Management Methods Manual

Identifying, Quantifying and Preventing BIM Related Cost and Time Impacts

INTRODUCTION

Building Information Modeling (BIM) has been widely used in the construction industry for over two decades. The advent of BIM brought with it the ability to view computerized design and construction drawings in three dimensions (3D), in many cases replacing the previous two-dimensional paper plans. BIM software identifies spatial conflicts through a process called “clash detection,” which permits the BIM user to modify the design and construction drawings (e.g., to relocate, resize or otherwise solve the obstruction), called “clash resolution.” This process allows clashes to be resolved prior to the commencement of prefabrication and construction operations. In small or medium sized projects, there is a wide variance in who is responsible for pre-construction clash detection and resolution. In some cases, this is done by the architect. In other cases, the general contractor (GC) or the largest subcontractor, usually the mechanical contractor, handles this task. In large or complex projects, the mechanical-electrical-plumbing-sheet metal (MEP/SM) design firm often conducts the clash detection and resolution. BIM has made a significant contribution to reducing the time and costs of construction coordination.

With the advent of the BIM process, the design and construction industry has progressed through a challenging learning curve. Designers and contractors had to learn new computer hardware and software techniques and had to train BIM technicians. New contract language needed to be developed to describe the requirements of BIM on individual projects, and new estimating and execution strategies had to evolve. Fully developed BIM models contain objects with full asset recognition. For example, a chiller depicted in a complete BIM model would include performance metrics, the manufacturer’s operation and maintenance data, and other attributes. These are often referred to as “intelligent objects.”

As it has evolved over the years, the BIM software platform has enabled a wide variety of related BIM software applications to increase its power and/or usefulness. For example, Revit® is now commonly used to produce virtual 3D MEP/SM models based upon the BIM platform. Although clash detection and resolution can be done in Revit, other BIM-related software applications, such as Navisworks®, Revizto™ and BIM 360™ Glue®, also produce clash detection reports.[1] Many small and medium-sized architectural and engineering (AE) firms use Revit or other similar BIM-based programs to depict their

[1] These products are mentioned as examples of what is currently used in the marketplace. MCAA does not endorse commercial products.

designs. It should be noted, however, that the industry is gradually moving towards the use of the full, intelligent BIM for the design, construction, operation, and maintenance of buildings.

Here, we will use the term BIM to refer to any 3D modeling software using a BIM platform. Ideally, the MEP/SM contractor should try to obtain the native BIM files prior to submitting its final bid for the project. The native BIM files can provide extremely helpful information regarding the stage of design coordination that has occurred and can affect the MEP/SM's bid price for both the BIM effort and the overall project. Where such inclusion is not possible prior to the bid, at a minimum, the MEP/SM contractor should submit a written request to be provided with the native BIM files before the contractor's BIM coordination process commences. If the native files are not provided prior to the bid, the MEP/SM contractor may wish to note that absence in their scope letter and include language limiting their liability for undisclosed design coordination issues.

The learning process – incorporating BIM into actual construction work – has been fraught with challenges such as estimating difficulties, managing BIM technician labor expenditures, and managing the process of changes in scope within the design and construction operations. Losses in the BIM budget codes for designers and contractors have been, in many cases, substantial. In addition to BIM labor cost overruns, delays in the BIM process have resulted in critical path delays on many projects. Here, we will provide guidance in promoting BIM management concepts that may reduce the risk to designers and contractors and potentially result in reduced losses to the professionals involved in the BIM process.

GENERAL DISCUSSION OF THE COMMON FORMS OF CONSTRUCTION CONTRACTS

How BIM is integrated into a construction project is, in most respects, a function of the form of the contracts between owners and their design professionals, between owners and the prime contractor, and between the prime contractor and its subcontractors. Here, BIM is viewed through the lens of the most prevalent types of contracts in the construction industry. How construction contracts define and integrate the BIM process can be the determinate factor in a successful BIM outcome. Here, we address the BIM process in terms of the three primary general types of construction contracts in use today: Design-Bid-Build (D-B-B), Design-Assist (D-A), and Design-Build (D-B). These will be used herein to address BIM's functionality and the challenges it presents to prime contractors and their subcontractors.

THE DESIGN-BID-BUILD FORM OF CONTRACT

For years, the most prevalent form of construction contract has been the D-B-B contract delivery system, wherein an owner prepares construction drawings and bidders offer lump sum prices to perform the work in a specified duration of time. As BIM has been integrated into the construction industry, contractors bidding the work may be required to include BIM costs in accordance with the BIM requirements contained in the owner's and/or the prime contractor's contract terms. In most D-B-B contracts, both the owner and the prime contractor include some form of BIM Execution Plan (BEP). Such plans set forth the requirements of the parties (e.g., the architect/design team, prime contractor, and the major subcontractors such as structural, mechanical, plumbing, sheet metal and electrical contractors). Coordination is a key element of a successful BIM operation on a D-B-B project and is summarized in the National BIM Standard publication[2]:

> "Normal and expected spatial coordination performed by the trade contractor after execution of a contract is not design. Rather, it is the reflection of the design in a three-dimensional model." (Emphasis added.)

