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COMMON CHALLENGES ASSOCIATED WITH DESIGN AND CONSTRUCTION DELIVERY USING BUILDING INFORMATION MODELING (BIM)

Whether you are an Owner, design professional, design consultant, construction manager, contractor, or subcontractor it is almost inevitable that you will encounter the use of Building Information Modeling ("BIM"), to one degree or another, in perhaps every design and construction project you are involved in. Many Owners today require that all of their projects, regardless of scale or complexity, be designed in BIM. Typically this decision is based on an assumption that using BIM will:

- Deliver a more complete design;
- Provide a better coordinated design that is less prone to design errors or omissions;
- Facilitate efficient design variations and changes;
- Clearly communicate design concepts to the contractor;
- Lead to more accurate estimates and schedules for construction; and,
- Produce an accurate, electronic version of the project.

And, in some instances it does. The promise of accurate, progressive, efficient, virtually error free design and construction with BIM is real but it is neither inevitable nor easy to achieve. Although the required technology is available and can be utilized, very few projects or project teams are organized or financed in a manner that will capture all of the BIM benefits.

Therefore, it is important to understand a few of the key ways that BIM is used, misused, and misunderstood in design and construction. Below we discuss six broad areas where challenges may be encountered in projects using BIM.

1. **Incomplete And Non-Collaborative BIM Use During Design And Construction Phases**

While there are projects where BIM is used for all aspects of design and construction, in industry practice today it is far more common for BIM to be used for a specific purpose, or purposes, within each project rather than holistically. BIM may be used for one or more of the following:

- Modeling of existing structures for remodel or renovation;
- Early electronic sketches which conceptualize building use, layout and basic design;
- More detailed models of the architecture and structure suitable for construction;
- Material takeoffs and estimation by contractors during bidding;
- Design models from Design/Build ("D/B") contractors;
- Detailed subcontractor models of Mechanical/Electrical/Plumbing components; and,
- As-built model of the completed project which may include architectural, structural, civil, mechanical, electrical, and plumbing disciplines.

The use of BIM may be required by the Owner, triggered by a contract requirement, or it may be employed because it is the preferred design or construction coordination tool of one or more of the project participants. In any of these circumstances, unless the BIM scope and output is tightly defined or specified, the expectations regarding the intended use of and reliance on the BIM model may **not** be realized. Consider the following common scenarios which show how the use of BIM, without clear definitions and agreements, can create conflict and increase project challenges.

A. **The BIM Model Created By The Architect/Engineer Team Is Not Shared With The Construction Team**

Architectural and engineering ("A/E") firms and their subconsultants are increasingly using BIM modeling programs for design. The design can be modeled conceptually; building forms and configurations can be viewed and shared with clients; modeled assemblies and the associated materials can be evaluated for appearance, cost, energy performance, and structural performance; as well as numerous other uses and benefits. The design is then typically completed, through the construction document phase, by further developing the BIM. The finished product, design documents intended to be suitable for construction, are then extracted or printed from the model, reducing them to a 2D "flattened" representation of the design. This is the printed version of the design that is permitted, bid, and typically recognized to be a contract document. The 3D information is essentially lost in that step. And, if it is not otherwise a contractual requirement, the construction team is then left to determine if building a new 3D model is necessary. This process – design modeling, flattening, and construction remodeling – can lead to unexpected changes in the design as the contractor determines how best to build the project using its own means, methods, and sequences. If there is critical dimensional information found in the A/E's model that is not fully represented in the "flattened" drawings, that information will have to be reestablished by the contractor for his model. This is particularly true of buildings with complex 3D geometry.

There are many reasons why A/E teams do not like to share their models with contractors or Owners. Models may be incomplete, include unresolved geometry, deviate from the "flattened" CDs, and in other ways provide a roadmap to the contractor for future claims. And, in most cases, A/E's are not obligated to provide their BIM information to contractors. This cautious and non-collaborative environment can create tension and increase the possibility of error. Consider a hypothetical scenario where the A/E takes issue with the contractor's interpretation of various 3D elements including complex 3D steel framing. As the contractor's steel detailer interprets the A/E's design, he creates his own 3D model to follow that design. This leaves the A/E in a position to critique the detailer's design based upon a 3D model that was never shared with the construction team. A repeating "revise and resubmit" review cycle, as the detailer attempts to satisfy the A/E, certainly could impact the progress of the work and could have been avoided if all of the recorded design information was shared with those responsible for building.

