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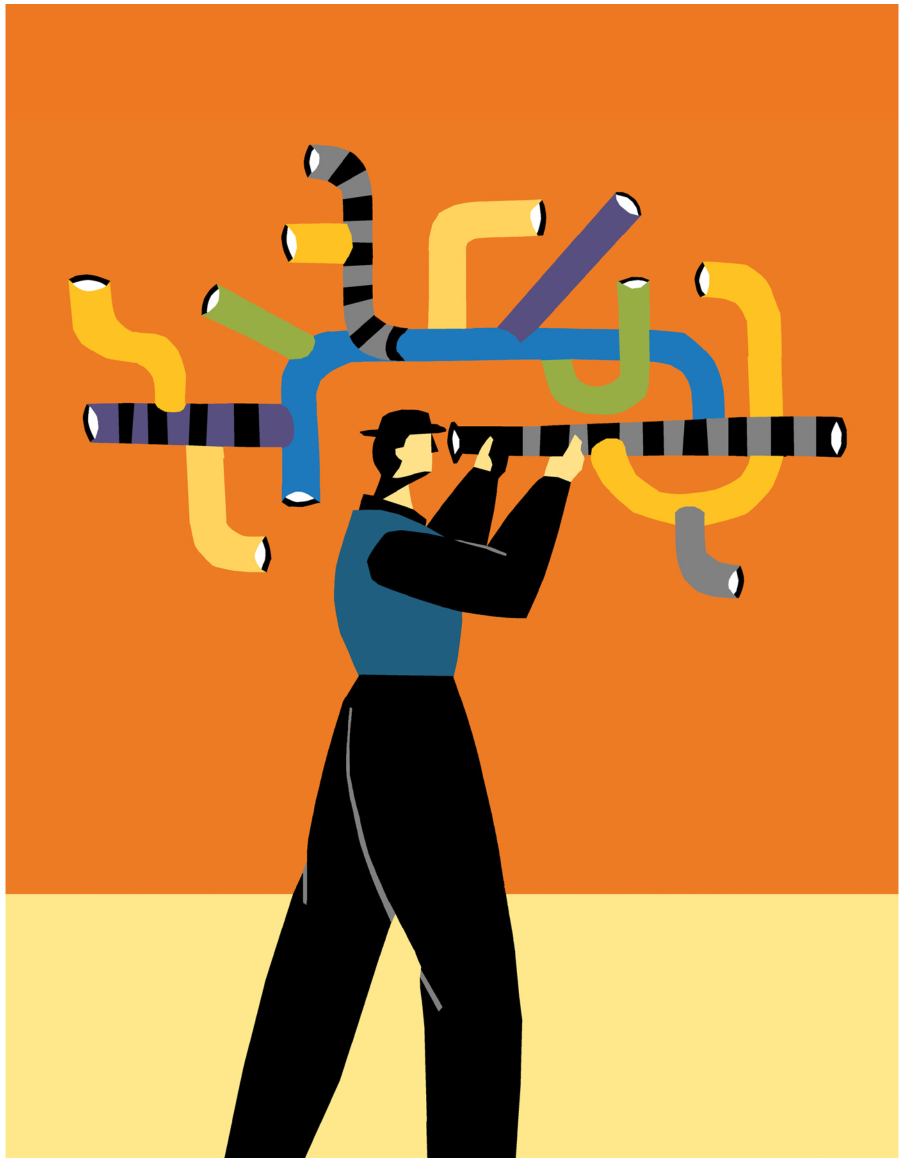

SMACNA BIM Primer

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Table of Contents

Introduction

Why BIM

Building information modeling or BIM and Integrated project delivery (IPD) are the latest in a long line of trends slated to transform the construction industry. However, BIM and IPD processes have been proven time and time again on many mainstream and highly complicated projects. To date, companies who have been utilizing BIM and IPD processes on their projects have claimed ROI's of over 500%[1] and this in the early stages of BIM development.

Systems contractors (herein defined as mechanical, electrical, plumbing, fire protection) were among the first to utilize BIM concepts through coordination efforts. Some even argue that these efforts were the first BIM type efforts for contractors. In spite of this accolade, many systems contractors have not kept up with the latest in technology and integrated BIM processes to maintain a competitive advantage. To compete in today's construction market, organizations will need to increase efficiencies in a time when project complexity is great and increasing, and project schedules are being reduced. BIM provides an effective way to do this.