This is a very important distinction for the contractor and is consistent with AIA A-[201], [2017] edition, which states:

> The Contractor shall not be required to provide professional services that constitute the practice of architecture or engineering unless such services are specifically required by the Contract Documents for a portion of the Work or unless the Contractor needs to provide such services in order to carry out the Contractor's responsibilities for construction means, methods, techniques, sequences, and procedures. The Contractor shall not be required to provide professional services in violation of applicable law.[3]

When the owner/AE/GC/construction manager (CM) produces an over-reaching BEP, MEP/SM contractors may be caught unaware of their rights and responsibilities and inadvertently cross the line from contractor coordination to design. Practicing engineering or architecture without a license is illegal in all 50 states. Moreover, most Commercial General Liability (CGL) policies for contractors specifically exclude coverage for engineering services. Therefore, a contractor inadvertently performing engineering can expose itself to enormous risk in the event of a failure deemed to be caused by negligent engineering services provided by the contractor. BIM may well blur the line between engineering and contracting depending on the scope and breadth of changes made in the BIM coordination process. It is the owner/AE/GM/CM's responsibility to provide the necessary leadership of the BEP process to ensure legal liability is not incurred by the subcontractors.

The issue of BIM coordination morphing into elements of design is a multi-faceted problem in the construction industry. Contractors should ensure that clear guidelines are provided to the BIM team. These guidelines can include examples of "stop points" at which the BIM coordinator must seek approval from the contractor to make changes to system locations and/or the sizes of elements such as piping and ductwork systems. Such "stop points" may also require submittal of system sizing and/or location to the engineer of record, in the form of a Request for Information that requires the owner's design professional to accept the proposed change before the BIM coordination process is concluded. Also, if this step in

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[2] "National BIM Standard – United States® Version 2"

[3] AIA-201A, General Conditions of the Construction Contract, 2017 Edition, 3.12.10

preparing the BIM documents requires the addition of materials (e.g., pipe, ductwork or fittings), based on the published definition of normal and expected coordination on a D-B-B contract, recoverable time and costs may be involved.[4] Keeping time records for the BIM coordination team is also an essential element of documentation of hours required to address uncoordinated design documents and the resulting added BIM hours to produce clash-free construction documents.

The BEP has become a significant component in D-B-B contracts in that the BEP sets forth how BIM will be developed and by whom. It is important that the prime contract documents identify the responsibility of the owner's design team as to providing complete electronic backgrounds to the prime contractor and its subcontractors. It is also essential for the prime contractor, prior to contract execution, to define who will prepare the BEP (i.e., the owner, the prime contractor, or others) and who will be responsible for discrete elements of the BEP by trade. Today, most large prime contractors include the detailed BEP in the subcontracts of the various trade contractors. The MEP/SM subcontractors should carefully study the prime contractor's BEP prior to offering lump sum bid prices for their respective scopes of work.

The most favorable requirement for the MEP/SM subcontractors who are required to implement BIM for their trades is one which causes the owner's design team to provide complete BIM "background" drawings to the prime contractor and its major subcontractors. Where the contract and/or the BEP is unclear in this regard, and on projects where the owner's design team refuses to provide to the prime contractor its background BIM drawing files, the BIM process can be severely impeded and the subcontractor's cost to perform BIM can increase substantially. This is true even if architectural and structural backgrounds are provided to the MEP/SM subcontractor but are in such a rudimentary state of completion (i.e., coordination) that such backgrounds provide no reasonably actionable data to the MEP/SM's BIM coordination teams. Thus, it is best practice for the prime contractor, in concert with its primary subcontractors, to ensure that the various contracts between the parties include the requirement for the owner's design team to provide electronic files containing the project's backgrounds based on a completed design. With these complete backgrounds, the prime contractor and its primary subcontractors can execute the BEP, including the BIM coordination drawings, in a much more cost and time efficient manner.

To the extent possible, the MEP/SM contractor should ascertain the Level of (BIM) Development (LOD) prior to providing a lump sum price for a project. The LOD that will be provided to the MEP/SM contractor can impact the cost of the BIM effort on a project. As can be seen in the American Institute of Architects (AIA) and BIM Forum LOD definitions contained on the following pages, the LOD can dictate the amount of BIM effort an MEP/SM contractor may have to estimate and to expend to produce coordinated drawings suitable for actual construction activities. For instance, LOD 400 is the level both the AIA and the BIM Forum cite as the level that will support fabrication and installation of systems. If an MEP/SM contractor estimates a project expecting an LOD of 400 and receives design drawings at an LOD of 250 or 300, the BIM effort to bring the lower LOD design documents to a level suitable for fabrication and installation may be significant. As noted above, the MEP/SM contractor should attempt to have the LOD defined in the subcontract documents, before submitting the lump sum price for the project.

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[4] See, published definition of normal and expected coordination on a D-B-B contract herein at page 14.

