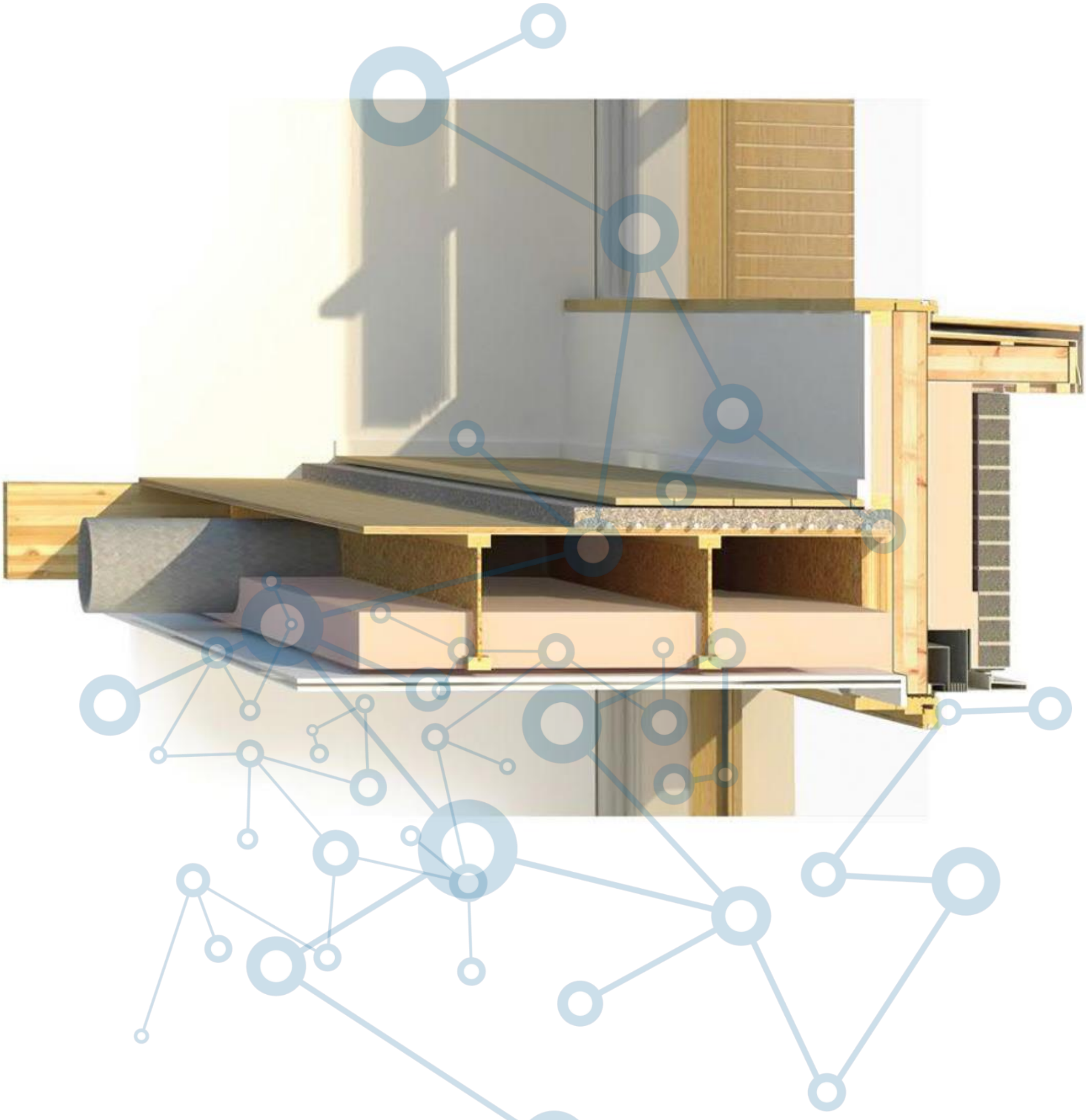

Building Information Modelling for Wood Buildings

AN INTRODUCTORY GUIDE

SCIUS Advisory

BIM One Inc. Virtual Construction & Technology

Building Information Modelling for Wood Buildings, An Introductory Guide was commissioned by Forestry Innovation Investment Ltd.

For more information about British Columbia wood products and the sustainably managed forests they come from, visit naturallywood.com

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Forward

BIM is a driving force in the digital transformation of the construction industry. BIM use coupled with lean processes and collaborative methods are enabling the delivery of more economical, sustainable and resilient buildings. Projects that implement these innovative approaches are showing significant benefits throughout the project lifecycle, across the industry supply chain, and for all types and scales of building projects.

BIM has the potential to unlock the power of timber design and wood fabrication for the building sector. Wood is a widely used construction material that contributes significantly to carbon reduction goals in building construction. The adoption of advanced technologies like BIM can enable digital fabrication and off-site construction that will lead to significant improvements in productivity, reliability, and quality. These innovations rely on designers and builders being conversant with digital design, collaboration and delivery methods.

This guide is intended to provide those working on timber projects with an introduction to how BIM works and the implications of adopting BIM — particularly for small businesses. It also aids those championing the use of BIM in conveying the value proposition to owners. For owners, the benefit not only lies in a more reliably executed project but also in its future management and operation. BIM enables the delivery of integrated, high quality, and well-organized information at building handover, contributing to improved asset value over the life of a facility.

It is my hope that the current enthusiasm for timber construction will be an important catalyst for the adoption of BIM in the building sector. I want to thank all the industry experts that contributed to this guide. Sharing ideas and experiences is a powerful way to build capacity and move the industry forward.

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Purpose of this guide

Wood is a popular and widely utilized construction material that plays an important role in addressing climate change due to its ability to store carbon. Wood lends itself to off-site construction techniques—for example, modern prefabricated light-frame units, mass timber and hybrid systems—which can be factory-produced to high levels of accuracy for speedy, reliable installation on-site. Today, advanced, highly engineered wood systems have the potential to disrupt the building industry.

Building Information Modelling (BIM) is a digital form of construction delivery and facility management that fosters collaboration and information exchange across the entire project team, over a building's entire service life. For wood projects, BIM enables architects, engineers and builders to unlock the advantages of off-site construction, leveraging the benefits of emerging timber technologies to deliver cost-effective, low-carbon buildings.

The purpose of this guide is to introduce BIM to building owners, design and construction professionals and suppliers who work in the world of wood buildings. It offers an easy-to-understand starting point for the adoption of BIM practices and illustrates the value that BIM can add in terms of improved efficiency, reliability and sustainability.

This is not a technical guide to BIM application, standards, etc., which can be found in other industry-accepted sources and which are referenced throughout. Rather, the contents draw on the insights and advice gathered from over twenty leading architects, engineers and builders who have worked on a wide range of advanced wood buildings in Canada. The guide's five chapters are designed to be either read in sequence to gain an understanding of the general concepts or broken out to serve as standalone references for sharing with project partners, colleagues and industry stakeholders. The recommended readership is identified at the start of each chapter.

Glossary

2D Documents

The traditional means of communicating building project information; soft and hard documents such as drawings and specifications.

Asset Information Model (AIM)

The Building Information Model used by a building's owner for its operation throughout its life cycle; derived from the building project team's model.

BIM Execution Plan (BIMx)

Typically drafted by the BIM leaders in the project management team, the BIM Execution Plan documents the vision, goals, requirements and approach the team will follow to ensure the digital model supports the design and construction tasks.

BIM Technology Stack

The BIM Technology Stack is the software workflow that the building project team utilizes to accomplish key design and construction tasks. The complexity and types of software can vary greatly depending on the owner's goals and building requirements, and the team's capabilities, methods and means.

Building Information Model (BIM) and BIM Model Elements

The Building Information Model is the digital asset created by the project team for the purpose of collaboration. It is not simply a 3D model; it is a digital form of project delivery and facility management that fosters collaboration and information exchange across the entire project team, and over a building's entire service life.

Common Data Environment (CDE)

The Common Data Environment is the central repository where construction project information is housed, and which provides key stakeholders with a digital representation of a building spanning the project life cycle.

Communication Strategy and Platform

A Communication Strategy is part of the BIM plan, providing a plan for the timely sharing (and notification of) information critical for design, construction and operational tasks as part of the building project. The platform is the means to access and update the team via shared, dedicated databases.

Dimensions

Dimensions describe how the digital model can be used to assist in design, construction and operation. Dimensions are aspects of the building project—including spatial relationships, project cost and schedule, or building energy performance—that the BIM can virtually simulate; a "twin" of the building, to help with analysis and decision-making.

Facilities Management (FM)

The broad operations of managing the built asset, covering the day-to-day, emergency or life cycle planning for the building.

Federated Information Model

A Federated Information Model is assembled from several distinct models from different disciplines into a single, complete model of the building, and is the product of higher Maturity Levels.

Information Management (IM) Plan

The Information Management Plan is integral to BIM, functioning as part of the BIM Plan to manage the production, collection and organization of information—a key part of facilitating BIM collaboration.

Level of Development, Level of Detail (LOD)

Level of Development describes the degree of richness of technical information in the digital model. The information can range from a rudimentary 3D form (LOD100) to a fully described digital twin (LOD 500).

Maturity Level

Maturity Level defines the level of collaboration expected of the project team. It determines who is involved in the digital model, their level of participation, and when they are required to be involved. The level of BIM Maturity ranges from none (e.g., paper-based exchange of two-dimensional information) to full life cycle-based management, supported by integrated, interoperable data systems.

Operations and Maintenance (O&M)

The technical operations of maintaining the built asset, led by professionals in a broad range of building services, sometimes referred to as building engineers.

Project Team

The project team comprises the owner, consultants, general contractors, trades and suppliers that are involved in the design and construction of the built asset. The team may also include owner agents such as operations and maintenance staff.

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Chapter 1: What value does BIM bring to wood projects?

Recommended for Design and construction professionals, suppliers, owners and policymakers

Summary

- Building Information Modelling (BIM) is a digital form of construction delivery and facility management that fosters collaboration and information exchange across the entire project team.
- Wood is an ideal material for digitally driven, modern methods of construction. It is a low-carbon material that is easy to mill and prefabricate off-site. It is light yet robust enough for handling and transportation, and easy to modify and attach on-site.
- BIM describes a dynamic process of creating information-rich models that support the management of the building throughout its life cycle, from planning and design through to operation and decommissioning. It provides timely and easily accessible information when and where it is critical, to assess and resolve issues, and to execute solutions.
- BIM is an important tool for delivering advanced wood buildings efficiently, particularly when paired with off-site construction methods.

1.1 Using BIM to deliver low-carbon wood buildings

Building Information Modelling (BIM) is at the centre of a digital transformation of the construction sector and the built environment. BIM is a digital form of construction delivery and facility management that fosters collaboration and information exchange across the entire project team, and over a building's entire service life. It brings together technology, process improvements and digital information to dramatically improve client experience, project outcomes and building operations. BIM is a "strategic enabler for improving decision-making for both buildings and public infrastructure assets across the whole life cycle"[1]. BIM is not new, but it is a growing trend around the world. It is "the technology-led change most likely to deliver the highest impact to the construction sector"[2]. The wider adoption of BIM could deliver 15 to 25 percent savings to the global infrastructure market by 2025[3].

What is a Building Information Model?

A Building Information Model is a digital representation of physical and functional characteristics of a building. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle. Depending on the life cycle stage, the Building Information Model may be:

A **Project Information Model (PIM)** during the building design and construction phases.

An **Asset Information Model (AIM)** when used during the facility management/building operations stage.

The primary benefit of BIM for any project is that it can improve the efficiency of day-to-day design and construction tasks. How BIM can (and, ideally, should) be deployed throughout the life cycle of the building for its value to be fully realised is illustrated in Figure 1.

[1] EU BIM Task Group, www.eubim.eu/downloads/EU_BIM_Task_Group_Handbook_FINAL.PDF
[2] WEF, Shaping the Future of Construction, 2016 www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf
[3] BCG, Digital in Engineering and Construction, 2016 http://futureofconstruction.org/content/uploads/2016/09/BCG-Digital-in-Engineering-and-Construction-Mar-2016.pdf; McKinsey, Construction Productivity, 2017 www.mckinsey.com/business-functions/operations/our-insights/improving-construction-productivity

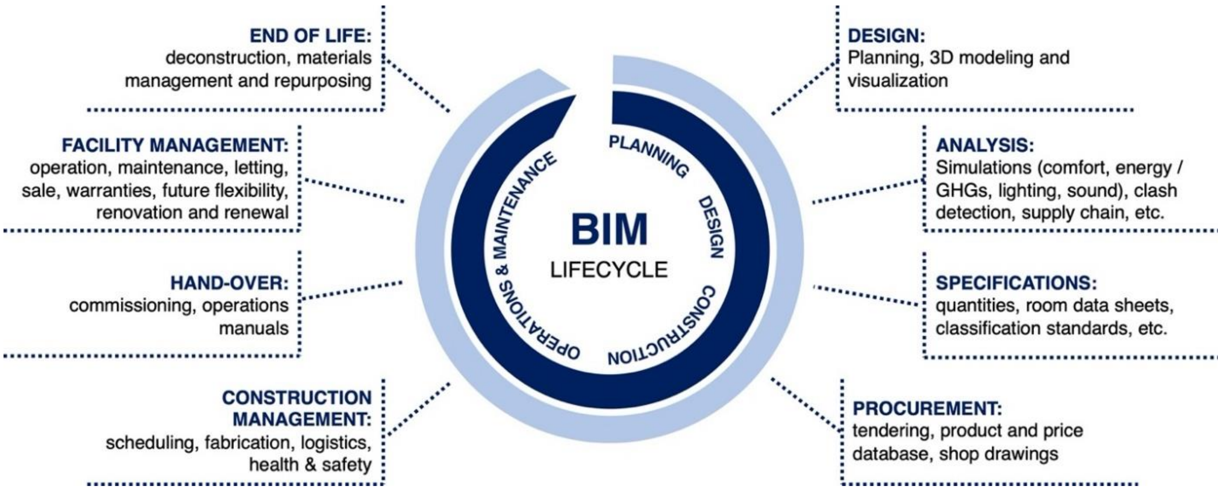


Figure 1: The BIM life cycle

BIM's basic premise is that it facilitates seamless collaboration by different stakeholders at different phases of the life cycle of a building "to insert, extract, update or modify information in the digital model to support and reflect the roles of that stakeholder."[4] From design inception to project hand-over, BIM has been shown to help improve team productivity, reduce uncertainty, control whole-life costs and environmental data, avoid rework costs, improve safety, reduce on-site waste and avoided errors. Then, once the building is operational, the as-built digital model and all the data contained within gives the owner an accurate record of the project and a powerful digital asset management tool. Other benefits include streamlined team communication, and improved project information quality and management.

Figure 2 summarizes the key characteristics of BIM and their advantages.

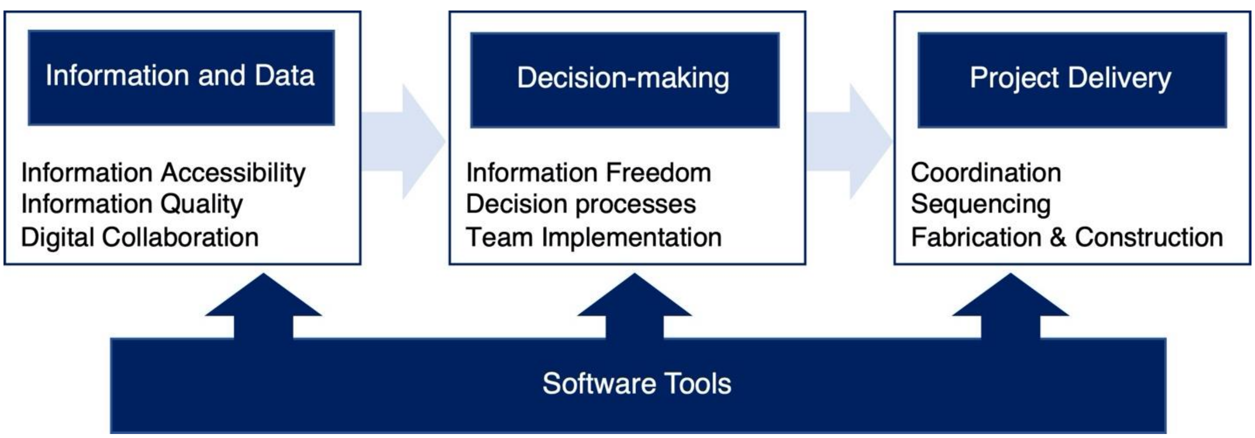


Figure 2: Key characteristics and advantages of BIM

[4] Source: National BIM Standard - US, Version 1.0: https://buildinginformationmanagement.files.wordpress.com/2011/06/nbimsv1_p1.pdf

The value to the owner and the project team is derived from:

- **Streamlined communication:** a federated 3D model of the building is accessible to all project participants. It makes for efficient communication, removes the potential for project divergence and minimizes administration burdens and errors.
- **Information management:** BIM provides a shared model that federates, organizes and communicates up-to-date information from all project participants. The model visualizes and organizes spatial, dimensional and physical data. It contains embedded non-graphical data, such as cost, performance (e.g., function, routines, maintenance, energy, embodied carbon) and technical specifications into a single source.
- **Process optimization:** BIM logically presents physical, systemic and informational relationships as a virtual copy of the completed building. This allows the team to efficiently make design, construction and operational decisions with the best available information. The information in the digital model is used as the basis for analysis, to make collective decisions and inform tasks for design, fabrication, construction and facilities management.
- **Accurate digital record:** Digital twinning pushes the model further, creating a digital facsimile of the building, where sensors, equipment and other systems can report operational data. It allows the team to track, optimize and plan maintenance, retrofits and commissioning. The model becomes the Asset Information Model (AIM) at hand-over and is the operations and maintenance manual, building operations dashboard, and a digital record of the building.

"BIM is the foundational platform of how we deliver projects and it's the basis upon which we build layer upon layer of data and information using multiple applications.*"*

~ Architect

"A barrier to wide-spread adoption of BIM practices in the building industry is our obsession with everything that can go wrong on a project—and reacting defensively against the rest of the project team. In contrast, BIM fundamentally demands a team to work together digitally from start to finish. You prove yourself a useful team player or a team laggard very *early on."*

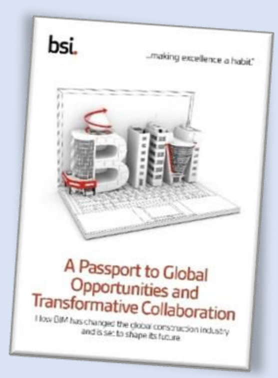
~ General contractor

BSI: Building Information Modelling and Collaborative Construction

Canada does not yet have a robust suite of BIM standards. For now, BIM practitioners are referring to leading international standards. The British Standards Institution (BSI) Group is the standards body of the United Kingdom. The Group is a respected member of the international technical community and has an active presence in Canada. BSI has published both standards and resources related to BIM, covering the project and business aspects of adopting and utilizing BIM.

Although not written with timber projects in mind, BSI identified several benefits that would be of value and particularly relevant for owners when considered in the context of linking the BIM process to Virtual Design and Construction (VDC):

- Faster and more efficient processes
- Increased productivity and faster delivery
- Reduced uncertainty
- Controlled whole-life costs and environmental data
- Avoidance of rework costs
- Improved safety
- Reduced on-site waste
- Prevention of errors



More information can be found here:
www.bsigroup.com/en-CA/building-information-modeling-bim

1.2 Using BIM for off-site wood construction

Wood is a popular and widely utilized construction material that plays an important role in addressing climate change due to its ability to store carbon. It is structurally strong, light and machinable, lending itself to modern methods of construction. The use of BIM for the delivery of wood buildings in Canada is still at an early stage of adoption and, when it is being used, it is primarily at the design phase of the project. However, there is growing recognition that BIM enables architects, engineers and builders to unlock the advantages of off-site construction, leveraging the benefits of emerging wood technologies to innovate design and construction, and deliver projects on-time and on-schedule.

Off-site construction involves the prefabrication or pre-assembly of elements away from the job site to accelerate construction schedules without compromising quality or cost. Wood structural systems for off-site construction include modern prefabricated light-frame units, mass timber and hybrid systems, which can be factory-produced to high levels of accuracy for speedy, reliable installation on-site. Today, wood is emerging as a material with high potential to disrupt traditional, site-focused construction, which is often highly uncertain, risky, and prone to levels of poor productivity, resulting in unreliable cost and schedules.

Leading practitioners surveyed for this guide use BIM for a range of off-site construction approaches, but most commonly when working with prefabricated structural elements and mass timber (Figure 3).

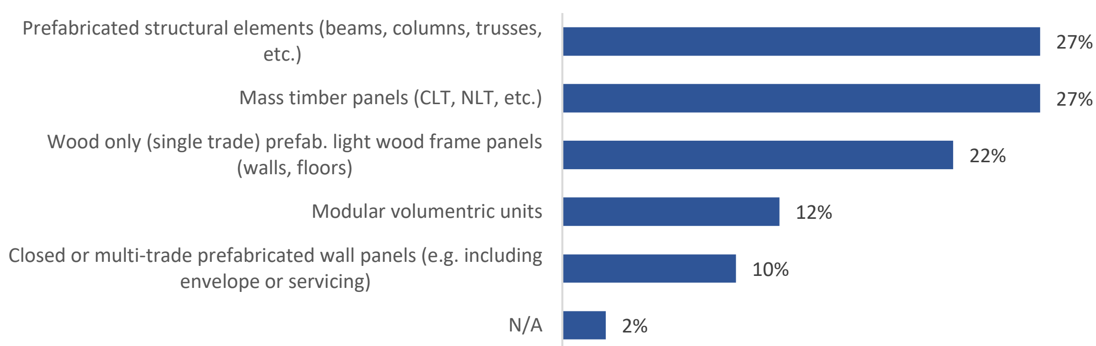
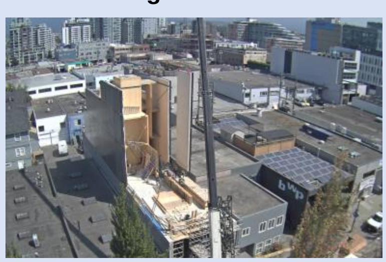


Figure 3: Off-site construction approaches in wood projects that used BIM
(From the survey of leading BIM practitioners, Appendix A1)

Examples of off-site construction methods using wood

Pre-assembly light wood frame panels and elements



Prefabricated mass timber panels

Modular units

Figure 4: Off-site construction methods

There are unique considerations when using BIM to plan and build a wood project. At the design phase, the team can use BIM to develop and verify the primary wood structure and carbon performance of the project. Then, the construction team can use the digital model to build the project virtually, which helps them to plan and execute the off-site fabrication of wood and system components and rehearse the on-site erection of the prefab components. Figure 5 presents a high-level BIM workflow and the steps that can be added when developing a wood project. This is discussed in more detail in Chapter 4.

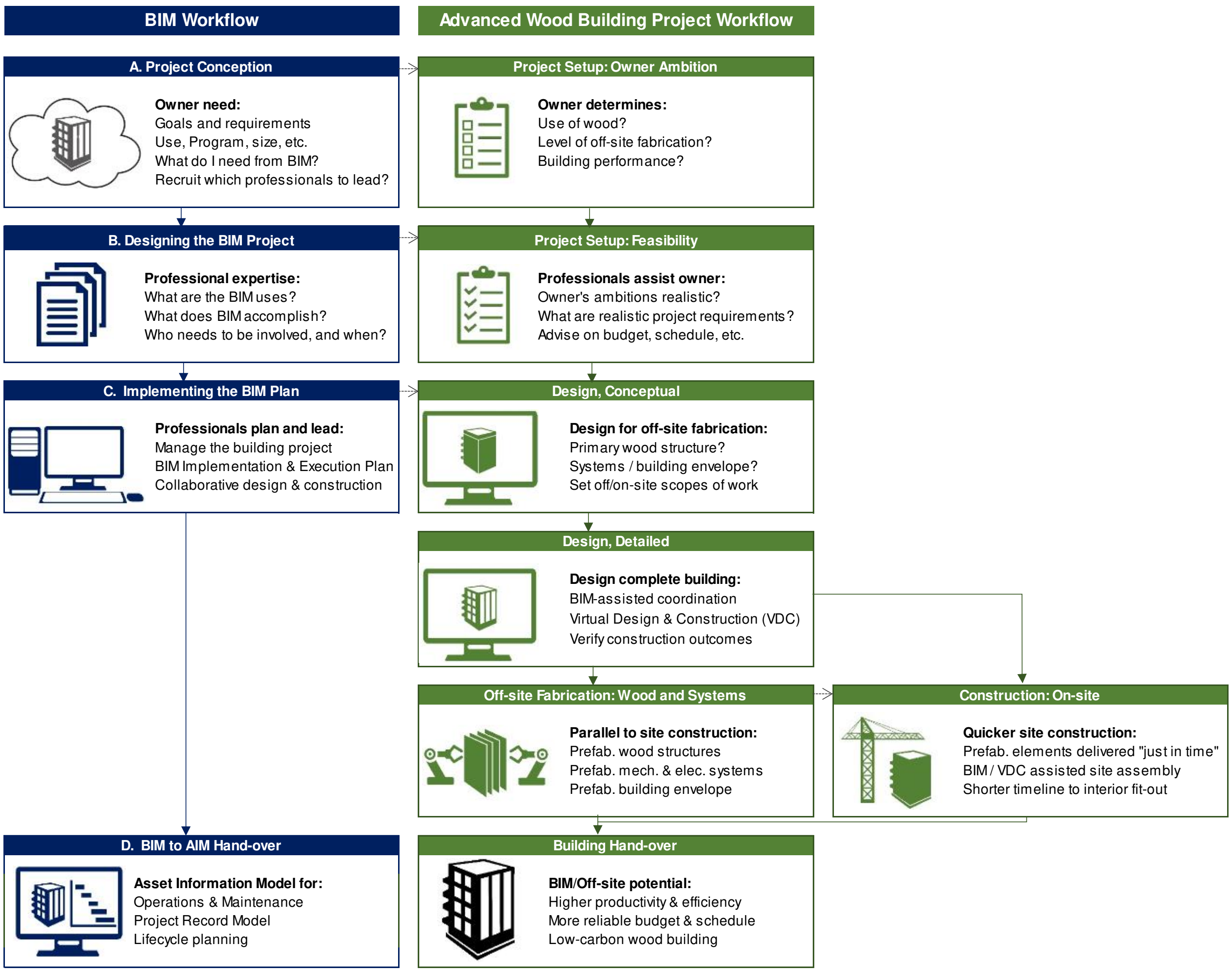


Figure 5: High-level BIM workflow illustrating the additional steps and considerations for an advanced wood project

"BIM allows for the design of standard assemblies, allowing users to store and apply solutions to new projects without the need to start from scratch. This also allows for continuous improvement (referencing KAIZEN). Standard assemblies can be upgraded over time to optimize existing and proven assemblies and kits of parts.

BIM also allows for standardization or "productization", creating large economies of scale in supply chains. If architects and engineers leverage the same standard assemblies, we can now provide a consistent, more predictable demand for standardized components (e.g. mass timber). This unlocks greater opportunity for mass automation in manufacturing to deliver at scale, resulting in lower cost of material and pre-construction time, as well as a massive uplift to manufacturing productivity. This is similar to the humble 2x4, produced, delivered and stored at your local big box hardware stores; or standardized mechanical equipment product lines. BIM can be the key to lower costs while drastically improving quality at *all stages of construction right through to the operation and lifecycle of the building."*

~ Software developer

Chapter 2: How is BIM defined? How do I ask for BIM?