Many owners and national organizations are developing contract documents and addendums outlining specific BIM requirements and processes to be utilized on their projects. Examples include the U.S. General Services Administration, the U.S. Army Corps of Engineers, the Associated General Contractors, and the American Institute of Architects. One specific document of interest to sheet metal and HVAC contractors is an AGC document outlining the MEP requirements for BIM (see appendix A). As is outlined in this document, it is common for oversight of the BIM coordination efforts to be assigned to sheet metal and HVAC contractors. This assignment comes not only with challenges but with significant advantages.

One of the most significant arguments for BIM is an increase in labor productivity. Labor is typically the largest and most variable cost on a construction project for any specialty contractor. Studies have shown that over 30% of labor hours spent on a construction site is wasted on unproductive activities. BIM including integrated processes has become a focal point in many self performing construction organizations to reduce and control labor costs.

Contractors continually cite productivity hampering issues such as weather, material flow control, equipment, and on-site coordination of trades as reasons for labor cost over-runs. BIM minimizes the impact of these costly issues by improving design, coordination, and enabling prefabrication. The increase in

[1] McGraw Hill Construction, SmartMarket Report on Building Information Modeling

productivity provides a good reason for undertaking the effort to implement a state of the art BIM program.

Quality of output is another major concern for contractors in the sheet metal and HVAC trades. Inferior quality of output can result in costs exceeding five times those of the initial cost of the work. BIM enabled prefabrication work that can be reasonably performed in a controlled shop environment will increase productivity, reduce labor costs, and improve the output quality of their contracted work when compared to doing the same work in an uncertain field environment. Additional cost savings includes the reduced workers compensation rates for work completed in the shop.

BIM and IPD Fundamentals

BIM Overview

The benefits of BIM are so abundant and multidimensional that 3-D, 4-D, and 5-D, have been replaced with X-D in many definitions and publications. Design and construction firms are utilizing the current BIM tools and processes from preconstruction through facilities management. Users have found BIM to be the meaningful differentiator helping them win more projects by providing superior value to the owner and at the same time improving their bottom line. Benefits are in large part the results of superior planning during preconstruction and include improved productivity, fewer change orders, and early identification and resolution of potentially costly problems.

Definitions of BIM and stated benefits vary widely and are often specific to an industry sector. The leading definitions contain the common concept of horizontal integration throughout the lifecycle of the project including design, construction, and facilities management (FM). This concept implies the passing of information throughout building lifecycle instead of information re-creation from one project participant to the next (e.g. designers to contractors, contractors to facilities management). "The NBIMS Initiative categorizes the Building Information Model (BIM), as [a] product, as an IT enabled, open standards based, collaborative process, and as a facility lifecycle management requirement".[2] These definitions, including the concept of horizontal integration, are more of a vision than a reality with much of the "I" or information in BIM still contained in industry silos. Reasons for these silos include; the current state of BIM technology including lack of interoperability, liability and ownership issues, education/experience, and many others. Additionally, much of the needed information is still not included in or tied to the model. The successful implementation of BIM in AEC and FM will require a fundamental shift in the way projects are designed, constructed, and managed. The development and move toward IPD is an attempt to make this shift a reality.

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[2] National Institute of Building Sciences, (2007) United States National Building Information Modeling Standard. http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf

BIM Benefits

Communication and Collaboration (3-D)

BIM tools and integrated processes facilitate improved communication among project participants through a variety of applications. BIM enables a collaborative design process, which improves constructability while maintaining budget and schedule. Even if designers do not participate fully in the BIM process, contractors are using BIM tools to identify errors in design and utilizing systems models (MEP, Structural, Architectural etc.) to coordinate the work resulting in fewer RFI's and change orders thus reducing waste/cost.

Contractors not involved in coordination drawings are also finding value in the use of BIM tools and processes. Virtual mock-ups of key components of the project enable less expensive visualization and help with the identification of constructability issues. Resolution of the constructability issues can be completed through a medium that all can understand (3 dimensional models and animations) in spite of the typical trade specific communication barriers. These models are then utilized to communicate to craft workers the correct installation with the benefit of an improved productivity rate. Other trades are developing what is being termed "lift drawings" where information from numerous 2D drawings is consolidated into a single 3D model. This model, with all pertinent information, is then provided to the craft workers for construction purposes reducing rework or work performed an in inopportune time (such as installing misplaced or missing sleeves after the fact). This effort significantly reduces errors that result from the foreman frantically flipping through numerous sheets of a typical drawing set to provide information to the crew. It also reduces the productivity killer of having crews idly waiting for a foreman to determine the next steps.