The BEP sets forth the manner in which the BIM process will take place on the project. The BEP may include definitions of terms, the LOD, the job descriptions of the project's BIM coordinator and the BIM manager, the BIM development and sign-off schedule, a description of what work activities cannot be performed until an area of the project has been "signed off" as coordinated, and other important considerations. The detailed requirements of the BEP will vary, depending on the terms of the prime contract and the various trade subcontracts, as referred to in the AIA's LOD guideline below:[5]

> **E203–2013 Section 1.4.4**
>
> **§ 1.4.4 Level of Development.** The Level of Development (LOD) describes the minimum dimensional, spatial, quantitative, qualitative, and other data included in a Model Element to support the Authorized Uses associated with such LOD.
>
> Each Model Element develops at a different rate. The Level of Development (LOD) framework allows the Project Participants to understand the progression of a Model Element from conceptual idea to precise definition and description. The LOD of a given Model Element informs the other Project Participants about how developed the information is expected to be, and the extent to which that information can be relied upon, at a particular point in time in the development of the Model. Identifying the LOD for each Model Element, along its development path, helps prevents other Project Participants from using the Model Element in an unintended manner or inferring greater precision than the Model Element Author intends. See the Guide topics under G202–2013, Article 2, for a detailed discussion of Levels of Development.

The LOD has been defined by the AIA in its Digital Document Guide, © 2020. This AIA BIM guide should be carefully reviewed by BIM coordinators and managers for MCAA (Mechanical Contractors Association of America), NECA (National Electrical Contractors Association), SMACNA (Sheet Metal and Air Conditioning Contractors' National Association), American Subcontractors Association (ASA), and The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The LOD provides guidance as to what level of development will be required, which is usually included in the BEP. The LOD can affect the amount of BIM labor the MEP/SM contractor includes in its lump sum bid estimate. AIA LOD definitions for LOD 100 through 500 are as follows:

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[5] *Guide, Instructions and Commentary to AIA Document E203-2013, Building Information Modeling and Digital Data Exhibit,* © American Institute of Architects.

G202–2013 Section 2.2

§ 2.2 LOD 100

§ 2.2.1 Model Element Content Requirements. The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e., cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

At LOD 100, Model Elements are in the form of narratives, program information, etc. An LOD 100 Model Element is not geometrically modeled, but may be included in a Model as a symbol that does not represent actual geometry. It is also possible that the Model Element is not individually represented in the Model in any graphical sense, but its existence can be derived from other Model Elements that are graphically represented in the Model. For example, the existence of a mechanical system can be derived from the square foot quantity associated with the floor slab that is represented in the Model at LOD 200.

LOD 100 elements are extremely useful early in the design process. They enable the designer to embed a great deal of intelligence regarding such things as approximate costs and system capacities in a Model consisting of nothing more than floors, and then to quickly derive overall costs and capacities as the Model is changed. Some Model Elements may remain at LOD 100 through to the end of the Project. See the discussion under "Cost Estimating" below.

G202–2013 Section 2.3

§ 2.3 LOD 200

§ 2.3.1 Model Element Content Requirements. The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

In general, LOD 200 elements are generic placeholders. This is the lowest level at which a geometric representation of a Model Element will appear. By contrast, in LOD 100, a Model Element may be graphically represented by a symbol, but it will lack any geometry. For an LOD 200 Model Element, the size, shape, location, orientation, and any data associated with the Model Element are approximate. LOD 200 elements are useful both early in the design process when specifics have not yet been determined (the designation of LOD 200 tells downstream users that the element may change) and in final Models when selection of certain items, such as lighting fixtures, is left to others or is met by a range of choices.

G202–2013 Section 2.4

§ 2.4 LOD 300

§ 2.4.1 Model Element Content Requirements. The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 300 Model Elements are specific assemblies, such as specific wall types, engineered structural members, system components, etc. The design of the Model Element is developed in terms of composition, size, shape, location and orientation. Constructability and coordination of other building components may require change to some Model Elements after they are designated LOD 300, but such changes should be minimized as much as possible. Other information such as cost, thermal characteristics, specifications, warranty, and operation and maintenance instruction may be attached to the element.

G202–2013 Section 2.5

§ 2.5 LOD 400

§ 2.5.1 Model Element Content Requirements. The Model Element is graphically represented within the Model as 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.

A designation of LOD 400 indicates that detail beyond that included in LOD 300 is to be provided, similar to the kind of detail that is traditionally supplied in shop drawings. Structural connections, slab-edge embeds, curtain wall details, and other items requiring special fabrication fall into this category. A Model Element qualifies as LOD 400 once all information necessary for fabrication and installation has been resolved.

Note that "fabrication," as the term is used here, refers to project-specific fabrication rather than manufacture of standard components. So, an LOD 400 store front Model Element would include the detail necessary to install it, but not to manufacture it. An LOD 400 custom metal railing Model Element would include detail necessary for manufacture.

G202–2013 Section 2.6

§ 2.6 LOD 500

§ 2.6.1 Model Element Content Requirements. The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

Note that the cited AIA document above permits the fabrication of elements of the project in LOD 400. Such elements can include pipe, sheet metal duct, and electrical system pre-fabrication elements. The successful clash resolution of the LOD 400 BIM model can, depending on the contract language, initiate the start of shop pre-fabrication and field fabrication of MEP/SM elements of the work.

Based on the AIA's definition of LOD 400, it would be reasonable for a MEP/SM contractor, in a D-B-B environment, to expect to receive bid documents to this level of LOD. However, it appears from a polling of MEP/SM contractors, the actual LOD on many D-B-B projects ranges between LOD 250 and 300. The preliminary LOD provided by the owner's design professionals or the prime contractor will directly impact the estimated cost of the BIM services required by the subcontract. There is a cost to the MEP/SM contractor to take LOD 250 or 300 design documents and refine those design documents to a point that pre-fabrication and field installation can commence (i.e., LOD 400), and this can be the root cause of BIM labor hour and cost overruns in the industry.

