Moving Beyond BIM – Essential Skills for Next Generation Engineers

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Abstract

To address the surging demand for Building Information Modeling (BIM) and Virtual Design Construction Managers (VDCM) throughout the National Capital Region, George Mason University initiated a new BIM course that is a synthesis of traditional CAD and GIS, combined with project design. The students formed into interdisciplinary "quasi" Integrated Project Delivery teams, used a variety of tools and methods to include Google Earth, Google Sketch Up, Autodesk Revit, and the US Army Corp of Engineers COBIE and Pennsylvania State BIM Project Execution Planning templates to work through a full BIM planning, design, and submission cycle.

Keywords
BIM, VDCM, CAD, GIS, COBIE, IPD

1. INTRODUCTION

To address the surging demand for Building Information Modeling (BIM) and Virtual Design Construction Managers (VDCM) throughout the National Capital Region, George Mason University initiated a new BIM course that is a synthesis of the traditional CAD and GIS courses, combined with project design. The students formed into interdisciplinary "quasi" Integrated Project Delivery teams, used a variety of tools and methods to include Google Earth, Google Sketch Up, Autodesk Revit, and the US Army Corp of Engineers COBIE and Pennsylvania State BIM Project Execution Planning templates to work through a full BIM planning, design, and submission cycle. Students were taught about integrated site design, space and massing, federal and industry physical security design and design basis threat, energy modeling, and LEED. Because both the federal government and industry are embracing BIM, students were also taught about the legislation, policy, and implementation challenges of BIM. Guest lecturers from government and industry discussed BIM Roadmaps, team composition, project management, integrated project delivery, contracting, and construction delivery methods. The capstone of the course was the student team presentation of their Team BIM Project and Lessons Learned. The students found the Google software to have a medium learning curve, and the Autodesk Revit software a steep learning curve, but once mastered, the software dramaticlly accelerated project design. The students also thought the new skills combined with the knowledge of industry and market drivers, and insights into BIM roadmaps, would make them more vaulable in the workforce.

2. INDUSTRY NEED FOR BIM AND VDCM SKILLS

Although Computer-Aided-Design (CAD), Geospatial Information Systems (GIS) and Building Information Modeling (BIM) software has been used for many years in the design and construction industry, the current generation BIM techologies are disruptive and dramaticlly impacting the way buildings are planned, designed, delivered, operated and maintained. The traditional Architect-Engineer-Construction-Operations & Maintance (AECOM) community is undergoing a major transformation; an industry born of the guilds and trades and notorious for inefficiency and lack of a data interoperability is trying to figure out how to tame the BIM technology tiger. Two or three years ago, the industry did not have BIM Manager or Virtual Design Construction Manager labor categories; now there is an exponential growth demand curve for engineers at all levels with BIM, CAD, GIS and project management skills who have the ability to deliver projects on time, on budget, and of the highest quality.

2.1 George Mason University Civil, Environmental, Infrastructure Engineering Department and Industry Demand Driven Curriculum

The Geroge Mason University Civil, Environmental, Infrastructre Engineering (CEIE) Department has grown from 73 students in 2001 to over 375 students in 2010. The growth is directly attributable to the strong federal presence, strong economic strength of local governments, and the private sector demand for technical services profesionals. While offering the traditional engineering curriculum, the CEIE Department is able to draw on a cadre of Adjunct Faculty who can quickly develop courses to provide the new skills sets required by the market. The CEIE 680 BIM course is an example of a course that is a synthesis of traditional CAD, BIM, GIS, and combined with Integrated Pproject Design (IPD), that is beginning to supply the demand for BIM and Virtual Design Construction Managers, IT-savy engineers with multidisciplinary skills, and with the speciality knowledge

to understand and interept the challenging federal physical security, IT security, and sustainability requirements for federal and commercial facilities.

3. LEGISLATION, POLICY, STANDARDS AND GUIDES, MARKET DRIVERS

To expose students to the broad topic areas, guest lecturers from government and industry discussed legislation, policy, standards and guides, and market drivers.

3.1 Legislation, Policy, Standards and Guides

Federal legislation, Executive Orders, Standards and Guides provide a framework for the use of BIM across government and industry. During the course, speakers discussed legislation, policy, standards and guides, and how BIM is being implemented in government and industry.

