# CONNECTING TECHNOLOGY, INDUSTRY AND RESEARCH: A VERTICAL INTEGRAL PROJECT COURSE FOR BIM EDUCATION OPPORTUNITIES

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**ABSTRACT:** Building Information Modeling (BIM) is utilizing CAD technology in a way that ultimately ties all the components of a building together as objects imbedded with information, and has been changing the way we design and build over the last 20-30 years. In Polytechnic Institute of NYU, there are four BIM courses offered which provide students with different levels of knowledge regarding BIM Technique, BIM Standards, BIM Guideline and Roadmap for Private and Public Implementation, BIM Application in Real Projects, the Cooperation of BIM and IPD for Public Works in New York City. With advanced BIM technology, BIM's integration into the construction process and its incorporation into project delivery systems, especially Integrated Project Delivery (IPD) are the bridges between technology, industry and research. This paper presents an integrated BIM curriculum with three modules: 1) BIM functions and Bid Preparation; 2) Time-Cost Trade-off Analysis; and 3) Problems Solving in BIM/IPD Environment. In this project-based curriculum developed by the common efforts of academia, public agency and industry, the objectives are: (1) to provide the information and skills needed to successfully implement BIM into the construction phase; (2) to identify BIM's role in construction and the project delivery system; (3) to develop a module in conjunction with leading BIM into project delivery system, particularly coordination between BIM and IPD; (4) to connect technology and research into industry. The course assessment was conducted and the results indicate that it is a successful reform in construction management education.

*Keywords: Building Information Modeling (BIM); BIM Education; Curriculum Integration; Project Delivery System; Integrated Project Delivery (IPD).*

## 1. INTRODUCTION

The National Institute of Building Sciences (NIBS) defines Building Information Modeling (BIM) as follows:

> A building information model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility.

BIM is becoming a huge success in design and construction firms worldwide, but its true value remains in fully implementing BIM across the life cycle and bringing full benefits to the industry by increasing technology use. BIM is changing the way projects are built and how business is conducted. We still have a long way to go before our industry changes the business process. In addition to the BIM standards and guidelines, the education curriculums also need to change to suit the construction industry culture change.

Educational institutes in many countries have started teaching BIM applications and have set up curricula for BIM related to the Architect, Engineer and Contractor (A/E/C) industry. In the U.S., several educational institutions are introducing BIM in their curriculum [1-3]. There are many ongoing modeling courses being offered at major universities in the U.S. and a few shorter training courses in institutions and associations. But it is noted that the courses for BIM are more focused on the BIM applications and program products, and those courses concentrate on design domains and seldom for the construction management process and project delivery system.

A vertical integral project course for BIM education was designed for the graduate construction management major at the Polytechnic Institute of NYU with four objectives: (1) to provide information and skills needed to successfully implement BIM into construction; (2) to identify BIM's role in construction and project delivery system; (3) to develop a module in conjunction with leading BIM into project delivery system, particularly coordinating between BIM and IPD; and (4) to connect technology and research into industry. The course described in this paper was designed through a joint effort of NYU academic senior professors, the New York City Department of Design and Construction (DDC), the W.J. Northridge Construction Corp. and Group PMX in New York who are representing public project owner, designer and contractor respectively in this academic environment

## 2. BACKGROUND OF CASE STUDIES

BIM is currently regarded by many people as the most powerful tool in the design and construction industry. It allows designers to analyze and explore alternative design concepts and iteratively optimize design outcomes. It allows contractors to rehearse or simulate construction, prepare cost data, prepare shop drawings and fabrication drawings, and coordinate with subcontractors, suppliers and fabricators to reduce misunderstanding and improve work efficiency. Owners can use the data to manage facility operations and maintenance throughout the project's life cycle. All key parties who get involved into the project can share the same model, which provides the basic communication platform for coordination and collaboration. Project management, project controls, design and analysis systems, material management, procurement, accounting, coordinated with the 3D computer model are processes which can be incorporated into a Building Information Model [4] (Figure 1).