The BIMForum publication offers the following levels of development used in the design and construction industry (note that the BIMForum does not include LOD 500 in its definitions because this level does not enhance the layout of elements of the project, while providing detailed operational and dimensional information on, for example, major equipment items):[6]

[6] *Level of Development (LOD) Specification Part 1 & Commentary for Building Information Models and Data*, © December 2019, BIMForum.

LOD 100

The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

BIMForum Interpretation: LOD 100 elements are not geometric representations. Examples are information attached to other model elements or symbols showing the existence of a component but not its shape, size, or precise location. Any information derived from LOD 100 elements must be considered approximate.

LOD 200

The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation: At this LOD elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation. Any information derived from LOD 200 elements must be considered approximate.

LOD 300

The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation: The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs. The project origin is defined and the element is located accurately with respect to the project origin.

LOD 350

The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.

BIMForum interpretation. Parts necessary for coordination of the element with nearby or attached elements are modeled. These parts will include such items as supports and connections. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.

LOD 400

The Model Element is graphically represented within the Model as 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.

BIMForum interpretation. An LOD 400 element is modeled at sufficient detail and accuracy for fabrication of the represented component. The quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs.

The MEP/SM subcontractor should evaluate the risks that are assigned to them as to required LOD, scheduling, leadership responsibility and the scope of the work to be completed with BIM. The LOD that is to be provided by the MEP/SM subcontractor may determine the relationship between when clash resolution has been reached for various areas or phases of a project, and when pre-fabrication and site fabrication of elements of the project can commence. Such relationships should be clearly defined by the contract, and/or by the prime contractor's Critical Path Method (CPM) schedule and should include relationships between the approval of clash resolution by the owner's design professionals and the commencement of pre-fabrication and site fabrication operations. At the point of clash resolution and area by area BIM coordination, it is highly advisable for the MEP/SM subcontractor to receive a signed release by, or acceptance of, the owner's design professionals prior to commencement of the work activities.

Oftentimes, the prime contract, the various trade subcontracts and/or the BEP do not define with enough specificity the role and scope of the MEP/SM's BIM leader. Will the MEP/SM BIM leader or manager be responsible only to incorporate its own activities into the BIM model or will the MEP/SM BIM leader or manager be responsible for clash detection and resolution for other trades, such as structural steel or concrete? Defining the scope of the various trade subcontractors for BIM responsibilities on a D-B-B contract delivery system is an essential element of the BEP, in concert with the terms of the various contract documents.

For the preparation of a D-B-B lump sum proposal, the MEP/SM subcontractor should include in its lump sum price the labor and time required to execute the BEP. This includes the cost of skilled BIM coordination labor and the hardware and software required by the subcontract to perform the scope of work included in the BEP. As of this writing, neither the MCAA's WebLEM® web-based labor estimating manual, nor any other known estimating publications, have provided detailed guidance as to how to estimate BIM labor hours on a D-B-B lump sum contract. Recently, NECA's ELECTRI International – The Foundation for Electrical Construction has published a manual titled Identifying BIM Related Costs Due to Changes that includes some general guidelines as to estimated BIM labor for electrical subcontractors. It is worth noting that NECA's publication cited above suggests a lower BIM labor estimate for electrical work scopes, as compared with mechanical, plumbing and sheet metal subcontractors.

MCAA's WebLEM does not include, as of this writing, labor estimating guidelines for BIM labor in a D-B-B subcontract. Currently, the MCAA is engaged in a process of collecting data from MCAA member firms that may provide guidance in estimating BIM labor on various types of projects, using various types of contract delivery systems.

Many contractors utilize a percentage of BIM labor to field erection labor hours, while other MEP/SM contractors include BIM labor hours (expressed as a forecasted job cost) in the lump sum proposal or on the estimated or budgeted dollar value of the overall project. Notwithstanding the method of BIM labor estimating used, it is advantageous for the estimated and actual costs for BIM operations to be tracked and reported as a project-specific direct cost, as opposed to a general corporate overhead indirect cost. In certain instances, project-specific BIM direct labor costs may be more easily recovered than BIM labor charges made to an indirect corporate (or overhead) cost code, in the event the MEP/SM subcontractor pursues a BIM claim.

Another important consideration is the extent to which the MEP/SM subcontractor will be required to manage the overall BIM process. For instance, if the MEP/SM subcontractor's BIM responsibility is limited in the BEP or in the subcontract to only coordinating the MEP/SM activities, then the BIM labor budgets listed above may prove sufficient. However, if the MEP/SM BIM "manager" is also required to coordinate structural and architectural features, the electrical and fire protection trades along with the MEP/SM elements of the work, this increased scope of BIM responsibility should be considered when the MEP/SM subcontractor is developing its overall BIM budget. It is important for the MEP/SM subcontractor and/or the BEP to clearly define the limits of the MEP/SM subcontractor's overall BIM management beyond the work directly within the MEP/SM subcontractor's scopes of work.