Figure 1 – Legislation, Policy, Standards, and Guides

3.2 Market Drivers

Legislation and policy can be broadly reflected in market and industry drivers; in the case of BIM, the federal government began to require projects to be delivered in BIM and began to develop BIM roadmaps and issue Solicitations For Offer and Requests For Proposals with BIM as a requirement. The General Services Administration BIM Guides and the US Army Corps of Engineers BIM Roadmaps and the industry use of Design-Build began the acceleration and adoption of BIM by the AECOM community. Many federal agencies are using BIM as part of the strategic capital facility investment plan, Master Plans, Space Plans, and Facility Operations and Maintenance Plans. The US Army Corps of Engineers MILCON Transformation initiative, the requirement for BIM reflected in the contracting Attachment F, Construction Operations Building Information Exchange (COBIE), and Army RFP's with BIM language are pushing the industry to use the software and develop the legal and professional framework to utilize BIM to its full potential.

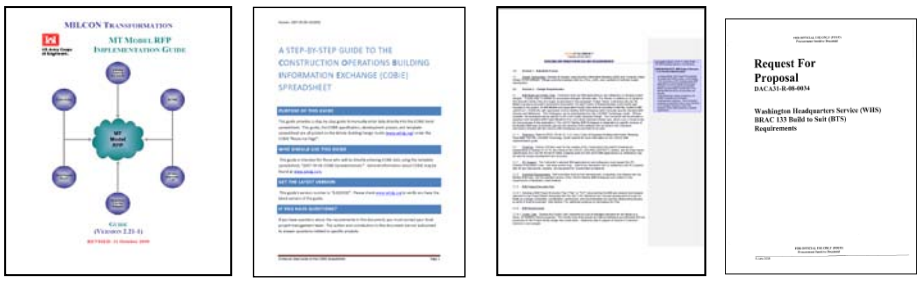

Figure 2 – USACE RFP Guide, COBIE, Attachment F, and BRAC 133 RFP with BIM

The federal government mandates to use BIM were initially partially driven by the need to bring a more efficient process for the delivery of facilities and obtain the highest quality facility and the best cost. The AECOM community, in turn began to realize the life-cycle of facility data and the reduction in waste that BIM could offer. A study by Trane[1] found that there was no single benefit of BIM that seemed to dominate, but rather a combination of several benefits such as clash detection, customer visualization, increased accuracy, and faster trades coordination. Likewise, the 2008 SmartMarket Report[2] found that the top benefits of BIM were eeasier coordination of different software and project personnel, improved productivity, improved communication, and improved quality control.

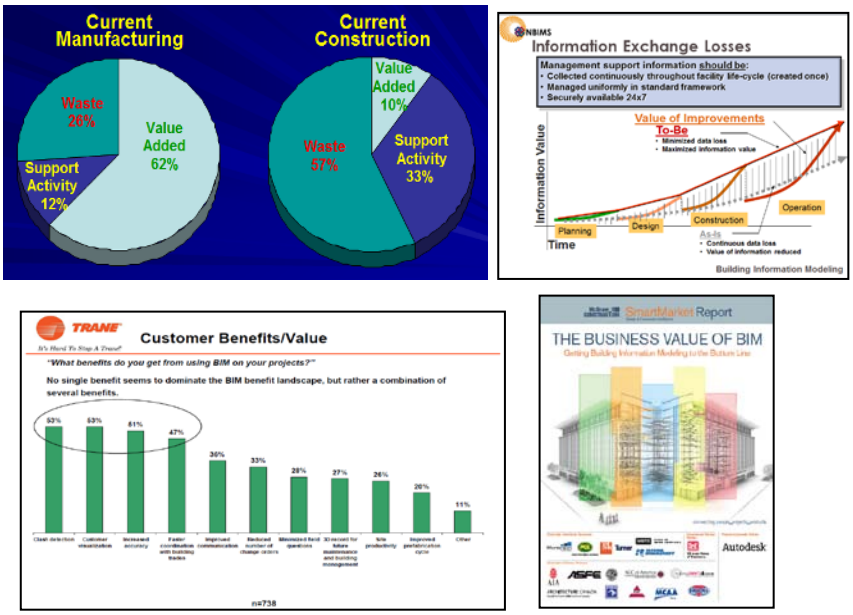

Figure 3 – buildingSmartAlliance, Trane and SmartMarket Reports

Executive Order 13514 Federal Leadership in Energy, Environment and Economic Sustainability, issued in October 2009, has 10 goals which include High-Performance Green Buildings, and enhanced local and regional planning, which in turn has established new markets and services that are BIM, GIS and O&M centric.