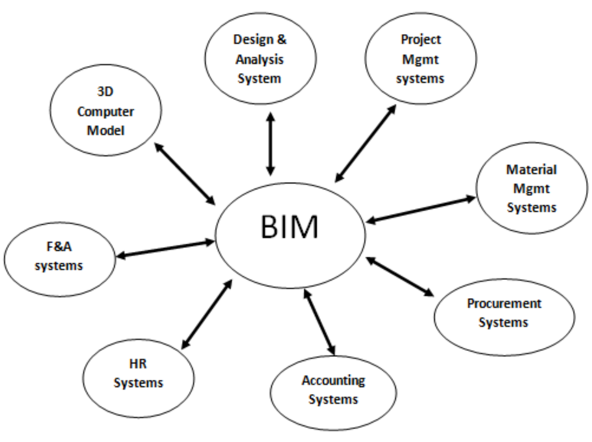



Figure 1 Integrated Building Information Modeling Processes [4]

BIM technology has arrived and is being used by designers, contractors, manufactures and suppliers to reduce rework and waste, and improve quality and efficiency. The use of BIM has risen significantly and will continue to rise. According to NIBS, BIM model is "a computable representation of all the physical and functional characteristics of a facility." The physical and functional characteristics are just data and information that can be referred, calculated, extracted, analyzed, manipulated, combined or related to other data. The information is provided by all project stakeholders including designers, contractors, manufacturers, fabricators, vendors and others who can contribute to optimize the design and construction during the lifecycle of the project. The design information can be linked to a contractor's cost estimation and constructability information to create a continuous cost data analysis required for a target value design. The contractor's schedule can be linked to a vender's timeline and a subcontractor's schedule in order to make sure the material and equipment supply chain runs smoothly. The design information is also linked with a fabricator's addendum to ensure building components are precisely manufactured, fabricated and delivered to the worksite.

Thus, BIM's promising future is collaborative by nature and focused on the whole project success including project workflows and seamless interactions rather than individual components of the project [5]. BIM information is centrally managed. The most powerful and sophisticated outcomes that can be obtained through BIM, can only be reached by communication and collaboration among all project team members. BIM offers a collaborative framework for multi-disciplines expertise, which means that BIM should be applied as early as possible in the project delivery process.

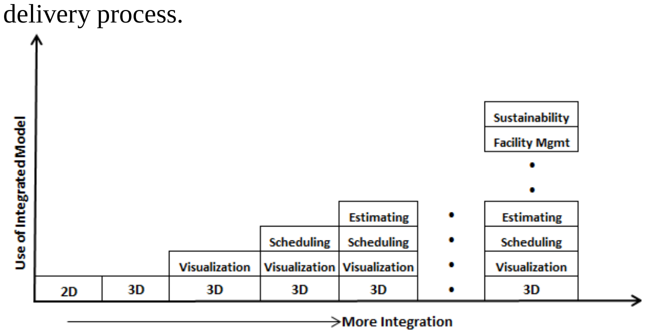



Figure 2 Evolution of Modeling Technology

Using BIM to solve complex and sophisticated problems will eventually lead to its use in collaborative settings in any project delivery system. The traditional project delivery models, such as Design-Bid-Build (DBB), Design-Build (DB) and Construction Manager as Agent or at Risk (CM/A or CM@R), cannot totally fulfill the collaborative template for BIM premises. In 2004 and 2006, the Construction Users Roundtable (CURT) generated two whitepapers urging significant changes throughout the construction process. Communication and coordination among project stakeholders is greatly encouraged. The shift is accelerated by the AIA California Counsel when AIA issued its *Integrated Project Delivery: A Working Definition* (developed by AIA California Council and McGraw Hill Construction in Jun 2007) and *Integrated Project Delivery: A Guide* (Developed by AIA National and AIA California Council in 2007).

IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication n and construction [6].

These AIA documents provide the theoretical framework and create a structure for IPD where the key stakeholders containing the owners, designers, contractors and significant trades are deeply involved in the project with information shared among them. It involves communication, collaboration, coordination, risk and award sharing among the project team, which leads to BIM by requiring a common language and platform for communication and collaboration.