Still another essential element in BIM cost management is the manner in which BIM labor hours are tracked, and how change hours are recorded separate from the planned BIM expenditures. In some cases, MEP/SM subcontractors have been denied BIM add-work cost proposals because they were not timely submitted and/or were not reasonably documented in terms of hours expended to resolve uncoordinated design drawings. It is a good practice to record BIM change hours on time and material (T&M) time sheets and, if contractually allowed, to invoice for these added BIM hours on the monthly payment applications. In some cases, the contract will require added BIM hours to be invoiced on the same change order proposal document as the added physical work, to the extent that the change involves both added BIM and field labor costs to address a design issue. Maintaining BIM added labor time records and timely invoicing for unanticipated BIM labor expenditures can facilitate the compensation to the MEP/SM subcontractor for added BIM operations.

MEP/SM subcontractors normally do not control the prime contractor's CPM schedule development. Very frequently, the prime contractors do not include detailed BIM activity subnetworks within the master CPM schedule. This has become a very serious project management issue, particularly when the contract language prevents the commencement of pre-fabrication, site fabrication and/or field erection activities until an area or phase of the project has achieved BIM coordination. If the contract requires review and approval by the AE prior to fabrication, it is recommended that the AE's approval be tied to the completion of the BIM coordination.

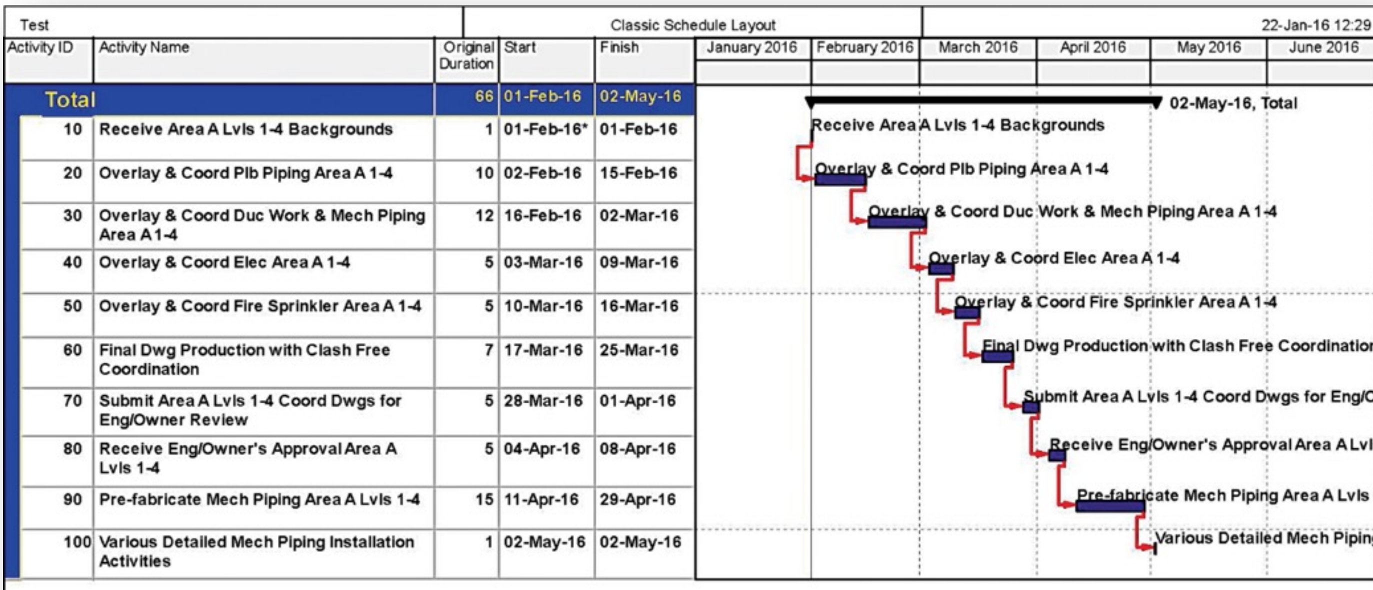
To the extent that the MEP/SM subcontractors can influence the prime contractor to include a detailed BIM activity subnetwork within the master CPM schedule, the project schedule will more accurately forecast the effects of BIM coordination progress within the project's master schedule. When BIM clash detection and clash resolution can be delayed by various parties, or by the condition of the bid set of drawings, critical path impacts may occur. It is essential that the MEP/SM subcontractors have the ability to identify and notify the prime contractor of actual or forecasted BIM coordination delays in the project's master schedule. In fact, such schedule delay quantification and notices are important and specific elements in most subcontracts with the prime contractor.

It is also very important that the BIM activities in the project master CPM schedule consider the LOD required to be achieved by the MEP/SM subcontractor's BIM coordination efforts. Moreover, it is important to define in the project master CPM schedule the contractual precedents that restrain the commencement of the MEP/SM subcontractors' pre-fabrication and site fabrication activities. Such precedents are often included in the prime contractor's contract or the MEP/SM's subcontract. To the extent that such precedents exist that restrain the start of pre-fabrication or site fabrication of system by the achievement of acceptable clash resolution and coordination efforts, those logic restraints should be included in the CPM schedule. Thus, if clash resolution is delayed, that delay will be shown in the project master CPM schedule and can be quantified by the MEP/SM subcontractor. If such a delay affects the critical path of the CPM schedule, then notice, as is normally required by the contract, can be provided to the prime contractor as to potential project schedule slippage.