The AECOM and software industries are now moving to 6D BIM that integrates the complete building life-cycle data, sometimes referred to as Facility Information Models (FIM). As BIM moves from 3D to 4D, to 5D, and now to 6D, the next generation engineers are using and creating tools and business processes that take the traditional linear facility delivery model and turning it into a parallel and multi-dimensional delivery process where Request For In-

formation, Change Orders, building system component clashes, and potential litigation issues are resolved in real time around the table and by video call with smart boards. Students now need to learn not just the technical use of the tools, but also topics such as Integrated Project Delivery, BIM Roadmaps, team composition, project management, acquistion and contracting, and construction delivery methods.

4. IPD+GE+GIS+CAD+BIM+LEED = NEXT GENERATION ENGINEER SKILL SET

The changing business processes, tools, and technologies are resulting in transformation across government and industry. Those organizations that embrace change and plan for change are those that are able to adopt and react to both disruptive, as well as evolutionary technologies. In the CEIE 680 BIM course, students formed into "quasi" Integrated Project Delivery teams, used a variety of tools and methods to include Google Earth, Google Sketch Up, Autodesk Revit, COBie and BIM Execution Planning templates to work through a full BIM planning, design, and submission cycle; simulating as closely as possible the emerging work enviornment.

4.1 Integrated Project Delivery Teams

As the AECOM industry continues the evolution from Design-Bid-Build, Design-Build, CM At Risk, and other delivery methods to newer forms such as Integrated Project Delivery, the course curriculums must change to incorporate learning objectives to meet the needs of the industry. IPD concepts and terminology was one of the first units taught early in the semester, based on the California IPD, Autodesk IPD with BIM, ConsensusDocs, AIA, and other industry standards and best practice. Creating a true IPD in an academic environment is challenging as the students do not have the multiple disciplines or skill sets required; the students formed into "quasi" IPD teams to replicate the functions and concept as closely as possible.

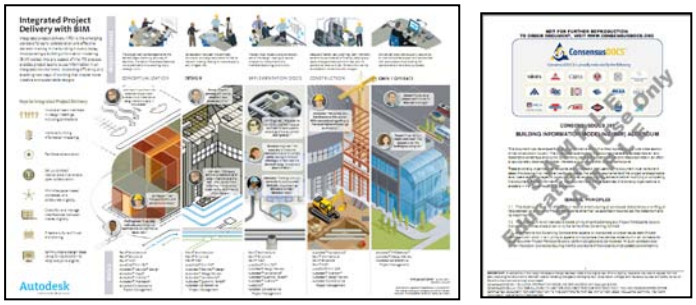

Figure 4 – Autodesk IPD and ConsensusDocs BIM Addendum

At the beginning of the spring 2010 semester, the class was polled to see how many students had worked with Google Earth, Google Sketch Up, CAD, BIM, and LEED applications or been involved with IPD. Of the 25 students, less than 5 could claim experience or knowledge of those application or IPD; by the end of the semester every student had become proficient with the applications, and for the students also completing their senior design project, had embraced the tools and use of the "quasi" IPD to set a new standard for senior presentations. Using the IPD framework, the students formed into 5 teams with 5 members each. The students were ready to embark on the first step, use of Google Earth and Google Sketch Up to create a georeferenced model of the new GMU Engineering Building.

4.2 Google Earth and Google Sketch Up Georeferenced Model

The students were given a scanned jpg of the new GMU Engineering Building floor plan and required to model the building, roads, and grounds in Google Sketch Up, and place the model back into Google Earth properly georeferenced.

Figure 5 - Team Shalaby and Team Patriots SketchUp Model in Google Earth

Many of the students were also seniors taking Senior Design; having used Google Sketch Up for the BIM course, they quickly adopted the tool to use for the design project and created models and full fly-throughs which were used in the design presentations and have set a new bar for the next senior design class to meet. Having gained some basic understanding of 3D modelling, space, massing, and georeferencing, the students were ready to tackle the next challenge, the BIM Project Execution Plan.

4.3 BIM Project Execution Planning Procedure

The student teams were provided the Pennsylvania State BIM Project Execution Planning templates[3] and each team created a project plan. Even though it was stressed multiple times for the teams to consider workflow and use of central file and worksets, the practical implications and potential flaws in the plans and how students might use university computing resources, Google Docs, Glove Box, Share Point, and other alternative file sharing schema was not fully appreciated until each team experienced multiple failures and learning by trial and error resulted in the BIM Project Execution Plan being a living document.