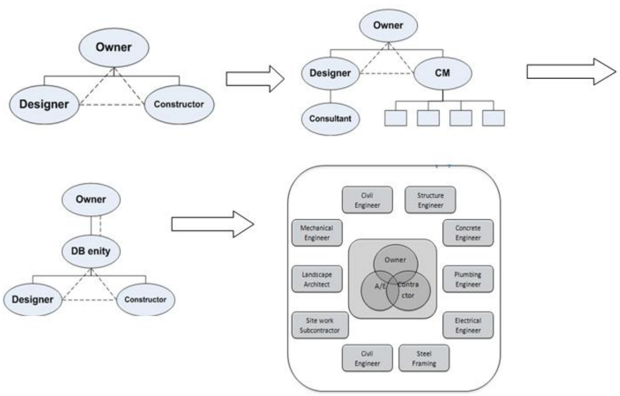



Figure 3 Project Delivery Evolutions (DBB-CM-DB-IPD)

Figure 3 shows the project delivery evolution in construction in recent decades. The evolution of construction project delivery has been pursuing the collaboration effort among the project parties and the advancement for decades. Along with the delivery evolution from DBB to IPD, the adversarial relationships among the stakeholders are gradually changing. IPD is philosophy and there are different levels of this philosophy accomplishment, such as IPD-ish or IPD-lite and pure IPD. The necessary of adversarial relationship changes to team work because only in the team environment can members share knowledge, openly communicate and support each other. Only in the team environment can the BIM be shared and improved based on all team members input. "It is understood that IPD and BIM are different concepts – the first is a process and the second a tool. Certainly integrated projects are accomplished without BIM and conversely, BIM is used as a non-integrated process. However, the full potential benefits of both IPD and BIM are achieved only when they are used together" [6-7].

## 3. RATIONALE FOR THE INTEGRTATED BIM COURSE

The goal of this integrated BIM course is to teach BIM in a way that transfers knowledge and skills in construction to solve real problems in a constrained project delivery environment. Several factors are essential for this integrated BIM course:

1. A broad understanding of basic BIM concepts, the available technology, the functions, legal constraints and insurance issues.
2. Information and skills needed to successfully implement BIM into construction.
3. Leading BIM into project delivery system, especially in IPD.
4. Connection between academic, research and industry, and the connection among technology, knowledge and practices.

Skill learning and problem solving are two main domains in this course that use a case study project and participants for lectures and workshops. The request for proposal (RFP) constrained by New York State Law, issued by a case study public project owner, the New York City DDC, provides the public procurement environment to test the applicability of BIM technology and IPD principles for collaboration among all stakeholders to add value to the project and to benefit all case study participants. The case study project is the Systems Management Engineering Facility III (SMEFIII), located on the Hanscom Air Force Base in Bedford, MA, a three-story, 100,000 square foot steel framed masonry building constructed in 1986. Students will receive a 3D model of SMEFIII, consisting of over 100 drawings. Extrapolating from the 1986 engineer's estimate of approximately ten million dollars, the case study estimate to construct the same building today is about $20 million. Particular location details of the case study building included special requirements for site access, material deliveries and work hours that would affect productivity. Figure 4 is a photograph of SMEFIII sometime after completion.

Figure 4 photograph of SMEFIII

AutoDesk Revit Architecture and MEP suites were used for modeling (Figure 5). Autodesk Revit Architecture software is BIM software and it promotes visualization of design options. Revit MEP software is also a BIM software for mechanical, electrical and plumbing (MEP) systems that provides facility capacity analysis and clash detection. Revit allows the integration among Architecture, Structure and MEP models, by which people can work on Architecture or Structure model separately and integrate them by linking the model in the Revit platform. Modifications are coordinated more consistently across the model with parametric changes. The ability to change a schedule and automatically update the model is a key benefit of Revit Architecture, Revit Structure and Revit MEP [8].

Given the 3D models in Revit formats, students are responsible to perform various typical construction management functions with the model and all other relational databases. Three modules were designed in order to reach the course objectives. In module one, students are responsible to prepare the cost estimation, scheduling and 4D simulation for SMEFIII and submit bids based on the requirement stated in the solicitation issued by the owner, New York City DDC. From this module, students will consolidate the modeling techniques, cost estimating and scheduling. In module two, Time-Cost trade-off analysis is performed to help students to understand the nature of construction full of uncertainties under many situations. In module three, a series of problems related with construction changes and design mistakes are given to class. Students are responsible for solving the problems using BIM functions and IPD principles.