Within the chapter titled "CPM Scheduling – a Roadmap to Success," a sample BIM CPM schedule subnet is included. This BIM sample schedule sub-net identifies and logically ties the various BIM elements on a D-B-B project and includes the activities of the designer/engineer of record (EOR) or entity responsible for final coordination sign off of BIM elements. This subnetwork should logically tie the EOR's acceptance of successful coordination to the start of pre-fabrication activities, which in turn are shown to restrain the start of field erection activities.

Delays to these chains of BIM clash detection/clash resolution and owner acceptance activities can cause critical path delays to the project's master schedule. Some MEP/SM subcontractors have negotiated language in their contract terms that require the development of a "mutually agreed to schedule." In any "mutually agreed to schedule," the BIM schedule activities leading to the owner's approval of coordinated drawings should be clearly shown, along with the requisite logic ties between the BIM activities and shop pre-fabrication and field fabrication activities, and other key activities such as the installation of hanger inserts.

FIGURE 4



Test — Classic Schedule Layout — 22-Jan-16 12:29

Activity ID	Activity Name	Original Duration	Start	Finish
Total		66	01-Feb-16	02-May-16
10	Receive Area A Lvls 1-4 Backgrounds	1	01-Feb-16*	01-Feb-16
20	Overlay & Coord Plb Piping Area A 1-4	10	02-Feb-16	15-Feb-16
30	Overlay & Coord Duc Work & Mech Piping Area A 1-4	12	16-Feb-16	02-Mar-16
40	Overlay & Coord Elec Area A 1-4	5	03-Mar-16	09-Mar-16
50	Overlay & Coord Fire Sprinkler Area A 1-4	5	10-Mar-16	16-Mar-16
60	Final Dwg Production with Clash Free Coordination	7	17-Mar-16	25-Mar-16
70	Submit Area A Lvls 1-4 Coord Dwgs for Eng/Owner Review	5	28-Mar-16	01-Apr-16
80	Receive Eng/Owner's Approval Area A Lvls 1-4	5	04-Apr-16	08-Apr-16
90	Pre-fabricate Mech Piping Area A Lvls 1-4	15	11-Apr-16	29-Apr-16
100	Various Detailed Mech Piping Installation Activities	1	02-May-16	02-May-16

Agreeing to the definition of "normal and expected coordination" in a D-B-B contract delivery system is an important element of maintaining a reasonable BIM labor and schedule estimate. The National BIM Standard – United States™ Version 2 (2012) contains a definition of "normal and expected coordination on a design-bid-build project".[7] This definition, found in Figure 5, was drafted by an ad hoc committee of senior construction firm executives from MCAA, SMACNA and NECA firms, sets forth the reasonable number of clash detection/clash resolution events, and defines what constitutes changes to the MEP/SM's subcontractors' base contract scopes of work. The MEP/SM subcontractor would benefit from including a specific definition of normal and expected coordination in its contract with the prime contractor, and the definition in Figure 5 has gained acceptance in the industry.

[7] While the National BIM Standard includes this definition as "Commentary," nowhere in this published BIM standard do the writers take exception to the definition of "normal and expected coordination" on a design-bid-build project.

FIGURE 5

Commentary

SMACNA, NECA, and MCAA, representing the sheet metal, electrical, plumbing and mechanical, have issued a definition of the traditional MEP coordination delivery process referenced in the standard.

a. Standard and acceptable industry practice for spatial coordination performed under the contract documents is a collaborative process executed between the primary installation contractors and overseen by the general contractor or construction manager. This practice for spatial coordination seeks to integrate objects, systems, and components into spaces allocated in the contract documents. Standard and acceptable industry practice for coordination does not include adding pipe, ductwork, fittings, conduits, cable tray, junction boxes, or other appurtenances to remedy spatial constraints. Such work falls beyond the scope of what is considered standard and acceptable industry practice for coordination and will be performed as expressly directed pursuant to the terms of the contract. Achievement of spatial coordination under the contract documents that represents standard and acceptable practice in the industry assumes:
    - The contract drawings have been fully designed and coordinated by the owner and/or its design professionals such that, if installed as shown on the contract drawings, the finished product will result in systems operating as designed by the owner and/or its design professionals.
    - Systems fit within the spaces allocated on the contract drawings as qualified below.

b. Spatial coordination that is standard and acceptable practice in the construction industry does not include relocating systems from their allotted spaces as shown on the contract drawings when such relocations require added materials, shop or field labor, or coordination time. Any such relocations or alterations of components and/or systems may compromise the integrity and/or the planned performance of the system(s) as designed by the owner and/or its design professionals. Responsibility for the integrity and/or planned performance of the relocated systems will remain the sole responsibility of the owner and/or its design professionals.

c. Depending on the complexity of the project, from one to three iterations each of clash identification and attempts at clash resolution are considered standard and acceptable industry practice for coordination. Further iterations fall beyond the scope of what is considered standard and acceptable industry practice for coordination.

d. The physical spaces for electrical, mechanical, sheet metal and plumbing equipment rooms must be adequate to allow for the installation of equipment as shown on the contract drawings. All designed spaces must include clearances in and around equipment as required by the contract documents, applicable codes and the equipment manufacturer's specifications. Adequate spaces must be included in the design to accommodate incoming and outgoing services to and from the equipment and for maintenance as required by the contract documents.