Model Based Schedules (4D)

The fourth dimension of time, derived from a typical CPM or line of balance schedule, added to a 3D model constitutes a 4D schedule. Utilizing this visual schedule improves the ability to communicate schedule information to all participants, including the owner. Increased participation in schedule development and refinement by more project participants improves buy-in of major players. Often the utilization of a 4-D schedule exposes scheduling and sequencing errors providing a better overall project plan. The value of improved communication is enormous and alone is sufficient reason to begin or advance the utilization of BIM tools in an AEC organization. The development of new tools and processes for improved communication will continue to be high on the BIM/IPD priority list.

Model Based Estimating (5-D)

Model based 5-D estimating holds extensive potential to improve estimator productivity and accuracy of estimates. To date, 5-D technology is still being refined with most firms limiting their use to parallel quantity take off (QTO) initiatives or providing a bill of materials for specific assemblies. The value in these efforts should not be minimized as model based QTOs often expose significant errors in manual quantities. These more accurate QTOs allow the contractor to adjust an estimate accordingly, providing the ability to be more competitive or reduce the amount left on the table. Model based estimating software programs capable of interfacing with existing estimating systems have only recently been developed. Other 5-D programs requiring database migration or the use of existing external databases have been in use for some time but represent a significant investment in time, money, and/or training. Given the current state of technology however, 5-D estimating is on the verge of becoming a mainstream reality among current BIM users and will provide an additional competitive advantage over non users.

As-Built and O&M Models

The production of model based and/or model informed O&M manuals provide additional value to the owner. Facilities maintenance groups, who often have influence with the owner regarding project team selection, generally welcome the opportunity to have access to as built models. In addition to providing information regarding locations of systems including components is the ability to link product data to specific components. Maintenance or system information specific to a given component can be attached. A significant differentiator for AEC firms including subcontractors is the ability to provide these as built models to the owner. A subcontractor who can provide and market this service will have an advantage over competitors and will add value to a GC competing for the project.

Pre-Fabrication

The development of the systems models for coordination enables pre-fabrication of sheet metal, pipe, plumbing, electrical and other systems. Some contractors have even used modeling to enable prefabrication of curtain wall and other architectural structural systems. Coordination models provide a level of detail reducing the number of decisions to be made in the field. Once models, including MEP, are fully coordinated, contractors can pre-fabricate directly from the model with confidence that the pre-fabricated parts will fit when installed on site. Prefabrication allows for considerable schedule reductions, improved quality, and superior productivity both on site and in the shop. The preceding paragraphs provide only a sample of benefits associated with BIM and IPD utilization, and in many ways are the results of BIM tool utilization without significant integration.

Integrated Project Delivery Overview

Integrated project delivery is the next generation of project delivery utilizing many of the same concepts as design build. IPD shifts the goal from individual organization success to project success including the success of the project team. Within this paradigm, the failure of one member of the project team is a failure for the project.

A true IPD contract could involve the creation of a single purpose entity LLC (SPE) including the designer, general contractor, and the owner. Major subcontractors are also contractually involved with the SPE and become party to the shared risk shared reward structure. This type of relationship fosters collaborative, project-centric behaviors in contrast to the typical adversarial, self-centric behaviors found on most projects today. In addition to the SPE contract, other transitional forms of IPD exist involving various levels of integration and collaboration.

It is important to note that many organizations are implementing IPD principles regardless of contract type thus realizing the benefits of integration without the formal IPD contract. The level of integration and collaboration are dependent largely upon the timing of involvement. If contractors are involved only after design is complete, it stands to reason that the level of impact contractors can have on design would be limited. However, benefit is still to be had through the identification of design errors or constructability issues prior to construction.

It is also important to note that firms are finding significant benefit in using the concepts of IPD to integrate functions within their own organizations. For contractors who perform different scopes of work such as duct, piping, and plumbing, coordinating and consolidating efforts within the firm can result in significant benefit. Some firms have strategically marketed their firms as single source providers of multiple services claiming schedule and price advantages as a result of integration.

