- Alignment of fabricated items with an agreed project coordinate and/or GIS system

- Classification metadata to be applied to elements to assist location and assembly.

References

- *BIM & VDC for Structural Steel American Institute of Steel Construction 2019*
- *Delivery Platforms for Government Assets – Creating a marketplace for manufactured spaces Bryden Wood & Centre for Digital Built Britain 2017*
- *DesigningBuildings Wiki:*
[https://www.designingbuildings.co.uk/wiki/Design_for_Manufacture_and_Assembly_\(DfMA\)](https://www.designingbuildings.co.uk/wiki/Design_for_Manufacture_and_Assembly_(DfMA))
- *DfMA Overlay to the Plan of Work Royal Institute of British Architects 2017*
<https://www.architecture.com/knowledge-and-resources/resources-landing-page/dfma-overlay-to-the-riba-plan-of-work>
- *Handbook for the Design of Modular Structures Monash University 2017*
<https://www.dropbox.com/s/dvzf0fg3p8lwdsh/Handbook%20for%20the%20Design%20of%20Modular%20Structures.pdf?dl=0>
- *National Guidelines for Digital Modelling clause 3.6*

2.19 3D control and planning (digital layout)

Description

A process using an information model to lay out construction works and building assemblies or automate the control of equipment movement and location. The information model is used to create detailed control points to aid in assembly layout. One example is the layout of walls using a total station with points preloaded and/or using GPS coordinates to determine if proper excavation depth is reached.

Refer to Penn State BPEPG [Appendix B-6](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: Appendix D, [Figure D.14](#)

Commentary

- Digital layout offers huge potential productivity improvements - set out tasks that took days can now be completed in hours – but all parties need to be procured to do this.
- The fullest benefits of digital layout are realised when it is applied to more than just setting out grids and RLs. Among other things, it can be used to set out individual hangers for services. This application is particularly effective if hanger inserts are set out on floor slab formwork from above. This is much easier than installing them from below using ladders, platforms, etc and working over the top of others.
- Set out points can be placed to millimetre accuracy, so coordination must be 100% correct – areas can no longer be half coordinated.
- Setout can only be accurate if the contractor establishes one common set of control points across the site for use by all parties, and this is not left to each individual trade.

Requirements definition

Consider the following items when defining EIR:

- If it is agreed to use design models for digital layout, the contractor's requirements should be included in the EIR. This includes the technical requirements, e.g. file formats, necessary to ensure compatibility of design models with setout equipment/total stations.

References

- *Using the BIModel directly for set-out BIMFix Blog 2013*
<http://bimfix.blogspot.com/2013/04/using-bim-directly-for-component-set-out.html>

2.20 Record modelling

Description

Record modelling is the process used to depict an accurate representation of the physical conditions, environment, and assets of a facility. The record model should, as a minimum, contain information relating to the main architectural, structural, and MEP elements. It has the potential to represent the culmination of all BIM throughout the project, including linking operation, maintenance, and asset data to the As-Built model (created from the design, construction, 4D coordination models, and subcontractor fabrication models) to deliver a record model to the appointing party.

Refer to Penn State BPEPG [Appendix B-5](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: [Appendix D, Figure D.15](#)

Example: [Appendix E, Figure E.6](#)

Commentary

- Generally, two types of record model should be available at the end of a project:
 1. One that represents the agreed/approved design intent, i.e. As-Designed (provided by the design team).
 2. One that represents the as-built state at the completion of construction (provided by the contractor).
- The design team is usually dependent on others (e.g. the contractor) for information about the actual position of installed items when producing an 'As-Designed' or 'For-Record' model. In these circumstances, they cannot vouch for their accuracy.
- Common definitions and interpretations of terms such as 'As-Built' and 'Record' model are not well established across the industry, so particular attention should be given to defining requirements for them.
- The purpose or intended use of As-Built models needs to be defined. While they can offer significant benefits for asset or facility management, it should be made clear if they are required for this purpose as it will influence the information that needs to be included. See [Asset management](#), [Building maintenance scheduling](#), [Building systems performance analysis](#) and [Space management and tracking](#).
- If BIM is used for site analysis [2.05], energy analysis [2.11], sustainability analysis [2.12] or code validation [2.13], design intent information for operations should be recorded in the record model for use during the operation of the asset.

Requirements definition

Consider the following items when defining EIR:

- The scope of As-Built or Record models, e.g. geometry only, geometry and data, models linked to documentation. This will be influenced by their purpose, e.g. record only, for operation and maintenance of the asset.
- The division of responsibilities for providing As-Built and Record information during each project phase.
- The level of information need for As-Built or Record information.
- The scope of data – *GSA BIM Guide Series: 08 – Facility Management* defines model types and three scopes of data (Tier 1, 2 and 3)
- The expected LOD for individual elements or element types, e.g. as defined in a LOD Table.
- The expected accuracy of as-built model elements, e.g. the tolerances for the location of a light switch could differ from those for a chiller. Define tolerances for key categories of items, e.g. ±10 mm, ±50 mm, or ±100 mm deviation from actual position.