Spatial coordination is a cooperative and collaborative effort between the design professional, owner, general contractor or construction manager, and the trade contractors. Normal and expected spatial coordination performed by the trade contractors after the execution of a contract is not design. Rather, it is the reflection of the design in a three dimensional model. Trade contractors rely on complete and accurate designs when bidding projects in order to provide accurate bid pricing. In return, trade contractors, such as those represented by the MCAA, SMACNA, and NECA, using that design, are able to produce reliable models by which the project can be constructed in a more efficient, timely and cost effective manner.

Establishing a specific definition of “normal and expected coordination” is essential to controlling BIM labor costs and schedule, because it helps establish a reasonable baseline from which extra work and extra time can be measured. When this practical “norm” is not achieved and the BIM team is required to perform extraordinary “coordination” of the designer’s documents, such condition usually results in unanticipated BIM operations, labor costs and in delay to the project’s master schedule. This chapter focuses on frequent BIM labor over-runs experienced on D-B-B contract delivery systems. It is expected, on D-B-B lump sum contracts, that the prime contractor and MEP/SM subcontractors are not required to design the project's systems – but are required to make minor adjustments to the systems as designed by the owner's professionals to provide for final "coordination." This final "coordination" does not entail added or relocated piping, ductwork, or electrical systems.

When "coordination" exceeds this published "norm," the MEP/SM subcontractor should have in place a method of recording added/unanticipated BIM labor hours. As previously noted, these added BIM labor hours should be discreetly tracked on T&M forms and timely submitted to the prime contractor as change order proposals. Added BIM labor costs, and time impacts, should not be held until the project concludes, but should be provided to the prime contractor, in accordance with the terms of the subcontracts, in a timely fashion such as with the monthly payment applications, or within discrete change order proposal submissions.

Performing BIM coordination on a D-B-B project is not the same as providing "design services. It is a computerized reflection of the design and coordination performed by the owner and its design professionals prior to releasing the drawings and specifications for competitive lump sum bidding. When the design is not properly coordinated prior to the time of contract award, BIM costs can be expected to grow, and in some cases, to grow exponentially. These added and unanticipated BIM costs and time impacts should be recoverable as a change in contract scope. It is a good business practice for MEP/SM subcontractors to track and timely submit such added and unanticipated BIM costs, and prime contractors and/or owners are obligated to evaluate, and if entitlement is found, to provide equitable adjustments to the MEP/SM subcontractors.

THE DESIGN-ASSIST FORM OF CONTRACT

D-A forms of contracts have gained much popularity in recent years. This is due to several factors that include, but are not limited to, the ability of the MEP/SM contractor to make coordination recommendations prior to signing a lump sum or guaranteed maximum price (GMP) subcontract. Unfortunately, there is not a generally accepted definition of the D-A process, which has predictably led to problems for the designer and contractor alike. A common definition of D-A is found in ConsensusDocs Document 541, which states:

> "***Design-Assist is loosely defined in the industry*** as a process by which the constructors collaborate with the project owner and the design professionals beginning in the design development phase to assist all parties in meeting the Project's objectives."[8] (Emphasis supplied.)

MEP/SM subcontractors who participate in D-A forms of contract have found that many, or in some cases, most of the design coordination issues are resolved before the design drawings are issued for pricing by the prime contractor and its subcontractor team. In such cases, the post-award BIM process by the various contractors is sizably reduced and commensurately, the BIM cost and time overrun risks are reduced as well.

[8] ConsensusDocs 541, Addendum to Agreements Between Owner and Construction Manager and Between Owner and Design Profession for Design-Assist Service.

As noted, in many D-A processes, the MEP/SM participants are required to provide pre-GMP or pre-subcontract BIM coordination budgets, or in some cases, fixed price proposals. In the former, if unanticipated, extensive BIM coordination efforts are required to coordinate the pre-contract or pre-GMP design, the MEP/SM participants may be able to negotiate changes to their BIM budgets. In the latter, the MEP/SM's pre-contract or pre-GMP budgets are "fixed," leaving the MEP/SM subcontractor to either absorb added BIM coordination costs, or to shift the BIM labor overruns to the fixed price or GMP submission. The risk in most D-A contract delivery systems is the possibility that the MEP/SM subcontractor who participated in the pre-construction coordination and pricing exercise may not be chosen or selected to construct the project. That is a known risk that can be potentially addressed by the business relationship between the owner, the prime contractor, and the MEP/SM subcontractors.

Once the GMP or lump sum contract is executed, the BIM process to finalize the coordination of the construction design follows along the same path as with a D-B-B contract delivery system. The principal difference is, as noted, the fact that much of the design coordination, BIM conflict identification and BIM clash resolution processes have already occurred during the period prior to entering into a fixed price or GMP contract.

The same protocols that have been set forth in the prior section on the D-B-B form of contract are applicable to the D-A form of contract. The quantity of the BIM clash detection and clash resolution should be expected to be highly attenuated due to the D-A contractor's meaningful influence on the design, as opposed to a traditional D-B-B contract delivery system. Thus, the MEP/SM's risk of BIM labor and schedule overruns are proportionally reduced, assuming the owner's design professionals do not re-design the project after execution of the prime and MEP/SM's contracts. If the mechanical contractor does not have meaningful influence in the design phase, then the risk of BIM cost overruns is much higher, primarily due to the fact that: (1) it must trust that proper design and design coordination between the various design disciplines has occurred, and (2) it will have inadequate time built into the schedule for design corrections if the mechanical design is poor or has been poorly coordinated with the other disciplines.