BIM and IPD are not synonymous yet most projects using an IPD contract, including a SPE, have utilized BIM because of the increased level of understanding through BIM enabled collaboration. Additionally, projects utilizing BIM are finding the concepts of IPD to be invaluable. The synergy of BIM enabled IPD is significant. Organizations that have successfully implemented BIM are utilizing IPD concepts and processes even if they are not calling it such.

BIM and IPD for Sheet Metal and HVAC Contractors

Many of the general benefits outlined in the above overview sections for BIM and IPD are being realized by sheet metal and HVAC contractors. This section will provide more insight into specific benefits for SMACNA members.

BIM, 3D CAD and Coordination

As mentioned previously, systems 3D modeling and coordination has been utilized for many years and in some ways was the first use if BIM concepts for contractors. Subsequently, this has placed some progressive systems contractors ahead of the curve. On many projects these contractors are given responsibility for coordination and, some argue, management responsibility for this scope of work.

Because of the early involvement of systems contractors utilizing 3D CAD, many of the modeling tools still in use today are 3D CAD instead of parametric or smart modeling tools. The main difference between 3D CAD applications and parametric or SMART modeling applications is the intelligence of the components. Intelligent components know their relationships to each other. In a 3D CAD model, if a component is replaced with a shorter component the other system parts are not aware of the change. The change requires manual movement of the other components creating more work for the modeler and the potential for an inaccurate model as some changes may be missed. In a parametric model the components would move to accommodate the new shorter part. However, many of the parametric tools do not utilize "real" or actual components in their models thus do not have the capacity to produce shop drawings or enable automated manufacturing . It is very likely that this challenge will be quickly overcome as venders add product specific libraries to their modeling applications.

Currently a wealth of BIM and 3D CAD software products are available to sheet metal and HVAC contractors. Determining the right application for a specific business is often a challenge. In addition to finding an application to fit an organization, some owners have software specific requirements necessitating a duel modeling effort. An additional challenge for systems contractors is the different needs and outputs for designers and contractors. Design models have different requirements thus different information associated with the model than construction models. Design models don't have component or part specific information and rarely is there a strong effort toward coordination. Some argue that coordination efforts by designers provides little value as constructors know how the system will be built and are better able to coordinate.

Another major challenge is the lack software interoperability. Each trade, be it structural, architectural, mechanical, electrical, or plumbing will likely use different modeling tools designed specifically for their trade. So how do these trade specific models become one "Building Information Model?" Several efforts are underway which allow export and import of geometric shapes as well as some model intelligence. One such effort is the development of a common file format "Industry Foundation Class" or IFC. Until this interoperability is fully realized, the industry will continue to bring models together for coordination and other efforts using software such as NavisWorks or Solibri. These applications combine 3D models of the different trades into a single model. However, information is lost in this integration effort. For example, information such as flow rate and material specification are not included in the integrated or "federated" model, but collision detection and reporting can be achieved. With IFC's some intelligence is maintained but more work needs to be done.

The coordination process utilizing a "federated" model has been utilized on many projects. To accomplish true coordination several iterations of collision reports, modeling fixes, and reintegration are typically needed. This coordination and integration process has become so common that many groups have optimized the coordination meetings process. In one coordination process a single coordination facilitator will integrate the multiple models and generate a report of issues. During the following coordination meeting, representatives from each trade make updates to their respective models and resubmit to continue the coordination process.

There are organizations that claim to produce coordinated drawings yet they are not utilizing the benefits of BIM. It has been repeatedly the case that, unless all trades are integrating their models into one 3D collision detection environment, the coordination output remains largely uncoordinated. These less successful attempts are exposed when owners or GCs hire third parties to produce a 3D Model from the “coordinated" 2D documents only to find a significant number of collisions or problems. The collision detection software packages provide a visual communication platform far superior to the technologies of the past (light tables). As adjustments of a pipe or duct are made, it becomes apparent how the proposed solutions will impact the other systems or solve the problem. As mentioned previously, BIM or a coordination modeling provides a level of confidence in the accuracy of the model to allow prefabrication. The benefits of prefabrication can have a significant impact on project and organizational profitability.