- The methods and procedures for capturing on-site information to update the model, e.g. laser scanning, site measurement.
- The process for verifying models with on-site conditions.

References

- *ABAB Asset Information Requirements (AIR) Guide* Australasian BIM Advisory Board 2018
- *COBIM Series 13: Use of Models in Construction*
- *GSA BIM Guide Series: 08 – Facility Management*
- *National Guidelines for Digital Modelling* clause 3.7

2.21 Digital twins

Note: The following items supplement and extend those for [Record modelling](#).

Description

A digital twin is a digital representation of a physical asset, process or system, as well as the provider of information that allows its users to understand and model its performance. A digital twin can be continuously synchronised from multiple sources, including sensors and continuous surveying, to represent its near real-time status, working condition or position. A digital twin enables users to visualise the asset, check status, perform analysis and generate insights to predict and optimise asset performance.

What distinguishes a digital twin from other digital models is its connection to the physical twin. In particular, the bi-directional exchange of data between the two. This differs from BIM, which traditionally does not include real-time data collected from the construction site or building in operation. A Building Information Model is converted to a digital twin by enriching it with static and live data, e.g. from the building management system.

Not included in Penn State BPEPG

Potential value

- Increased productivity and collaboration facilitated by access to current information.
- Reduced construction and operating costs facilitated by data-driven decision making.
- Improved safety through real-time tracking and reporting of hazards.
- Optimised asset performance and sustainability through real-time monitoring, analysis and comparison of performance against intended performance and parameter assumptions.
- Ongoing compliance through checking of regulations and codes as they are amended.

Resources required

In addition to those for Record modelling:

- The technological infrastructure including sensors, actuators and communication systems to maintain the link between the model and its physical twin.
- On-going organisational and human resources support for maintenance and management.

Team competencies required

In addition to those for Record modelling:

- Ability to address interoperability issues between the systems required for implementation.
- Ability to clearly communicate to the organisation ultimately responsible for maintaining and managing the digital twin what resources they will require.

Commentary

- This BIM use description is directed primarily at the use of digital twins during the operational phase of assets. Additional requirements for their use during the delivery phase may need further definition.
- An As-Built model will probably need to be modified for the specified purposes, but a good quality model is the foundation a digital twin.
- A digital twin does not always need to be a 3D model - it can simply be a digital representation of a physical asset. Neither do digital twins always need to have real time access to all performance data – they need only provide relevant information and data whenever it is required for informed decision making, i.e. just in time rather than real time. Commonly required real time data includes that for security breaches, health, safety and environment (H&SE) breaches, utilities availability and/or pressure data, but specific requirements will depend on the organisation.
- The scope, maturity and complexity of digital twins can vary enormously. This has significant implications for on-going maintenance and management, so must be defined carefully. Frameworks and metrics are available to assist definition. Refer to the ABAB Digital Twins Position Paper for details.
- Facility and asset management requirements will determine what information needs to be incorporated in the model and what links to systems in the physical twin need to be established. Refer to [Asset management](#), [Building maintenance management](#), [Building systems performance analysis](#) and [Space management and tracking](#) for guidance on defining requirements.
- This subject is closely tied to the concept of the Internet of Things (IoT) because linking the digital model to its physical twin usually relies on IoT technologies including sensors, wireless access points (WAP) and low power wide area networks (LPWAN).
- Consistent identification and naming conventions need to be applied to all IoT devices so they can be effectively managed.

Requirements definition

Consider the following items when defining EIR:

- The parties responsible for the provision of each element required for implementation, e.g.:
 - As-Built model;
 - installation of sensors, actuators, communication links, etc;
 - testing and commissioning of the complete digital twin system;
 - training of the system's operators.
- Purposes/use cases of the digital twin.
- Scope of the digital model. A number of frameworks and metrics can be used to describe digital twins including maturity and complexity. Refer to the ABAB Digital Twins Position Paper
- Scope of the data to be collected from the physical twin, e.g.:
 - Systems to be monitored
 - Type, accuracy and location of sensors
 - Means and format of reporting and analysis of data
- Scope of control of the physical twin by the model, e.g.:
 - Systems to be controlled
 - Division of control functions between the digital model and other systems, e.g. Building Management System (BMS)
 - Type and location of sensors, actuators, digital controllers, WAPs, LPWAN, etc.
 - Level of autonomy of control by the model.
- Interoperability with appointing party's systems.
- Naming conventions for WAPs, sensors, controllers and other electronic devices.
- Defects liability period.

- Instruction manual/User guide: content and format
- Training in the use of the digital twin: Personnel to be trained and scope of training.