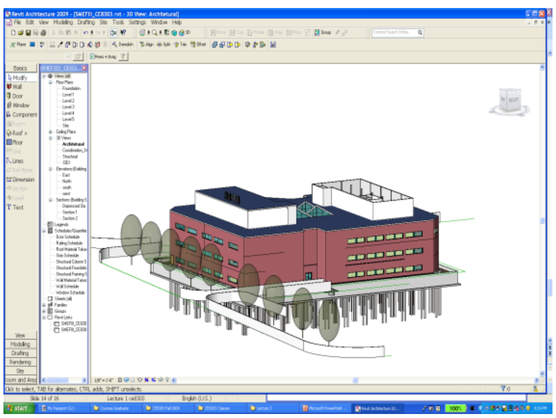


Figure 5 Revit Model of SMEFIII

## 4. EDUCATION MODULES

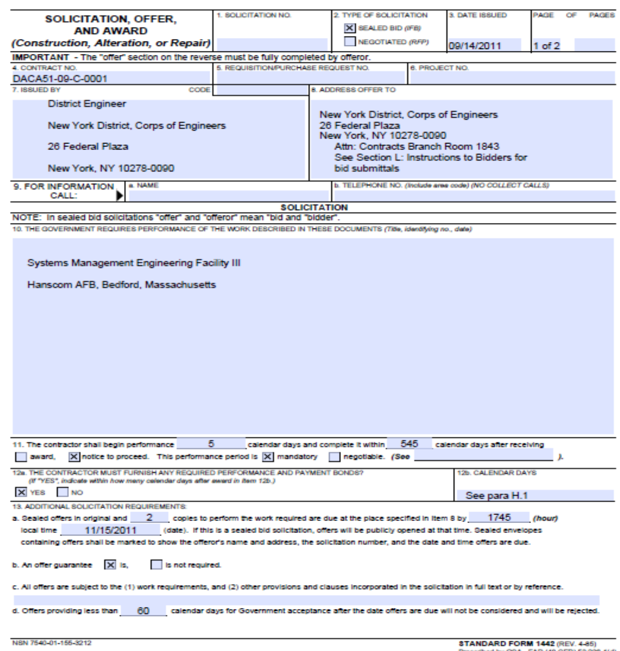
### 4.1 Module 1: BIM Functionality and Bid Preparation

This Module follows a traditional project-based BIM course in which students improve the model and perform BIM functions. Since this course has two prerequisites, Construction Modeling Techniques and Construction Operations Using BIM, students are getting used to BIM and BIM-related software applications, some of which are available online via the class webpage and others directly from the software providers. Some of the software applications are Autodesk Revit and Navisworks, and Primavera Project Planner (P6) from Oracle. Microsoft (MS) PowerPoint presentation tutorials prepared by teaching assistants (TAs) provide easy to follow, step by step support.

For the first ten classes, the students are assigned to four-member teams. Each team is assigned the role of general contractor and is responsible for the following:

1. Develop a cost estimate for the project using the provided preliminary BIM model, including a work breakdown structure (WBS) for the project, allowances for not yet designed elements in the model, and prevailing wage rates for Bedford, MA.
2. Create a base schedule and alternative schedules, including WBS, a Budgeted Cost of Work Scheduled (BCWS) from 0 to 100 percent, and a labor resources usage matrix.
3. Produce a 4D model of the project based on daily progress that demonstrates the concepts for the project's construction.
4. Prepare a construction management proposal, being as specific as possible, as to how to employ BIM and IPD.

Each team is acting as a general contractor and is required to submit a sealed bid, containing one original and two copies, to a specified office by a specified time. All bid requirements are stated in the solicitation form (Figure 6).