B. Modeling By Owner Consultants, Architect Consultants, And Subcontractors

A BIM can be produced by any member of the design and construction team and, at some point, most if not all of those team members will be producing model elements or relying upon the models of others for coordination. This creates opportunities and challenges.

With BIMs being produced by various design consultants in advance of construction, the A/E and the contractor may both have the ability to identify and remedy conflicts in 3D space prior to construction. As a result, Owners may assume that an advanced design and constructability review will take place. But that may ***not*** be the case if the design and construction contracts do not provide for it. It is common for a certain degree of coordination to be expected of the A/E and the contractor per industry custom, but if that coordination and conflict checking is anticipated to be done electronically, the method(s) and extent must be explicitly stipulated. It is possible for a BIM project to use the conventional methods of identifying design conflicts and other issues in a conventional 2D manner; and many do.

Consider models created by MEP subcontractors which may be generated from the A/E's performance specifications or from undimensioned 2D line diagram drawings produced by the A/E; or structural models which may be assembled by the structural engineer to calculate member sizing and configuration and then rebuilt by the steel subcontractor to determine exact locations and connection methods; or architectural models which may be created to visualize the design, further refined to establish layout locations and appropriate clearances for finished walls, shafts, and doors; and refined again for millwork and interior trim placement. All of these reflect uses of BIM models but they are very different in their utility for the overall project team.

The mere existence of a model does ***not*** ensure its accuracy or its utility across disciplines. With current technology it is practical and convenient to combine and overlay various models but the accuracy and tolerances of those models may vary. For example, a steel structural model, built by the steel supplier for fabrication purposes, may comply with American Institute of Steel Construction ("AISC") tolerance standards but the adjoining curtain wall system, which may also need to attach to the steel, may be modeled by the window supplier to another level of detail and tolerance for its own design and fabrication purposes. It may not be enough to simply view the models together to coordinate them. Although this issue of coordinating tolerances between disciplines is nothing new, the perceived reliance on models, as opposed to 2D design information, can result in a level of naïve confidence in dimensional accuracy, 3D space, and location that is unfounded based on the potentially conflicting models.

C. It Is Not Practical To Model Everything

Put simply, it is ***not*** practical to model everything. Modeling takes time and adds to project time and cost. As a result, decisions have to be made as to what will be modeled and to what extent. The decisions are often memorialized in a BIM execution plan, ("BIMXP"), which is then tied to a design schedule. Within the BIMXP, it is also common to define the "*Level of Development*" ("LOD") of the model. The LOD specification may be close to 200 pages in length, containing LOD definitions describing what will be included. Language from an LOD, in this case LOD 400, may include the requirement to model:

> "... a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element."

While this is a reasonably effective method for defining

what will be done and when, it still invariably leaves portions of the building and building systems un-modeled and does not fully address the impacts of late design changes or alterations.

2. Dilution Of Design Ownership By The Designer Of Record

In most jurisdictions, direct design oversight by the A/E is a requirement that is directly tied to the standard of care. In order to be legally responsible for the design, the Architect or Engineer Designer of Record ("DOR") must have a certain amount of control over the production as well as the coordination of the design. But with various design and construction parties producing and revising BIMs up to and through construction, the clarity of that responsibility can become vague and the ability of the DOR to monitor, control, and coordinate changes in the design that he is perhaps professionally responsible for as DOR, can become strained. Take for example these four common scenarios:

A. Preconstruction Modeling Input By The Contractor And Subs

Preconstruction services provided by the contractor – for example, a constructability review of certain structural or building envelope systems - are common. This may include any type of modeling which supplements the DOR's efforts and which is a tool for construction including additional building components, detailing, etc. In a BIM project, that design input may be provided in model form by the contractor or its subcontractors. While this may be considered to be a practical way to get input from the contractors regarding preferred systems or constructability, it also may put the DOR in the position of understanding and defending modeling produced by others if problems arise. Just because an element is modeled by someone else does ***not*** necessarily mean that modeler owns the design; the DOR is still typically responsible for portions of the design that are not stamped and signed by other professionals.