References

- *ABAB Digital Twins Position Paper* Australasian BIM Advisory Board 2021
- *Digital Twin – Towards a Meaningful Framework* Arup 2019
- *Digital twins from design to handover of constructed assets* RICS 2022
<https://www.rics.org/oceania/wbef/home/reports-and-research/digital-twins-from-design-to-handover-of-constructed-assets/>
- *Enabling an Ecosystem of Digital Twins - A buildingSMART International Positioning Paper* buildingSMART International (bSI) 2020
- *Principles Based Digital Twins: A scoping review* Centre for Digital Built Britain (CDBB) 2019
- *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* Australia and New Zealand Land Information Council (ANZLIC) 2019 www.anzlic.gov.au/
- Smart Cities Council Australia and New Zealand (SCCANZ) <https://anz.smartcitiescouncil.com/>
- *The Gemini Principles: Guiding values for the national digital twin and information management framework* Centre for Digital Built Britain (CDBB) 2018

2.22 Asset management

Description

A process in which an organisation's asset management system is bi-directionally linked to a record model, or data within the record model is imported into the asset management system to aid the maintenance and operation of a facility and its assets. (See [Record modelling](#).) These assets, consisting of the physical building, systems, surrounding environment, and equipment, must be maintained, upgraded, and operated at a level of efficiency and cost-effectiveness that satisfies both the owner and users.

Asset management assists financial decision-making, short and long-term planning, and generating scheduled work orders.

Asset management uses data contained in a record model to populate an asset management system, which is then used to determine the cost implications of changing or upgrading building assets. The bi-directional link also allows users to visualise the asset in the model before servicing it, potentially reducing service time, reducing risks and improving health and safety.

Refer to Penn State BPEPG [Appendix B-3](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

Penn State BPEPG [Process Maps](#)
None

Commentary

- The operational phase typically represents 70 – 80% of the total life cycle cost of a built asset. BIM enables a more effective way of capturing asset information for operational purposes during the construction phase than traditional paper-based methods.
- Well-structured quality asset data can significantly improve the long-term performance of an asset and reduce associated management costs.
- These benefits rely on the process being well planned and managed from the outset and the participation of the asset's operators in the definition of requirements.
- A structured process should be used to define the asset information required by the asset owner or operator. The *ABAB Asset Information Requirements (AIR) Guide* includes guidance on setting priorities for the assets to be included in the asset information model (AIM) and the property sets for each. At a minimum, the AIM should include all items or equipment subject to statutory or regulatory requirements, e.g. fire doors, fire dampers, cooling towers and pressure vessels or tanks.
- Coupled with a Soft Landings approach, BIM can significantly improve the commissioning and handover of a building to its occupants. It can also provide them with a better understanding of how its systems function so they can get the best performance from them. However, these benefits rely on the early and continued involvement of the occupants during the project.
- Using industry standards such as COBie will facilitate the ready exchange of information.
- Individual model elements generally do not need to be as geometrically detailed in models to be used for facility management as for construction, e.g. an element could be accurately modelled in its as-built location but only developed to Level of Development (LOD) 200.
- Asset management information should include data about systems as well as individual assets, and clearly show their relationships to assist understanding of the potential impact of issues with individual assets on the system(s) they are part of.

Requirements definition

Consider the following items when defining EIR:

- The party/parties responsible for delivering asset information (e.g. certain information should come from the designer, while other information is best delivered by the contractor)
- The asset groups for which data is required.
- The property sets for each asset group.
- The schema or format in which information will be provided, e.g. COBie
- Naming conventions/designation/coding systems for asset types and instances, e.g. VBIS
- When the asset information is to be delivered. (e.g. certain information may be available during design, other information may be delivered progressively as construction progresses)
- Whether provision needs to be made for asset tracking or monitoring and, if so, what form it will take.

References

- *ABAB Asset Information Requirements (AIR) Guide* Australasian BIM Advisory Board 2018
- *BIM for Facility Management* Schley and Haines AST & FM: Systems 2015
- *COBie*: <https://www.wbdg.org/bim/cobie>
- *COBIM Series 12: Use of Models in Facility Management*
- *Data Requirements for the Construction and Management of Buildings – A Guide for Clients* UK BIM Alliance 2017
- *Developing a Cross-Sector Digital Asset Information Model Framework for Asset Management – Project 2.51 Final Research Report* SBEnrc 2019 <https://sbenrc.com.au/research-programs/2-51/>
- *Digital Asset Information Management (DAIM): A Guide and Manual – Final Industry Report, Project 2.51* SBEnrc 2018 <https://sbenrc.com.au/research-programs/2-51/>
- *FMA Good Practice Guide Digital Facility & Asset Management*
- *FMA Good Practice Guide Facilities Information*
- *GSA BIM Guide Series: 08 – Facility Management*
- *National Guidelines for Digital Modelling* clause 3.7
- *The Business Case for Asset Tracking & Monitoring* IPWEA 2021 https://www.ipwea.org/ipweacommunities/emergingtechnology/asset-tracking?_zs=9Q0Uk&_zl=s6w72
- *The Soft Landings Framework Australia and New Zealand 2014* Chartered Institution of Building Services Engineers (CIBSE) ANZ 2014 <https://www.cibse.org/networks/regions/australia-new-zealand/anz-regional-news/the-soft-landing-framework-australia-new-zealand-m>
- *Unlocking the value of BIM for asset management* BIM in NZ 2018 www.biminnz.co.nz
- *Using COBie with Existing Housing Asset Information - Case Study Report (Project 2.46)* SBEnrc 2017 <https://sbenrc.com.au/research-programs/2-46/>
- *Victorian Digital Asset Strategy* Department of Treasury and Finance [Victoria] Office of Projects Victoria 2022 <http://www.opv.vic.gov.au/Digital-Build/Victorian-Digital-Asset-Strategy>
- *Virtual Buildings Information System (VBIS)* www.vbis.net.au