**SOLICITATION, OFFER, AND AWARD**
*(Construction, Alteration, or Repair)*

1. SOLICITATION NO.
2. TYPE OF SOLICITATION: [X] SEALED BID (IFB) [ ] NEGOTIATED (RFP)
3. DATE ISSUED: 09/14/2011
PAGE 1 OF 2 PAGES

**IMPORTANT** - The "offer" section on the reverse must be fully completed by offeror.

4. CONTRACT NO. DACA51-09-C-0001
5. REQUISITION/PURCHASE REQUEST NO.
6. PROJECT NO.
7. ISSUED BY CODE
District Engineer
New York District, Corps of Engineers
26 Federal Plaza
New York, NY 10278-0090
8. ADDRESS OFFER TO
New York District, Corps of Engineers
26 Federal Plaza
New York, NY 10278-0090
Attn: Contracts Branch Room 1843
See Section L: Instructions to Bidders for bid submittals
9. FOR INFORMATION CALL: a. NAME b. TELEPHONE NO. *(Include area code) (NO COLLECT CALLS)*

**SOLICITATION**

NOTE: In sealed bid solicitations "offer" and "offeror" mean "bid and "bidder".

10. THE GOVERNMENT REQUIRES PERFORMANCE OF THE WORK DESCRIBED IN THESE DOCUMENTS *(Title, identifying no., date)*
Systems Management Engineering Facility III
Hanscom AFB, Bedford, Massachusetts

11. The contractor shall begin performance 5 calendar days and complete it within 545 calendar days after receiving [ ] award, [X] notice to proceed. This performance period is [X] mandatory [ ] negotiable. *(See* ).

12a. THE CONTRACTOR MUST FURNISH ANY REQUIRED PERFORMANCE AND PAYMENT BONDS? *(If "YES", indicate within how many calendar days after award in Item 12b.)* [X] YES [ ] NO
12b. CALENDAR DAYS: See para H.1

13. ADDITIONAL SOLICITATION REQUIREMENTS:
a. Sealed offers in original and 2 copies to perform the work required are due at the place specified in Item 8 by 1745 *(hour)* local time 11/15/2011 (date). If this is a sealed bid solicitation, offers will be publicly opened at that time. Sealed envelopes containing offers shall be marked to show the offeror's name and address, the solicitation number, and the date and time offers are due.
b. An offer guarantee [X] is, [ ] is not required.
c. All offers are subject to the (1) work requirements, and (2) other provisions and clauses incorporated in the solicitation in full text or by reference.
d. Offers providing less than 60 calendar days for Government acceptance after the date offers are due will not be considered and will be rejected.

NSN 7540-01-155-3212
**STANDARD FORM 1442** (REV. 4-85)
Prescribed by GSA - FAR (48 CFR) 53.236-1(d)

Figure 6 Solicitation Form for SMEFIII

Lectures address planning, development, design, pre-bidding activities, bidding strategies and construction, including the challenges to be anticipated in each of these phases. Scheduling and cost estimating workshops are conducted to help students to

1. Integrate a schedule with the BIM using Primavera P6 and Navisworks;
2. Understand and demonstrate the concept of simulation, cost estimating, scheduling, procurement and information integration;
3. Understand the process of competitive bidding and bid strategy models.

Project deliverable materials included a proposal and a presentation by each team. Figure 7 shows a team's cost estimate and schedule for SMEFIII.

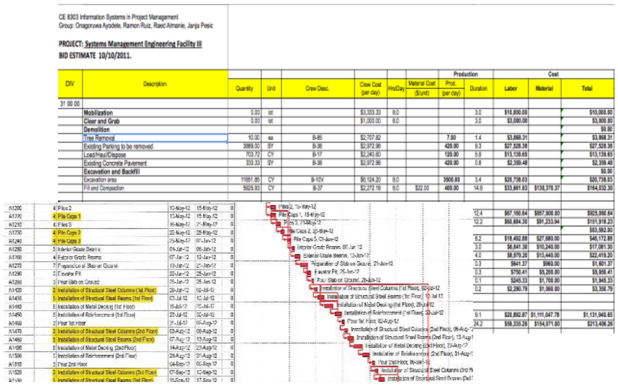


Figure 7 Schedule and Cost Estimate for SMEFIII

## 4.2 Module 2: Time-Cost Trade-off Analysis

The time-cost trade-off problem is a major problem for complex and large-sized construction projects. Schedule crashing, compressing or time-cost trade-off analysis is a scheduling technique used to reduce the original duration of critical path activities by allocating more resources or changing the scope while maintaining quality, to meet a specific deadline with the least incremental cost [4]. Total project cost is the sum of the direct and indirect costs of performing the project activities. Direct costs for the project are directly associated with project activities, such as labor, material, equipment, and subcontractor costs. Indirect costs are not directly associated with a particular activity or a specific project, such as marketing, bonds, insurance, taxes, interests, and overhead and office expenses. Increasing the pace of activities to decrease project duration will increase the project direct costs since more resources must be allocated to accelerate the activities. But, the indirect cost will decrease by decreasing project duration, if they are relatively stable over the life cycle of the project (figure 8 and figure 9).