It's easy to foresee how BIM is revolutionizing the concept of "As-Built." As 3D coordination efforts become increasingly more effective, the concept is shifting to "Build As-Modeled." Many software packages have the capability of annotating elevations and dimensions of the 3D model into 2D construction documentation. Automated updates of this information, allow the coordination team to produce a detailed documentation set from the coordinated model, with little rework due to the modeling changes. Many systems are now connected to surveying equipment facilitating both layout and validation. With this level of accuracy, it becomes more difficult for field workers to install systems contrary to the coordinated model. The accountability created through this accuracy of information creates another reduction in waste in the field.

Another concept being discussed is the shift from "Design Build" to "Build to Design." The idea of over sizing fans to account for unplanned bends and pressure drops is fading. Rather, from a schematic layout, the coordination model can be communicated to the design team to facilitate a more conservative design assist process. Once all of the components are accurately sized within a coordinated model, the design team can safely specify and apply links to cut sheets and O&M manuals to the modeled equipment.

4D Scheduling

Furthering the use of the "I" in BIM, many 3D modeling software packages facilitate a quantity take-off of the specific runs, parts, and fittings that comprise a model. Some applications have Microsoft Excel based quantity exports that can be formatted to produce full estimates, while others have built in customizable databases for the same. Most organizations generate estimates based upon quantities and units/man-hour rates. Surprisingly, rarely are these productivity rates linked to the schedule. Recent advances in software have led to companies implementing quantity and productivity based schedules. In these new applications, task durations are derived from the quantities and productivity rates rather than a somewhat arbitrary percentage of the overall schedule. Additionally, because the quantities are pulled from a model, activities can be separated by location such as floors or zones. Location based scheduling derived from model based quantities and production rates has not only made scheduling practices much more accurate, but also more visually intuitive. Software now gives us the ability to see what trades are working where and when. Some have called this schedule collision detection of your labor force. Schedules can now be optimized to create a smooth, labor collision free work flow. These schedules can also be tied back to the 3D modeled quantities to produce what the industry is calling a 4D simulation model. This animation can be used for analyzing schedules like never before. It's very difficult to see scheduling mistakes on a Gant chart. However, while viewing a 4D animated schedule it becomes easy to see a roof top unit placed on the roof before the roof structure is in place.

Preparing for the Shift to BIM and IPD

Challenges to BIM and IPD Implementation

The AEC industry is fragmented and not trained to play well together. Traditional project delivery methods by their nature are adversarial and have created a mindset of self or organization centric attitudes and behaviors. This traditional paradigm greatly inhibits the realization of the full benefit of BIM. The most successful BIM projects are utilizing some form of negotiated contract other than design bid build (DBB).

IPD utilizes many of the same concepts of the design-build (DB) and in fact, DB is a form of integrated project delivery. With this in mind, the various forms of IPD are subject to the same challenges experienced by so called DB projects. Contrary to the seemingly apparent benefits of DB project delivery, several studies have found that DB projects show little benefit over traditional DBB projects on several measures. One possible explanation of these findings is that companies claiming design-build capabilities to win the work, execute the project working under the DBB paradigm. In other words, one of the biggest challenges to integrated project delivery methods is an opposition to change. IPD requires a willingness to work together even if it means giving a little and trusting project partners. Those who have found success in BIM and IPD implementation recognize that trusting and giving a little is often synonymous to an investment translating into returns for all.

Often problems with implementation are a result of the organizational structure of a company or companies. If the companies trying to execute a DB strategy have an organizational structure and processes that support DBB then problems will arise. The company and project structure may be detrimental to DB fundamentals. Additionally, the communication capabilities of traditional 2-D documents hinder the level of collaboration necessary for DB success. BIM tools enable IPD, including DB, through collaboration enabled by more effective communication.

Keys to BIM and IPD Implementation

BIM and IPD integration is best accomplished by developing an integrated organization, integrated processes, and working within an integrated contract if possible. Currently many organizations are forcing the BIM/IPD peg into the traditional AEC hole with notable but constrained success. Continuing to work within the non integrated model of BIM groups and departments will greatly limit capitalization of opportunities for organizations looking to realize the benefits of IPD/BIM. The benefits of organization and project integration are as significant as the difficulty associated with implementation in an industry averse to change.

Review of Best Practices

Though it would be a challenge to find any organization that has perfected every BIM process, there are a few recurring BIM Coordination practices that have continually proven successful. The ideas of developing a Coordination Protocol, extending coordination to “no fly zones”, and applying the concept of "Co-location" are all great practices.