2.23 Building maintenance management

Description

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. A successful maintenance program will improve building performance and reduce repairs and overall maintenance costs.

Refer to Penn State BPEPG [Appendix B-4](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#) Template: Appendix D, [Figure D.16](#)

Commentary

- The fullest benefits of asset management data in the model are realised when a bi-directional exchange of data is established with the maintenance management tools and systems used by an organisation including payment, procurement, and supply chain management tools.
- Foundational asset data included at the beginning of the asset life cycle including economic life expectations and relevant operating parameters associated with whole of life maintenance and replacement assumptions can contribute to the long-term optimisation of a facility's performance.
- A digital twin and associated data sources can provide the relevant information when it is required for informed decision making, i.e. just in time rather than real time may be adequate.

Requirements definition

See Digital twins and Asset management.

References

- *COBIM Series 12: Use of Models in Facility Management*
- *GSA BIM Guide Series: 08 – Facility Management*
- *National Guidelines for Digital Modelling* clause 3.7
- *FMA Good Practice Guide Digital Facility & Asset Management*
- *FMA Good Practice Guide Facilities Information*
- Virtual Buildings Information System (VBIS) www.vbis.net.au
- Department of Treasury and Finance [Victoria] Asset Management Accountability Framework <https://www.dtf.vic.gov.au/infrastructure-investment/asset-management-accountability-framework>
- Department of Treasury and Finance [Victoria] Office of Projects Victoria Victorian Digital Asset Strategy <http://www.opv.vic.gov.au/Digital-Build/Victorian-Digital-Asset-Strategy>

2.24 Building systems performance analysis

Description

A process that measures how a building's performance compares to the specified design. This includes how mechanical systems operate and how much energy a building uses.

Other aspects of this analysis include, but are not limited to, ventilated facade studies, lighting analysis, internal and external CFD airflow, and solar analysis.

Refer to Penn State BPEPG [Appendix B-1](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)
Template: [Appendix D, Figure D.17](#)

Commentary

- Quality commissioning data captured through BIM processes can provide benchmark information essential for effective performance monitoring and analysis.
- Foundational asset data included at the beginning of the asset life cycle including economic life expectations and relevant operating parameters associated with whole-of-life maintenance and replacement assumptions can contribute to the long-term optimisation of a facility's performance.
- Real-time monitoring, analysis and comparison of systems' performance against intended performance and parameter assumptions also enables the optimisation of a facility's overall performance.
- The fullest benefits of asset management data in the model are realised when a bi-directional exchange of data is established with the asset and facility management tools and systems used by an organisation.
- A digital twin and associated data sources can provide the relevant information when it is required for informed decision making – just in time rather than real time may be adequate.
- Asset information should include data about systems as well as individual assets, and clearly show the relationship between the performance of individual assets and the system/s they are part of.

References

- *COBIM Series 9: Use of Models in MEP Analyses*
- *COBIM Series 10: Energy Analysis*
- *FMA Good Practice Guide Digital Facility & Asset Management*
- *FMA Good Practice Guide Facilities Information*
- Virtual Buildings Information System (VBIS) www.vbis.net.au
- Department of Treasury and Finance [Victoria] Asset Management Accountability Framework <https://www.dtf.vic.gov.au/infrastructure-investment/asset-management-accountability-framework>
- Department of Treasury and Finance [Victoria] Office of Projects Victoria Victorian Digital Asset Strategy <http://www.opv.vic.gov.au/Digital-Build/Victorian-Digital-Asset-Strategy>

2.25 Space management and tracking

Description

A process in which BIM is used to effectively distribute, manage and track the use of spaces and related resources within a facility. A facility building information model enables the facilities management team to analyse the existing use of the space and effectively apply transition planning management to any applicable changes. Such applications are particularly useful during a project's renovation, where building areas are to remain occupied. Space management and tracking ensure the appropriate allocation of spatial resources throughout the life of the facility. This BIM use benefits from the utilisation of the record model. This application often requires integration with spatial tracking software.