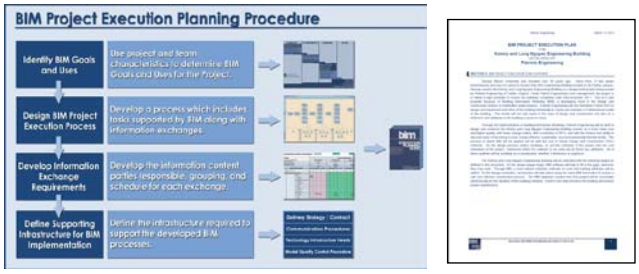

Figure 6 – BIM Template and Team Patriots BIM Project Execution Plan

For an academic exercise, the project planning templates are fairly complex and most students did not have the IT, industry, or BIM experience to be able to fully complete the templates. However, the students did appreciate the use of the template to keep track of the various methods used before success with the IT systems was achieved.

4.4 Team Project

The team project presentation of their BIM and Lessons Learned was the capstone of the course. For the Team Project, each of the student IPD Teams had to model the recently completed Long and Kimmy Nguyen Engineering Building on the GMU Fairfax campus. The teams were provided the GMU campus topographical data in CAD format, and allowed to use any combination of computing resources available to create the BIM and presentation. Each team had to present the team BIM, with each team member speaking for at least two minutes. The team presentation had at a minimum to include the following BIM features:

- Topo and building pad
- Exterior (3 curtain wall options)
- Interior walls, doors, windows
- Stairs, railings, elevators (one of each)
- Dimensions and Tags (external, internal)
- Views and Sheets (north-south, east wall section, develop and use team sheet)
- Schedules and Details (door, room, foundation, wall, roof)
- Rendering and Walkthrough
- Time – 25 minutes, 5 minutes Q&A

As each course unit was taught, the students began to incorprate the technical skills using Autodesk Revit 2010 with the design requirments. All of the teams complted the assignment, and exceeded the minimum requirements. Once students began to fully use the software, they quickly began to enhance the model to include placing furniture and landscape features, energy and LEED analysis, and multiple renderings.

Figure 7 –Revit Team Project Topographical, Elevation, Space and Structure Standard Sheet and Lobby Rendering

The student teams took different approaches to setting up the IT environment and splitting the “quasi” IPS project work assignments. During class sessions, when one student figured out a problem, often they would go to the board and share the solution with the other students. Some of the Lessons Learned were:

- Team members should regularly update the BIM Project ExecutionPlan
- Teams should decide on use of work sets and central file setup before starting the project
- School desktop computers are wiped clean every night, resulting in loss of data and links that have to be recreated on each log in
- School desktops although running 64-bit and 4 megs of RAM, took several hours to process one rendering; teams would commadeer multiple computer labs and run several rendersings at once and students took turns manning the computers while others attended class
- Use of the school networks to share a central file was not allowed by school IT policy, a networked computer lab with a server that remains in place for the semester (i.e., no daily wipes) is needed
- Use of alternate file sharing applications such as Google Docs and Glove Box don’t recognize Revit extensions and can’t synchronize a central file, while Share Point and Grove stored and allowed access back to file, but could not act as a network central file
- Changes in workflow and team assignments are as important as production of the actual BIM
- The initial Revit learning curve is steep, but once the teams began to build on each subsequent step, the speed and accuracy accelerated; each team “started over” more than once from the topographical map and building pad
- Just like CAD, Undo is still the most used feature

The students were asked to rate the course difficulty and level of hours required against other senior and graduate courses. The course was rated as difficult and taking more hours to complete than other courses, and on par with the senior design project. However, the students also expressed high satisfaction with the exposure to the full suite of tools, IPD, and understanding of the market drivers that would likely give them a skill set and resume that would stand out in comparison to their peers.

5. CONCLUSION

The George Mason University CEIE 680 BIM Course was developed to provide the industry and market desired skills for engineers with the education and training to provide state of the practice professional services. These skills include BIM, CAD, GIS, and IPD, augmented with the understanding of the legislation, policy, standards and guides that are rapidly being developed as a result of the BIM impacts in the marketplace. Students felt the course provided a new skill set that would be of value in the workforce.

6. ACKNOWLEDGMENTS

The course was highly enriched by the guest speakers who brought their domain knowledge and experience to share; giving up their evening and personal family time to speak to the students. Their time and commitment is gratefully acknowledged:

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- Kurt Maldovan, Design & Construction Visualization Coordinator, Jacobs
- Mark De Gama Rose, Design Technology Manager, Jacobs
- Deke Smith, Executive Director, building**SMART**alliance
- John Harriman, Chief Mechanical Engineering, SmithGroup
- Louise Sabol, Director of Technology Solutions, Design + Construction Strategies
- Charles Matta, Chief Office of Modernization, GSA
- Robert Bank, Chief, Civil Works Branch Engineering & Construction, US Army Corp of Engineers

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