B. Mechanical Electrical And Plumbing Design Handoff

BIM modeling by subcontractors is especially common for Mechanical, Electrical, and Plumbing ("MEP") work. For those disciplines, the MEP engineers have traditionally provided contractors with 2D line diagrams, schedules, and specifications of the design in order to establish the basis. These subcontractors have also been early adopters of BIM as the models facilitate their own work and tend to minimize rework. But, increasingly MEP design engineers are doing their own modeling and that creates interesting questions about the responsibility for the specific placement of the ducts and equipment as well as the responsibility to coordinate with structure and other services. If the responsibilities and risks are not clearly defined amongst parties and by contract, confusion may arise.

In one hypothetical but common example, MEP design consultants are contracted to produce a Design Development ("DD") level model which can then be shared with the MEP contracting team at the end of the DD phase. The MEP BIM is then further developed, modified, and coordinated by the MEP contractors as is the BIM of the building structure and envelope. If conflicts then arise in the field during construction, there will be arguments how the conflict originated, possibly from the original MEP consultant BIM. The model(s) provided by the design consultants may have given the impression of a more complete and spatially accurate design than was practical at that stage in the development of the design.

C. Design Assist

Design Assist is sometimes employed in situations where the Owner believes that its selected contractor can benefit the design, either by utilizing its construction expertise to save cost or by providing alternative detailing that will be more efficient to construct. In any case, a Contractor who is providing assistance toward the completion of the design is rarely held responsible for that aspect of the design even if the contractor is involved in providing input into an associated BIM. In most cases, the DOR still has the ultimate responsibility for the design and will also be responsible for ensuring the rest of the BIM is

coordinated with any/all design assist elements. This is equally true for BIM and non-BIM project; BIM does ***not*** change that dynamic.

D. Design Build

It is not uncommon for a traditional design-bid-build project to include D/B elements where a portion of the design and construction process may be turned over to the Contractor. For those elements of the project – for example, a custom curtain wall or panelized wall system – that portion of the design will be produced under the contractor's contract and will be stamped and signed by the alternate professional. For BIM projects, the Design Builder will typically produce the BIM components for its scope of work but leave it to the DOR to coordinate the model and to identify any conflicts or missing components. If conflicts do exist, it can be a time consuming burden to sort out the source(s) of conflict and it is in this interface between models where conflict often occur. As with Design Assist, this is true for BIM and non-BIM projects alike.

3. Designing In 3D But Authority Having Jurisdiction Reviews In 2D

One of the great benefits of BIM is being able to see the building structure, systems, and finishes in 3D space with the perception that "what you see is what you will get" in the completed building. Yet, most permitting jurisdictions still perform their review and approval of the design in a 2D, "flattened" form. And, while the process of creating 2D drawings from the model has become more streamlined as BIM technology has improved, the conversion to 2D sheets for permitting, bidding, and other traditional design and construction functions can create a new set of issues. For example:

- The model must be resolved in 3D prior to permit submission; thus it is more difficult to put off certain design decisions until a later time.
- Any minor updates to the model will also impact the 2D output; if the Authority Having Jurisdiction ("AHJ") requires as built or record sets, as some do, the updates will have to be tracked tightly.
- The 2D drawing output will always be a reflection of one moment in time of the BIM
- For contractors or AHJs who rely on 2D output for submittal packages, change orders, agency approvals, permit updates, and other evaluations, either the model will have to be updated to produce current 2D output or there will be a discrepancy
- Over the project's complete life cycle, there is more work associated with maintaining a current and complete BIM in addition to the 2D drawings required for permitting.