Refer to Penn State BPEPG [Appendix B-2](#) for summaries of:

- Potential value
- Resources required
- Team competencies required
- Selected resources

Penn State BPEPG [Process Maps](#)

None

Commentary

- As part of defining BIM requirements for space management, an organisation should first develop a strategic space management plan (SSMP). The SSMP should outline space management objectives and describe what a space management system needs to do to support them. It also includes the organisational structure and the roles and responsibilities required for the system to operate effectively.
- Stakeholder support, risk management and continuous improvement are important considerations in the establishment and operation of a space management system.

Requirements definition

Consider the following items when defining EIR:

- The appointing party's SSMP, policies, standards, processes and procedures for space management.
- Data required for assessing conformance with required space-related standards, e.g. Green Star, WELL Building Standard®
- The standard method of measurement that is to be used for spaces, e.g. AIQS Book of Areas.
- How spaces will be named and designated.
- The space classification system that will apply for analysis and reporting.
- How data in the model will be exchanged with the appointing party's space management system.
- Use cases to be supported, e.g.:
 - Reporting on occupancy rates.
 - Meeting room booking optimisation.
 - Reporting on space usage patterns to underpin investment/upgrade business cases.

References

- *Best Practices for Space Management to Maximize Your Corporate Real Estate Investments* Schley FM:Systems 2019
- *WELL Building Standard* International WELL Building Institute (IWBI) <https://standard.wellcertified.com/well>
- *What do Facility Managers need from BIM? Case: openBIM for Space Management at Universities* buildingSMART International 2022 <https://buildingsmart-1xbd3ajdayi.netdna-ssl.com/wp-content/uploads/2022/05/Industry-Insight-What-do-Facility-Managers-Need-from-BIM.pdf>

2.26 Emergency response planning

Description

A process in which emergency responders access critical building information in the form of a model and information system. The BIM model provides critical building information to the responders that helps improve their response and minimise safety risks. Dynamic building information can be provided by a Building Management System (BMS), access control and security system, and potentially a space management system, while static building information such as floor plans and equipment schematics, resides in the virtual model. These two systems can be integrated via a wireless connection, and emergency responders linked to the overall system. The model coupled with the BMS and other systems can clearly display where the emergency is located within the building, possible access routes to the area, possible occupant numbers, and other harmful locations and materials within the building.

Refer to Penn State BPEPG [Appendix B-25](#) for summaries of:

- [Potential value](#)
- [Resources required](#)
- [Team competencies required](#)
- [Selected resources](#)

Penn State BPEPG [Process Maps](#)
None

Commentary

- An as-built model can be used to evaluate the physical security and survivability of a facility.
- The project team should liaise with local emergency service providers to establish their information requirements, understand their technical systems and agree emergency protocols.

Requirements definition

Consider the following items when defining EIR:

- Selection of available emergency responders.
- Emergency responders' notification protocols.
- Communication protocols.
- Occupant responsibilities for coordinating responses by emergency services.
- Technical integration of the facility's systems with those of emergency responders.

References

- *National Guidelines for Digital Modelling* Appendix B, Item 5

3 BIM ENABLERS/ENABLED BY BIM

There are many items that enable a more effective application of BIM or leverage the value of its core functionalities. Most of them can be used in conjunction with the BIM uses described in this appendix.

Figure 3 groups them into rough categories depending on whether they are largely technological, cultural, provide data inputs to the modelling process or make use of data from models.

The purpose of the figure is to show how these items that regularly feature in articles on technological innovations in the construction industry relate to core BIM practices.

BIM enablers and items enabled by BIM can offer significant benefits that may not be immediately apparent. For example, photogrammetry-equipped drones can capture large amounts of highly accurate geometrical data in minutes that would otherwise take weeks by traditional methods. Likewise, GIS digital setout can have offer substantial improvements in accuracy and productivity. Nonetheless, a careful assessment of the business case for each should be undertaken when considering them for a specific project.

Input enablers	Core enablers		Output enabled
Barcodes, QR codes & Radio Frequency Identification (RFID)	Object-based parametric modelling applications	Structured data	3D printing, additive manufacturing
	ICT enablers		AI and machine learning
Drones	Cloud-based platforms	Internet	Blockchain
GIS location finding	Edge computing	Low Power Wide Area Network (LPWAN)	CAAMS, CAFM, CMMS
Ground-penetrating radar (GPR)	Geographic Information Systems (GIS)	Mobile/cellular networks	DfMA
Internet of Things (IoT) sensors	Global Navigation Satellite System (GNSS), Global Positioning Systems (GPS)	Smartphones, Tablets, Hand-held devices	Digital fabrication
Laser scanning, Light Detection and Ranging (LIDAR)		Wi-Fi, Bluetooth	Digital Twins
Photogrammetry	Cultural enablers		Generative design, Parametric design
	Collaborative procurement methods	Object libraries	GIS field tracking
	Common Data Environment (CDE)	Open standards	GIS digital setout
	The Golden Thread	Whole lifecycle perspective	IoT controls & actuators
	Information as an asset	Whole supply chain coordination view	Robotics
			Smart Cities, Smart Infrastructure
			Virtual, Augmented & Mixed Reality

Figure 3: BIM enablers/Enabled by BIM

3.1 Core enablers

These items are fundamental to BIM – it could not exist without them.