Recommended for Design and construction professionals, suppliers, owners and project managers

Summary

- BIM leverages digital tools to collaborate and exchange information to create rich, digital models useful for the entire life cycle of a building project. To achieve this, three parameters guide a BIM delivery process and are critical when procuring a BIM project and setting the BIM requirements:
  - Maturity Level
  - Levels of Development (LOD)
  - Dimensions
- A BIM project's success depends on how well it is set up at the start and the owner needs to be committed to the process. The project's BIM requirements need to be included in the RFP and tendering documents.

For owners and project leaders to understand how to ask for BIM to be used on their projects, it is first necessary to define the basic mechanics of BIM. BIM encompasses a dynamic process of creating information-rich, digital models for the entire life cycle of a building project. Within this broad definition, three parameters set the frames of reference for BIM, which can vary depending on the owner's goals and building requirements, project type, life cycle phase, etc.:

1. **Maturity level:** establishes the level of collaboration and integration of the project team with the BIM process.
2. **Level of Development (LOD):** describes the depth or "richness" of technical information in the model.
3. **Dimensions:** refers to how different data and information are utilized together over the budling's life cycle.

2.1 Maturity Levels

Maturity Level defines collaboration, which is one of the key characteristics and value propositions of BIM. By extension, Maturity Level determines who is involved in the digital model, their level of participation, and when they are required to be involved. The level of BIM Maturity ranges from none (e.g., paper-based exchange of two-dimensional information) to full life cycle-based management, supported by integrated, interoperable data systems (Figure 6).

Organizations such as buildingSMART Canada[5], PennState College of Engineering[6] and the British Standards Institute (BSI)[7] have developed reference materials for a common understanding of the levels of BIM Maturity that describe the communication and collaborative processes of the project team.

[5] https://buildingsmartcanada.ca
[6] https://bim.psu.edu/
[7] https://www.bsigroup.com/en-CA/building-information-modeling-bim

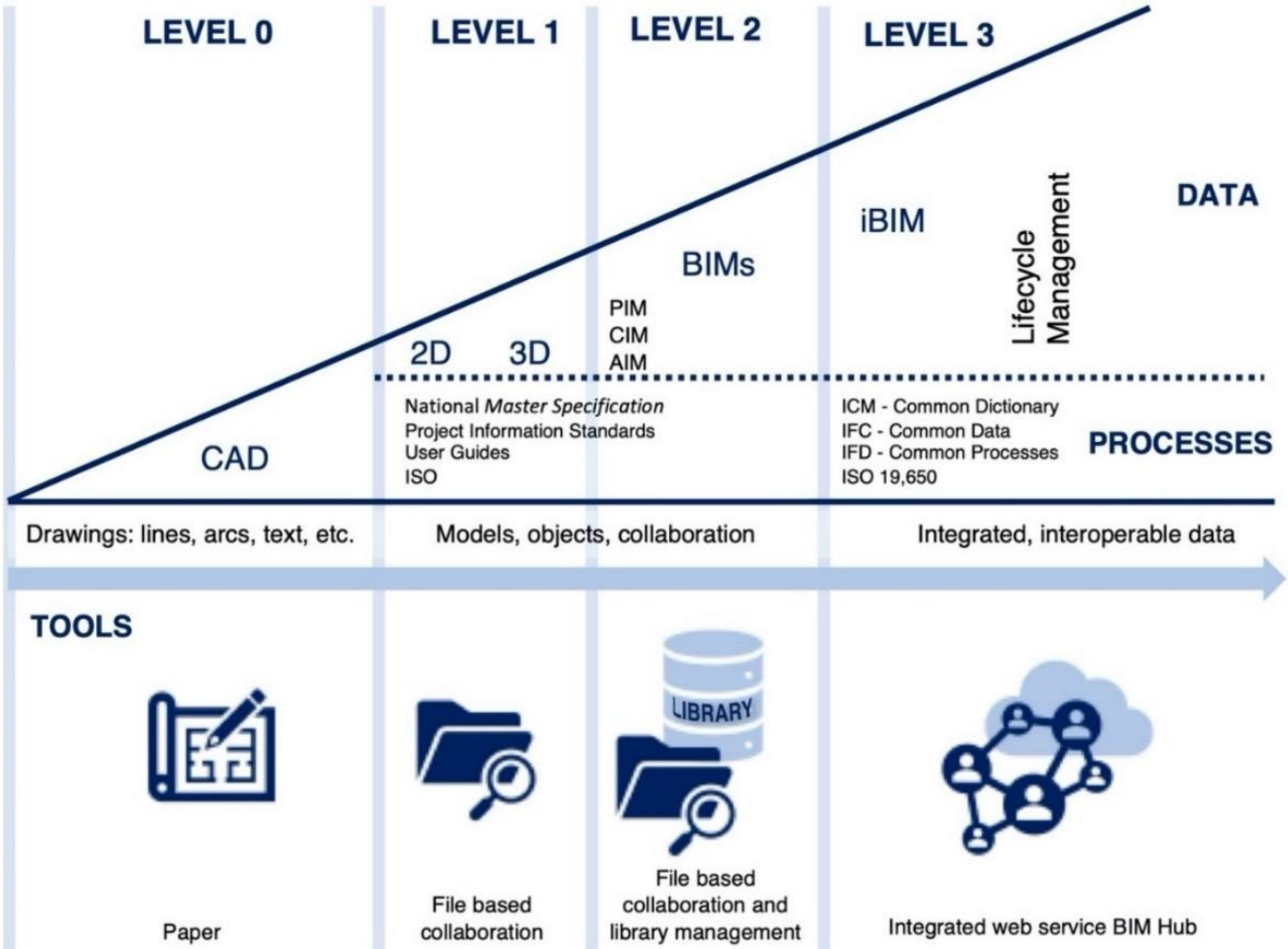


Figure 6: BIM Maturity levels—the BIM "wedge"
(Adapted for the Canadian context from Bew & Richards (2008), BIM Client Maturity: Literature Review)

BIM Maturity Levels vary according to client needs, as well as the demands of the project itself. For example,
a hospital project may require high BIM Maturity Levels due to the complexity of the building, the number of stakeholders involved, and the amount and technical complexity of information required by the health care authority client. Other projects may only require high BIM Maturity Levels from certain project team members — who, when, and how involved in BIM is best determined by consultants, contractors and suppliers during project setup. The BIM Maturity Levels are summarized below with comments on the advantages that each level offers the project team over traditional methods and any limitations or watchpoints to be aware of.

What is a federated Building Information Model?

The term federation refers to a group within which organizations, systems and networks operate in a standard, collective and connected environment. A federated BIM is assembled from several distinct models from different disciplines into a single, complete model of the building, and is the product of higher Maturity Levels.

Level 0 BIM – Low Collaboration	
Each stakeholder creates and manages their own data with little opportunity to share digitally.	
Advantages over traditional methods	**Limitations and watchpoints**
None. This is the simplest form of 2D CAD.	Level 0 BIM was effectively made obsolete with the adoption of CAD in the early '90s when it became easy to exchange digital files.

Level 1 BIM – Partial Collaboration	
Typically, Level 1 involves a mixture of 3D and 2D CAD, as well as a basic Information Management plan. A 3D model is developed early in the project for visualization purposes (e.g., renderings for regulatory approvals and leasing). Then, a switch to 2D workflows occurs at the end of the conceptual phase, where the 3D model is used to set up the 2D CAD process for the ongoing schematic and design development, and finally contract documentation. Project information is then contained within 2D drawings and accompanying specification documents.	
Advantages over traditional methods	**Limitations and watchpoints**
None. The 3D BIM model is only used to generate a 2D set of drawings and is not considered a source of data.	The model may be shared within the design team for basic coordination and information extraction. Each team member creates and manages their own data.

Level 2 BIM – Full Collaboration	
Level 2 is defined by the utilization of the 3D model to communicate, coordinate and make decisions. At this level, BIM is "an information exchange process which is specific to that project and coordinated between various systems and project participants"[8] and can be executed using either: ▪ a common file format or compatible BIM software, which allows the 3D models to be integrated into a composite, federated digital representation of the building, or ▪ a unified 3D model that is updated and shared with all team members at agreed-upon times. Level 2 BIM is the most prevalent form of BIM practice in Canada today. Project team members use products such as Autodesk Architect Engineering and Construction Collection[9] and work with shared or linked models either through cloud-based applications or simple model exchange (see Appendix A.2 for commonly used applications in Canada).	
Advantages over traditional methods	**Limitations and watchpoints**
During the design phase, the 3D model can be used for planning, design, energy simulations, clash detection, etc. Sharing a common 3D model (whether integrated or unified) allows the team to communicate accurate, up-to-date information, enabling the team to make decisions collaboratively and efficiently.	The model may be shared for basic coordination, information extraction and collaboration, but is primarily used to generate a 2D set of drawings and is interpreted together with paper-based specifications. Switching to 2D erodes many of the advantages offered by a 3D model such as efficient decision-making. The information management aspects of BIM are typically not implemented at all.

[8] Source: Scottish Futures Trust. More information at: https://bimportal.scottishfuturestrust.org.uk
[9] https://www.autodesk.ca/en/collections/architecture-engineering-construction/overview

Level 3 BIM – Full Integration

Often referred to as "openBIM", Level 3 comprises full integration of all project participants into the BIM process through design and construction. Hand-over of the project documents and data is handled digitally through the BIM model which then serves as the basis for building operations. The model becomes a digital asset and facility management tool for the life of the building. The collaboration required of the project team members to deliver this level of BIM Maturity can be much more intensive than normal practice, and it is common for the terms of engagement to be laid out in contractual terms.

The owner, consultants, contractor and trades all work within a unified BIM, which is updated and shared at agreed-upon times. Particularly, the model serves as a digital twin of the building.

Advantages over traditional methods

The digital model is the primary information record, often being guided by the BIM Execution Plan (see Chapter 4). While 2D documentation can be utilized (including drawings derived from the BIM), the model is main source, aggregator and organizer of the project information—yielding superior use of the data and information.

This level of BIM deployment benefits the owner, builder, trades and suppliers, through reduced fabrication cost and time. Other project participants may yield the advantage of better time management leading to improved project outcomes.

Limitations and watchpoints

There is a significant level of project planning up front at which time the project's modelling and data requirements, collaboration protocols and file output protocols need to be established.

Requires the adoption of open data standards to set clear and consistent parameters for electronic data exchange and management.

openBIM

buildingSMART Canada is the Canadian chapter of buildingSMART International and home to Canadian BIM and digital project and asset life cycle delivery standards and best practices development. There is a wealth of resources including the Canadian Practice Manual and a range of practical toolkits available at https://buildingsmartcanada.ca.

buildingSMART defines openBIM as a collaborative process that is inclusive of all participants, promoting interoperability to benefit projects and assets throughout their life cycle. It is based on open standards and workflows that allow different stakeholders to share their data with any BIM compatible software. openBIM ensures that:

- **Interoperability** is key to the digital transformation in the built asset industry
- **Open** and neutral standards should be developed to facilitate interoperability
- **Reliable** data exchange depends on independent quality benchmarks
- **Collaboration** workflows are enhanced by open and agile data formats
- **Flexibility** of choice of technology creates more value to all stakeholders
- **Sustainability** is safeguarded by long-term interoperable data standards

2.2 Levels of Development (LOD)

BIM Levels of Development (LOD—also referred to as Levels of Detail) define a BIM project's required technical depth and breadth in the digital model. The information can range from a rudimentary 3D form (LOD100) to a rich, fully described digital twin (LOD 500) (Figure 7).

LOD establishes how much detail is expected for the technical elements within the model. LOD is communicated to the consultants, suppliers, contractors, and trades people when they join the project, to gauge how much effort will be required, and when. Less common and under-utilized in Canada, LOD can also incorporate the building owner's in-service, life cycle requirements into design and construction. BIM Forum's Level of Development Specification provides examples at each LOD.

Level of Development (LOD) Specification

BIM Forum's Level of Development (LOD) Specification is an industry accepted reference that enables practitioners in the architecture, engineering and construction (AEC) industry to specify and articulate with a high level of clarity the content and reliability of Building Information Models at various stages in the design and construction process.

Available for free download at: https://bimforum.org/lod/

Figure 7: BIM Levels of Development from LOD 100 to LOD 500 (Image source BIMETICA[10])

It is essential for the core project team (owner, consultants, contractor) to define and set the LOD for specific scopes of work pre-project. This ensures that all members of the project team (including the trades and suppliers) are hired with clear roles and responsibilities and a full understanding of the BIM requirements for the project.

LOD for wood projects that use off-site construction methods can vary depending on the owner's goals and building requirements but are typically based on coordination and fabrication milestones for the primary wood structural system, including related steel connections and concrete foundations. LOD facilitates information sharing critical for off-site prefabrication, modular systems or kits of parts, as well as quick, safe and efficient on-site assembly. Post fabrication, the digital model serves as a virtual "master" of the building's structure (already set for fabrication) that governs downstream elements, such as mechanical systems selection and building envelope detailing.

LOD 100 – Pre-Design

[10] A selection of images describing LOD can be found at http://manufacturers.bimetica.com/technical-and-legal-bim-file-auditing/

LOD 100 provides a low level of development with minimal or no non-graphical data. It aligns with the traditional concept phase where schematic, primitive forms are used to establish the basic concept. Design elements may be represented non-geometrically (e.g., by a symbol or simple block). LOD 100 outputs are generally used for visuals and communicate the designer's vision.

LOD 200 – Schematic Design

An LOD 200 model offers a generic graphical representation consisting of approximate size and form. The LOD 200 model has minimal non-graphical data that may include the approximate size, quantities and location of a building element. It is still considered a low level of development that is only usable during early design for the purpose of permit acquisition or marketing. However, there is sufficient information for the project team to begin preliminary high-level coordination.

LOD 300 – Design Development

At LOD 300, model elements are graphical representations of objects or assemblies. LOD 300 includes non-graphical data related to the element. Objects are placed accurately to facilitate coordination and design development. The model can be the foundation for carbon and energy analysis. Coordination focusing on hard clashes between design disciplines occurs here, and the constructor utilizes the model to review constructability and coordination. LOD 300 is typically used for Construction Documentation on relatively simple buildings where complex geometry and data is relatively low (single-family and low-rise residential, light commercial, light industrial, etc.).

LOD 350 – Construction Documentation

Model elements at LOD 350 are geometrically accurate representations of objects or assemblies that also include non-graphical data (such as weight, cost, manufacturer, installation information, etc.). Objects are placed accurately to facilitate coordination. LOD 350 typically occurs on complicated projects where there is a high degree of detail and/or complex geometry and close collaboration is crucial.

LOD 400 – Construction Phase

LOD 400 model elements are geometrically accurate representations of objects or assemblies, where the fabricator takes production information directly from the model, eliminating the need to prepare separate shop drawings. LOD 400 includes non-graphical data related to the object or element. Objects are placed accurately to facilitate construction coordination, sequencing, logistics, etc. The model allows coordination between the design and construction teams, including trades, fabricators and suppliers.

LOD 500 – As-Built

At LOD 500, model elements represent the as-built, field-verified physical attributes of the elements in the project. It includes graphical representations of objects and assemblies along with all the non-graphical data related to those elements. An LOD 500 model captures any changes between how objects and assemblies were designed and how they were installed on-site. The model does not need to be highly detailed, but accuracy is critical. The LOD 500 model forms the basis for the building hand-over and building operations manual; for example, the size and location of HVAC ducts may be represented, though information about the location of the flanges may not be required.

2.3 Dimensions

In addition to LOD, BIM can also have different dimensions, which describe the usage of the data and information federated in the digital model over the building's life cycle (Figure 8).

3D: Modelling

- The digital representation of the intended design or existing condition. The combination of 3D digital model elements and associated information (data) are developed during the design process and facilitate coordination of all consultants' design models and are also used for clash detection.
- The 3D model can be utilized for visualization, early building performance analysis, sustainability evaluation, preliminary cost analysis and the generation of documentation (drawings). Inter-disciplinary collaboration, clash detection, and design review are all aspects associated with 3D.

4D: Time (Scheduling)

- Linking model elements, assemblies and data to a timeline to represent construction sequencing and scheduling. 4D is typically used to show an intended time lapse of the construction schedule.
- For example, in a prefabricated timber building a 4D BIM model can use the project data to develop the transportation schedule and the installation sequence for the installation of timber panels.

5D: Cost (Quantification)

- By linking model elements and assemblies along with the schedule (4D) to establish related costs, the 5D model can be used to quantify materials and the cost of construction. Several timber prefabricators and mass timber suppliers can generate project costs directly from a BIM model.
- Model-based estimation of construction, estimating the capital costs including the cost of purchasing and installing components or assemblies. The 5D model can help the project team to visualize the progress of construction activities and its related costs over time.

6D: Performance

- The 6D BIM model is all about analytics. It is about linking the BIM model to the tools that the project team need to measure and validate the proposed design for building performance, such as energy, GHG emissions, ventilation, thermal comfort, etc.
- There are numerous specialty tools that link to the BIM model that can conduct analysis (thermal envelope performance, life cycle analysis, computational fluid dynamics, etc.) that are important for timber projects. The 6D modelled data can serve as a baseline for comparison to actual performance.

7D: Facility Management & Maintenance

- The 7D BIM model is more commonly referred to as the Asset Information Model (AIM) and is used to hand-over, maintain and manage the building. Linking model attributes and data to support facilities management and operation, the AIM streamlines asset management over the life of the building and provides a database for ongoing tracking, maintenance and management.
- For example, the maintenance schedule can be linked to a piece of equipment (such as a heat pump or window) so all the relevant data is accessible (supplier, warranty, specifications, service history, etc.).

8D: Deconstruction

- The 8D BIM model involves the building "afterlife," the decommissioning, demolition, repurposing or recycling of a building or structure. All the data captured within the BIM model can be used to refurbish, re-configure and, ultimately, decommission the building. It can inform the deconstruction team how best to dismantle the structure, and the types and quantities of materials involved.
- This dimension of BIM has rarely been tested within the timber building sector but prefabricated and mass timber systems offer great potential for disassembly and re-use at the end of life.

Figure 8: The Dimensions of BIM applied to wood buildings

3D BIM is primarily focussed on geometry, spatial information and the corresponding data (wall types, room numbers, etc.). 3D BIM describes the "what" of the project. Each next dimension (4D, 5D, etc.) enhances the model with an extra data layer providing information on the "how", "when", "for how much (cost)", and more. Dimensions describe how the digital model can be used to assist in design, construction and operations, and are key to BIM's "walk backwards" approach to a building project. Early on-boarding of consultants, the general contractor and key trades and suppliers allows the owner to establish the dimensions that will best meet the building requirements and satisfy the owner's goals. This in turn provides the means to set Maturity Level and LOD to ensure tasks and responsibilities will result in data and information being collected, produced and shared virtually through BIM.

For wood projects contemplating off-site construction methods, 3D (model), 4D (time) and 5D (cost) will facilitate the integrated, collaborative design needed to deliver the speed, quality and safety benefits. For high performance projects, 3D and 6D (model and performance) can be the cornerstone of energy simulations and virtual envelope detail mock-ups required to meet actual building performance.

> *"The "I" in BIM is a crucial factor in why BIM is such a significant advantage for executing and managing* building project delivery; otherwise, we're just using BIM as a design tool and underutilizing the vast potential of this amazing resource. Utilize the information within your model to provide value-added information to your project.*"*
>
> ~ Architect

2.4 Asking for BIM

The successful delivery of a BIM project starts at the very beginning of a project. For owners to define how and to what extent BIM is to be used for their projects within the competitive tendering process, it is advisable to develop a BIM Requirements Specification document to include in RFPs. This document sets out the requirements, the project participants' roles and the ownership of the data. It also describes expectations during the various project stages (design, construction, hand-over, operation, etc.). The topic of project sponsorship and the role of the owner will be discussed in more detail in Chapter 3.

BC Housing BIM Requirements Specification for Vienna House

SummitBIM (https://summitbim.com) is a B.C.-based BIM consultancy that assisted BC Housing in developing BIM requirements that were piloted for Vienna House (www.viennahouse.ca), a proposed zero-emissions timber mid-rise social housing project in East Vancouver which aims to test out promising materials, strategies, and processes to advance solutions to affordability, climate change, and social equity. The project provides an ideal opportunity for project partners to demonstrate the benefits of following a true digital process from start to finish, rather than using digital technology to generate traditional output. BC Housing plans to study the project results to assess how they can be applied to future projects.

Chapter 3: How does BIM work in practice for advanced wood buildings?

Recommended for	Design and construction professionals, owners and policymakers
Summary	▪ BIM leverages the power of collaboration (Maturity Level) and information management (LOD and Dimensions) to yield better outcomes. BIM accomplishes this by federating all project stakeholders into a digital twin of the building, providing a virtual sandbox to design, simulate, rehearse and validate tasks and operations, to confirm project outcomes will meet the owner's requirements. ▪ Establishing a Common Data Environment (CDE) enables project participants to collaborate effectively and securely, given that the software used by consultants, contractors, trades and suppliers will vary. ▪ Virtual Design and Construction (VDC) is the method of creating a wood project virtually before doing it in the real world. VDC is a powerful extension of BIM that is valuable when using off-site construction methods. It leverages the digital model to support construction planning, scheduling, budget and cost estimation capabilities. ▪ BIM software workflows are critical. Each project's software ecosystem and workflow will vary depending on the owner's requirements. It is essential for teams to establish BIM software workflows early in the project to minimize technical hurdles.

Day-to-day, BIM's value comes from the "virtualization" of the building project and its operations. Its major impact is on project information and data, decision-making and collaboration. This chapter looks at how information and data can be managed in practice, how BIM supports decision-making processes and how, in turn, both information management and BIM-based decision-making inform digital project delivery methods. A brief overview is given of the software tools and technologies available for use on wood building projects. Finally, to put all these pieces together, a BIM-based project workflow shows the adaptations and considerations for an advanced wood project.

3.1 Information and data

BIM amalgamates, organizes and communicates high-quality, up-to-date information to the project team within a Common Data Environment (CDE). The CDE is the central repository where construction project information is housed, and which provides key stakeholders with a digital representation of a building spanning the project life cycle. Using BIM mitigates some of the common access, version or completeness issues of traditional contract documents by digitally contextualizing, collecting in a single source (the digital model) and/or complementing 2D drawings and specifications. The benefits are better information accessibility, information quality and digital collaboration, which all lead to improved decision-making.

Information accessibility

The federated model allows the entire project team to access the information in real time. BIM contextualizes information in a virtual copy of the building; the model represents physical, dimensional, spatial information graphically in 3D. It references non-graphical information, specifications, standards, tolerances, etc., within model elements.

With this capability comes the need to establish proper sharing protocols, typically in a BIM Execution Plan, so that the right information from the right source, gets into the right person's hands at the right time. This is why the Maturity Level, LOD and Dimensions need to be established pre-project, with the right professionals assisting in both project setup, and defining the protocols in the BIM Execution Plan.

Information quality

> *"The energy model will only be as good as the data input,* and as accurate as the assumptions are reasonable and realistic—*garbage in, garbage out."*
>
> ~ Building envelope & energy expert

BIM federates or combines all the project participants' expertise into the model, providing the team with the best available information in the digital model for tasks, coordination and analysis. The risk of poor quality, or incomplete information adversely impacting the project (e.g., for take-offs, modelling and analysis) is reduced. However, the earlier that project participants get involved, and with a concise BIM Execution Plan that clearly allocates information accountability, the better informed the project team will be for the building project. The BIM Execution Plan still requires a communication plan to ensure accurate information from the appropriate team member reaches the group at the right time, and that an accessible communication platform ensures information accessibility. A BIM Communications Plan also yields information continuity, minimizing the time needed for each of the project team members to become familiar with overall project progress (Figure 9).

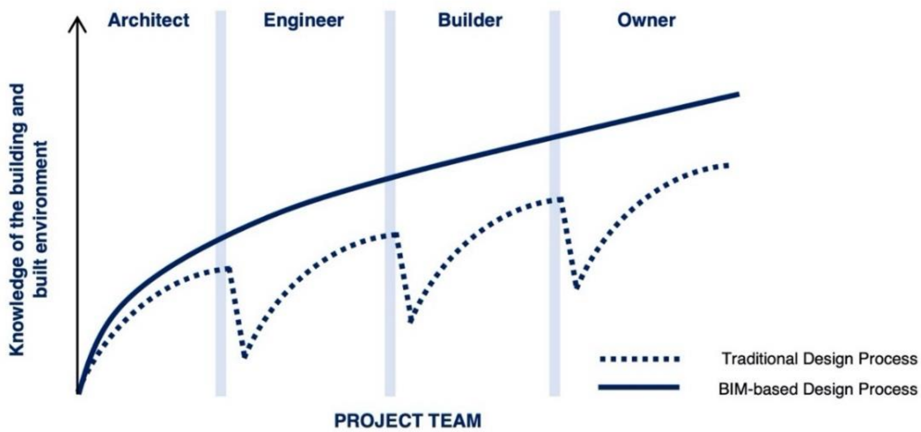


Figure 9: The BIM knowledge creation curve compared to traditional practice
(Adapted *from 2017, "Crossrail BIM Principles"*[11])

Digital collaboration

Digital collaboration allows the entire supply chain to participate collectively, using various software tools and applications to visualize, access and assess project information through the secure CDE. The contents of the CDE are not limited to assets created in a BIM environment; the CDE also includes documentation, graphical models and non-graphical assets. It provides a single source of information that can be used to collect, manage and disseminate all relevant approved project documents and assets.

[11] Source: "Crossrail BIM Principles" – available at: https://learninglegacy.crossrail.co.uk/wp-content/uploads/2017/02/12F-002-03_Crossrail-BIM-Principles_CR-XRL-Z3-RGN-CR001-50005-Revision-5.0.pdf

Practices and standards for information management

BIM's demand for deliberate information management can be quite overwhelming for those new to BIM. Retaining a BIM consultant for this purpose may be important for a team's first BIM project. A few examples of practices and standards for guidance:

BS 1192-4:2014 Collaborative production of information:
https://www.thenbs.com/PublicationIndex/documents/details?Pub=BSI&DocId=307854

NBS BIM Toolkit:
https://toolkit.thenbs.com/

3.2 Decision-making

BIM provides the required depth and breadth of information to facilitate collaborative, decisive decision-making by defining the necessary Maturity Level, Level of Development and Dimensions of BIM (described in Chapter 2) and providing access and timeliness of data and information through a CDE.

Information freedom

The digital model is the mode of information exchange. It offers the potential for any member of the project team to see (and potentially interact with) all aspects of the model. While unlimited access and the free flow of information have many advantages, agreements, procedures and protocols need to be in place in the BIM Execution Plan, as well as the Model Management Plan (see Chapter 4) to ensure the model is not cumbersome or confusing. Particularly, project teams need to set procedures on how to handle, use and collaborate with in-progress or under-development information to ensure shared information is useful, and to avoid misunderstandings.

"IP concerns [copying, reproduction, etc.] should not really be a big issue: details, documents, etc. are already available across project teams, planners, etc. Terms that manage IP today can likely be updated to cover digital *BIM assets as well."*

~ Architect

Decision processes

The availability, speed and quality of information offered by BIM requires an owner and project team that can operate at the same tempo to take advantage of BIM's decision-making capabilities. Collaborative strategies (such as Lean Planning Methods[12]) can help break down barriers to information exchange and decision-making. However, teams can execute BIM without strict policies, although it takes a significant level of trust and a teamwide commitment to put the best interests of the project first. A clear communication plan and platform helps ensure constructive and timely collaboration properly supports the decision-making process.

BIM-supported workflows can not only manage the relevance, timeliness and accuracy of information sharing so the right information goes to the right person at the right time, it can also help prioritize tasks, thereby reducing the potential for distractions, "paralysis by analysis", or wasted effort.