545 Day Monthly Project Cash Flow

| | Apr 2012 | May 2012 | Jun 2012 | Jul 2012 | Aug 2012 | Sep 2012 | Oct 2012 | Nov 2012 | Dec 2012 | Jan 2013 | Feb 2013 | Mar 2013 | Apr 2013 | May 2013 | Jun 2013 | Jul 2013 | Aug 2013 | Sep 2013 | Period Tota |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | $1,149,843 | $628,943 | $919,075 | $825,474 | $726,564 | $735,910 | $685,337 | $1,015,402 | $973,610 | $895,979 | $1,500,399 | $1,412,570 | $1,233,996 | $1,390,768 | $1,012,357 | $657,858 | $559,714 | $550,320 | $16,874,120 |
| Cumulative | $1,149,843 | $1,778,787 | $2,697,862 | $3,523,336 | $4,249,900 | $4,985,809 | $5,671,146 | $6,686,548 | $7,660,158 | $8,556,137 | $10,056,537 | $11,469,107 | $12,703,103 | $14,093,871 | $15,106,228 | $15,764,086 | $16,323,800 | $16,874,120 | $16,874,120 |

455 Day Monthly Project Cash Flow

| | Apr 2012 | May 2012 | Jun 2012 | Jul 2012 | Aug 2012 | Sep 2012 | Oct 2012 | Nov 2012 | Dec 2012 | Jan 2013 | Feb 2013 | Mar 2013 | Apr 2013 | May 2013 | Period Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | $1,478,950 | $1,013,100 | $1,342,106 | $1,163,770 | $983,171 | $1,334,492 | $1,472,357 | $1,826,952 | $1,760,098 | $1,590,010 | $1,651,429 | $1,327,143 | $901,845 | $816,663 | $18,662,085 |
| Cumulative | $1,478,950 | $2,492,049 | $3,834,155 | $4,997,926 | $5,981,097 | $7,315,588 | $8,787,945 | $10,614,897 | $12,374,995 | $13,965,004 | $15,616,434 | $16,943,577 | $17,845,422 | $18,662,085 | $18,662,085 |

365 Day Monthly Project Cash Flow

| | Apr 2012 | May 2012 | Jun 2012 | Jul 2012 | Aug 2012 | Sep 2012 | Oct 2012 | Nov 2012 | Dec 2012 | Jan 2013 | Feb 2013 | Mar 2013 | Period Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | $1,668,775 | $1,195,876 | $1,681,149 | $1,340,303 | $1,518,834 | $1,731,697 | $2,321,325 | $1,967,636 | $2,010,652 | $1,785,004 | $1,070,989 | $984,971 | $19,277,211 |
| Cumulative | $1,668,775 | $2,864,650 | $4,545,799 | $5,886,102 | $7,404,936 | $9,136,634 | $11,457,958 | $13,425,594 | $15,436,247 | $17,221,250 | $18,292,239 | $19,277,211 | $19,277,211 |