Object-based parametric modelling applications

Software for creating virtual models composed of parametric objects enables the efficient production of information about an asset that can be used for many purposes. It offers significant advantages as a design tool because information is automatically updated as the model is changed.

Structured data

Modelling applications are very powerful tools but in practice their effectiveness ultimately relies on how well the data entered into them is structured and managed. Standards are an effective means of structuring data. Their application ensures consistency by all users and helps improve the reliability of data inputs and outputs.

3.2 ICT Enablers

The following Information and Communication Technology systems extend the functionalities of BIM software beyond the desktop. They enable stakeholders to work together remotely, including those in the field.

Cloud-based platforms

Includes platforms for groups to work remotely on the same model, manage coordination issues and share files.

Edge computing

This refers to data processing and storage that is done in proximity to the source of the data, rather than being sent to a remote computing location, e.g. cloud, to be processed. It improves response times and saves bandwidth. Edge computing can form part of the architecture of an IoT system.

Global Information Systems (GIS)

A system that integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information.

Global Navigation Satellite Systems (GNSS)

This is a broad term encompassing different types of satellite-based positioning, navigation and timing (PNT) systems used to accurately map locations on the earth's surface. Global Positioning System (GPS) is one such type of system. The data from these systems is used by Global Information Systems (GIS).

Internet

The global system of interconnected computer networks that uses the Internet protocol suite (TCP/IP) to communicate between networks and devices. It enables the ready sharing of information across the globe.

Low power wide area networks (LPWAN)

Wireless networks designed to allow long-range communication at a low bit rate between devices such as sensors. They operate at a lower cost with greater power efficiency than traditional mobile networks. They are also able to support more connected devices over a larger area. LPWAN devices employ battery-powered transceivers and typically form part of an IoT system.

Mobile or cellular networks

Wireless communication networks of multiple radio transmitters used to transmit voice signals and data over wide geographic areas. They enable mobile phone users to connect to other mobile phones and the internet.

Smartphones, tablets, handheld devices

These easily operated, ubiquitous devices enable ready access to the information carried on mobile and Wi-Fi networks.

Wi-Fi, Bluetooth

Short range wireless technologies that enable devices such as computers, tablets, printers and speakers to connect to the internet and other devices.

3.3 Cultural enablers

The best technology in the world is worthless without the necessary social and cultural support structures to make effective use of it, particularly for activities such as design, construction and asset management that rely on the successful collaboration of many stakeholders. The following shared conceptions engender a culture of collaboration.

Collaborative procurement methods

Traditional procurement methods fostered a siloed approach to information management.

Procurement methods such as integrated project delivery (IPD), Alliance and Early Contractor Involvement (ECI) contract delivery systems leverage the opportunities afforded by ICT enablers to improve the sharing of information.

Common data environment (CDE)

Usually cloud-based, a CDE provide a single source of information in a managed environment for all users, regardless of their location. While their technical implementation can take many forms, their key feature is the collaborative workflow described in AS ISO 19650 for managing information content. See [5.5 Common data environment](#).

The Golden Thread

The concept of a contiguous thread of safety-related information about a building. It is both the information that enables understanding of the building (e.g. details of active and passive fire safety systems) and the steps needed to keep both the building and its occupants safe – now and in the future. It includes the management processes required to keep the information accurate, up-to-date, fit for

purpose and accessible to those who need it throughout the building's life cycle.

Information as an asset

The recognition of the significant value of the asset information created during a project's design and construction phases that can be used for the operation of an asset. This drives the adoption of standards and processes that facilitate its efficient delivery.

Object libraries

Quality object libraries can significantly reduce the duplication of effort entailed in multiple modellers creating commonly used content from scratch each time it is required. Library content based on manufacturers' data and created in conformance with industry standards and best practice will contribute to the production of better quality, more reliable models. This creates greater certainty, but good content management across an organisation and projects is also required.

Open standards

Rather than confining stakeholders to a single suite of proprietary software, open standards such as buildingSMART's Industry Foundation Classes (IFC) enable interoperability between the many types of software necessary to deliver a project. Standards such as AS ISO 19650 provide procedural frameworks and a common language for a shared approach by a diverse group of stakeholders.

Whole life cycle perspective

This perspective is linked to the recognition that the information about an asset is a valuable asset in itself. This requires all stakeholders to extend their commitment beyond their traditional responsibilities.

Whole supply chain coordination view

The complexity of modern construction projects and large number of contractors and suppliers involved means that particular attention must be paid to managing the flow

of information up and down the supply chain for everything to be delivered in a timely manner. The early engagement of a supply chain specialist helps to reduce reworking by ensuring accurate coordination.