[12] More information about Lean can be found at the Lean Construction Institute website, administered by the Canadian Construction Association: https://www.cca-acc.com/best-practices-resources/lcic

"BIM for decision-making is currently limited due to fear of sharing information and liability—paradoxically, withholding or ignoring information is actually r*iskier and increases legal exposure."*

~ General contractor

3.3 Digital project delivery

"Using Revit, we were able to build the building the first time virtually—with limited budget and effort impact and no actual risk. This allowed us to build the project for real the second time with more foresight and a lot more *confidence."*

~ Site manager

BIM as a digital twin of the project is ideally suited for Virtual Design and Construction (VDC). VDC is the method of creating a construction project virtually before doing it in the real world. VDC allows the general contractor to virtually "shake out" performance, constructability and coordination before physical construction starts—where people, material and equipment are hired, purchased and mobilized. Where BIM and VDC integration provides a significant advantage for advanced wood buildings is through leveraging BIM's integrated model, for coordination, sequencing, and fabrication and construction. These are discussed below.

*"*BIM lets us build virtually. It offers true integrative design and life cycle analysis, as well as construction planning and sequencing—all without handling physical materials. From simulating in-service buildings to rehearsing construction operations, the BIM is a risk and uncertainty management tool: what is designed, can be built, and will ultimately work.*"*

~ General contractor

Coordination

The digital model helps coordinate the work during design and construction. With the right practices agreed upon and adhered to in the BIM Execution Plan, BIM can relieve much of the burden of paperwork and reduce errors associated with traditional project administration. BIM helps the team to identify downstream issues and challenges early, to resolve them before they become a problem. For example, BIM, as a single source of updated information, supplements (or replaces) the hard copies and Change Order documents that are often confusing or misplaced during construction.

BIM Project feasibility tools

Scottish Futures Trust BIM adoption tools help owners and project managers with BIM project feasibility for public projects over £2 million.

More information available at: https://bimportal.scottishfuturestrust.org.uk/

> *"BIM is well*-known to be a useful tool for design coordination, but where it can yield significant benefit is in the integration of construction, building operation and asset management. 4D (time), 5D (building) and 7D *(operational) information during design, as defined in the BIM Plan, informs the design team's "design intent",* ensuring these critical downstream requirements are accounted for and designed into the building. This also highlights the importance of collaborative frameworks, including those traditionally left out: occupant representatives, FM staff, etc., that can help set building requirements, and check them over the process of *design."*
>
> ~ Project manager

Sequencing

3D, 4D and 5D dimensions are used for the virtual sequencing or virtual build of the project. This is particularly important when coordinating with the off-site construction processes and transporting and installing the prefabricated wood elements—each of which needs to be identified and tagged so the right piece goes in the right place. VDC planning can help the project team realize the benefits of "Just in Time" delivery (minimizing wait times, reducing the need for on-site storage, decreasing potential for damage, etc.). Builders who are experienced with off-site constructed wood structural systems, may conduct numerous virtual builds ahead of the final erection program to rehearse each construction task before they get on-site, where errors, assumptions and re-work can have significant cost, schedule and safety implications.

> *"Information continuity—that "golden thread" of inf*ormation from design through to execution—is perhaps the most under-*rated but critical factor of success on a building project: you can't react to what you don't know. Along* with the right project delivery model, BIM is one of the best tools to support information continuity on a project *from start to finish."*
>
> ~ General contractor

Fabrication and construction

BIM is the cornerstone of Designing for Manufacturing and Assembly (DfMA). DfMA leverages BIM—and the collaboration, coordination and detailed information inherent with higher Maturity Levels and LOD—to directly input element information (beams, panels, etc.) into manufacturing software to instruct fabrication equipment. This can eliminate communication and coordination errors between design and fabricator, reduce or eliminate shop drawings, and fabricate components precisely.

> *"Today, BIM is capable of accuracy far beyond the construction capabilities of the AEC industry. The limiting* factor is common practice: we use powerful computer programs *to produce 'dumb' paper construction drawings* rather than computer-*aided manufacturing."*
>
> ~ DfMA expert

As BIM unlocks the benefits of off-site construction, the lines between design, fabrication and on-site assembly begin to blur. Indeed, BIM is starting to open the door for DfMA for buildings—a design approach commonly associated with the mass-production of consumer goods and vehicles. While some manufacturers have developed BIM "objects" of their products for insertion into the model for take-offs and sizing (there are numerous aggregated libraries available), the shift to full DfMA using BIM is not yet mainstream. DfMA requires a shift in mindset for designers as it puts questions of manufacturing and assembly at the front end of the design discourse. While DfMA has huge potential benefits for the industry, it requires designers who are well-trained in manufacturing processes, constraints, parameters, assembly sequences and scheduling, and on-site logistics to implement successfully—and includes close collaboration and coordination with manufacturing and fabrication specialists (engineers, trades, machine operators, etc.).

> *"BIM streamlines the structural and fabrication design, eliminating design duplication*, and minimizes downstream construction errors while improving build quality—*saving time, money and headaches."*
>
> ~ Supplier

There are numerous systemic barriers to the adoption of DfMA such as lack of capacity, contractual conflicts and prevailing industry culture[13]. However, the emerging wood systems (such as mass timber) and the advanced technology used in manufacturing plants are starting to force change with several manufacturers pushing for access to the digital model from which to fabricate the components. For example, using advanced digital tools, companies such as Intelligent City in British Columbia are finding ways to simplify the design of a building product, assembly or whole building, so it is possible to manufacture and assemble it more efficiently, in the minimum time and at a lower cost.

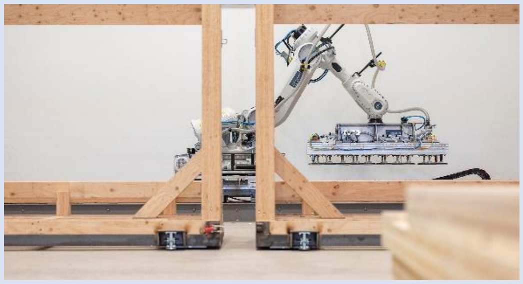
Building Transformations —a nationwide community of practice and a complete online resource for owners, consultants, contractors and the construction supply chain

Building Transformations (formerly CanBIM) is a not-for-profit organization that serves as a national voice on all aspects of digital construction. It is a community of practice that convenes events, symposia and online webinars looking at how digital project delivery impacts how firms procure, design, construct, and operate today's built environment from pre-design to building operations. There are pre-recorded sessions from industry leaders that offer instruction and insights in digital transformation in the construction industry, covering a range of stakeholders and project phases, and using real-world examples.

https://www.canbim.com

[13] Sheryl Staub-French, Erik A. Poirier, Francisco Calderon, Imen Chikhi, Puyan Zadeh, Divyarajsinh Chudasma, Shitian Huang, "Building Information Modeling (BIM) and Design for Manufacturing and Assembly (DfMA) for Mass Timber Construction" (2018) www.naturallywood.com/wp-content/uploads/2020/08/bim-dfma-for-mass-timber-construction_report_bim-topics-research-lab.pdf

Working at the intersection of planning and manufacturing—Intelligent City's Approach to BIM and DfMA



Monad Granville Project (images courtesy Intelligent City)

Vancouver-based Intelligent City (https://intelligent-city.com) has developed a highly integrated one-stop solution to design and pre-fabricate sustainable, net-zero, multi-family urban green buildings at better quality and lower costs for owners, operators, and tenants. The company's Platforms for Life (P4L) solution incorporates mass timber, design engineering, Passive House performance, automated manufacturing, and proprietary parametric software. Because of this high level of integration, Intelligent City has developed a workflow that converges typical BIM planning and DfMA principles.

While typical BIM serves the purpose of sharing 3D models between project team members, the levels of development required for fabrication or construction is usually added by contractors or manufacturers at a later stage when feedback on design is expensive, and sometimes impossible, to incorporate. Intelligent City's approach is quite the opposite. Their mass timber building components and systems were developed with manufacturing possibilities and constraints in mind. From the outset, the team established integrated processes for design, engineering, software development, building systems development and manufacturing automation, ensuring that each part is calibrated to work efficiently within their technology ecosystem. As a result, sets of parametric rules are defined, with which an infinite variety of building designs can be realized—all of which are guaranteed to be producible.

By developing a building system based on manufacturing principles, Intelligent City has also created a design system as a digital tool. Instead of adding manufacturing information to a BIM model, the company works with highly informed digital models from the beginning. Manufacturing information such as shop drawings, computer numerical control (CNC) or robot code is stored as meta data. This allows BIM models to be shared with different levels of information based on the type of collaboration with consultants, trades, and contractors. This approach allows detailed quantity extraction and accurate costing at the earliest stages of design.

3.4 Software tools

The BIM software landscape is developing quickly and there are many tools that lend themselves to wood building projects. On the following pages, a series of figures lay out the ecosystems of software from a snapshot of the global universe down to an illustrative Technology Stack suitable for a wood building in Canada. Figure 10 presents a constellation of software tools and technologies developed by Jens Voshage that demonstrates the breadth and depth possible with BIM across the design, construction and operations supply chain. Voshage has experience both with CREE[14], a EU-based pioneer in the development of turnkey, digital delivery of hybrid mass timber technology for high-rise projects, as well as an BIM instructor with British Columbia Institute of Technology.

> *"The architecture, engineering and* construction industry often get seduced by the power of digital tools. For example, demanding a 100% clash-free model is unrealistic: a virtual model is not the real thing. The project team must set priorities and applying BIM tools strategically where it can provide a project (and building owner) *the most benefit."*
>
> ~ Senior BIM technologist

Figure 11 lays out the range of software tools in use in Canada for delivering wood buildings roughly organized by LOD, BIM Maturity level and/or applicable project phase. It is important to note that the technologies used by project teams may vary based on the owner's requirements, the project team's methods and means of delivering the building project, cost, expertise and other factors. Figure 12 offers insights from industry on the BIM software ecosystem as it applies to wood buildings in Canada.

To determine which tools would work best for a particular project, the software workflow should be established pre-project, during development of the owner's goals and project requirements and set out in the BIM Execution Plan (see Chapter 4). Once the goals of using BIM have been established, it is possible to set up the BIM software requirements. Lastly, mapping the project team's software resources helps to establish the necessary information exchange procedures. While some file exchanges may require a few touch-ups to reconcile the data, other systems may require parts of, or the entire, model to be re-built—a consideration for some proprietary VDC systems.

A plan to manage the practical aspects of information exchange and software interoperability needs to be developed at the time that the software systems are being selected for the project, including compatibility or project administrative requirements for the different software being deployed. Typically, this is done in a BIM Execution Plan. For wood projects, this means that that the structural engineer, suppliers and specialist fabricators all need to be involved in the project as early as possible, as they have critical software requirements, workflows and information exchanges that need to be set up to lead to early execution of off-site fabrication, and rapid on-site erection.

> "BIM has gained a solid place among consultants and is used every day by most firms. And the specialization in wood construction is the movement from the digital world to the physical world undertaken by CNC *interfaces and "Industry 4.0" assembly s*ystems.
>
> The integration of software suites with manufacturing is where I believe we will see the largest changes in the next few years, which will have the biggest downstream affect on the built environment. Software *"bridges" are* the backbones that make this movement possible and will need to be further developed and scrutinized to fully realize the advantages offered by manufacturing and assembly *technology."*
>
> ~ BC-based mass timber supplier and fabricator

[14] www.creebuildings.com

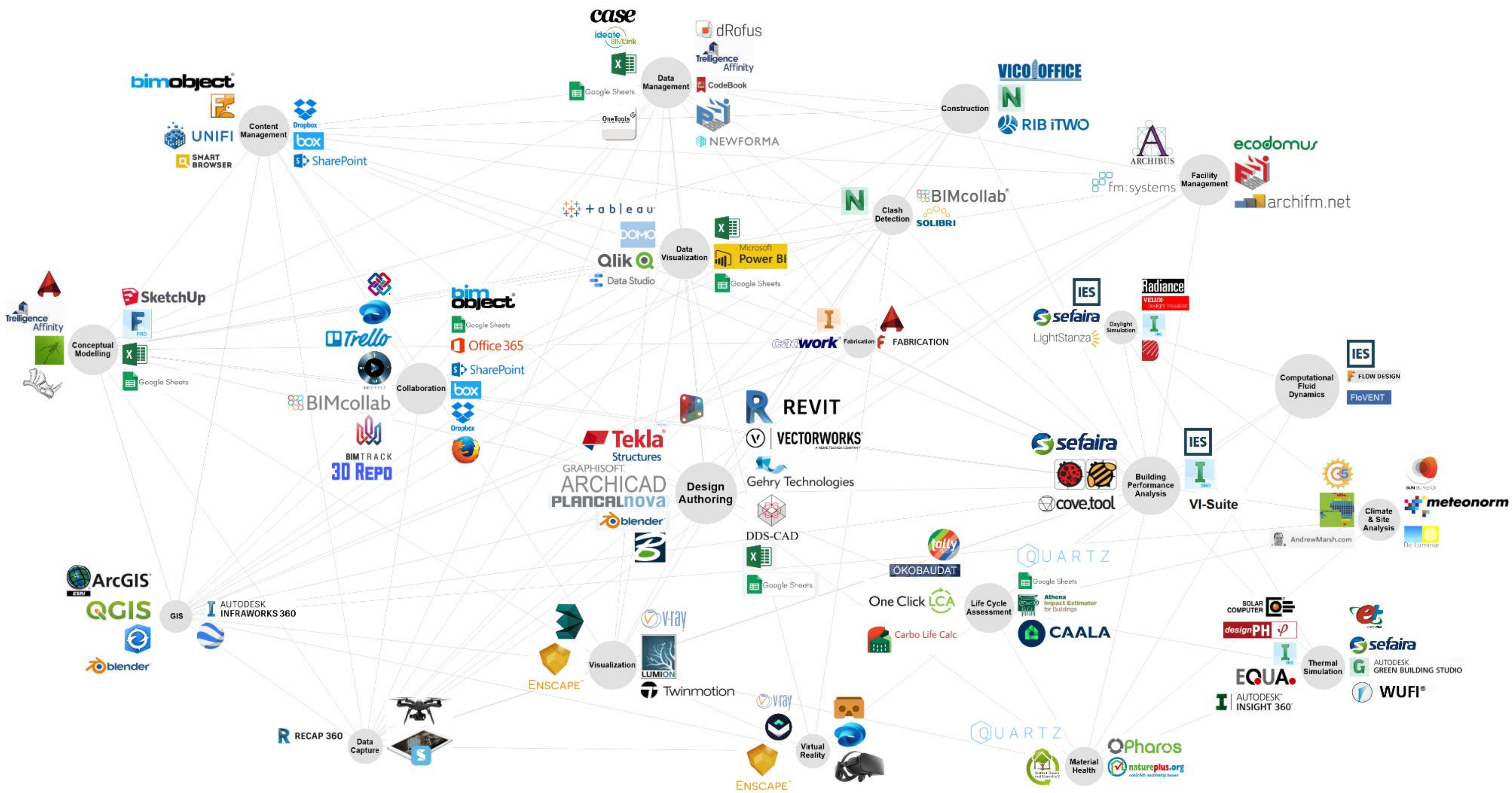


Figure 10: BIM software ecosystem for wood buildings
(Image source: Jens Voshage)

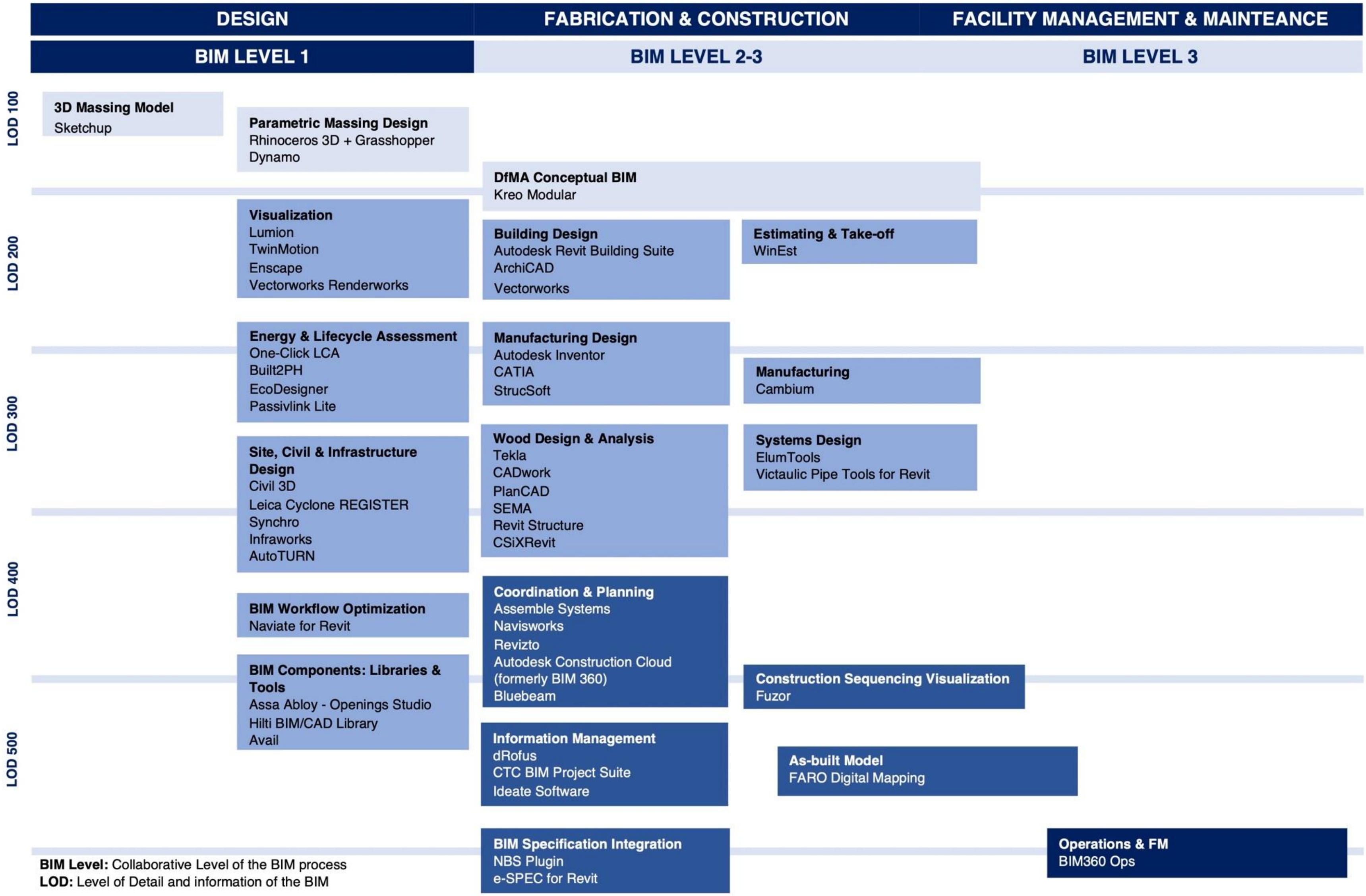


Figure 11: BIM software ecosystem for wood buildings in Canada

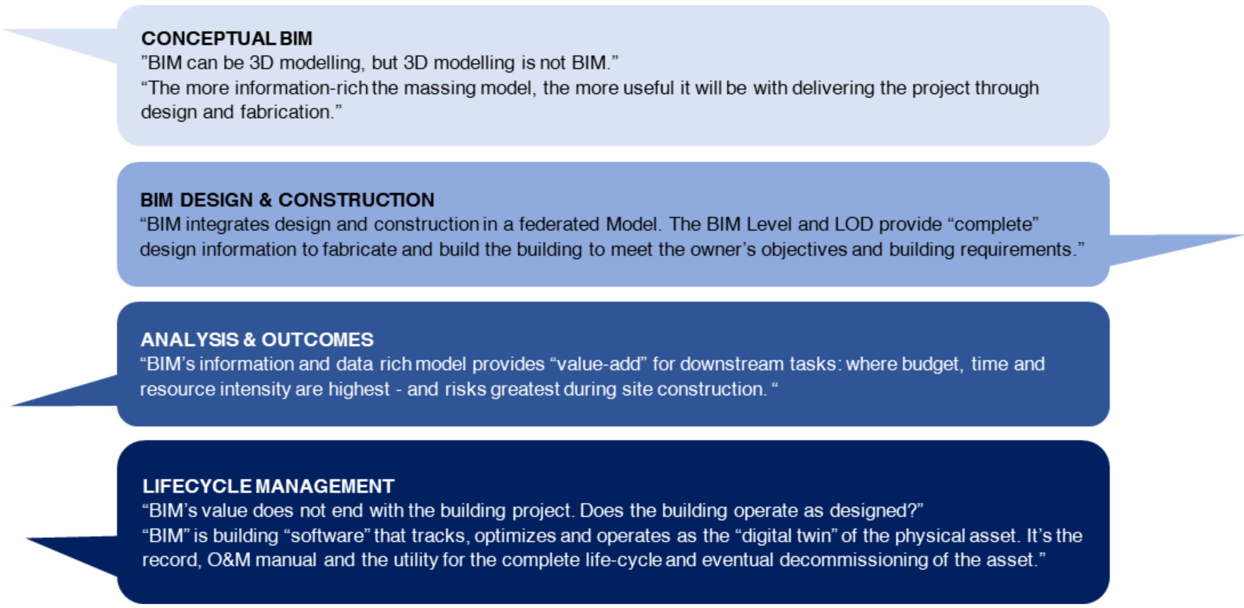


Figure 12: Insights from interviewees on the BIM software ecosystem arranged by lifecycle stage

Distilled from the range of software options presented in Figure 11, Figure 13 presents a simplified flowchart of software tools that BIM practitioners working on advanced wood projects are using today. Brief introductions to each software application are provided in Appendix A3.

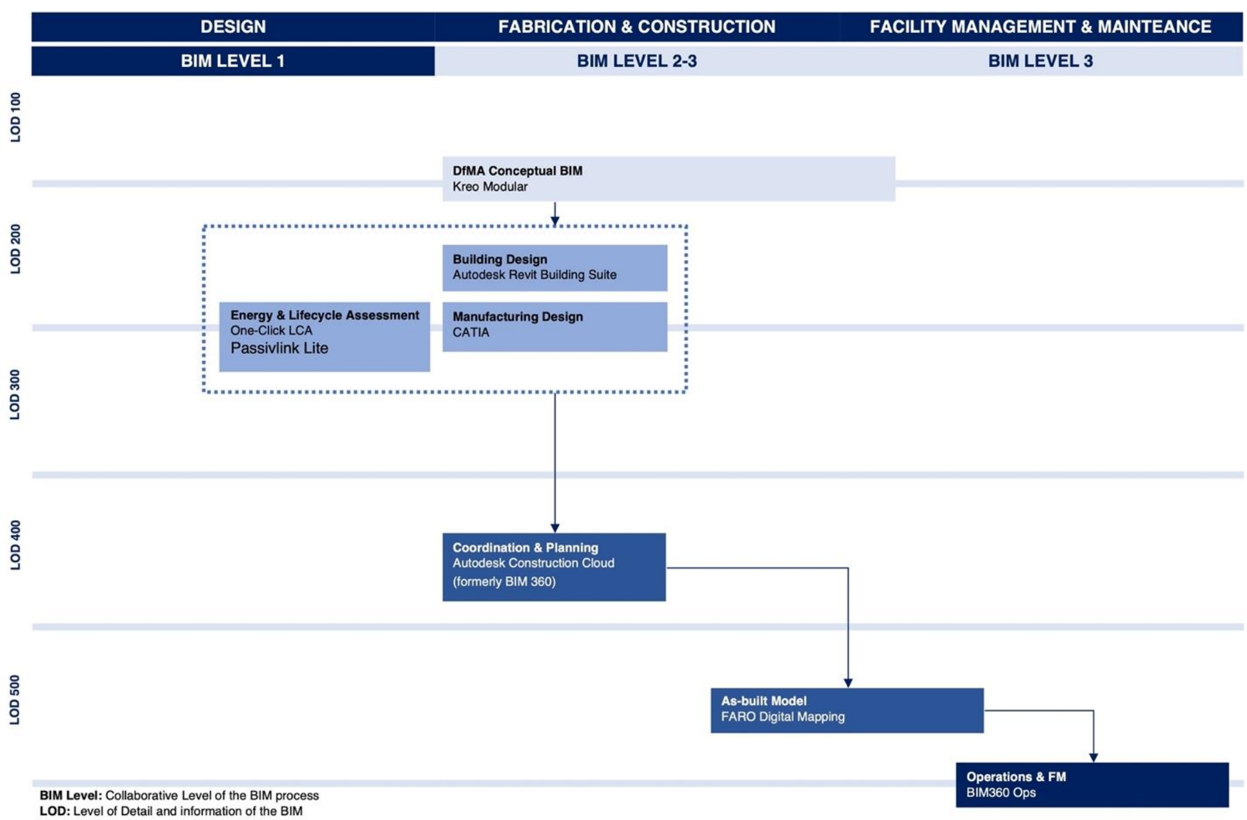


Figure 13: Illustrative BIM software workflow suitable for wood buildings

3.5 Putting it all together, the BIM workflow

Building on Figure 13, the workflow diagram in Figure 14 sets out the steps in delivering a project using BIM and highlights the additional considerations when working with advanced wood projects, from inception to hand-over. It contextualises the BIM tasks with the project program highlighting how the digital model and information development proceeds in lockstep to the design and construction of the building.