THE D-B FORM OF CONTRACT

This contract delivery system is less frequently applied because it requires, in most cases, highly sophisticated prime contractors and subcontractors. This is true because with a D-B contract delivery system, the prime contractor and trade contractors take on the responsibility to design the project, or in some cases, to complete the design of the project. Oftentimes, an owner will provide Owner Project Requirements (OPR) for a proposed project, including certain appearance items, design, performance, and spatial requirements. From this data, the prime contractor and its lead subcontractors must obtain, unless in-house professionals are available, design professionals to develop and/or complete the owner's parameters.

Because the full, or substantial, design development is being provided by the prime contractor and its principal subcontractors, the risk and liability for "design defects" falls in part, or in whole, on the construction team. Such potential "design defects" can include defects that result in coordination errors that may be identified during the final BIM coordination steps once the construction process commences. "Unanticipated" BIM cost and schedule over-runs become difficult to recover since, under most D-B contract delivery systems, design and coordination defects are the responsibility of the D-B construction team.[9]

In some cases where coordination labor losses and schedule impacts are so pronounced, the MEP/SM subcontractors may have an avenue to recover unanticipated design and coordination costs and schedule impacts onto the lead design team, or to the owner if the owner has instituted project scope changes. However, the potential complexity and the cost to pursue such internal design and coordination claims by the principal subcontractors make recovery speculative and expensive.

CONCLUSION

There are guidelines that can assist the MEP/SM contractor in preparing a reasoned and reasonable BIM labor estimate or budget on most types of construction contracts, and to track and recover added and unanticipated BIM costs due to changes in scope or design. The following practices can aid in the development and control of BIM costs in the construction environment.

1) To the extent reasonably possible, in the pre-bid period, evaluate the completeness of the owner's designs against the respective published LOD definitions. The LOD to be provided at the outset of a project should, in most cases, influence the BIM labor bid or budget.

2) Read and evaluate the owner's or the prime contractor's BEP and ensure that each item of MEP/SM responsibility is addressed in the bid price or the construction budget.

3) Confirm that each member of the owner's or prime contractor's design team will timely provide 3D backgrounds to the MEP/SM subcontractor.

4) Request, in writing, that the owner or prime contractor include in the detailed project CPM schedule a subnetwork of BIM activities, including clash detection, clash resolution and coordination sign-off activities that are predecessors to the start of pre-fabrication and/or field installation activities.

5) For the MEP/SM subcontractor, track and account for the estimated and the actual BIM bid labor hours or costs as a direct cost of the project and charge them to a project-specific cost code, rather than accounting for these costs as home office general and administrative (G&A) costs.

6) Establish BIM labor time sheets for the MEP/SM subcontractors' BIM team to record base contract and change hours. For change hours, code the added BIM labor to codes that tie the added work to discrete pending or requested change order codes or numbers.

7) Define for the BIM team the process of coordinating the owner's or prime contractor's design team member regarding what constitutes reasonable coordination as opposed to design modifications (reference the published definition of normal and expected coordination in a design-bid-build contract environment contained herein).

[9] Whether any of these cost overruns can be recouped through professional liability insurance is an issue that is beyond of the scope of this chapter.

8) Caution the BIM team not to voluntarily change or modify the owner's or prime contractor's designs without approval from the owner, prime contractor and/or engineer of record as necessary. Remind the BIM team that BIM is coordination, not design.

9) Draft BIM guidelines that provide to the BIM team a definition of coordination as opposed to design for each specific contract type (i.e., D-B-B, D-A or D-B)

10) Even if the MEP/SM subcontractor accounts for BIM labor as a direct cost of the project, in some instances the contract documents might include a provision stating that BIM labor costs are included in the contractually specified overhead mark-up for change orders and as such, they cannot be separately charged in the change order proposal. Where added BIM labor costs are one component of a larger change, these types of clauses typically will be enforced according to their terms. Where the MEP/SM subcontractor is only seeking recovery of added BIM labor costs because the design documents are incomplete, defective or poorly coordinated, application of this type of clause becomes much more complicated. In either case, the MEP/SM subcontractor would be well-served to negotiate this type of clause out of its subcontract before execution.

APPENDIX

A number of published decisions have grappled with the distinction between the contractor's duty to coordinate, on the one hand, and defective design that is subject to the implied warranty of design under *United States v. Spearin, 248 U.S. 132 (1918)*, on the other hand. Compare, *Appeals of M.A. Mortenson Company, ASBCA Nos. 53146, et al (2005) ("A government design that does not provide adequate space to accommodate the work required to be accomplished within that space, regardless of any amount of coordination efforts by the contractor, is defective …")* with *Appeals of M.A. Mortenson Company, ASBCA Nos. 53105, et al (2004) ("While the government impliedly warrants the correctness and adequacy for the job of its design specifications and drawings … the implied warranty does not eliminate the contractor's duty to investigate or inquire about a patent ambiguity, inconsistency, or mistake when the contractor recognized, or should have recognized, an error in the specifications or drawings … Thus, appellant bears the burden to prove that it complied with the contract, but that a defect in the drawings, which it could not have recognized with reasonable effort, was responsible for its claimed extra costs.")*

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