3.4 Input enablers

Devices for capturing real-world data or systems acting as a repository of reference information for models can significantly increase the efficiency and productivity of BIM processes.

Barcodes, QR codes and RFID

Marking an item with a unique barcode or QR code enables it to be identified by using a visual scanner. Radio Frequency Identification (RFID) use a similar principle but store data on a silicon chip that can be read by a radio scanner. They enable items to be identified and tracked in the supply chain and on site for project management purposes. They can also be used for rapid identification of assets and linking information about them to asset management systems. The data they store can incorporate industry standards such as Global Trade Item Numbers (GTIN) that can be linked to product information. Having this information available on site from day one reduces the amount of work at project handover. See [Site utilisation planning](#) and [Asset management](#) in this appendix.

Drones

Camera or LIDAR-carrying drones can be used to access otherwise inaccessible areas or provide higher vantage points for the collection of images for maintenance inspections or for photogrammetry. See [Existing conditions modelling](#), [Record modelling](#) and [Building maintenance management](#) in this appendix.

GIS Location finding

See [Global Information Systems](#) (GIS). Enables physical locations to be accurately linked to corresponding locations in models. This is

particularly important for widely distributed assets such as linear infrastructure. It can also be paired with other enablers such as laser scanning and barcodes to enhance their usefulness.

Ground-penetrating radar (GPR)

Radar pulses are used to create an image of subsurface conditions including utilities, e.g. pipes, cables without the need to excavate. See [Existing conditions modelling](#) in this appendix.

Internet of things (IoT) sensors

Describes physical objects embedded with electronic devices such as computing/sensing chips that connect and exchange data with other devices and systems over the Internet or a LPWAN. This offers the advantage over barcodes and RFIDs of providing continuous, real-time data without the need for someone to collect it manually with a scanner.

Sensors for a range of phenomenon such as movement, temperature, pressure, flow rates, voltage and light levels can be embedded in structures, plant or equipment and linked via the internet, LPWAN, etc to their virtual equivalents in models. This is key to creating an active digital twin. See [7.3.4 Digital twins](#) in the Guide and [Digital twins](#) in this appendix.

Laser scanning, LIDAR

Laser scanning or Light Detection and Ranging (LIDAR) can be used to scan existing site features including topography, buildings and building services to create a point cloud file (a large collection of accurate spatial reference points) that can be imported into a model for reference and/or further development. This process is quicker and more accurate than traditional methods and be used for surveying otherwise inaccessible items. Accurate site data provides the basis for more accurate designs. See [Existing conditions modelling](#) and [Record modelling](#) in this appendix.

Photogrammetry

3D measurements are extracted from a series of digital photographs by image processing software. GIS can be used to geo-locate them. A lower cost alternative to laser scanning for smaller areas, e.g. rooms or where less accuracy is acceptable. See [Existing conditions modelling](#) and [Record modelling](#) in this appendix.

3.5 Outputs enabled by BIM

The information in models can be processed to enhance the functionality of software applications or shared with other digital systems or devices to inform or operate them, offering significant improvements in accuracy and productivity compared to more established methods. The following items make use of outputs from BIM or enhance its use.

3D printing, additive manufacturing

The process of using data from a virtual model of an object to drive a 3D printer that replicates it as a physical object. Materials for printed items include plastics, metals and ceramics. Walls or whole buildings can be 'printed' in concrete.

Artificial intelligence (AI) and machine learning (ML)

AI is based on advanced algorithms embedded in software to mimic cognitive functions such as learning and problem solving. Early applications to BIM include automating repetitive modelling and model checking tasks. ML is a sub-branch of AI concerned with enabling computers to learn, adapt, and perform desired functions autonomously.

Blockchain

A system of recording digital transactions in a ledger that is duplicated and distributed across a wide network of computer systems with the intention of creating a permanent and unalterable record. Its value to BIM includes generating an auditable trail of project

transactions such as RFIs, instructions, amendments and information exchanges.

CAAMS, CAFM, CMMS

Data from models can be exported to Computer Aided Asset Management Systems (CAAMS), Computer Aided Facility Management (CAFM) or Computerised Maintenance Management Systems (CMMS), or to directly control equipment and services or via systems such as Building Management Systems (BMS) and Traffic Management Systems (TMS). Sensors are used to feed data to the model and controls, and actuators are used to control physical systems from the model. See [Asset management](#) in this appendix.

Design for Manufacture and Assembly (DfMA)

A design approach that focuses on ease of manufacture and efficiency of assembly. By simplifying the design of a product, it is possible to manufacture and assemble it more efficiently, in the minimum time and at a lower cost. It can be adopted for the off-site prefabrication of construction components such as concrete floor slabs, structural columns and beams. BIM is well-suited to this type of design approach and to prefabrication because of the accuracy it enables.

Digital fabrication

Computer-aided design & computer-aided manufacturing (CAD/CAM) refers to the process of using data from a virtual model of an object to drive Computer Numerical Control (CNC) machinery to fabricate the physical object. See [DfMA](#) and [Digital fabrication](#) in this appendix.