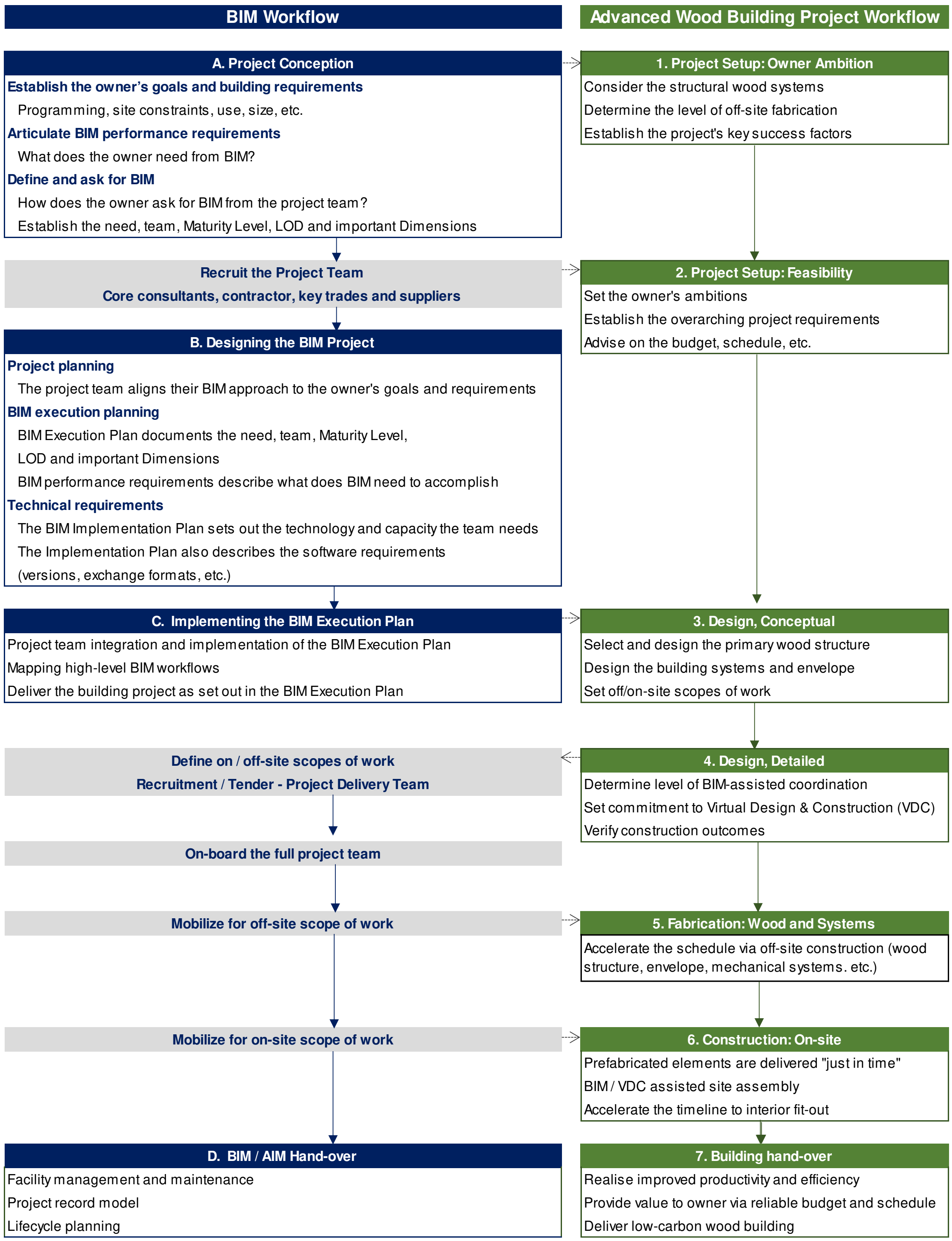


Figure 14: BIM project workflow illustrating adaptations and considerations for advanced wood projects

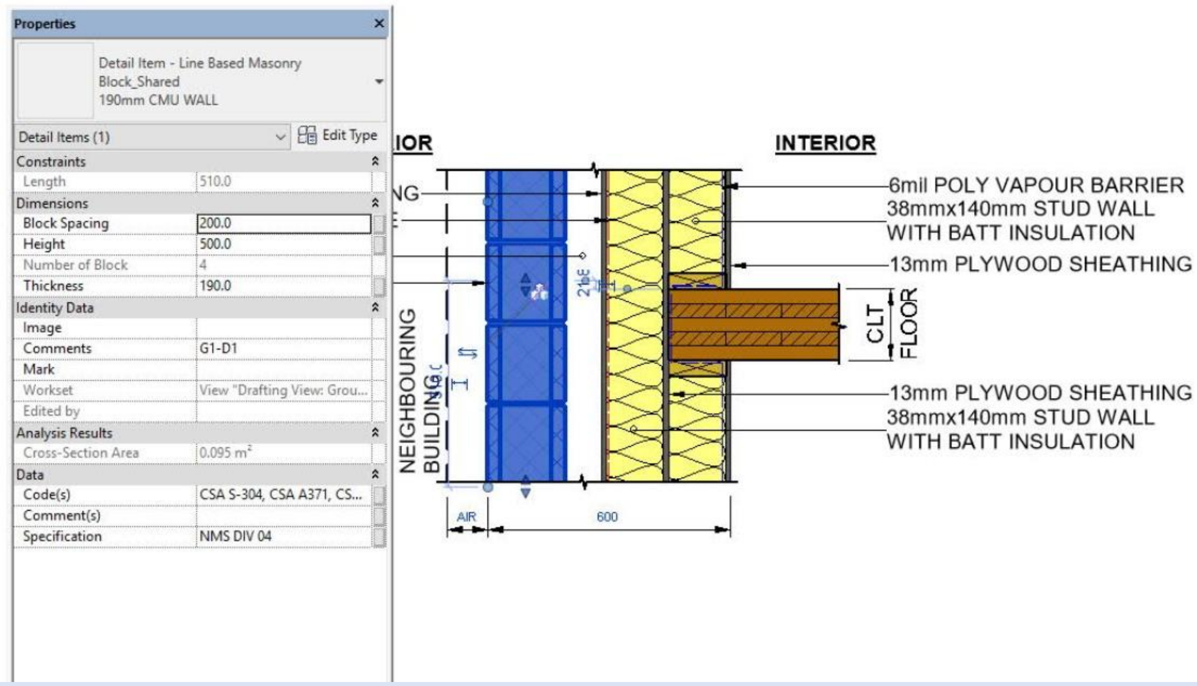
Revit-based software workflow example

A Revit file and Use Guide is provided with this document to demonstrate how Revit can be used to design and deliver wood buildings. Using a series of best-practice details for a selection of innovative wood buildings, it demonstrates Revit-based Levels of development and how information can be embedded to support collaborative design development and project delivery. It also provides a tangible example of how files can be used to pull information from the BIM to accomplish carbon calculation or cost analysis for the project team to assess and make decisions on a low-carbon, wood building project. The workflow demonstrated in the guide demonstrates the multi-software workflow that is commonly utilized today to accomplish a range of task. This workflow can have utility for owner, consultants, construction managers / general contractors, as well as wood suppliers and fabricators.

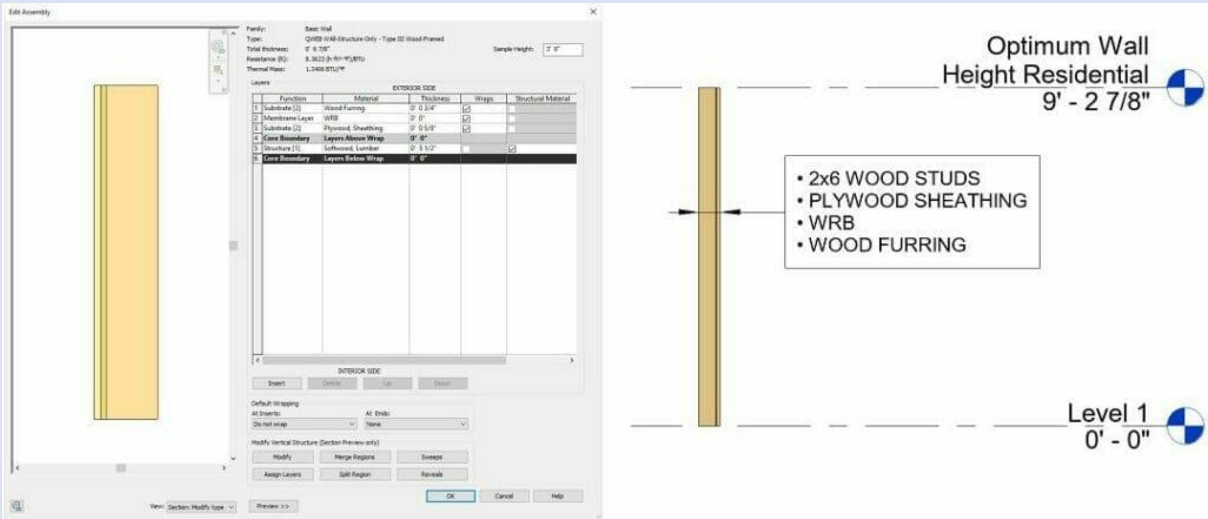
The files are available on canbim.com:

PDF file: BIM Parametric Detail Users' Guide
Revit 2021 file: BIM Parametric Revit Details

Sample detail



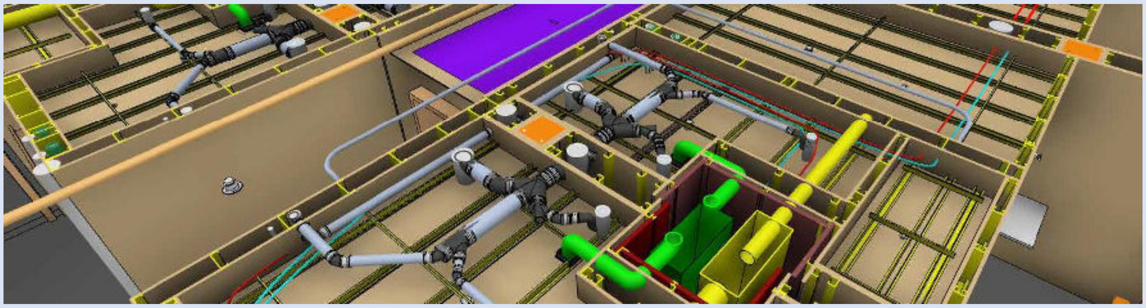
Practical digital tools for timber—Offsite Wood



Wood-specific digital tools are starting to become available. In 2021, the Quebec Wood Export Bureau launched Offsite Wood which offers a library of structural wood product families - glulam post and beam, mass timber floor assemblies, and custom enclosure systems - as a free BIM plugin for Revit. The details, models and objects have been developed for several Quebec-based manufacturers and include the dimensions, fire resistance, sustainability profile, life-cycle data, Environmental Product Declarations, and product families.

For more information, visit: https://offsitewood.org

UBC Brock Commons Tallwood House: mass timber project software workflow



Precise integration of services with mass timber structure (source: CADMakers)

BIM VDC application: Experimental Tall Wood Student Residence
Key BIM Team: Fast & Epp (prime), Structurlam (mass timber supplier), CADMakers (VDC Integrator), Acton Ostry Architects, Urban One Builders, Stantec.

CADmakers (www.cadmakers.com) manage the BIM through design, fabrication and construction, to ensure the BIM yielded what was needed, and that the wide range of software preferred by the project team would be federated and leveraged in a useful way, such as with the highly successful virtual sequencing of the mass timber kit of parts. For example, the suite of software used by the team included:

- 3DEXPEREINCE, Dassault Systèmes
- AutoCAD, Autodesk
- Cadwork, Cadwork informatik AG
- Cambium, Hundegger
- CATIA, Dassault Systèmes
- RFEM and ETABS, Dlubal
- SketchUp, Trimble
- VectorWorks, Nemetschek

Specific team members may have also utilized more than one program: for example, Structurlam utilized Cadwork and Cambium for mass timber modeling and fabrication, and utilized CATIA for 4D construction with CADMakers, the VDC Integrator on the project.

More details available at www.naturallywood.com/wp-content/uploads/2020/08/brock-commons-design-modelling_case-study_naturallywood.pdf

Chapter 4: How do I set up a BIM project?

Recommended for:	Consultants, contractors, owners and policymakers
Summary	▪ BIM's success starts with proper setup of the building project to leverage BIM throughout project delivery from design to operations. ▪ The BIM Execution Plan provides the critical framework for BIM, aligning the team's roles, responsibilities and activities. ▪ One of the largest shifts that BIM projects require is the extent of owner involvement. For an owner's first BIM project, a BIM consultant can act as the owner's representative to guide the process.

This Chapter looks at how to organize the team members to deliver a BIM project effectively. To understand the roles and responsibilities of the project team members when embarking on a BIM project, it can be useful to take a high-level view of the three key perspectives or layers as to how projects are set up and managed.

1. **Project sponsorship layer** – The owner or project sponsor.
2. **Project management layer** – The prime and key consultants, contractor and/or project manager.
3. **Project delivery layer** – The project team, all other consultants, trades and suppliers.

Each layer has its own set of work practices. PAS 1192-2 (British Standards Institute, 2013) provides a helpful outline of core BIM related activities from this high-level view (Figure 15). The activities are corroborated by practitioners in Canada and discussed in more detail on the next page.

> *"Projects often haphazardly adopt BIM, leading to "BIM for the sake of BIM". BIM is setup for success at the start of a project: aligning BIM requirements to the project's goals and getting the team on-*board to leverage *BIM to successfully deliver a client's building."*
>
> ~ Engineering firm BIM specialist

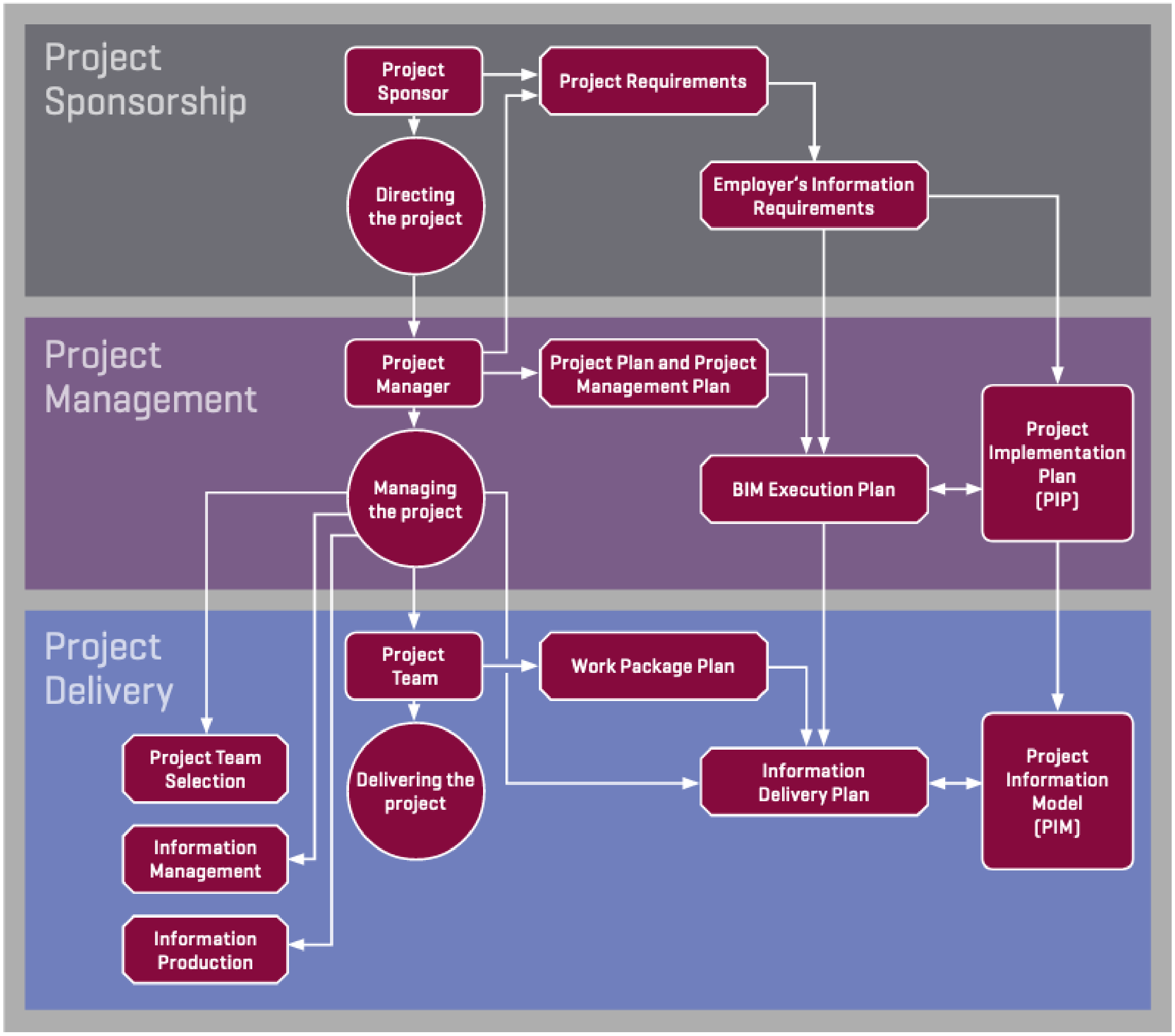


Figure 15: Outline of core BIM related activities in PAS 1192-2 (British Standards Institute, 2013) (Sourced *from RICS "Building Information Modelling for Project Managers",* 2017)

4.1 Getting ready for the first BIM project

Regardless of discipline or company size, industry leaders agree that BIM will touch all aspects of the business—from how new business is won through to project execution. There are management considerations at the organizational level, the project team level and the individual level, as discussed below.

Organizational Level: Creating a BIM culture

Managers must strategically choose which technological changes to embrace, given the constrained bandwidth for absorbing organizational change. This is particularly true for architecture, engineering and construction firms working with wood in Canada. Most firms are small with extremely limited technology budgets; organizational structures tend to be flat, organic, and it is not uncommon for roles to be ill-defined, with staff doing more than one job.

The biggest barriers to BIM adoption are a rigid corporate culture and lack of buy-in at the leadership level. There is no doubt the transition to BIM will have its challenges, but the long-term benefits can be significant.

Project Team Level: Establishing a framework for collaboration

To realize the advantage of sharing mission-critical information for effective decision-making means not prioritizing one team member's needs above any other and having the right people in the room early on with a clear understanding (and agreement) of how the team structure and dynamic will work.

Traditional project delivery methods, such as Design-Bid-Build or competitive bidding, tend to create internal competition within the team and may place undue emphasis on the opinions of one team member over others, potentially jeopardizing the best interests of the project. This is largely due to how the roles and responsibilities are established and, most significantly, how risk is apportioned. Experienced industry professionals suggest that project teams contemplating their first BIM project consider the form of contract/project delivery method, legal requirements surrounding information management and protection, and setting up a Team Charter. BIM technical and software requirements must also be set up with team-wise collaboration foremost in mind.

Individual Level: Technical readiness and fluency

BIM's information and data organizational capabilities are enabled by powerful software: in Canada, the most used is Autodesk's Revit Building Suite. However, to unlock this potential, individual project team members need to be competent in its use. At this time, training for Revit is focused on design application and training programs, which are available at most local technical colleges and through specialized BIM consultancies; a good deal of training is also available through software resellers and eLearning platforms. However, the technical depth and focus of these courses may be more than is necessary for owners, and/or misaligned with the needs of contractors or trades. Communities of practice are emerging, coalesced by organizations such as Building Transformations that represent industry leaders from a wide range of disciplines. Currently, specialized training on BIM/VDC for wood projects is being developed in partnership with qualified BIM consultants. Specialty wood suppliers and fabricators are developing in-house expertise with specialty VDC and DfMA software that plugs into the digital model, with training support from software resellers.

> *"Using items from existing BIM libraries can be very convenient - but putting materials/products into BIM libraries takes time and money. Consequently, the newest and most innovative products/materials can potentially not be found in any library. Hence BIM projects need a motivated team to make sure the information is truly up-to-date."*
>
> ~ BC-based mass timber expert

GET BUY-IN FROM THE TOP
"BIM expects Owners and Senior Partners to be project participants: Decision-makers must be available to participate in information and decision-making throughout the BIM project. They do not need to "Model": they just have to be aware of the Common Data Environment and the collaborative, decision-making workflows to ensure the flow of information is utilized effectively."

TAKE IT STEP BY STEP
"One of the biggest changes will be cultural. Moving to a digital environment requires a shift away from traditional processes, and people typically do not like change. Transitioning people slowly gives them the opportunity to get comfortable with working in the digital environment."

INVEST IN TECHNOLOGY
"It may be time to overhaul your network, including computers and software. Think of this overhaul as an investment in the future. Providing your people with the right tools will ease the transition to BIM."

"Revit is the most common in North America but is not the only BIM program. Research and acquire BIM software and tools that suit your needs and that fit local (industry) BIM practices before your first project. Verify that your hardware (computers) meets the minimum specification prior to purchasing software, 3D modeling requires a high level of computing power to be able to operate effectively."

ESTABLSH DATA PRACTICES AND STANDARDS
"Information sharing and privacy, protecting digital assets (IP) or supporting open communication with external project participants are important. Review and assess current practices and standards to see if they can easily be adapted to meet the needs of BIM projects."

"Set up a common data environment. Organizations need to have policies and procedures for handling, managing and protecting project-related information that may be sensitive or proprietary. Access to information, and the team being confident their information is protected, can mean the difference between success or failure."

REVAMP OUTDATED OR INEFFICIENT WORKFLOWS
"Adopting BIM creates an excellent opportunity for revamping your entire workflow. Utilizing BIM will create efficiencies and streamline your processes, allowing you to deliver a better product, faster. Whether you are an organization of 1 or 10,000, making BIM part of your work will fundamentally change your production. Embrace this change and commit to the integration process, and you will reap the rewards of a strong, efficient, modern business that is poised to take on all BIM projects."

INTEGRATED PROJECT TEAMS
"Decision-makers from the owner and project team are organized closer to, and focused on, the project's "value-generating" design and construction tasks – balanced with participants' autonomy, so an individual's work is not burdened by the team. Your team structure and organization are crucial to effective communication and the management of information as well as modelling best practices."

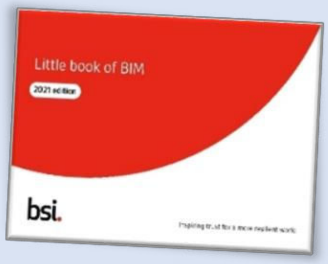
Figure 16: Quotes summarizing the practical suggestions gathered from interviews with industry leaders for architecture, engineering or construction companies contemplating their first BIM project

4.2 Project sponsorship – the owner's role

Set the project goals and requirements

The successful BIM project starts with the end in mind and with a clear understanding of the value proposition of a digitally delivered project. The project goals and requirements need to be hard-wired into the Requests for Proposal (RFP), contracts and terms of service for the key consultants, contractor and, potentially, key suppliers and trades that will make up the project management team (see Chapter 2 on how to ask for BIM). BIM's potential for life cycle planning will require a more intensive and potentially broader stakeholder consultation, including leasing and operations staff.

BSI – Little Book of BIM



To help orient decision-makers and get senior-level buy-in, the UK-based BSI put out a helpful "Little book of BIM" in 2021. It serves as a quick reference to some of the key terms which are commonly used in describing BIM and its related processes, as well as links to the key standards. Available for download at: www.bsigroup.com/en-CA/building-information-modeling-bim/bim-design-construction/little-book-of-bim/thank-you-little-book-2021-ga-03ri

Articulate BIM performance requirements: what does the owner need from BIM?

The owner defines and aligns goals and building requirements to the digital model's performance requirements. This ensures the project team joins the project with a full understanding of the capabilities and resources they need to have available. Figure 17 sets out the key topics the owner's BIM requirements should cover for wood buildings utilizing off-site prefabrication.

Defining the wood building project's conceptual off-site, on-site and building performance goals need not be technical or complex; goals and requirements need to be clear for the design and construction professionals to relate to BIM uses. However, it is a significant advantage if the owner can, at a minimum, understand Maturity Level, LOD and Dimensions.

	BIM Project Organization		
	Owner **Architect** **Construction Manager/ General Contractor** **Structural Engineer** **Envelope Consultant**	**Wood and Steel Suppliers and Fabricators** **Envelope Trade**	**Tenants** **Leasing Staff** **Property Manager**
Goals	Use, form & size target Net-zero carbon life cycle performance goal Budget & timeline target Wood off-site construction	Relevant Management Team members to designate, recommend recruitment and coordinate for wood off-site construction	Owner to designate and coordinate – per the building tenant and operational requirements – net-zero service life, wood building operations
Extent of Involvement	Pre-design to hand-over	Early design to hand-over	Pre-design, consultation, design to hand-over
Project Goal Setting & Plan	Sets goals and building requirements	Advises design, fabrication and construction	Consult during goals and building requirements development
BIM Planning & Utilization	BIM Planning Sets and leads BIM Plan	Follows and advises BIM Plan	Consulted during BIM Planning (as required)
Virtual Design & Construction	Full BIM Workflow, full project coordination and collaboration	Integrated BIM Workflow, scope of work coordination and collaboration	Not typically required
Information sharing	Full exchange of project-critical information	Supports scope-related exchange of project-critical information	Provide project-critical information as needed

Figure 17: *Example of owner's BIM requirements for wood buildings utilizing off-*site prefabrication

Define how BIM is to be used for designing and building advanced wood systems

In addition to the owner's typical RFP practices and stating the BIM goals, the owner must clearly state their desired ambitions relating to the advanced wood technologies and off-site construction processes (if applicable), using the BIM parameters described in Chapter 2:

- BIM Level: Advanced Wood Building Management Teams require Maturity Level 3 to successfully federate the digital model for off-site fabrication, and Virtual Design and Construction that supports speedy, safe site erection.
- LOD: Higher LOD for wood and carbon performance provides the depth and breadth of information needed to design the primary wood structure, energy and envelope performance, and coordinate on-site construction with the off-site fabricated elements.
- Dimension: 4D (time), 5D (cost) and 6D (performance) are dimensions that align with advanced wood buildings leveraging off-site construction, providing critical insight of the downstream impact on construction and final building performance.
- Other BIM considerations: Contract type for collaboration, agreements managing information and data sharing (privacy, security, etc.) and owner-side technology requirements.

Recruit the advanced wood building team

Specialists may be required when contemplating a wood project that proposes to use innovative technology and/or off-site construction methods. The core team may consist of the following, depending on the owner's ambition:

Owner	Wood Suppliers and Fabricators
Architect	Steel Specialty Suppliers and Fabricators
Construction Manager/General Contractor	Envelope Consultant
Structural Engineer	Envelope Trade

4.3 The BIM Execution Plan

The project team validates and articulates the project goals in the technical requirements for BIM-delivered design and construction. This requires the technical and professional expertise of the management team because it is reliant on seamless integration of BIM and the design, construction and operational outcomes. The consultants, engineers, general contractors and key trades and suppliers need to understand, strategize, establish and agree to the scope of work that will deliver the owner's building.

This step is essential for ensuring efficient BIM project delivery. Only the necessary tasks and activities, and the BIM requirements that support them, are rationalized, set and agreed upon by the team. These requirements are then established in the BIM Execution Plan (or BIMx), which formalizes the mechanics of implementing BIM on projects and how BIM's performance will result in project success.

Figure 18 provides an example of a BIM use matrix or pick-list which the owner, with expertise from the project management team, can use to set out the BIM functions. One example of a software tool that can help owners with this process is Plannerly[15], which has developed a series of ISO 19650-compliant BIM planning templates. (See next page for a description of the ISO 19650 standard.)

Organization for Collaboration

BIM's built-in requirement for collaboration can be supported by collaborative requirements in contracts or project agreements. For organizational considerations, three key items need to be determined:

- **Who collaborates:** Who will need to be a part of the collaborative effort and when, for the project to be successfully delivered?
- **How to collaborate:** Which digital platform to use, and what will be the team practices?
- **When to collaborate:** Defining a schedule according to weekly model exchange and project milestone dates.

[15] Plannerly ISO 19650 templates page at: https://www.plannerly.com/what-is-iso-19650

Plan		Design		Construct		Operate	
	Programming	X	Design authoring		Site utilization planning	X	Building maintenance scheduling
X	Site analysis	X	Design reviews	X	Construction system design		Building system analysis
		X	3D coordination	X	3D coordination	X	Asset management
			Structural analysis	X	Digital fabrication		Space management/ tracking
		X	Energy analysis		3D control and planning	X	Disaster planning
		X	Mechanical analysis	X	Record modeling		Record modeling
		X	Electrical analysis				
		X	Code validation				
	Phase planning (4D modeling)	X	Phase planning (4D modeling)	X	Phase planning (4D modeling)		Phase planning (4D modeling)
X	Cost estimation	X	Cost estimation	X	Cost estimation		Cost estimation
	Existing conditions modeling		Existing conditions modeling		Existing conditions modeling		Existing conditions modeling

Figure 18: Example BIM use matrix for o*wner's* project planning

The BIM Execution Plan is the tool that the project team uses to define and detail how BIM will be employed by the entire project team, to satisfy the owner's goals and building requirements for the foreseeable service life of the building. The BIM Execution Plan can be as simple or complex as the project requires. However, this is an important and usually substantial document that is intended to be maintained by the project team (often the BIM leaders) throughout all phases of the project.

ISO 19650 organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)

As the use of BIM grows, there is a need to create an international framework that allows the industry to work together across projects and national borders. First published in 2018, the ISO 19650 standard series now has 5 parts and is the industry accepted standard for managing information over the whole life cycle of a built asset using BIM.

The suite of ISO 19650 standards is available here: www.iso.org

The UK BIM Alliance has developed guidance documents for ISO 19650 that are available here: https://www.ukbimalliance.org/information-management-according-to-bs-en-iso-19650/

BuildingSMART Canada leads the development of BIM standards in Canada and is developing a Canadian Annex to ISO19650. https://buildingsmartcanada.ca

The BIM Execution Plan defines tasks, schedules and information requirements, designates BIM leaders, and defines information exchanges such as the project technology infrastructure (project management software, shared file servers, communications platform, etc.) that will complement the BIM process. Figure 19 presents a simplified BIM project execution planning procedure.