For projects which have a requirement to have complete and current approved drawings at the site at all times, any changes the 3D BIM may have to be updated, converted back into 2D hard copy drawings, approved, and returned to the site. This creates a greater burden for the DOR, particularly in those circumstances where the contractor's subcontractors are producing or updating model elements.

4. Undefined Or Unclear Design And Modeling Responsibilities

It is important that all project participants understand who is contributing model elements to the BIM, what those elements are, when they will be supplied, and to what level of detail and precision. As previously noted, this is typically communicated in the form of a BIMXP. Within the plan, a LOD can be established for each anticipated model element along with other information to guide the modelers as they progress through the project. But many projects utilizing BIM do ***not*** have a shared or agreed to execution plan. Consider these actual examples where:

- The BIM implementation plan is ***not*** agreed to or approved by all of the necessary project participants
- The timing and cost associated with an initially ambitious modeling program may be reevaluated as other project costs grow, reducing the modeling scope outside of any revised written agreement
- The use of BIM may ***not*** have been planned for a project but may evolve more organically as it is adopted by specific team members for their own purposes and then added as a contract requirement by an Owner who recognizes the potential benefits.

With modelers of different disciplines relying on drawing

or model information for dimensions, available space, and attachment of their own work, and with the DOR possibly using the model for overall project coordination, the potential for error is great.

5. **BIM Activities Taking Place Outside Of Design Or Construction Contracts**

As already noted, BIM production may occur whether or not it is defined as a requirement in the design or construction contracts associated with a project. This should ***not*** come as a surprise because for many design firms, BIM software is the only design and drawing software they use; 2D drafting is no longer an option. The same is true for MEP contracting firms, many of whom were the earliest adopters of the BIM technology. While there is no inherent harm in utilizing BIM in the absence of a contract requirement to do so, the presence of model elements may lead project participants, including Owners, to improperly conclude that they may rely upon the completeness and accuracy of the model for their own purposes.

For example, an Owner's equipment supplier may attempt to make use of an A/E's BIM, created internally for permitting purposes, to locate anchorage points for that equipment. This is a risky approach if the model was not required by the A/E's contract and is ***not*** otherwise independently verified for its accuracy. The temptation to informally share limited model information should be resisted when that model has not been incorporated as a named contract document. Similarly, the contractor may be using its own combined model to coordinate its subcontracted trades but if those trades do not have a contractual commitment to produce accurate models, the coordination may not be valid.

6. **Loss Of Data And Improper Version Control**

Modeling an entire building in BIM is no small undertaking. Multiple, sizeable and dynamic files must be uploaded and updated on a regular basis as the design is developed and finalized in anticipation for construction. These files will be worked on in the various offices of the respective designers, consultants and contractors whether or not they are hosted in the cloud or saved only on local servers and manually shared. The timing and management of the versions or uploads must be tracked regularly, typically by the DOR. If this is not well planned and executed, there may be unnecessary, additional work required to correct or update model components that were based on outdated base model information. A common approach is to "freeze" or stop further development of certain base elements of the model at a specific time to allow other discipline modelers to utilize an unchanging background model. Yet, even with this strategy in place, belated design changes related to additional coordination, Owner changes, or corrections of errors and/or omissions may still create newer versions of certain BIM elements. Change management and model/document updating is particularly important when dealing with BIM.

Also, as with any electronic file, there is always a chance that the files the BIM is dependent upon will be lost, corrupted, or, as previously noted, confused with prior file versions and possibly overwritten. As was the case with 2D Computer Aided Drafting ("CAD") files, backups and backup management is the best protection. And these functions should be handled internally as well as externally – simply because the BIM file(s) are saved in the cloud does ***not*** mean that they are completely safe. Local backups and offsite backups are an important part of ensuring that months and years of effort are not lost forever.