Digital twins

A digital representation of an asset to support operational functions. What distinguishes digital twins from building information models in general is their linkage to the physical asset they represent and the exchange of data between them. See [7.3.4 Digital twins in the](#)

[Guide](#) and [Digital twins](#) in this appendix for more details.

Generative design

Creating alternative design solutions in model authoring software by applying form generating algorithms to a range of inputs and output goals. It can be used to design , develop or evolve elements, systems or complete built assets more or less autonomously.

GIS Field tracking

Very small devices called ‘tags’ which store GPS data about their location can be attached to items so their position can be tracked using a device that reads this data, e.g. a smartphone with a purpose-made app. This can enable tracking of items moving along the supply chain and/or on site. See [Site utilisation planning](#) in this appendix.

GIS digital set out

Spatial data from a model can be loaded into a robotic total station: an electronic-laser surveying instrument that can be used to identify locations in physical space with a high degree of accuracy. They enable work to be set out much more quickly and reliably than traditional methods, particularly in less accessible locations such as overhead soffits. See [3D control and planning \(digital layout\)](#) in this appendix.

IoT controls and actuators

Just as sensors can feed data from physical assets to virtual models of them, controls and actuators incorporated in plant and equipment can be operated by data from models. This is key to creating an active digital twin. See [7.3.4 Digital twins](#) in the Guide and [Digital twins](#) in this appendix.

Parametric design or modelling

The creation of models based on a series of pre-programmed rules typically used to define relationships within and between model

objects and elements so that when one is changed, the others are automatically changed.

Robotics

The use of robots to automate construction tasks such as information gathering, carrying materials, and assembling building elements guided by geospatial data or spatial data derived from a model.

Smart cities

The digital twin concept extended to cities (buildings, open space, infrastructure, utilities) for the purposes of data collection, analysis, simulation, management and control including urban and transportation planning. See [7.3.4 Digital twins](#) in the Guide and [Digital twins](#) in this appendix.

Smart infrastructure

The digital twin concept extended to infrastructure for the purposes of data collection, analysis, simulation, management and control. See [7.3.4 Digital twins](#) in the Guide and [Digital twins](#) in this appendix.

Virtual reality (VR), augmented reality (AR), mixed reality (MR)

With VR, headsets which block out all view of the wearer’s surroundings are used to display computer generated images directly in front of their eyes. In the instance of BIM, this is usually proposed designs for a built asset. VR provides a more immersive experience for the viewer than 2D or 3d renderings including walk-through videos, giving designers and end users a more accurate picture of what the design will be like. With AR, lenses enable the viewer to see what is in front of them, and the headset also overlays this with an image of the model as seen from their position. This is useful for showing what a proposal will look like in the context of its surroundings. MR enables the viewer to interact with and manipulate both physical and virtual items and environments. See [Design review](#) in this appendix.

4 REFERENCES

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NATSPEC National BIM Guide

This document is one of a suite of documents forming the *NATSPEC National BIM Guide*. You can download or view the other documents here:

<https://bim.natspec.org/documents/natspec-national-bim-guide>

5 ANNEX 1: MAPPING BETWEEN ABAF AND NATSPEC BIM USES

		ABAF BIM Competency Framework use	Ref.	NATSPEC National Guide BIM use
Project Delivery	Authoring	Existing Conditions Model Authoring	2.1	Existing conditions modelling
		Design Model Authoring	2.4	Spatial programming
			2.6	Design authoring
		Construction Model Authoring	2.15	Construction documentation
			2.17	Construction system design (virtual mock-up)
			2.18	Digital fabrication
	As-Constructed Model Authoring	2.20	Record modelling	
	Communication	Visual Communication	2.7	Design review
	Coordination	Disciplinary Models Coordination (Clash Detection)	2.14	3D coordination
		Model Validation	2.13	Code validation
	Simulation and analysis	Site Selection Analysis	2.5	Site analysis
		Structural Performance Analysis	2.8	Structural analysis
		Lighting Performance Analysis	2.9	Lighting analysis
		Energy Performance Analysis	2.11	Energy analysis
			2.10	Engineering analysis (Mechanical, other)
		Sustainability Analysis	2.12	Sustainability analysis
		Construction Planning and Simulation (4D modelling)	2.3	Phase planning (4D modelling)
		Site Logistics Modelling (an extension to 4D modelling)	2.16	Site utilisation planning
		Cost Analysis (5D modelling)	2.2	Cost management (5D modelling)
Operation	Monitoring Maintenance	2.23	Building maintenance management	
	Monitoring Asset Performance	2.22	Asset management	
		2.24	Building system performance analysis	
		2.21	Digital twins	
	Space Utilisation Management	2.25	Space management and tracking	
No match	N/A	2.19	3D control and planning (digital layout)	
		2.26	Emergency response planning	

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