Key Components of a BIM Project Execution Plan

The following categories might be considered chapter headings and need to be addressed within a typical BIM Project Execution Plan (BIMx):

- Plan overview
- Project information
- Key project contacts
- Project goals/BIM uses
- Organizational roles/staffing
- BIM process design
- BIM information exchange
- BIM and facility data requirements
- Collaboration procedures
- Quality control
- Technological infrastructure needs
- Model structure
- Project deliverables

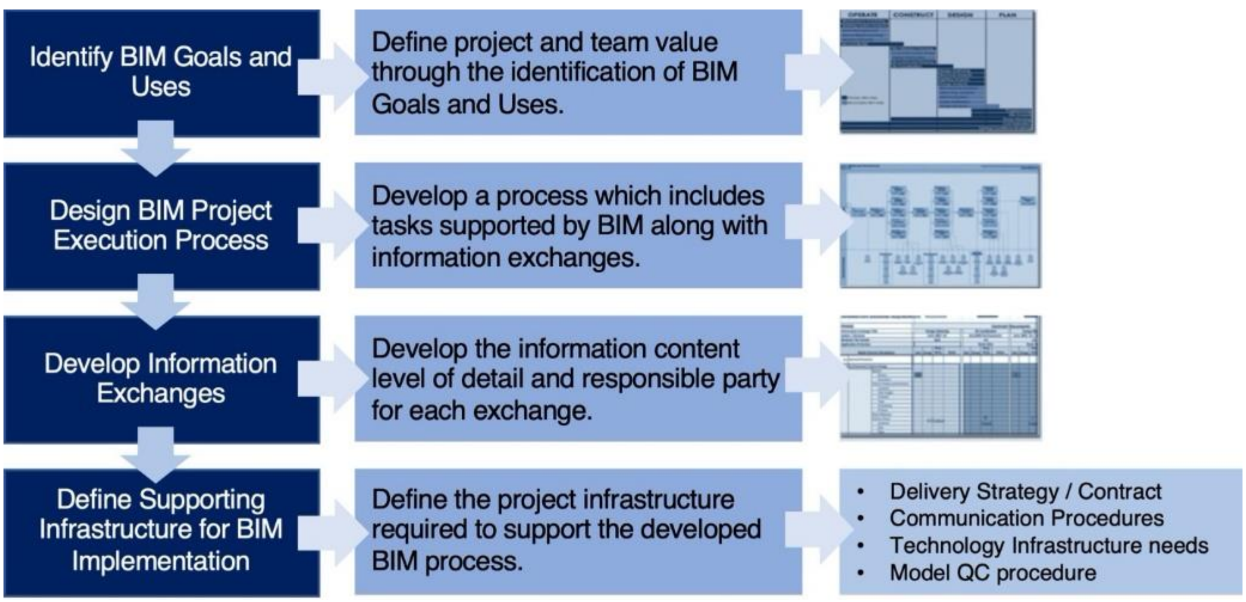


Figure 19: Example BIM project execution planning procedure adapted from *PSU "BIM Project Execution Planning Guide"*

BIM Project Execution Planning Guide

Penn State University's "BIM Project Execution Planning Guide, Version 3.0" is widely used to assist with the BIMx planning process. It provides template worksheets, procedures and guidance on developing BIMx Plans.

Available for free download at https://bim.psu.edu

The BIM Execution Plan runs parallel to and in support of the project. It is used to manage information processing and coordination, decision-making and the production of the digital model to deliver the building project. The objective of the plan is to eliminate uncertainty of what to model, information requirements, etc., and to ensure BIM is only used where it provides value to the building project. While the BIM Execution Plan can be extensive and detailed depending on the project, some of the key planning elements documented in the Plan include:

- **BIM goals and use planning:** The goals and building requirements developed during the Management Team's project planning is often developed into a list or matrix that aligns them to relevant BIM deliverables, specific tasks, and the program(s) of choice that will be utilized. The Management Team provides their expertise to define the required Levels, LOD and Dimensions for the rest of the Project Team.
- **BIM mapping and information exchange:** Mapping of the BIM process designs (often as a flow chart) the parallel BIM Plan: visually designating tasks, their responsible parties, tasks' required input/output and information exchange, and their deliverables at each phase of the building project (see "Management and quality control planning").
- **Technological infrastructure:** The mapping also allows the team to consider software requirements and logistics, such as program versions, licenses and networking, as well as any hardware requirements, such as project servers or databases, or ensuring the team has powerful enough computers to work together.
- **Common Data Environment (CDE):** Centralised repository of information providing many advantages in terms of collaboration, but it must also be set up considering some administrative or logistical items, including:
    - Where will the CDE "live"? In the cloud, at the architect's server, or other?
    - How does the team manage file versions, file naming and software compatibility? What agreements are necessary to protect the data of the owner, and other participants, without negatively affecting project tasks and activities?
- **Management and quality control planning**: Management planning details the who, what, when, how and why of BIM project delivery. Model management, led by the BIM leaders, becomes important as the design team acclimates to a BIM workflow. Effective management underpinned by clear role assignment and reporting structure is required for the project team to ensure that the model data remains coordinated, well-structured and efficient. Secondary benefits include reduced errors, improved consistency between team members and gains in production efficiency.
- **Communications**: Communication planning is set by the project management team (with feedback from the entire project team) and managed by the BIM leaders. The communication plan and platform are practically inseparable from the BIM process; it ensures the information in the BIM gets to the team effectively and in timely fashion.

- **Implementation planning**: To be set up correctly from the start to fully utilize BIM for wood, off-site construction, the project team must be able to use BIM correctly for successful project performance. The goal is for the project team to be fully aware and agree upon the BIM capabilities, tasks and outputs at the time of recruitment.

  The management team advises and supports the owner with developing the strategy to recruit the project team, including recommending when and how to procure the necessary consultants, trades and suppliers. This may include non-typical strategies such as design-assist and design-build for trades and suppliers, or can be more traditional, procuring through public, competitive tenders post-design phase; this is completely dependent on the owner and project management team's experience and judgement on best means and methods to achieve the project's goals and requirements.

Project team on-boarding and familiarization with the BIM Execution Plan

All members of the Project Delivery Team (all consultants, key trades and suppliers) can be procured or hired as necessary by the owner, but all should be familiar with the BIM Execution Plan, reviewing it regularly to maintain cohesion between the Plan and project. This can include BIM on-boarding or workshops as part of project start-up meetings.

> *"BIM planning is not just for BIM: it also acts* as a pre-project rehearsal. The team can discuss, shake out and plan the project before actual *design and construction."*
>
> ~ Project manager

Mapping high-level BIM workflows

Workflow planning, accomplished as part of BIM mapping and management planning, maps out the day-to-day tasks of project participants, which can act as a work plan. The project sponsor and management team work together to ensure the BIM Plan supports the tasks and activities that will deliver on the owner's goals and building requirements. The BIM Plan's overlay of relationships, key information exchanges and responsible parties, creates the parallel BIM workflow for all participants to follow from project start to finish. Workflow mapping helps manage when and how project participants might (or might not) participate in the BIM process, coordinating and optimizing productivity and project delivery efficiency at the project level. Not every scope of work needs to be deeply and technically involved in the BIM; there are three high-level workflows to consider (Figure 20).

The production workflow within the BIM environment and the information exchange necessary to support it are quite different from traditional processes—necessitating deliberate communication planning regardless of the specific BIM software employed. With BIM, more information is being exchanged, with more project participants (including the owner, general contractor and key trades and suppliers), starting at an earlier stage in the design process, lasting through to project hand-over if necessary.

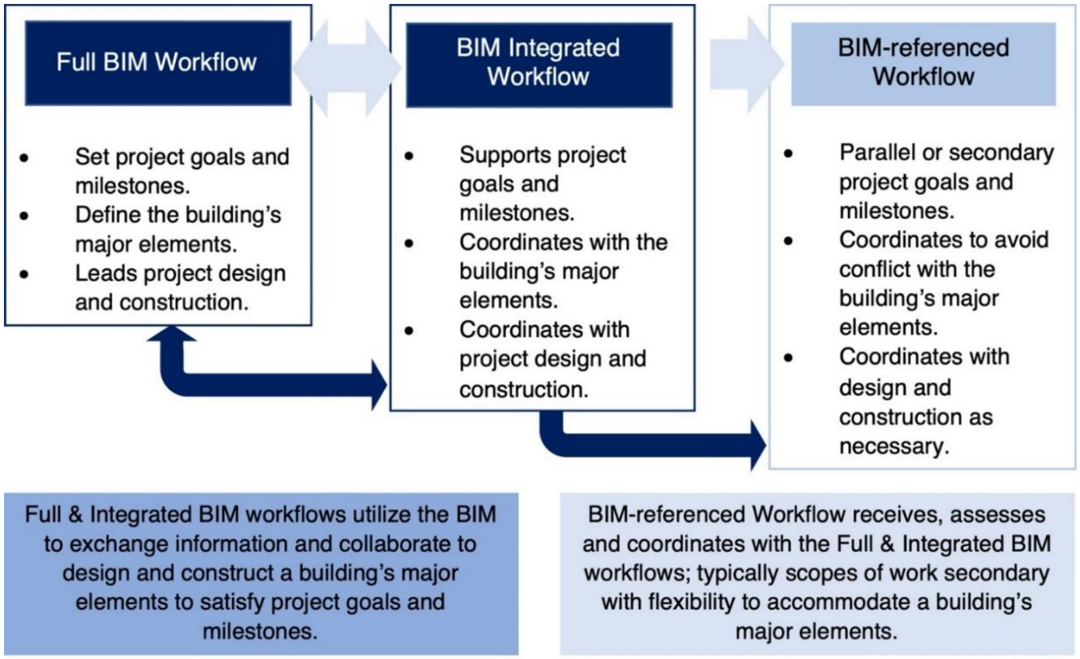


Figure 20: High-level BIM workflow descriptions

Adhering to the BIM Execution Plan

Typically, any changes to the BIM Execution Pan as the project progresses must be agreed upon by the project's BIM Leaders. Any updates approved by the owner are shared with the applicable team members and the BIM plan is updated to reflect the change. While a BIM project may have more people than is typical involved, effective upfront planning, coordination of design and construction tasks, and proficiency with BIM mean that the process can eliminate duplication of effort and reduce errors. The team's efforts are focussed on critical tasks leading to a tapering down of effort from the detail design stage onwards.

However, for this to work, the BIM Execution Plan must be managed and adhered to. The upfront effort to plan, coordinate and streamline can be derailed if a consultant, contractor, trade or supplier breaks away from the BIM Execution Plan and the BIM workflows. When this happens, the project reverts to traditional project delivery and all the efficiency benefits are lost.

"In North America and Europe, high-performing project teams tend to work as if they belong to the same organization—*it's likely not a coincidence that these teams are the most s*uccessful leveraging digital off-site *construction successfully for mass timber."*

~ Wood off-site construction expert

"BIM paired with off-side construction (DfMA) will fundamentally change the industry. From moving most construction into fixed facilities with controlled environments, to equipping a shrinking workforce with digital tools and new skills, very few professionals have learned to leverage this potential—*yet."*

~ Wood off-site construction expert

4.4 Delivering a BIM project

BIM's highly collaborative, accessible information does change project delivery on a day-to-day basis. It can alter the owner-consultant-contractor relationships and open new opportunities, strategies and tactics—even new business models. These are captured in the experiences of BIM practitioners in Canada in Chapter 5.

While BIM can be utilized as an Asset Information Model (AIM), this is still quite unusual in Canada today. Section 5.5, Operations and Asset Management, provides a description of how an AIM can be utilized by the owner for operations and maintenance, as a project record model, and for life cycle planning of the built asset.

From visualization to construction sequencing – digital project delivery solutions for 1 Lonsdale Avenue in North Vancouver

BIM VDC Application: High-performance envelope details, construction coordination and sequencing

BIM Team: Hemsworth Architecture, Equilibrium Consulting, Naikoon Contracting Ltd.

Erected in just 10 days, 1 Lonsdale Avenue Commercial Building was built to rigorous Passive House design standards to meet the owner's energy efficiency and sustainability goals. Hemsworth Architecture, Equilibrium Consulting and Naikoon Contracting Ltd. used BIM early in the design process to visualize and develop the project design, optimize the structural system, then "virtually" build the project before the mass timber elements arrived on site. A rendering of the project is on the far left and an image of the completed building is on the far right.

More details available at www.naturallywood.com/project/1-lonsdale-avenue-commercial-building

Chapter 5: What are the keys to success in BIM delivery?

Recommended for: Design and construction professionals, suppliers, owners and project managers

Summary

- Insights from industry leaders offer practical lessons when using BIM for each stage of project delivery (project setup, design construction, and facility management and maintenance).

This guide has drawn on the advice of consultants, general contractors and trades who are working on advanced wood projects using BIM. Their experiences with the project delivery process are summarized in this chapter, from initial setup to facility management and maintenance. Even though BIM is an evolving field in Canada and the approach to BIM may vary from practice to practice, these experienced practitioners offer practical lessons from the field for those embarking on BIM for the first time, in the context of designing and building with wood where possible. Each section sets out the keys to success and the potential watchpoints, challenges and limitations.

5.1 Project setup

Keys to success

The right team at the right time

When BIM is well defined in RFPs, the early selection and hiring of consultants, the contractor, key trades and suppliers leads to more resolved designs earlier that can significantly improve construction outcomes. Hiring a BIM consultant can help the owner to define the BIM goals and needs.

Plan! Plan! Plan!

A successful BIM project takes more planning up front. The BIM Execution Plan is where all the BIM administrative information resides and allows the team to proactively discuss and agree upon information requirements, exchanges and processes required for design and construction.

This can be a significant advantage compared to traditional project delivery because it helps the team to manage expectations and alleviate uncertainties before the project team fully mobilizes.

Maximizing prefabrication and modular

The decision to utilize off-site wood construction must be made at the start of the project. The benefits, challenges and considerations of off-site construction sets the tone for the entire project and must be set up at the conception of a building project. The speed, cost and effort advantages may be significant.

The specialty wood fabricator should be included as part of the design team. The BIM Execution Plan helps with coordination between structural design, off-site construction and on-site construction (services, site erection, etc.), often catching errors and conflicts early, minimizing the need for rework later.

Watchpoints

BIM technical limitations

BIM are data rich, but the ability to utilize the information to the fullest potential can still be logistically difficult due to software limitations. BIM programs are technically complex and require hands-on use to become proficient. BIM adoption may impose a steep learning curve on some owners, consultants, contractors and suppliers.

Information liability

BIM's requirement for sharing information and collaborative decision-making brings fears of liability arising from perceived loss of professional control, or the potential misuse of information. These concerns are best addressed in agreements as a team pre-project, to ensure everyone is comfortable before the project starts.

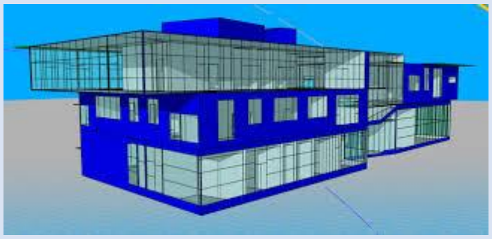
Intellectual Property (IP) concerns

The use of federated BIM can raise concerns about IP related to proprietary digital assets or processes. Shared ownership of the BIM asset and components typically requires IP to be defined in RFP documents and project contracts.

Information Management (IM)

IM is a critical part of BIM but is not typical in traditional projects. As project complexity increases —higher levels of BIM Maturity and LOD— organizing information in BIM can be overwhelming. A BIM Manager (or "champion") should be a designated role within the project team tasked with managing the information framework. Another option is to have an external BIM consultant act as the BIM manager.

priMED Mosaic Centre, Edmonton AB – fostering project resiliency through BIM collaboration



BIM VDC application: BIM design, construction & management under a Hanson Bridgett IPD Standard Agreement

BIM Team: Cuku's Nest Enterprises Ltd (owner), Manasc Isaacs Architects, Chandos Construction, Clark Engineering, Manasc Isaac (Elec. Engineer), Fast & Epp

Completed in 2015, the Mosaic Centre is a high-performance office building that utilized an innovative hybrid timber, steel and concrete structure. A key element of the combination of BIM within an IPD collaborative framework is team resilience. During construction, an unexpected issue related to the design of a shear wall could have resulted in an additional cost of $270,000. An impromptu meeting on-site found a solution that reduced the cost to change the wall to $80,000 while meeting the structural requirements. Utilizing BIM under IPD, the team developed a level of trust and a working relationship that solved difficult issues for the benefit of the project, while balancing individual needs: the team later found enough savings elsewhere in the project to cover the outstanding cost increase that could have become a cause for dispute.

More details available in the report Strategies for Collaborative Construction – Integrated Project Delivery Case Studies

5.2 Design

Keys to success

Coordination and clash detection

BIM is a powerful tool for coordination and clash detection and, as software capabilities continue to evolve, more of these tasks can be automated. BIM can also include visualization tools such as VR/AR or "walk-throughs" that can catch issues the clash detection process may not be looking for—such as for critical envelope details. However, setting a goal of 100% clash-free is not desirable; it should be focused on project-critical outcomes.

Site and as-built integration

Laser scans of the site or as-built conditions provide highly precise information (e.g., point clouds) that can be integrated into BIM to help in designing and planning for renovations or retrofits—especially useful for phased projects.

Watchpoints

Information quality

BIM's information advantage is only as good as the quality of data. This is particularly important when including time-sensitive data that might become outdated quickly such as wood commodity material pricing data, carbon databases or in-services energy performance information.

Poor BIM etiquette leads to bad experiences

Despite growing adoption in BIM software, the lack of application of best practices and management protocols has resulted in disappointment and frustration. In the absence of industry accepted standards (which are emerging), the quality of BIM etiquette can be varied.

Keys to success

Automating data integration

With appropriate plugins, BIM can automate information or data integration tasks. For example, solar path data can parametrically design sun-shading, instead of manual modelling—which can be imprecise, prone to error, or be time-consuming.

Communicating the design

Buildings with complex systems (structure, services, etc.) benefit from having the complex elements modelled to a high LOD for coordination and clarity. This allows the specialty trades, fabricators and suppliers to view and navigate a 3D model to better understand their scope during tendering, resulting in a more accurate price.

Digital specifications

Specifications linked with the digital model add significant value as the central source of accurate information, reducing risk of errors and miscommunication. Several software developers have automated specification generation software that populates specifications based on model elements utilized within the digital model.

Timely feedback to inform design

Being deliberate and disciplined with BIM can provide accurate, up-to-date information that can provide instant feedback to the team. For example, energy modelers can utilize BIM to start their simulations early (and run more options) to usefully inform the project design.

Computational design

Computational design—BIM design utilizing parametric, formula-based constraints—is a powerful method to assess, select and rationalize possible solutions, as well as visually communicate the impact on building design. During the early stages of the project, the design team can utilize parametric modeling and the computational power of the cloud to simulate dynamic variables, analyze design scenarios and develop best case options. As the design team changes specific project variables, such as structural requirements or design limitations, the model can reflect the real-time impacts of the metrics in the digital model.

Watchpoints

Project cash flow needs to recognize upfront planning and setup time

The amount of upfront planning and setup time to leverage BIM's advantages downstream are more than may be contemplated in a traditional project. This means the cash flow requirements need to be front-end loaded.

BIM exposes the design-construction gap

The hand-off from design to construction can expose significant coordination and communication issues. The use of BIM in conjunction with collaborative project delivery frameworks (e.g., IPD, Lean, etc.) can help to bridge this knowledge gap. Many of the specialty wood fabricators and installers are BIM-capable and these approaches help them to get involved in the design early.

Using BIM for CAD

The BIM Plan must be set up and strictly followed to support successful delivery of downstream tasks such as off-site construction or virtual design and construction. Today, where BIM is employed for wood projects, it is predominately used to produce 2D contract documents. These BIM do not have the information, the precision or the configuration to be fully leveraged for VDC. This is partially due to a misunderstanding of BIM or not knowing off-site construction requirements, such as fabricator's software, CNC equipment, etc. All have requirements that must be incorporated into the BIM Execution Plan. Similarly, high-energy performance, such as VDC-supported passive house detailing, also need to be incorporated into the BIM Execution Plan to be successful.

Letting designers design again

BIM, and the digital workspace it supports, can shorten communication lines through team integration or automation of calculation and simulation tasks. This can provide instant feedback, allowing for quicker iterative design and analysis. However, the expertise to understand results or interpret the feedback is still required. Digital tools can streamline design, but they do not eliminate the need for skilled technologists, trades, etc., rather enhance their knowledge and expertise.

An article from 2020 describes one Archicad workflow that provides quicker, useful feedback to designers: www.thomsonarchitecture.ca/2020/08/15/archicad-ecodesigner-and-passive-house/

BIM/VDC can unlock the scheduling advantages of a prefabricated mass wood structure

A unique feature of Brock Commons' design and construction processes was the intensive use of virtual design and construction (VDC) tools and methods. The schedule and performance advantages afforded by the precision of advanced timber fabrication and modular elements—and unlocked using BIM and VDC—meant that the 18-storey wood structure was complete less than 70 days after the prefabricated components arrived on site, approximately four months faster than a typical project of this size.

Image sources: CadMakers (images of detailed model), naturallywood.com

The Brock Commons Construction Modelling Case Study is available at www.naturallywood.com/resource/brock-commons-construction-modelling-case-study

5.3 Prefabrication and off-site construction

Keys to success

Quality and precision off- and on-site

Using BIM, factory manufactured components (including elements such as mass timber panels) can be made off-site with precise dimensions, configurations, fit, etc., that align with the model.

BIM and VDC can also support the installation planning and process of prefabricated elements. This is particularly important for wood post and beam, CLT or modular systems, but extends to other scopes of work. For example, BIM virtual mock-ups and sequencing can be invaluable for Passive House envelope details, mechanical systems in tight service rooms and planning for weather protection.

Watchpoints

Control project schedule volatility

Project schedule volatility needs to be controlled to prevent coordination issues with fabrication timelines and the installation of prefabricated units. BIM can help with scheduling to avoid unforeseen knock-on costs (rescheduling the crane, storage of prefabricated elements, etc.) but the modelling scope and protocols need to be established upfront and budgeted for.

Keys to success

Multi-trade prefabrication

Most wood off-site construction offerings are single trade processes. BIM unlocks the potential to combine trades, whereby insulation, windows, services, rainscreen and other elements can be added off-site. This takes more coordination upfront than traditional projects but can dramatically improve the time taken to enclose the building while protecting the wood structure from the weather.

Designing for fabrication

Integrating the fabricator's model into the project's BIM, ensures manufacturing constraints are realistically included into project considerations. Having the fabricator as an integral part of the BIM team can allow them to assess aspects of the design that are suited for prefabrication as well as review logistics, such as delivery or site requirements, and help plan on-site erection.

Schedule and cost reliability

Amalgamating and setting structural and fabrication design within BIM requires close, upfront coordination between the structural engineer of record and the fabrication supplier. Both need to be brought onto the team during the design phase and allowed to collaborate freely and integrate their BIM to accomplish this. The current practice of modelling the project twice for off-site construction—once by the structural engineer during design and again for fabrication during construction (shop drawings)—is costly, time consuming and error-prone. Minor design issues can explode into significant construction challenges.

Watchpoints

Construction liability concerns

Modelling and manufacturing tolerances must be coordinated in the BIM Plan and in specifications; today, BIM and CNC fabrication accuracy and precision exceeds human capabilities. However, some fabricators question the accuracy and clarity of BIM for off-site construction given prevailing BIM practices among some consultants of producing a design model that is only capable of generating 2D documents. Instead, what needs to be precisely modelled and what does not, has to be agreed upon upfront.

Prefabrication requires upfront effort

Prefabrication requires significantly more effort upfront with a larger team, which changes the project plan and cash flow requirements.

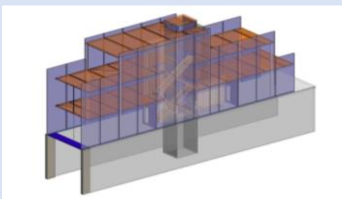
Consultants, trades and suppliers need more time and effort to coordinate during the crucial design phase, even with the help of BIM.

Software interoperability

Software interoperability and workflow must be discussed and defined in the BIM Execution Plan. The BIM software used for design is different from BIM for Fabrication and Construction. Revit is the leading BIM design platform but is not commonly used by fabricators, who prefer more structural-specialized programs such as Solidworks or Tekla.

oN5 four storey mass timber commercial building, Vancouver

Rendering



BIM Model

BIM VDC application: High-performance envelope details, construction coordination and sequencing

BIM Team: Hemsworth Architecture, Timber Engineering Inc., Naikoon Contracting Ltd.

The design model was created in Vectorworks by Hemsworth Architecture, then converted into a Solidworks structural model by Timber Engineering Inc., forming the model for CNC fabrication of the cross-laminated timber (CLT) structure and envelope panels.

The Passive House performance envelope details were developed collaboratively within the Vectorworks model and fully finished offsite. The model was re-built in Revit by Naikoon Contracting Ltd. to allow the team to collaboratively plan and sequence site construction down to 15-minute increments, while ensuring critical connection and envelope details, safety and delivery on the tight urban site was completed successfully. Several virtual builds were conducted to refine the sequencing. Given the tight mid-block site, the panels were flown in from the back of the delivery truck.The prefabricated structure and envelope was erected in 13 days.

For more infromation: www.naturallywood.com/project/on5-building/

Automated CLT production

Virtual build

Installation

5.4 Construction

Keys to success

Visualizing the work

BIM allows project stakeholders to visualize final outcomes prior to construction. This extends to:

- Reviewing digital versions of final built form, based on submittals and alternates.
- 3D envelope details, steel to wood assemblies and connections.
- Linking to photos, 3D scans, etc., that can be used to monitor the work on-site.
- Virtual replacement for shop drawings and field mock-ups that can add fees and slow down progress.
- Producing model-based site instructions that can be incorporated into the record model for hand-over.

Augmented Reality (AR) powered by BIM brings computer-generated objects into the user's physical environment, overlaying the digital model with the real world. Using mobile applications, headsets, and other smart devices, AR can superimpose digital objects into the real world. AR is gaining popularity on construction sites to aid in constructability. It can be used to track and document how projects are progressing and can even improve site safety where AR devices (like glasses or mobile devices) can scan labels placed in specific areas or objects.

Coordination and sequencing

The federated BIM allows the team to rehearse the construction of the entire project starting with administrative requirements such as site organization, staging, temporary works, crane deployment and safety planning. Allowing the project team to "populate" the construction model with the who, when and how can improve project resilience (the ability to manage unforeseen situations) and predictability. 4D BIM at its most detailed can become a step-by-step assembly program for key building elements—or the entire building.

A single source of truth

The federated model allows the builder to plan construction from one centralized model of the building, rather than extrapolating from a series of separate drawings and specifications. The use of BIM under a collaborative framework and with information liability addressed, reduces the risk of information getting lost in the hand-off from designer to builder.

Watchpoints

Keeping BIM updated during construction

Actively keeping the digital model up to date during construction can be time-consuming if not properly planned (fees, process, etc.). Software add-ons help facilitate tracking and assigning responsibilities when changes are made either during the design phase or on-site, allowing the project team to communicate and track changes so the model maintains similarity with the constructed building.

Today, 3D point cloud scans can be conducted on-site, and compared with BIM for clash detection during construction. This workflow provides the design team with accurate as-built conditions while concurrently progressing the building system coordination for ease of constructability. This can be valuable when a tenant fit-out is occurring at the same time as base building construction.

Some trades may have limited BIM capabilities

While specialty mass timber trades and fabricators are generally well-versed in BIM, the overall success of a BIM project relies on all key trades being able to participate. Most trade companies are small and BIM/VDC software can be expensive. Designates within the project team can function as BIM support for those with limited capabilities—but this can result in contractual/administrative conflicts.