HOW TO MITIGATE BIM RISKS

While there are numerous challenges associated with the use of BIM, there are several way to manage them and to accomplish the ultimate goal of using BIM to deliver a more successful project in an efficient, cost effective, and virtually error free manner. The following strategies can help lay the groundwork for this success:

1. **Adopt BIM Early In The Life Of The Project:**

If possible, communicate to all project stakeholders the intention to use BIM from project inception with clear and documented concepts about how it will be used. Adopting BIM later and without clear purpose can add confusion, time, and cost rather than capturing the benefits.

2. **Use Established BIM Contracts And Addenda:**

There are a variety of contract document forms that are designed for projects using BIM, such as the AGC's collaboratively developed ConsensusDocs and the AIA's forms. Like other contract documents, these address a variety of unexpected consequences of using BIM and allocate risk accordingly. The use of standard contract forms minimizes the risk of conflicting or uncoordinated terms which may cloud the understanding of BIM use. These agreements also typically define whether or not the BIM design will be legally considered to be a contract document and whom, other than the Architect or Contractor that produced it, will be able to retain possession at the end of the project.

3. **Define Design And Modeling Roles As Well As Planned Model Exchanges And/Or Sharing:**

It is important to clearly define design and modeling roles in advance of performing that work. Using the prior example of MEP modeling, if those subcontractors are expected to be responsible for producing a MEP BIM with accurate routing, attachment details, and connections to equipment - and they will ***not*** be able to rely upon any 3D models developed by the Design MEP consultant as a basis for their own modeling work - that limitation should be defined in the appropriate contracts.

4. **Determine What Will Be Modeled, To What Level Of Precision, And At What Time In The Development Of The Design:**

It is critical that the extent and accuracy of modeling is well defined. While this may be expected to be a natural outgrowth of the objectives and processes that are defined for the project BIM, it is actually a separate set of parameters which needs to be explicitly defined. A BIMXP, along with an accompanying set of LOD parameters and schedule milestones for each portion of the model, can be used for this purpose.

5. **Discuss And Document The Intended Project Use(S) And End Use(S) Of The BIM:**

The BIMXP noted above may also be used to memorialize the true purpose of using BIM for the project, as there are often many. In most cases, BIM is seen as a way to save either time, money or both but that is not always the case. Sometimes BIM use is just a byproduct of the way designers and contractors work while other times the Owner is looking for a detailed model for ongoing facility management use. In each case, the quality, accuracy, and completeness of the completed BIM will vary.

6. **Establish Accountability For Coordination And Redundancy For Backups:**

The BIM model must be internally coordinated, just as a traditional 2D drawing set is. It must also be coordinated across revisions, modifications, and file versions. Due to the complexity of a 3D model, the potential for costly design rework is high if coordination is ***not*** centrally monitored and controlled. And, even though many of the files are now hosted in the cloud, it never hurts to maintain some redundancy in those backups.

The promise of accurate, progressive, efficient, virtually error-free design and construction with BIM may be achievable but it is also elusive. By increasing the knowledge that each stakeholder has as to how BIM will be used in their construction projects as well as the challenges are commonly encountered with those uses, it is possible to maximize the benefits and minimize the challenges of using BIM. BIM use is inevitable – why not use it in a way that benefits rather than hinders your project?

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Christopher Nutter is a Director in the Global Construction Practice office in Seattle, Washington and the West Coast representative of the Professional Liability and Construction Defect Group. With more than 20 years of experience in the design and construction industry, Chris advises clients on commercial, residential, institutional, and government projects, nationally and globally. Chris's work includes technical analyses of design and construction processes and performance for corporations, contractors, developers, municipalities, design firms and insurers. He has managed and directly performed forensic, consulting and architectural design services including field assessments and surveys, repair and construction protocols and document production, and building envelope analysis among others. As an expert, Chris has been qualified and has testified at mediation and in U.S. Courts and Arbitration venues. He has offered expert opinions regarding errors and omissions, defective design and construction, building envelope performance, and architectural standard of care. Chris is a is a registered architect in multiple states, a Member of the American Institute of Architects (AIA), certified by the National Council of Architectural Registration Boards (NCARB), and is accredited as a LEED AP BD+C by the United States Green Building Council.

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