Coordination Protocol

Developing a 3D Coordination Protocol is key even though it could vary slightly for each project. This protocol can be flooded with necessary file naming conventions, color schema, and uploading rules. Whatever the protocol, it is critical that the rules be agreed upon and followed by the entire coordination team. The protocol should also include a System Priority Structure, System Elevation Structure, and Collision Identification and Ownership rules.

Although all systems are highly important, some take up more space, are more difficult to relocate, and are less easily modified for obvious reasons. To avoid arguments and ensure a systematic approach, a "System Priority Structure" is a critical protocol. Common system priority structures have begun with HVAC Main Duct Systems followed by gravity piping due to the elevation limitations etc. Each team might choose differently, but the idea is to agree on fixing the most constrained systems, with regards to size and flexibility, first. To compliment this rule set, the option of staggering the beginning modeling effort section by section may be considered.

A system elevation rule could also be a great initial start. Obviously, if the MEP subs were ever given enough room to simply stack HVAC Duct above Mechanical Pipe above Electrical, etc, etc... this rule would be flawless. Even though it would be a rule that's frequently broken, attempting to place specific systems within a given elevation of the interstitial space whenever possible will eliminate an enormous amount of initial collisions.

No Fly Zones

Common omissions during coordination are accessibility, operational space, and code enforcement. Each trade knows very well where they will need access or space for maintenance, flow adjustments, and code enforcement. Space allocations for these considerations rarely get placed into a coordination model. Extend your coordination efforts to include "No Fly Zones" and give your systems the operational space required. Discuss with your team the importance of planning for operation and maintenance. Examples of no fly zones include clearance for rising valve stems and a "no fly box" placed in front of electrical panels to represent the proper clearance.

Co-Location

The project timeline will typically drive many decisions about communication between trades, collisions avoidance and resolution, and facilitation of the process. Many projects have found "Co-location" to be one of the most beneficial conditions enabling the coordination process. Co-location is the concept of having as many of the multiple trades' modelers as possible share one physical working location. The benefit is the improved efficiency of communication. Similar results can be achieved with telecommunication these days as well. Screen sharing allows trade modelers from remote locations to view the same model and coordination issues simultaneously. This efficient communication allows for live adjustment in each trades model to achieve coordination. Obviously, the coordination meetings of old have not vanished; rather they've just changed shape. Instead of light tables and mountains of plans on tables, now our coordination meetings consist of all trades with their laptops surrounding a projection screen of the integrated model and clash detection report. True co-location includes systems modelers working in the same location outside of the coordination meetings. During true co-location, systems detailers can coordinate with other systems detailers throughout the modeling process. This is the true "co-location" that is desired. The more frequent this condition is possible, the better the coordination efficiency.

The AGC Spatial Coordination Requirements

The AGC BIMFORUM has recently distributed a document outlining spatial coordination requirements. It is likely that information from document will find its way into contract documents and will influence GC requirements for coordination. The document is also informative to the processes procedures and requirements for effective coordination. For this reason it has been included in this document as appendix A.

Benefits of Implementation

In spite of the difficulty of implementation, integration has been utilized on several large and small projects with resounding success. The pioneers of BIM enabled IPD have found success through alliances with likeminded project partners. These “A teams” have begun to make the paradigm shift necessary for successful integration. They have also initiated appropriate changes to the organizational structure for the company and project teams, which includes new and changed roles within each organization. Early integrated projects have found improvements in collaboration and communication even beyond what has been realized through the use of BIM tools alone. Subcontractors working on these integrated projects are realizing cost, schedule, and quality improvements so significant that they are pledging estimate/cost reductions for future BIM/integrated projects. Additionally, integration will provide opportunities to realign roles and responsibilities of the organizations allowing for improved productivity. An example of responsibility realignment is the opportunity for a single contractor to install all hangers required for MEP installation prior to installation of any duct, pipe, conduit, or cable trays. For companies currently utilizing BIM, organization and project integration (IPD) is the next big step toward realizing the full potential of current and future BIM tools and will provide additional meaningful differentiation for those willing to implement.

Appendix A: MEP Spatial Coordination Requirements for Building Information Modeling

This document from the Associated General Contractors of America (AGC) will be added soon.