However, most cloud collaboration platforms have scalable licensing according to the needs of the user. For example, a license for a project team member who only needs to view the model and communicate with the project team costs less than a fully featured license allowing a modeler to upload and manipulate the model. Additionally, there are readily available free BIM viewers.

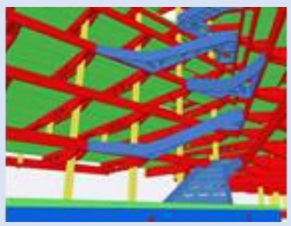
Keys to success

Installation instructions

Some scopes of work can be coordinated during design and used as installation instructions during construction. For example, when mechanical engineers and trades collaborate in the digital model during design, the equipment layout, runs and mounting can all be "pre-coordinated" with structural, code requirements, etc. This results in an efficiently laid out system that can be installed quicker and with fewer conflicts. This is useful in mass timber buildings where the wood ceilings and services remain exposed.

Watchpoints

Tekla – Bjergsted Financial Park, Stavanger, Norway

BIM VDC application: Interdisciplinary, mass timber design, fabrication and construction

Key BIM Team: Degree of Freedom (Structural Engineer), Helen & Hard and Saaha (Architect), Creation Holz (mass timber technical support) Moelven Limtre AS (mass timber fabricator)

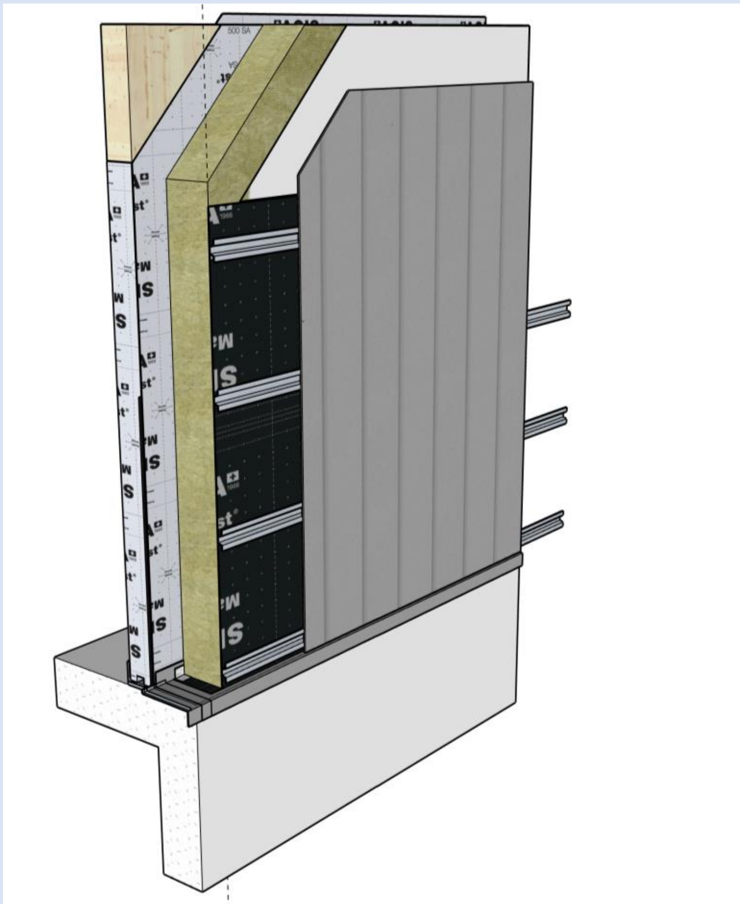
Retaining key project team members early and adopting BIM collaboration, the team designed the CLT and LVL structure with the help of Tekla, creating a 3D model detailed enough to allow fabrication without additional shop drawings beyond the BIM.

Tekla notes:

"It is very important to highlight that the BIM model from designers is used directly by the timber fabricator, translated into their own software, and later used for the CNC machine at the factory. There are no additional form/shop drawings, as everything is detailed in 3D."

More information available from Tekla: www.tekla.com/bim-awards/finansparken-bjergsted

BIM for construction: Trades are critical BIM team members



SketchUp digital envelope "mock-up".
Image courtesy Pacific Timberworks

At a minimum, contractors, trades and suppliers should be comfortable with navigating and pulling information from the BIM, and updating information as the project progresses, for mass timber on-site construction (OSC) to be successful.

However, for teams to fully benefit from wood OSC, trades will need BIM skills and be a part of BIM delivery. For example, in B.C., Johannes Schneider and Olav Felgendreher (Pacific Timberworks) combine expertise in both engineering and carpentry, using BIM as an extension of their experience to support numerous successful mass timber projects in Canada.

Connecting design teams with trades who have both field experience and the technical competencies to help design practical connection and envelope details, incorporate site assembly considerations and coordinate with other trades, is critical to ensure a prefabricated building design can be built efficiently, quickly and safely.

Traditional design and construction silos in Canada will need to be significantly disrupted to unlock the advantages and benefits of wood OSC. The trades have traditionally been the most isolated from the design phase—yet, they have the experience and know-how critical to ensuring what is designed can be built.

5.5 Operations and asset management

The use of BIM for facility management and operations and maintenance (FM & O&M) is the key value proposition for owners. It is developed from the start to serve as a long-term business and operational planning tool. However, the use of BIM for FM & O&M is at the earliest stages of adoption in Canada—particularly when it comes to wood buildings. The adoption of BIM, so far, has primarily been driven by the efficiencies afforded to the design process. The industry practitioners interviewed for this guide were cautious about providing insights given they have little experience in this area. Many of the following comments are based on professional opinion as opposed to track record.

Keys to success

Commissioning and verification

BIM has considerable utility for commissioning, especially with complex mechanical and electrical systems or for energy performance. Indeed, BIM offers the opportunity for comprehensive and/or focused simulation, delivering high-quality information for system optimization.

Transitioning the PIM to the AIM needs to be contemplated at the start of the project

The BIM Project Information Model (PIM) can transition into the Asset Management Model (AIM) at hand-over if it is properly defined as part of the project requirements at the outset. It needs to be included in the BIM Execution Plan and the model must be updated throughout the fabrication and construction phase. The delivery of an AIM is rarely done for wood buildings in Canada but as the shift towards prefabrication continues, it may become more common.

The transition from PIM to AIM can be more involved than traditional turn-over (ideally requiring LOD 500, 6D-8D information). However, an as-built model can still be provided and provide for building operations regardless of the LOD, depending on the client and project demands.

Digital Twin for facility management

Depending on the level of digital expertise of the facility management staff, the digital model can be used as a digital twin of the completed building for the purpose of optimization, monitoring, performance tracking and troubleshooting. If kept up to date, the model can also facilitate renovations or repurposing as well as end of life decommissioning, providing information about assemblies, equipment and materials. It can even be used for deconstruction, and for re-use, salvage and environmental concerns.

Watchpoints

Discontinuous relationships

BIM facilitates information continuity across a building asset's life cycle if properly managed. However, leveraging BIM to manage information to facilitate long-term building operations is hampered by the fact that the BIM champions are currently within the design or construction team and most building projects end after the warranty period.

Operations and maintenance activities are often under-resourced with limited digital or BIM utilization

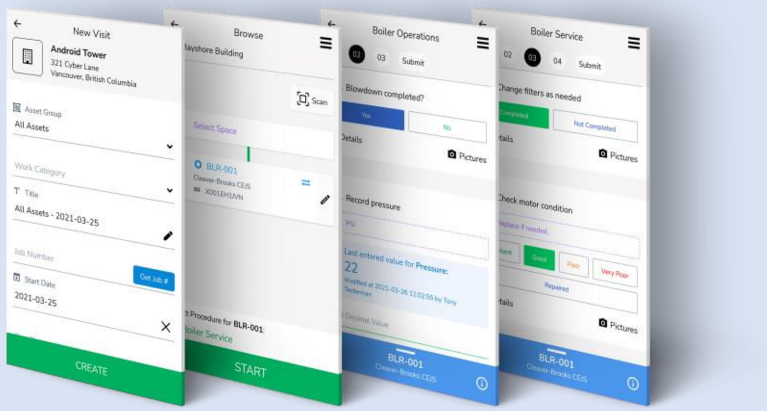
With an increasing number of affordable and easy to use facility management (FM) platforms on the market, more building owners are expected to see the value of setting up Asset Information Models for long-term FM. The pressures of sustainability and controlling building operational and maintenance costs means that digitization is gaining popularity.

Traditionally, O&M plans have been triage-driven (fixing things when they break instead of scheduled maintenance), often relying on low-bid contractors with limited understanding of the asset they are retained to manage. The operations and FM process for many buildings is one of the last sectors of the real estate industry to make the shift from analog to digital processes.

> *"BIM adoption by owners and owner operations and FM staff are rare. This can be a significant barrier to a key* benefit of BIM—using the digital twin as a means to operate, optimize and plan the building asset throughout its full life *cycle."*
>
> ~ Project manager

> *"Today, BIM's data power is woefully under*-utilized globally. Technical and regulatory challenges aside, integrating shared databases, perhaps at the regional or provincial level, could make highly accurate climatic, energy or cost modelling (to name a few) a 1-*click operation."*
>
> ~ BIM specialist, Canadian engineering firm

UBC – Built Space Digital Twin



BIM and digital twin for FM and O&M planning is about leveraging a data-rich “copy” (BIM) of the physical building asset. This can be as simple as Code-marked equipment and systems for managing and planning for O&M and can include fully integrated FM software with Internet of things devices, used to track and optimize building performance—often in real-time. For example, BuiltSpace is a Canadian company that has developed a Service Twin platform to solve the “as-built” data acquisition/verification challenge.

The system captures shared high-fidelity construction, materials, service workflow, equipment commissioning, operational and asset condition data at the point of service. This submission describes digital construction, commissioning, and hand-over of submetering assets by QMC Submetering Solutions.

More details available at www.builtspace.com

Looking ahead

The analog to digital shift in the construction industry is well underway. Investments in construction technology are soaring and businesses of all sizes are looking for ways to get involved. The industry practitioners interviewed for this guide recognize the opportunity to embrace digitization and industrialization afforded by the evolution of advanced timber systems. Many are looking ahead and thinking about future applications of BIM and the digital tools that enable efficient building design, construction and operation.

BIM FOR PERMITTING

"BIM for permit processing is limited in Canada because BIM is not fully recognized as a digital form of permit submission or the permit "document". Although some regions are exploring a digital process, the digital/BIM literacy, legal and regulatory definitions for digital models are still in their infancy. These terms will be required if BIM's potential for detailed simulation, design documentation, etc. is going to be leveraged for confirming regulatory or permit requirements."

BIM-ENABLED ENVIRONMENTAL DESIGN FOR OPERATIONS

"Environmental concerns will be a large factor in the construction industry, not only addressing the environmental and safety of the construction process but also the efficiency and resiliency of the building operation. Buildings will be "recycled" due to the increasing cost of construction and the inefficiencies of demolishing an existing building, so we will see buildings being repurposed or refitted. Industry software leaders are developing software that will mimic how people interact with the building environment to show statistical data such as usage and movement of people indoors and out. Programs like this will allow us to create efficient buildings that are more pleasant to work and live in. Ultimately people will be able to interact with the building using their smart device."

THE INTEREST IN MASS TIMBER MIGHT BE WHAT IS NEEDED TO DRIVE ADOPTION OF LIFECYCLE-FOCUSED DIGITAL ASSET MANAGEMENT

"With the growing interest in high performance mass timber systems for a wide range of uses, the need to design and operate them to meet their stringent performance goals throughout their life cycle will be required. This may be the spark that ignites interest in BIM for FM."

"One overlooked aspect is managing the building's end of life. Deconstruction is the safe, environmentally appropriate way to salvage, recycle and efficiently dispose of materials, components and equipment. An accurate BIM model can "reverse" the construction sequence to begin planning efficient and safe disassembly of the building virtually, before actual operations begin. Wider BIM adoption today, as an accurate record model kept up to date, can help enable future deconstruction on a wider scale in the future."

DESIGN FOR MANUFACTURING & ASSEMBLY (DFMA)

"DfMA differs from prefabrication and modular construction by utilizing BIM as both the design and fabrication model: what is modelled forms the instructions for fabrication equipment. This streamlines the prefab process, accelerates the schedule and eliminates communication errors. The automobile and aircraft industries connected digital design with manufacturing long ago, realizing the benefits of rapid prototyping, digital simulation and economies of scale. Many aspects of building construction have not adopted similar workflows despite repeatable components, standardized sizes and the opportunity for prefabrication. But - using BIM - there is no reason why they couldn't."

Figure 21: Insights from interviews with industry leaders in Canada on the future of BIM

Appendices

A1. Survey of leading BIM practitioners

A key source of information for this guide was a survey of leading BIM practitioners who were selected based on their experience in innovative and/or off-site wood construction projects. Additionally, insights and advice gathered from the interviews are quoted throughout the guide.

Survey respondents

The survey was organized into two groups of BIM practitioners to capture perspectives from those at the leading edge of BIM adoption ("pioneers") and those who are interested in BIM but have only recently embarked on their BIM journey ("fast followers").

Pioneers

- Are considered experts in BIM (have completed at least one BIM project).
- Have a history of exploring and pushing the limits on BIM—theoretical or in practice.

Fast followers

- Understand BIM and have some experience with BIM in practice.
- Have expressed interest in using BIM but have not yet completed a BIM project.

The following professions were represented in both groups:

Architects
Engineers
Structural
Mechanical
Energy
Owner Representatives
Project Managers
General Contractors
Wood & Mass Timber Suppliers
Modular Building Supplier
Researchers
BIM Instructors

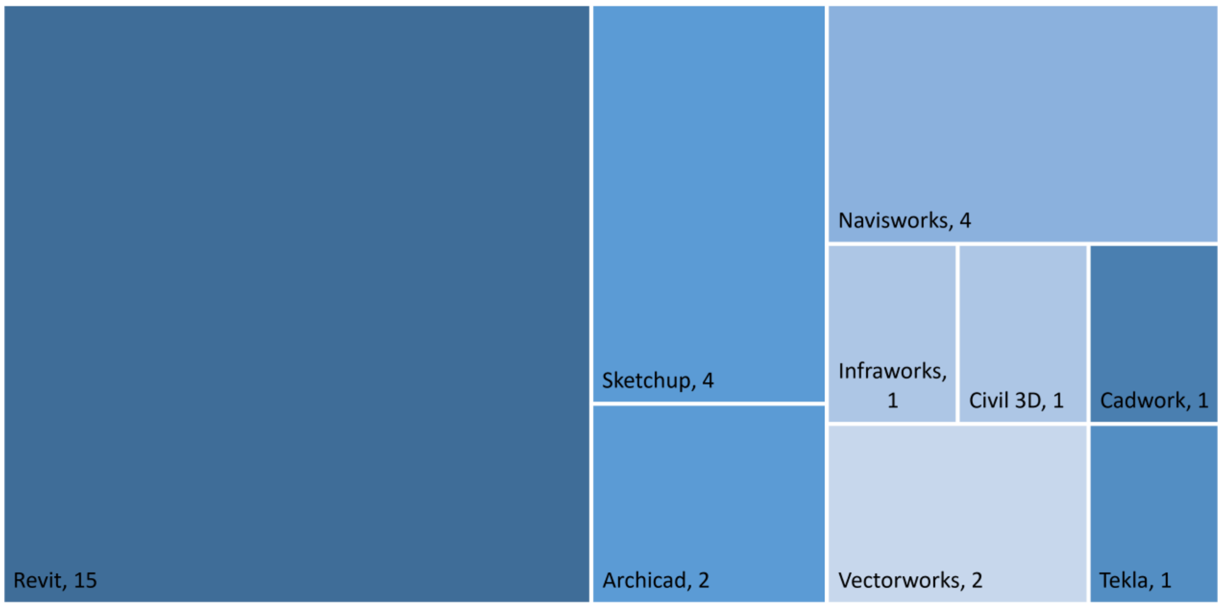
Industry professionals were invited in May and June 2021 by email to either participate in an in-depth interview or to complete an online survey. 25 interviews were completed with 14 pioneers and 11 fast followers. The online survey gathered 19 responses from 10 pioneers and 9 fast followers. 84 percent of the respondents were based in British Columbia with the remaining 16 percent from across Canada.

A2. Resource lists

The following lists of software programs, platforms, apps and other resources were generated from the survey of practitioners and organized in order of popularity. In the survey of leading BIM practitioners, respondents identified applications that they used when working on wood projects.

Primary BIM programs

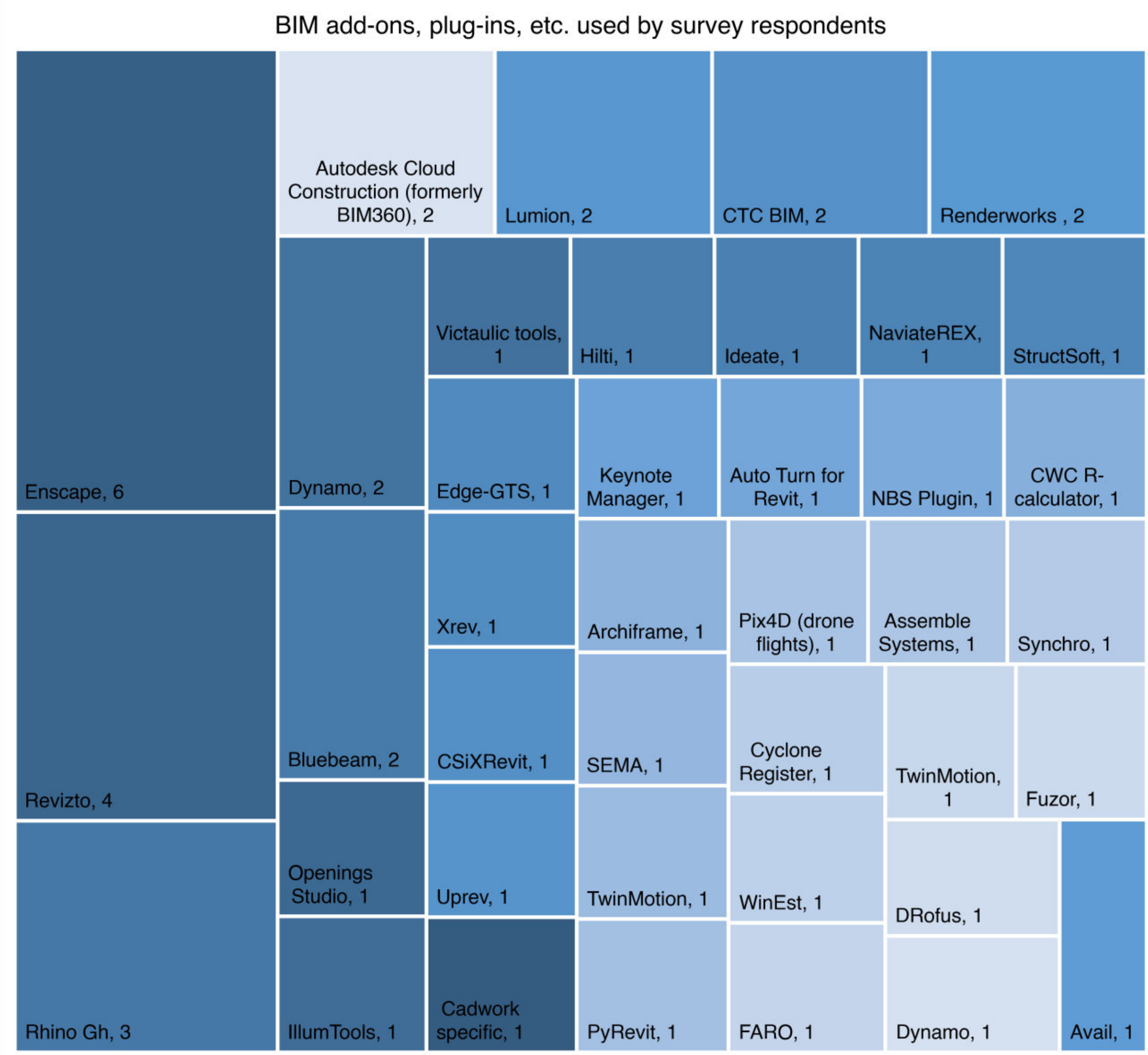
BIM programs utilized by survey respondents



BIM Programs	
Revit	https://www.autodesk.ca/en/products/revit/overview
Sketchup	https://www.sketchup.com/
Navisworks	https://www.autodesk.ca/en/products/navisworks/overview
Archicad	https://graphisoft.com/solutions/archicad
Vectorworks	https://www.vectorworks.net/en-CA
Cadwork	https://www.cadwork.com/cwen/Home
Infraworks	https://www.autodesk.ca/en/products/infraworks/overview
Civil 3D	https://www.autodesk.com/products/civil-3d/overview
Tekla	https://www.tekla.com/us

Other programs mentioned	
Autodesk BIM 360 Ops O&M & FM BIM	https://www.autodesk.com/bim-360/facilities-management-software/
Dlubal REFM	https://www.dlubal.com/en-US

Add-ons and Plug-ins applicable to wood projects



BIM add-ons, plug-ins, etc.	
Enscape	https://enscape3d.com/
Revizto	https://revizto.com/en/
Rhino Gh (Example: for Revit)	https://www.rhino3d.com/ https://www.rhino3d.com/inside/revit/1.0/
Autodesk Cloud Construction (formerly BIM360)	https://www.autodesk.com/bim-360/
Bluebeam	https://www.bluebeam.com/
CTC BIM	https://www.ctcsoftware.com/
Dynamo	https://dynamobim.org/
Lumion (Visualization)	https://lumion.com//index.html

BIM add-ons, plug-ins, etc.	
Renderworks (Visualization)	https://www.vectorworks.net/products/features/renderworks
Archiframe (Timber Structures)	https://archiframe.fi/en/
Assemble Systems	https://assemblesystems.com/
AutoTurn for Revit (Vehicle Simulation)	https://autoturnonline.com/integrated/
Avail (Library)	https://getavail.com/
CSiXRevit (IM Transfer)	https://www.csiamerica.com/products/csixrevit
CWC R-calculator	https://cwc.ca/design-tools/effective-r-calculator/
Cyclone Register (Laser Scan)	https://leica-geosystems.com/products/laser-scanners/software/leica-cyclone/leica-cyclone-register
DRofus (IM)	https://www.drofus.com/
Edge-GTS (VDC)	https://edge-gts.com/
FARO (Measuring & Site Data)	https://www.faro.com/en
Fuzor (VDC / Fabrication)	https://www.kalloctech.com/
Hilti (Library)	https://www.hilti.ca/content/hilti/W1/CA/en/engineering/software0/hilti-software/mep/bim-cad-library.html
Ideate (IM)	https://ideatesoftware.com/
ElumTools (Lighting Simulation)	https://lightinganalysts.com/software-products/elumtools/overview/
Keynote Manager (Revit Keynote Manager)	https://revolutiondesign.biz/products/keynote-manager/features/
Naviate REX (Rebar Extension)	https://www.naviate.com/
NBS Plugin (BIM Specification Plugin/App)	https://www.thenbs.ca/
Openings Studio (ASSA) (Library / Design Tool)	https://www.assaabloy.com/group/en/about-us/our-solutions/openings-studio
Pix4D (drone flights) (3D Drone Scanning Data)	https://www.pix4d.com/
PyRevit (Revit Pattern & Document Manager (link via RevitPure)	https://revitpure.com/blog/10-amazing-pyrevit-features-to-save-insane-amounts-of-time
SEMA (BIM file format converter)	https://www.sema-soft.de/en/whats-new/special-offers/sema-solution/bim-ifc-with-sema/
StructSoft (Revit Structural frame tool)	https://strucsoftsolutions.com/
Synchro (Construction Management)	https://www.bentley.com/en/products/brands/synchro
TwinMotion (Visualization, animations & VR)	https://www.unrealengine.com/en-US/twinmotion
Uprev (Revit Revisions Manager)	https://apps.autodesk.com/RVT/en/Detail/Index?id=5513670845846828779&appLang=en&os=Win32_64
Victaulic tools (Pipe/Mech. Design tool)	https://www.victaulicsoftware.com/
WinEst (Estimating Software & Database)	https://gc.trimble.com/
Xrev (IM / Sheet Tool)	https://www.xrev.com.au/

Other BIM add-ons and plug-ins mentioned in the context of high-performance, advanced wood building projects	
BIM2PH (Passive House Institute BIM Tool)	https://passivehouse.com/04_phpp/06_bim2ph/06_bim2ph.html
Interactive Thermal Envelope Tool (BC Housing web-based tool)	https://thermalenvelope.ca/
CWC Wood Design Tools (On-line listing of wood design tools)	https://cwc.ca/design-tools/
Design PH 2.0 (Passive House Design tool)	https://designph.org/
Dietrich's timber framing software	www.dietrichs.com/en/applications/timber-framing-software
GESTIMAT (Greenhouse gas emissions estimator) – via https://cecobois.com/	https://cecobois.com/calculatrices/
Graphicsoft Eco Designer BIM-based energy analysis	https://graphisoft.com/downloads/ecodesigner
e-SPECS for Revit (Revit-based Specification & Manual creation tool0	https://e-specs.com/products/especs-revit/
Insight (Autodesk simulation engines and building performance analysis)	https://www.autodesk.com/products/insight/overview
Offsite Wood	https://offsitewood.org/
PassiveLink (Revit exporter for PHPP)	https://www.passivlink.com/
RETScreen (NRCan Low-carbon planning, implementation, monitoring and reporting tool)	https://www.nrcan.gc.ca/maps-tools-and-publications/tools/modelling-tools/retscreen/7465
Simpson String-Tie (Revit BIM Library)	https://www.strongtie.com/drawing/drawing-finder-for-revit
Stora Enso BIM Toolkit (Wood Supplier Library & Data)	https://www.storaenso.com/en/products/wood-products/bim-toolbox
StrucSoft MWF (Wood Pro Revit-based wood framing tool)	https://strucsoftsolutions.com/mwf-pro-wood/
QWEB Offsite Wood Construction (Revit-based Wood Element Library)	https://quebecwoodexport.com/en/bim-offsite-wood-construction-at-your-fingertips-with-qweb/
WoodWorks Software 2.0 (2020 edition, wood structural engineering program)	https://woodworks-software.com/canadian-edition/

A3. BIM software for wood projects

Kreo Modular – DfMA Conceptual BIM

Applicable project phase	Pre-design
Used by	Owner, architect
Link	https://modular.kreo.net

About the software

Developed by Kreo Software, Kreo Modular is an example of AI-powered parametric software that deals with the manufacturing and assembly of structures upfront. It configures the project to suit the kits of parts, components or prefabricated elements that are offered by manufacturers. For example, for its European clients, Kreo has preloaded all the mass timber products manufactured by Stora Enso and the system links to availability, pricing, energy efficiency information and more.

There are also standard modular units that are familiar to the North American market and other structural systems are being uploaded on an ongoing basis. Kreo also preloads geo-based zoning data along with standard building typologies so users can find their project location and the system will configure and optimize the design based on the modules available.

Applicability to wood buildings

Generative tools such as Kreo Modular link to and/or inform the digital model and are well suited for the fast conceptual design of componentized, prefabricated and/or modular wood construction. Kreo Modular's ability to automatically generate and price out iterations of primary wood structures based on zoning, efficiency, building type and structural system in a matter of minutes, demonstrates the power of digitization and prefabrication to dramatically improve efficiency right from the start of the project.

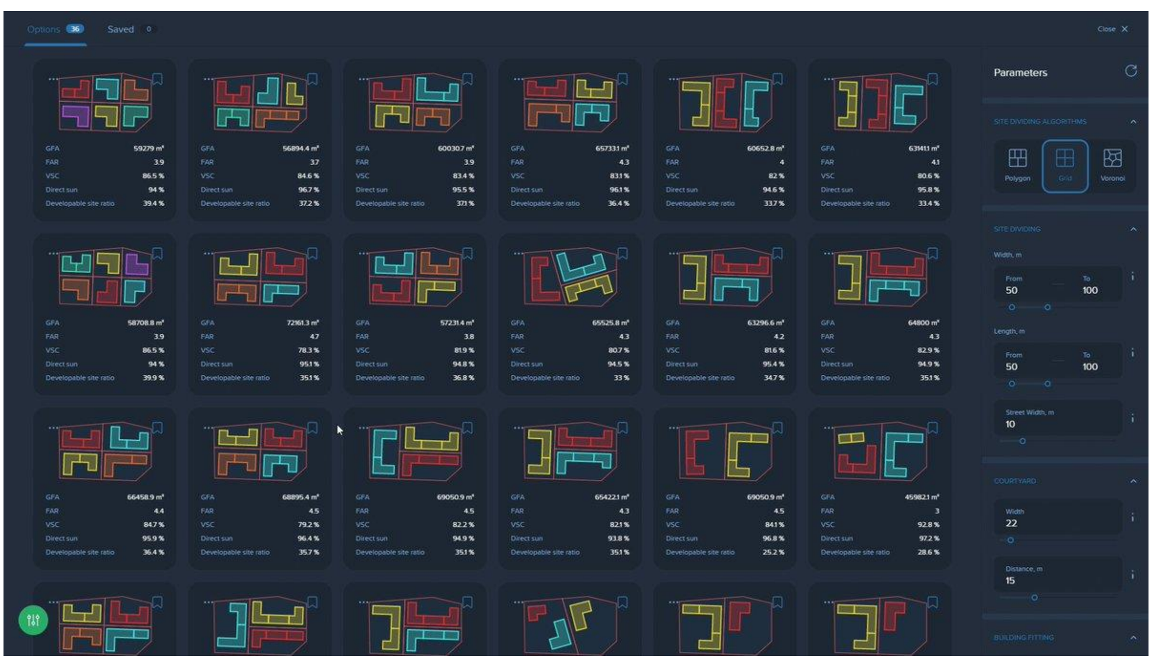


Image source: Kreo Software

Autodesk Revit – BIM Design & Construction

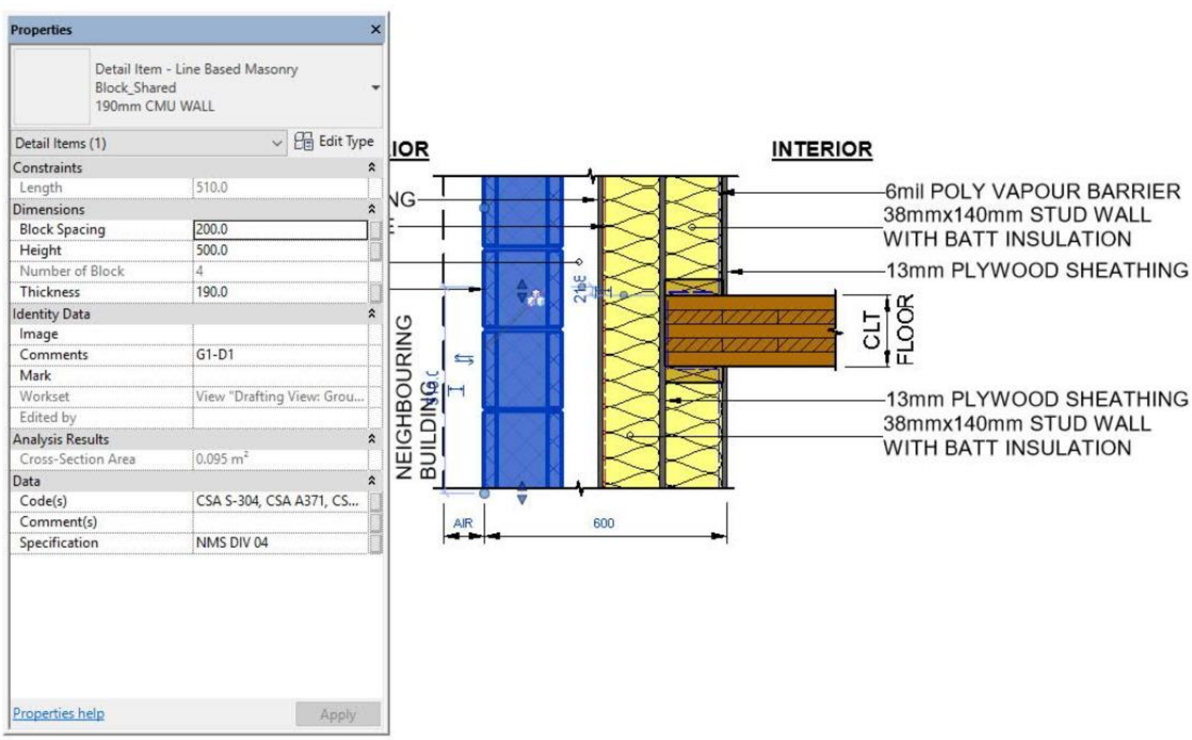
Applicable project phase	Design
Used by	Owner, consultant team, construction manager/general contractor, wood supplier and fabricator
Link	www.autodesk.ca/en/collections/architecture-engineering-construction/overview

About the software

Revit is one of North America's most used BIM software platforms, and the one that the industry leaders interviewed for this study use the most. Autodesk has a substantial ecosystem of design, analysis and construction that either directly plugs in or complements BIM design and construction.

Applicability to wood buildings

A Revit file and Use Guide is provided with this document to demonstrate how Revit can be used to design and deliver wood buildings. Using a series of best-practice details for a selection of innovative wood buildings, it demonstrates Revit-based Levels of development and how information can be embedded to support collaborative design development and project delivery. It also provides a tangible example of how files can be used to pull information from the digital model to accomplish carbon calculation or cost analysis for the project team to assess and make decisions on a low-carbon, wood building project. The workflow demonstrated in the guide demonstrates the multi-software workflow that is commonly utilized today to accomplish a range of tasks.



Passivlink Lite & One-click LCA – Energy & life cycle assessment

Applicable project phase	Design
Used by	Architect, mechanical and envelope engineer, construction manager/ general contractor, wood supplier and fabricator
Links	www.passivlink.com www.oneclicklca.com

About the software

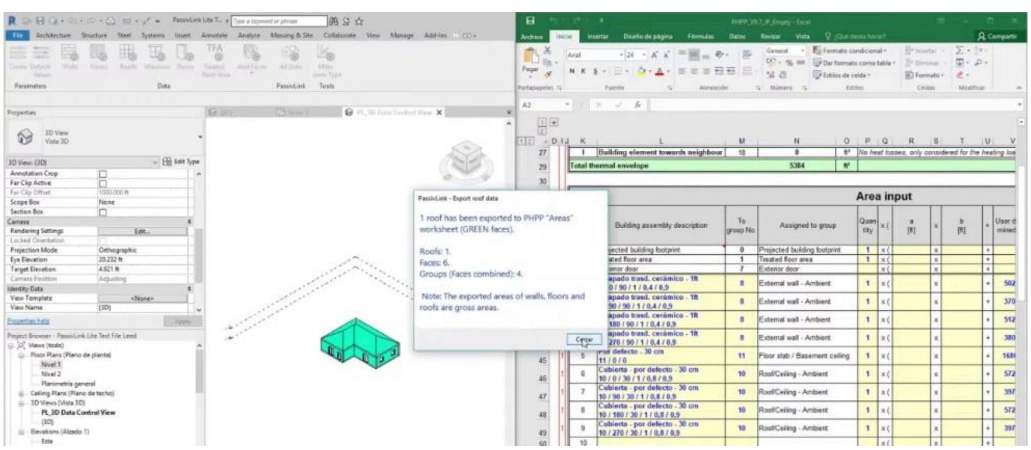
Passivlink Lite and One-click LCA are examples of BIM plugins that support building performance analysis. Passivlink Lite exports Revit data to the Passive House Planning Package (PHPP).

One-click LCA pulls data such as building areas, energy consumption, water consumption, construction site operations, emissions and removals from the digital model, and links to a database of ISO 14040 and ISO 14044 compliant Environmental Product Declarations (EPDs) to generate a snapshot of the project's life cycle impacts.

Applicability to wood buildings

The integration of analytical tools to evaluate the operating and embodied energy and emissions of buildings is evolving and new and improved tools continue to emerge. The ability to quickly evaluate the environmental impacts of wood buildings is important given wood's thermal resistance and significant role as a low embodied carbon material. These "embedded" functions are a critical advantage of federated BIM, making for easier assessment of the project based on the different scopes of work and building components.

With the increased uptake of Revit, more software developers are creating plugins for a wide range of compatible specialty applications. Nevertheless, the level of integration with BIM software can still vary in terms of levels of development, project type and other factors. For example, there is an extensive area of opportunity for further developing and integrating local LCA databases following the level of development (LOD) models. Further, compatibility with Revit (or other BIM systems) is not guaranteed and some plugins can be expensive, highly specialized and/or not suitable for all projects. For example, Trimble offers a free Connect Extension[16] for BIM tools that do not have native integration to One Click LCA.



[16] https://oneclicklca.zendesk.com/hc/en-us/articles/360021976039-Trimble-Connect-Integration

CATIA – Manufacturing design

Applicable project phase	Design, Fabrication
Used by	Architect, structural engineer, construction manager/general contractor, wood supplier and fabricator
Link	www.3ds.com/products-services/catia

About the software

CATIA allows architects, engineers, owners and governments to build and collaborate beyond the limits of traditional project execution methods, with a range of 3D modeling and experience solutions that span throughout the whole design, engineering and delivery process.

Like Revit, CATIA can be used to create high levels of development models fully compliant with industry standards (IFC). However, CATIA also allows designers to develop models that conform to prefabrication or industrialized construction methods such as modular or off-site fabrication. Like Kreo, it can also geolocate the model so the construction project can be managed in the context of the city or territory.

Applicability to wood buildings

Manufacturing software like CATIA is particularly suited to designing, planning and fabricating wood structural systems and is growing in popularity among leading wood designers.

With CATIA, manufacturers can use the digital model in parallel to Revit to design the prefabricated wood structure for fabrication. Understanding the software compatibility, and its impact on the workflow, is a critical consideration pre-project, and requires the right consultants, general contractors, trades and suppliers to be retained early enough to be incorporated into RFP’s, BIM Plans, etc., during project setup.

CATIA was used to model the mass timber installation and sequencing for UBC Brock Commons Tallwood House.

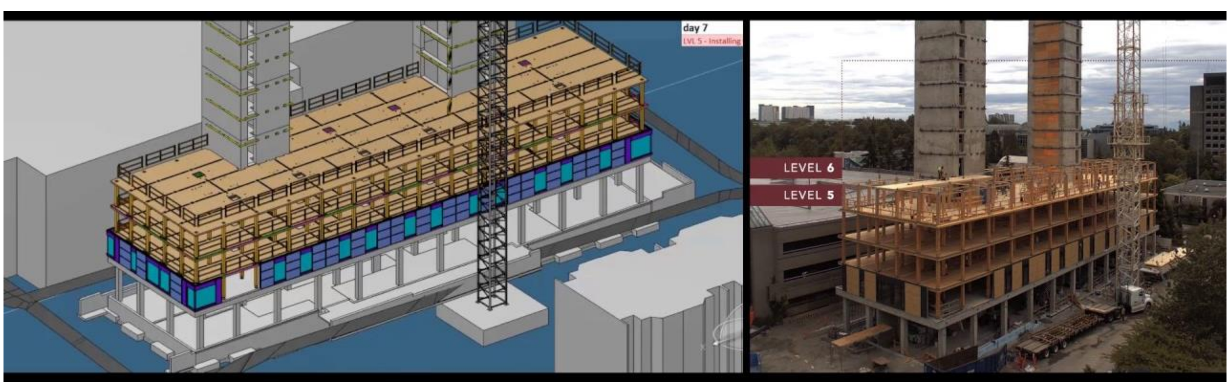


Image courtesy of CADMakers

Autodesk Construction Cloud (formerly BIM360) & Navisworks – Coordination & planning	
Applicable project phase	Construction
Used by	Architect, structural engineer, construction manager/general contractor, trades
Links	https://construction.autodesk.com www.autodesk.ca/en/products/navisworks/overview

About the software

BIM360, which is now part of the Autodesk Construction Cloud platform, is an Information Management platform that allows the project team, the owner, consultants and general contractor to collaborate, review, coordinate and assess the project as the design matures.

Navisworks combines design and construction data into a single model. It is effective at identifying and resolving clash and interference problems before construction, and it can aggregate data from multiple trades to better control outcomes.

Applicability to wood buildings

The Autodesk Construction Cloud platform offers the ability to virtually collaborate and coordinate the federated BIM for construction during the design process, which is vital for managing the construction team's downstream tasks, construction risks and trade planning.

Navisworks is popular among wood designers and builders for its ability to digitize the project review process and improve coordination. It is the tool commonly used to conduct virtual builds prior to construction. Project teams can use Navisworks to visualize the sequencing to ensure prefabricated wood structures, which are fabricated off-site, will not conflict with downstream, on-site scopes of work.

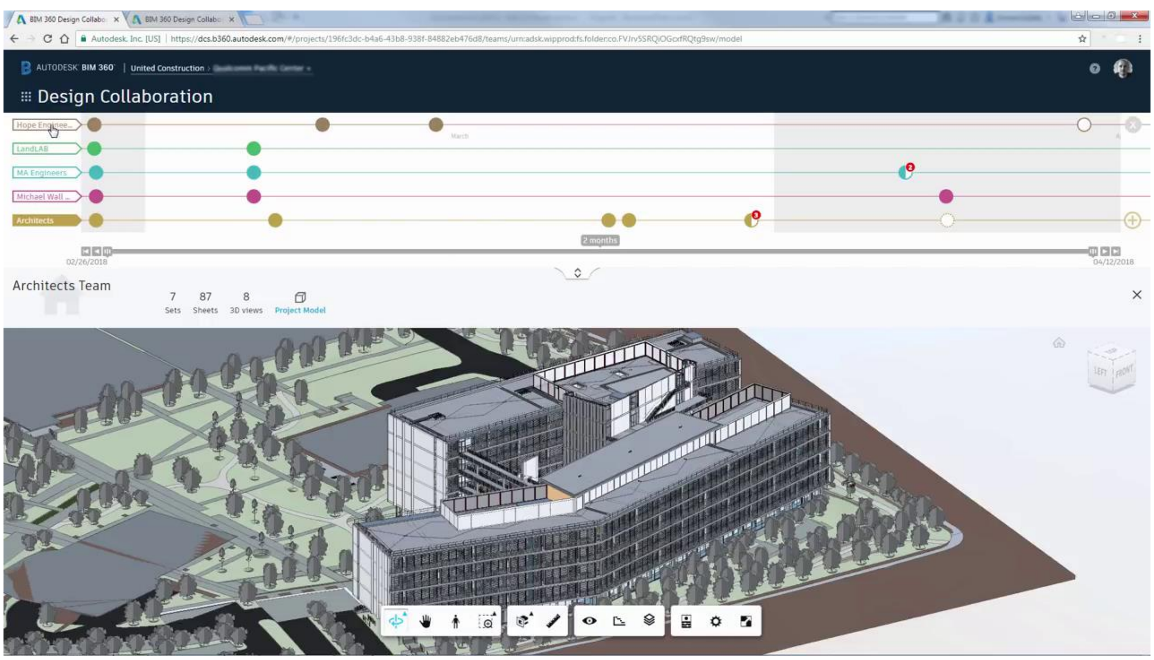


Image source: Autodesk Construction Cloud platform [17]

[17] Autodesk Construction Cloud, https://construction.autodesk.com/products/autodesk-bim-collaborate/

FARO Digital Mapping – As-built model	
Applicable project phase	Construction, hand-over
Used by	Owner, architect, structural engineer, construction manager/general contractor, trades
Link	www.faro.com

About the software

The digital model can be linked to specialized technologies that document the construction process through to completion. FARO provides 3D measurement or inspection tools that can capture existing situations to a high degree of accuracy. Faro's As-Built™ software provides on-demand, accurate and complete information of the as-built site.

Applicability to wood buildings

BIM is an ideal platform for as-builts. Integration of scanning tools and software such as FARO Digital Mapping can provide detailed physical as-built information for the Revit-based BIM—especially for renovations and additions. This eliminates re-work and errors if the team is fully BIM capable.

FARO Laser Scanner technology and FARO BuildIT Construction Software™ can be used to demonstrate that the construction follows the digital model, which can be valuable when dealing with tight tolerances achievable through offsite construction.

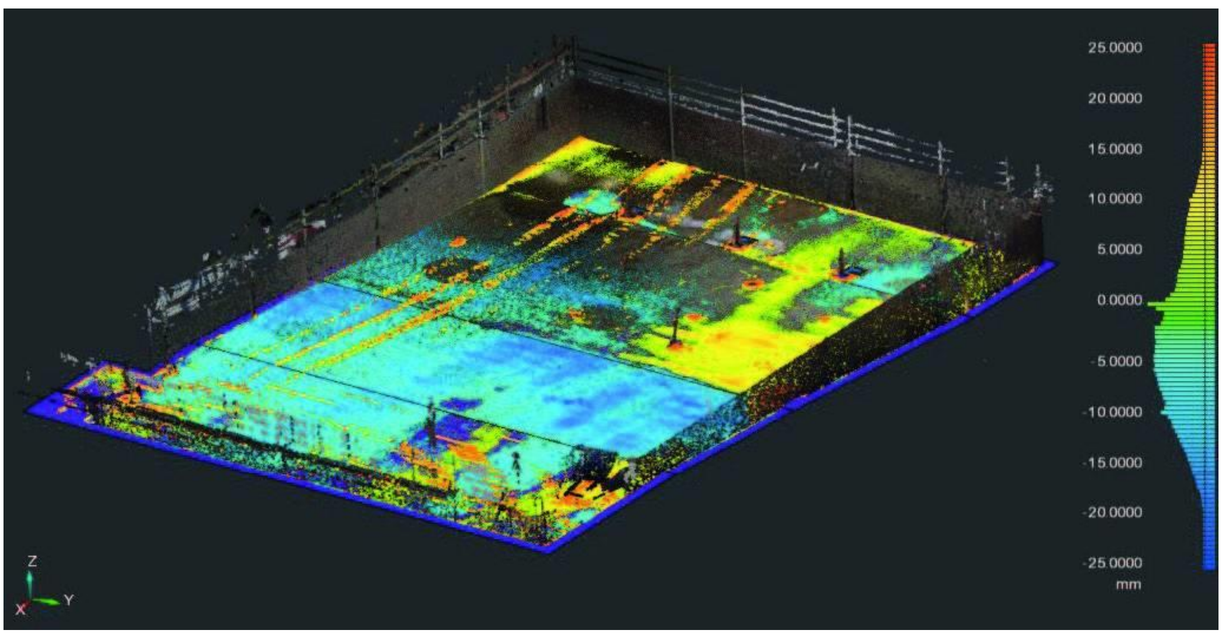


Image source: FARO BuildIT Construction Scan vs Model Surface Deviation Analysis[18]

[18] FARO – Case Study, https://www.faro.com/en/Resource-Library/Case-Study/digital-construction-verification-to-meet-strict-tolerances

Autodesk BIM360 OPS – Operations & FM	
Applicable project phase	Facility management & maintenance
Used by	Owner
Link	www.autodesk.com/bim-360/facilities-management-software

About the software

BIM360 Ops is an Autodesk product that transfers the building project's BIM into an Asset Information Model (AIM). The AIM is the building's digital twin that allows facilities management staff to track, optimize and plan maintenance of the building asset after it is built. Drawing information and data from the as-built BIM streamlines information flow, providing continuity from design intent (energy performance, embodied carbon, etc.) to operations for the life of the building.

Applicability to wood buildings

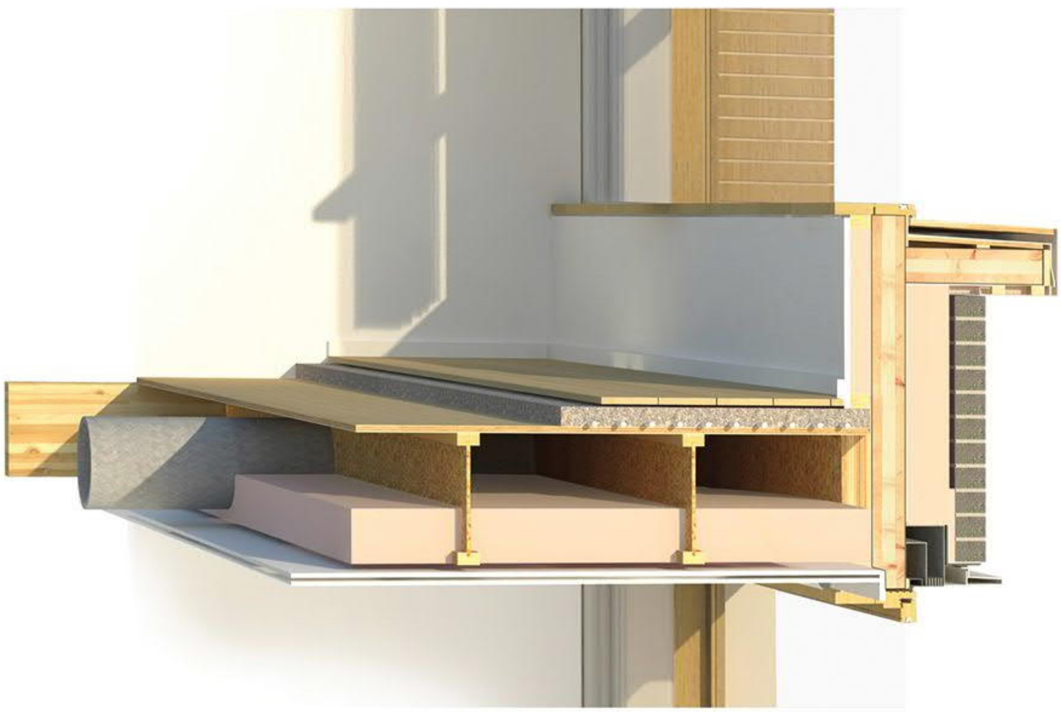
Commonly used for large, complex facilities, the use of BIM for facility management and maintenance is still in the early stages of adoption when it comes to the operations of wood buildings (which may be smaller and simpler). Nevertheless, efficient facility management and maintenance for the life of the building offers tremendous value and cloud-based, collaborative tools such as BIM 360 OPS are getting easier to use.

AIM can enhance facility management, providing the foundation for mobile access to operations and maintenance information (including 3D information), wayfinding, integration with Internet of things networks and real-time monitoring of building automation systems and performance tracking. For wood buildings, it is critical for operators to know how to maintain wood structures, what to do if they are damaged and how to repair or replace them; all this information can be prepared by the project team and incorporated into the AIM.

REVIT DETAILS USER'S MANUAL

SCIUS ADVISORY
Helen Goodland

BIM Use Case Guide



JUNE 2021

A Carbon Neutral Company

CANADA BEST MANAGED COMPANIES Platinum member

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1 PURPOSE

Associated Engineering (AE) was previously engaged to produce intelligent 2D mass timber Revit details to support modern design and construction process to deliver efficient, affordable and sustainable building. Roughly 20 per cent of global GHGs are from buildings with a further 20 per cent estimated to be embodied in construction materials. Wood solutions – such as mass timber – and the technologies that are being developed to deploy them have the potential to disrupt the way buildings are designed and constructed. This manual is intended to guide the users of the extended usage of these intelligent parametric details. As most of the processes are typical and simple among the industry, it is the aim that the parametric data in the details can be further used in design analysis, quantity estimating, schedule planning, and construction execution. The tasks are limited to a simple data extraction process followed by an example to utilize those given parametric values.

2 PROCEDURES

The procedures outlined in this manual are only an example of parametric detail usage. The details used are limited to Case Study 1 details. The process can be altered to suit the needs of other application purposes. It is however essential to note that the details' application should be reviewed and approved by professionals before proceeding with construction.

In the following example, data is pulled from Revit and the results are used to estimate the embodied carbon level by estimating the material quantities. We will use the cross-sectional area from each material in the details and calculate the linear length to which they are applied in an assumed structure.

For example, to get the vertical material volume for a continuous 19 mm plywood layer in the exterior wall, we take the cross-section thickness to multiply the total length of 10 m of the specific detail in the building parameter, and times by the 1.2 m level height. This is simply applying the formula of 0.019 m (Thickness) x 10 m (Length) x 1.2 m (Height) = 0.228 m^3 (Volume).

For horizontal elements such as floor slabs, we take the 175 mm thickness of the CLT slab and multiply the applied floor area. 0.175 m (Thickness) x 100 m^2 (Area) = 17.5 m^3 (Volume).

Out of the many possible usages of the material estimation from these parametric details, the cost of material and labour could be potentially one of the most valuable items to consider during the preliminary design phase.

2.1 Detail Data Extraction

2.1.1 Parameter Modification

As an example, the details in Case Study 1 only have been generated in such a way as to allow their information to appear in Revit schedules. To create/modify family parameters that can be schedule, the parameters must be Shared Parameters. For this embodied carbon calculation exercise, the values we are interested in the detail items are the 'Height', 'Thickness', and the calculated 'Cross-Section Area'.

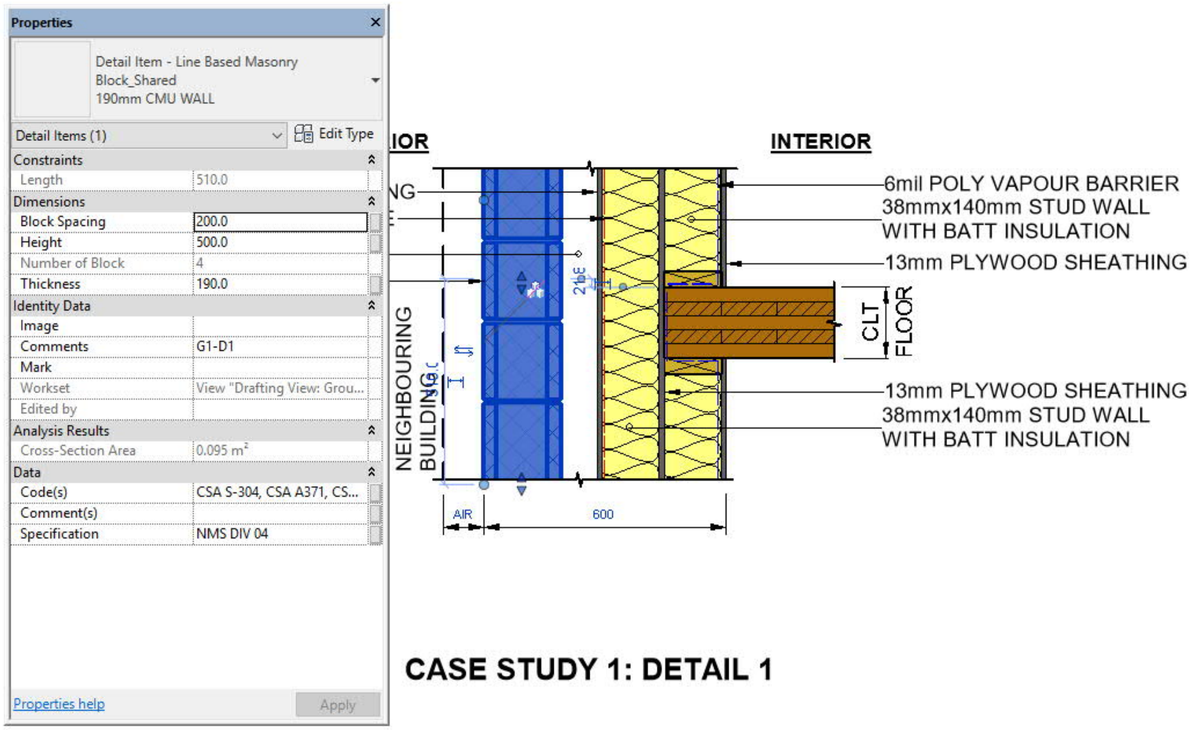

Figure 2-1:
Parametric Detail Items

2.1.2 Parameter Scheduling

To create a Detail Item (category) schedule, go to 'View' under 'Schedule' and select 'Schedule/Quantities'. Select 'Detail Items' as the schedule category and click 'OK' to finish. In the 'Schedule Properties' dialogue box, go to 'Fields' and 'Edit' to select the relative fields that are suitable for the task. Apply any 'Filter', 'Formatting' and 'Sorting/Grouping' options to organize the schedule.

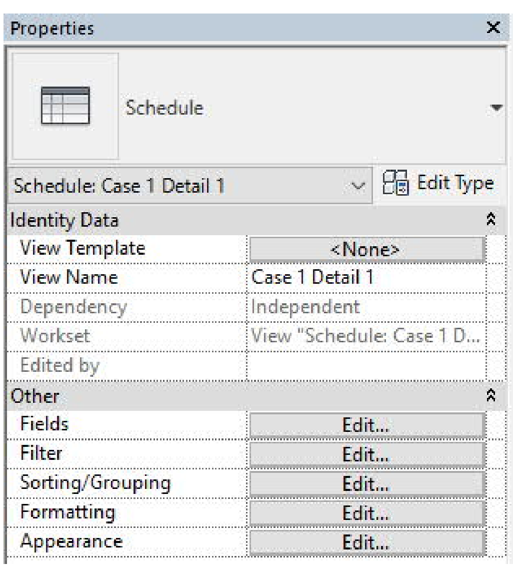

Figure 2-2:
Schedule Properties

In the schedule shown below, we filtered the elements by the 'Detail No.' and sorting by the 'Type'.

<Case 1 Detail 1>									
A	B	C	D	E	F	G	H	I	J
Detail No	Specification	Code(s)	Comment(s)	Type	Thickness (m)	Height (m)	Stud Spacing (m)	Stud Thickness (m)	Manufacturer
G1-D1									
G1-D1	NMS DIV 04	CSA S-304, CSA A371, CSA A165, CSA A179		190mm CMU WALL	0.19	0.5			ABC Manufacturer
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	38x140	0.14	0.038			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	38x140	0.14	0.038			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PT PLYWOOD SHEATHING	0.013	0.777088			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.3			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.31			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.788175			DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, ANSI / DPA PRG 320-2011	Keep wood products constantly protected	5 Ply CLT Floor	0.175	0.475			RD Country
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Structural design to be confirmed by P. Eng	38mmx140mm STUD WALL	0.14	0.82834	0.4	0.038	GHI Inc.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Structural design to be confirmed by P. Eng	38mmx140mm STUD WALL	0.14	0.82834	0.4	0.038	GHI Inc.
G1-D1	NMS DIV 07	BCBC		WATERPROOFING MEMBRANE	0.001	0.81			XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.332398			XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.19			XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.315			XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.125			XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.125			XYZ Company
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.811241			GHI Inc.
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.257			GHI Inc.
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.24193			GHI Inc.

Figure 2-3:
Case 1 Detail 1 Parametric Detail Value Schedule

2.1.3 Data Exporting

Export the collected information by going to the 'File' tab, 'Export' as 'Reports', and select 'Schedule'. The report will be exported in a text file (.txt) format. Import the text file data to an Excel spreadsheet by going to the 'Data' tab, get & Transform Data 'From Text/CSV' file. Load the text file and Edit the information in the 'Query Editor' and organize it to suit your preferences.

Detail No.	Specification	Code(s)	Comment(s)	Type	Thickness (m)	Height (m)	Stud Spacing (m)	Stud Thickness (m)	Cross-Section Area * 1m (m²)	Manufacturer
G1-D1									0	
G1-D1	NMS DIV 04	CSA S-304, CSA A371, CSA A165, CSA A179		190mm CMU WALL	0.19	0.5			0.19	ABC Manufacturer
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	38x140	0.14	0.038			0.00532	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	38x140	0.14	0.038			0.00532	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PT PLYWOOD SHEATHING	0.013	0.777088			0.013	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.3			0.013	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.31			0.013	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Keep wood products constantly protected	13mm PLYWOOD SHEATHING	0.013	0.788175			0.013	DEF Ltd.
G1-D1	NMS DIV 06	CSA 086, ANSI / DPA PRG 320-2011	Keep wood products constantly protected	5 Ply CLT Floor	0.175	0.475			0.175	RD Country
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Structural design to be confirmed by P. Eng	38mmx140mm STUD WALL	0.14	0.82834	0.4	0.038	0.0133	GHI Inc.
G1-D1	NMS DIV 06	CSA 086, PART 9: BCBC, CSA B111, CSA 0121 (PLY)	Structural design to be confirmed by P. Eng	38mmx140mm STUD WALL	0.14	0.82834	0.4	0.038	0.0133	GHI Inc.
G1-D1	NMS DIV 07	BCBC		WATERPROOFING MEMBRANE	0.001	0.81			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.332398			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.19			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.315			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.125			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC		6mil POLY VAPOUR BARRIER	0.001	0.125			0.006	XYZ Company
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.811241			0.14	GHI Inc.
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.257			0.14	GHI Inc.
G1-D1	NMS DIV 07	BCBC	Insulation to be confirmed by others	140mm BATT INSULATION	0.14	0.24193			0.14	GHI Inc.

Figure 2-4:
Case 1 Detail 1 Detail Values Import from Text Files Reporting Material Cross-Sectional Area

2.2 Material Volume Calculation

Below is an example of a building applied with Case Study 1 details. First, the linear length of each detail in the building is calculated and listed in the table below. The Building Parameters at Level, Length (m) x Height (m), in **Figure 2-5** is multiplied by the vertical 'Thickness' from Figure 4 above to get the Material Volume at Level (m^3), shown in **Figure 2-6**. The Material Volume of the horizontal elements are calculated by the 'Thickness (m)' in **Figure 2-4** multiplied by the Floor Area (m^2) in **Figure 2-5**.

Parameters at Level	Case 1 - Detail 1 (m)	Case 1 - Detail 2 (m)	Case 1 - Detail 3 (m)	Case 1 - Detail 4 (m)	Height (m)	Floor Area (m²)
Parking Level	40.59		34.9		3.95	1273.85
Level 1		60.75	40.3	4.5	2.84	540.95
Level 2		15.5		4.5	2.84	540.95
Level 3	34.89			4.5	2.84	518.3
Level 4			17.51	4.5	2.87	518.3
Level 5	29.6	17.51		4.5	2.87	518.3
Level 6	29.6	17.51		4.5	2.87	518.3

Figure 2-5:
Building Parameters of Case 1 Details

Material Volume at Level (m³)	Plywood Sheathing	CMU	Timber Wall Studs	Insulation	CLT	Vapour Barrier	Water Barrier	Non-comb. Panelized W	Concre
Parking Level	11.921	30.463	6.901	105.938	445.848	8.946	0.962	24.814	
Level 1	5.385		4.892	110.068	221.762	8.609	1.035	20.601	91.962
Level 2	0.738		0.750	22.763	104.606	1.321	0.264		91.962
Level 3	5.319	18.827	3.007	45.451	92.939	2.973	0.595		88.111
Level 4	1.474		6.183	17.946	92.963	0.387		2.325	88.111
Level 5	5.239	16.141	3.429	61.163	192.460	4.056	0.811		88.111
Level 6	5.239	16.141	3.429	61.163	192.460	4.056	0.811		88.111
Volume Sum	35.315	81.571	28.593	424.492	1343.036	30.348	4.478	47.740	536.367
Superstructure	**23.394**	**51.108**	**21.691**	**318.554**	**897.189**	**21.402**	**3.516**	**22.926**	**536.367**

Figure 2-6:
Material Volume by Level

By getting the material volume, we can now visualize how much material is used per floor in the building.

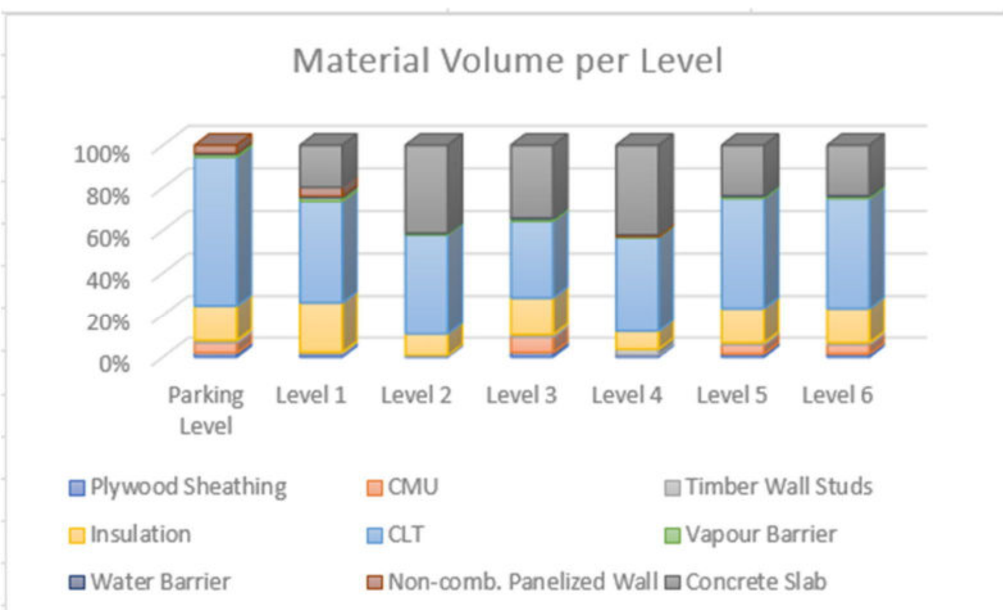

Figure 2-7:
Material Volume

2.3 Embodied Carbon Quantity Calculation

To estimate the building material impact on the environment, we need to analyze its impacts in a life cycle. Life cycle analysis (LCA) is a method used to evaluate the environmental impact of a given product through its life cycle from extraction and processing of the raw materials, manufacturing, distribution, use, recycling, to final disposal. The amount of embodied carbon is generated throughout the process of construction depends on the material used.

"*Embodied carbon refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials. Embodied carbon is a significant percentage of global emissions and requires urgent action to address it."* - (University of Washington, 2020)

As operational energy targets become more stringent it is expected that throughout the useful life of a building, about 50% of its carbon footprint comes from the embodied carbon, the other 50% comes from the operating energy which relates to lighting, air conditions, heating, appliance consumption, and other equipment. In this example, we are only focusing on the embodied carbon, before building occupancy/operation.

Using a Carbon Footprint Calculator such as EC3, the program will multiply the estimated material quantities with the Environmental Product Declaration (EPD) to generate the estimate of embodied carbon. EPD is a third-party verified label for the environmental impacts of the product. It requires sustainability professional to analyze the data and generate a report; a program operator to verify and publish the declaration; data about the inputs to the product, energy consumed and any chemical process emissions; and a set of Product Category Rules (PCR) to standardize the declaration.

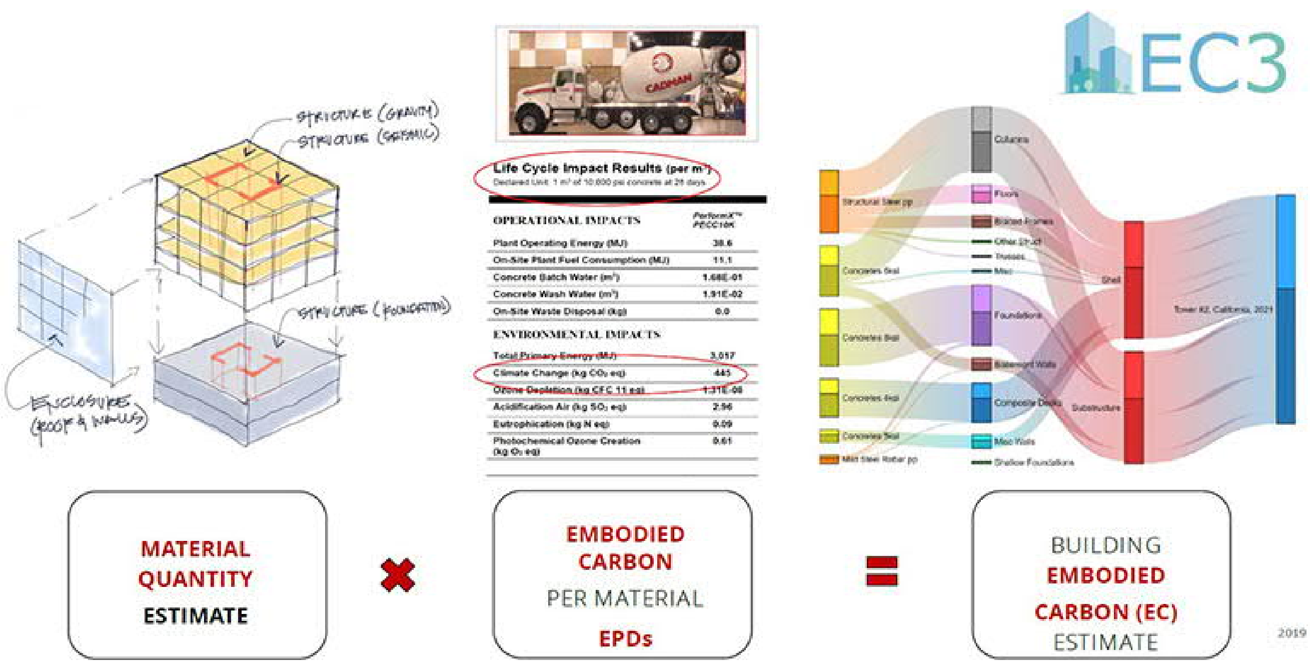

Figure 2-8:
Calculate the Carbon Footprint of Buildings with the EC3 Calculator (Pierson, 2019)

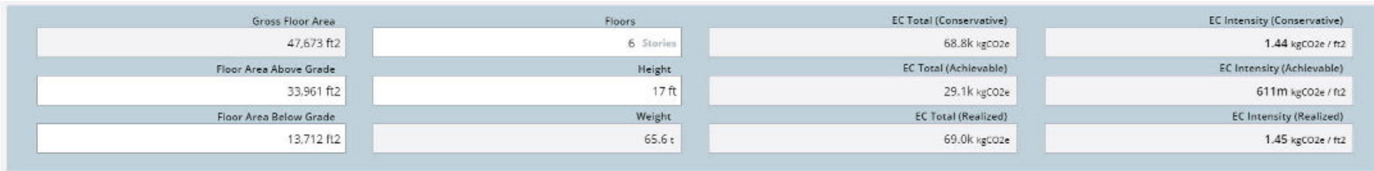

Figure 2-9:
Estimate Embodied Carbon Calculation from EC3

Once we have the estimated amount of embodied content, we can further compare different product's EPDs to meet a lower greenhouse gas emission target. For example, the EPD of the selected plywood product below provides the manufacturer, the location of the manufacturing plant, the product name, the product description, its embodied carbon volume per m³ and shows if it is below the Carbon Leadership Forum (CLF) Baseline, and the straight-line distance of transportation. The information could be used to identify not only the material carbon volumes but also to estimate the cost for the material and labour required later during the construction phase.

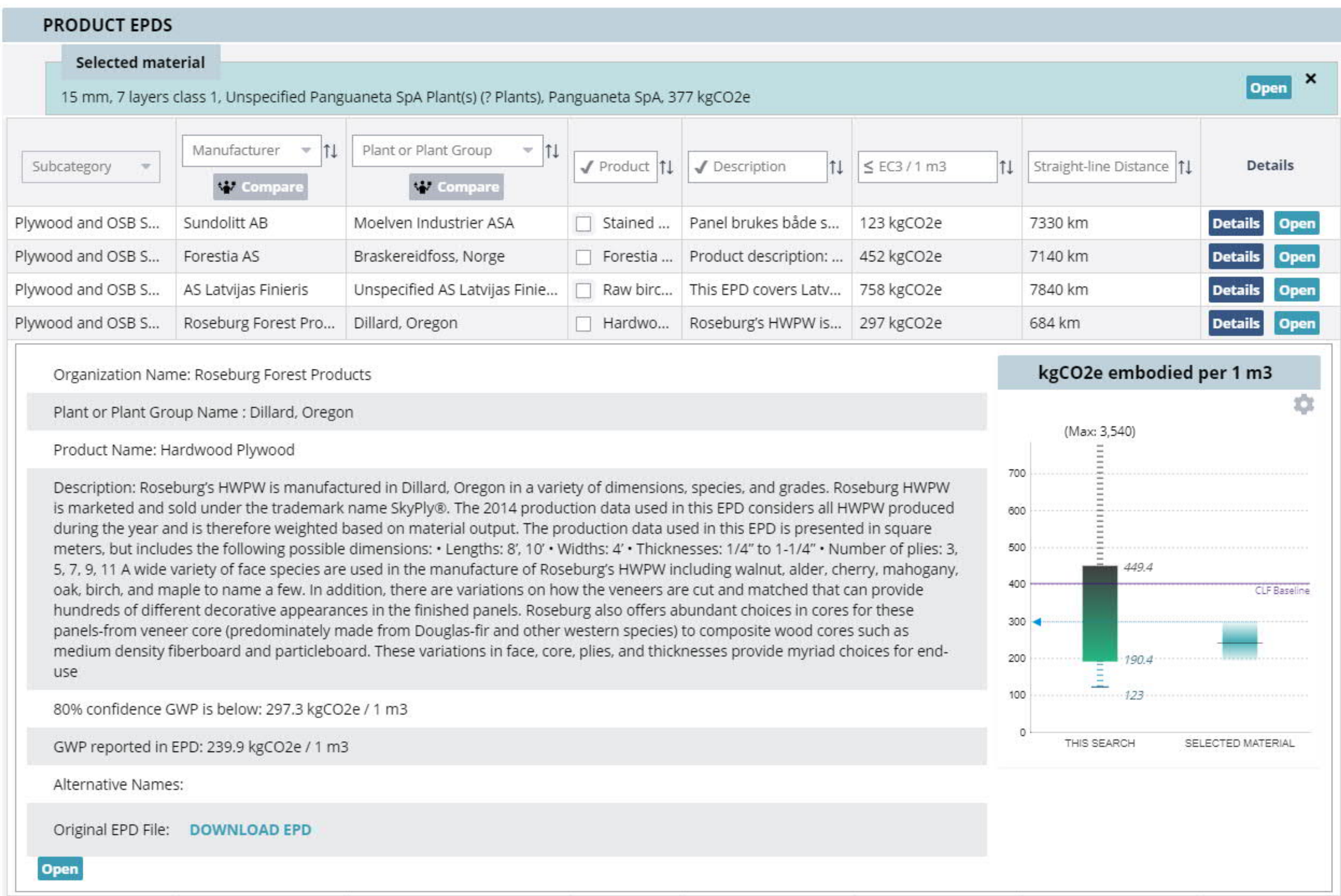

Figure 2-10:
Plywood EPD Details

2.4 Material Cost Calculation

2.4.1 Parameter Modification

To extend the use of these parametric details, we can also utilize the 'Cost' information within the detail items. To enter the material and labour cost of a material, select the detail element in the drafting view. In the 'Properties' panel click 'Edit Type' and enter the cost value in the "Cost" row.

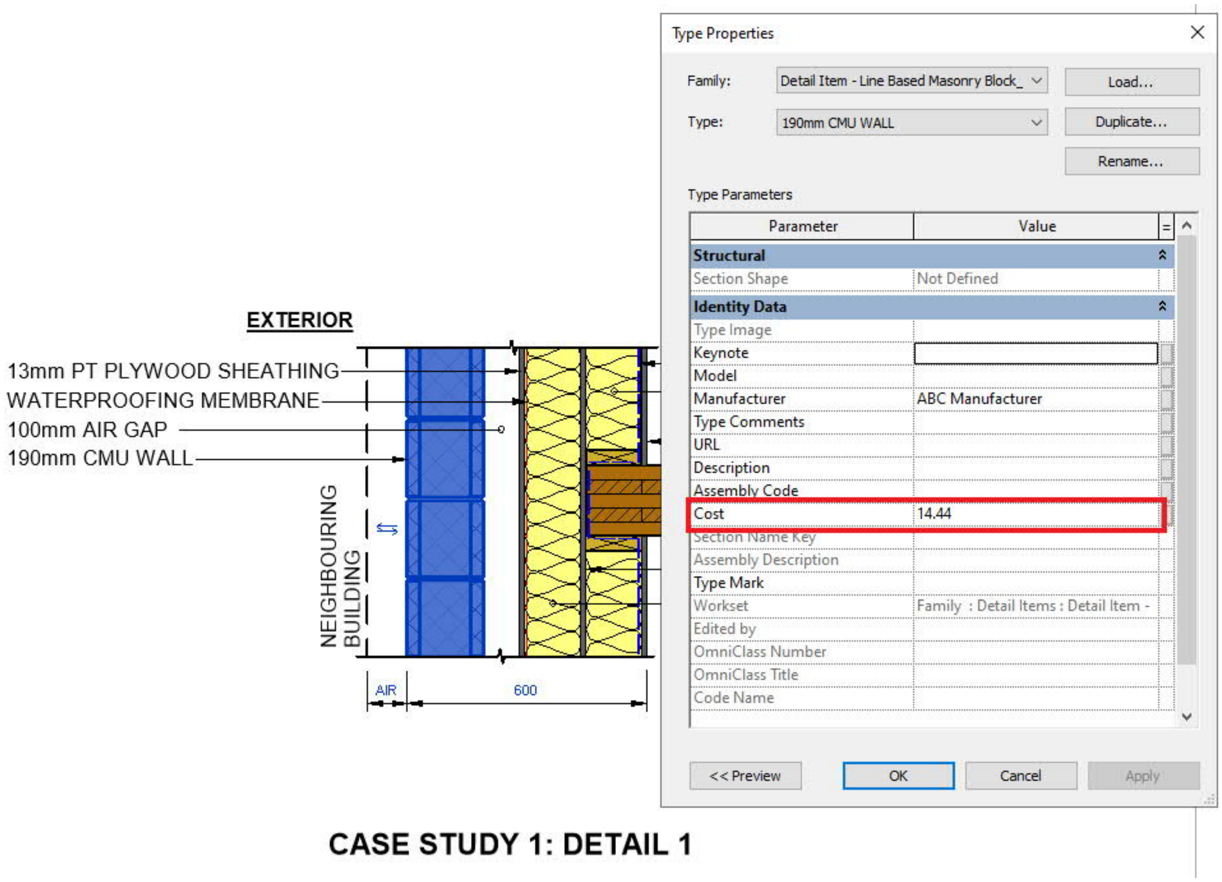

Figure 2-11:
Family Cost Parameter

2.4.2 Parameter Scheduling

Adding the 'Cost' field to the schedule by editing the 'Schedule Properties'. Refer to Section 2.1.2 for instructions.

2.4.3 Data Exporting

Export the material cost data to Excel for calculation. Refer to Section 2.1.3 for instructions.

2.4.4 Cost Calculation

Using the same information in **Figure 2-5** – Building Parameters of Case 1 Details, we now have the material and labor cost of each material by level.

Material & Labor Cost at Level ($)	Plywood Sheathing	CMU	Timber Wall Studs	Insulation	CLT	Vapour Barrier	Water Barrier	Non-comb. Panelized Wall	Concrete Slab
Parking Level	$ 341.14	$ 215.31	$ 1,178.06	$ 9.85	$ 445.85	$ 461.73	$ 48.46	$ 68.59	
Level 1	$ 154.09		$ 961.89	$ 28.32	$ 488.84	$ 444.38	$ 52.15	$ 56.95	$ 91.96
Level 2	$ 21.13		$ 147.54	$ 7.65	$ 179.05	$ 68.16	$ 13.31		$ 91.96
Level 3	$ 152.20	$ 133.07	$ 442.70	$ 5.46	$ 101.40	$ 153.43	$ 29.95		$ 88.11
Level 4	$ 42.19		$ 173.76	$ 2.92	$ 101.51	$ 20.00		$ 6.43	$ 88.11
Level 5	$ 149.91	$ 114.08	$ 547.98	$ 11.84	$ 276.34	$ 209.36	$ 40.87		$ 88.11
Level 6	$ 149.91	$ 114.08	$ 547.98	$ 11.84	$ 276.34	$ 209.36	$ 40.87		$ 88.11
Volume Sum	$ 1,010.56	$ 576.55	$ 3,999.91	$ 77.89	$ 1,869.34	$ 1,566.41	$ 225.59	$ 131.96	$ 536.37
Superstructure	**$ 669.42**	**$ 361.23**	**$ 2,821.85**	**$ 68.04**	**$ 1,423.49**	**$ 1,104.69**	**$ 177.13**	**$ 63.37**	**$ 536.37**

Figure 2-12:
Material & Labour Cost by Level

The pie chart below shows each material cost in amount and percentage of the sample project.

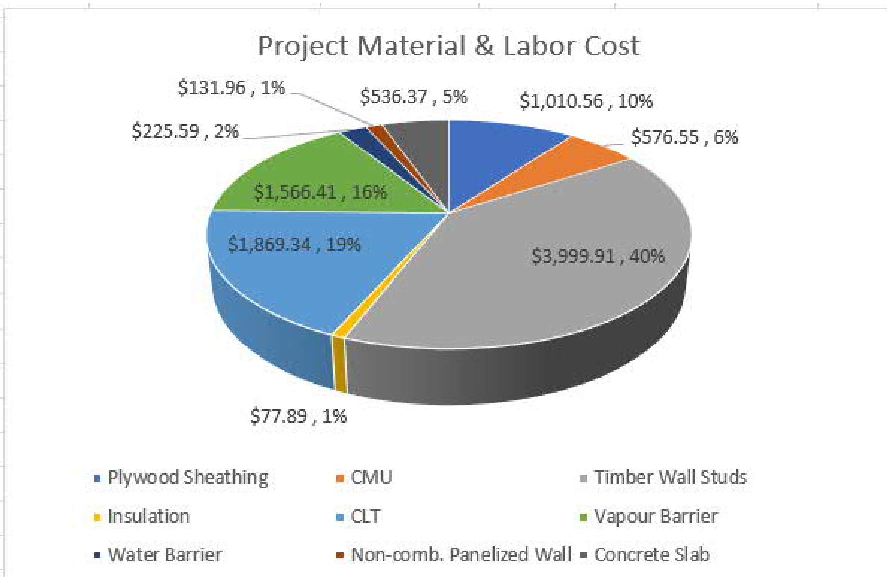

Figure 2-13:
Project Material & Labour Cost Pie Chart

3 SUMMARY

The purpose of these examples is to show that the details used in preliminary designs do not need to be static details. Those detail items used in the Case Study examples are parametric and hold information that is useful to the project. Utilizing these values for concept design calculations not only saves the effort from building a whole 3D model for preliminary analysis, they could also provide a bigger picture to the project, such as cost and scheduling during the construction phase. The available fields of the contents within each detail item are not limited to the default Out-of-the-box Revit categories. More custom categories can be added to suit any users need, and the information can be easily pulled out of Revit for analysis.

4 BIBLIOGRAPHY

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University of Washington. (2020, December 17). *Embodied Carbon 101.* Retrieved from Carbon Leadership Forum: https://carbonleadershipforum.org/embodied-carbon-101/

CLOSURE

This report was prepared for the SCIUS ADVISORY Helen Goodland to support the use of the parametric Case Studies Revit details.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

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EF/EG/fd