Figure 8 Cash Flows for Three Schedules

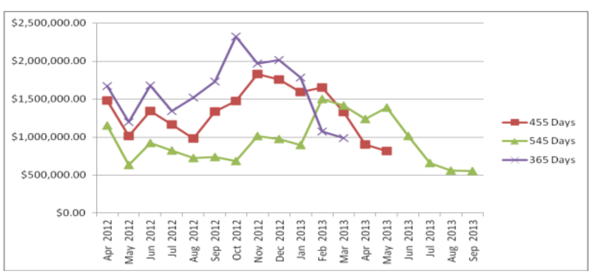



Figure 9 Time-Cost Trade-off for SMEFIII

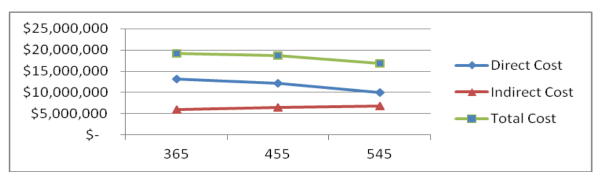



Figure 9 SMEFIII Time-Cost Trade-off Relationship

The solicitation for SMEFIII issued to the class requires each team to prepare the base bid at 545 days (18 months) and two alternative bids at 455 days (15 months) and 365 days (12 months), respectively.

Table 1 SMEFIII Direct, Indirect and Total Cost

| Days | Direct Costs | Indirect Costs | Total Cost |
|---|---|---|---|
| 365 | $13,234,940 | $6,042,271 | $19,277,211 |
| 455 | $12,142,263 | $6,519,822 | $18,662,085 |
| 545 | $10,026,291 | $6,847,829 | $16,874,120 |

The project time-cost relationship can be represented graphically by plotting project duration against direct, indirect and total cost values. One team's work is shown in table 1 and figure 9.

Reducing the duration of the project by 16.5% and 33% increases the total cost of the project by 10.6% and 14.3% respectfully.

In week ten, all teams submit bids with their base bid and two alternatives bids and the proposals illustrate the strategies used to compress the schedules. Since a public agency (DDC) is assumed to be the owner, the project is awarded to the lowest responsible and responsive bidder. The awarded bid will be used for the next module of the course.

## 4.3 Module 3: Problem Solving in BIM and IPD Environment

The last five weeks of the course are devoted to various fact patterns or "situations" designed for the students, acting in the roles of archetypal participants - owner, designer, contractor - to implement principles of

IPD and BIM. Student teams are reconfigured for the IPD environment experiment. Each team is comprised of an owner, a designer, a contractor and a subcontractor. The following player guides are given to each team:

1. You feel you cannot relax the requirement to complete SMEFIII in one year. You gave your word to the user.
2. You have a 5% contingency ($800,000) so you can give some on the cost growth.
3. Quality cannot be compromised.
4. You want to be fair with all parties. For this project to be successful, it must be successful for all parties.

Contractor and subcontractor guide:

1. You have to make money on this job. Losing money is not an option. You made a fair bid for a reasonable price.
2. You want the owner to have a successful project and you are willing to do everything possible to make the schedule except violate the first point.
3. Quality cannot be compromised.
4. You want to be fair with all parties as long as you do not violate the first point.

Designer guide:

1. You have been paid your design fee and are being paid for providing design services during construction. You are responsible for ensuring the contractor satisfy/s the design intent, e.g. you evaluate shop drawings and are responsible to the owner for quality control.
2. You cannot lose money on this job. You run a low cost operation and your credit is stretched to the limit. Your house is mortgaged for this job.
3. You want to be fair to all parties subject to the constraints above.

Once the integrated teams are established, the class begins the BIM and IPD experiment. The IPD method has all project stakeholders (owner, designer, contractor and subcontractor) involved in the construction process and all have an equal voice in project decision-making. The project teams must use BIM techniques and IPD principles to address the problems described in each of three "Issue Packages" set forth below (Table 2) in a manner that eliminates waste, saves time, improves productivity, and creates a "win-win" outcome for all the involved parties.

In the IPD environment, the student team acts as the project executive team. The project management team has been replaced, so that the day-to-day functions traditionally performed by the project management team are performed by the project executive team. The target cost for construction is the lowest responsive bid. Each of the three Issues Packages includes three construction issues, which the teams are required to resolve by using BIM coordination and IPD principles. Each week, for each Issue Package, the student teams present their solutions to the class and guest cast study participants and submit a written report.

Table 2 BIM and IPD Issues Packages

| **Issue package I** | **Brief Description** |
|---|---|
| Schedule Issue | Shop drawing submission has 2 weeks late. |
| Value Engineering | Foundation piles change from 12"ϕ to 10-3/4"ϕ. |
| Quality Control | Pile driving mistakes happen during construction. |
| **Issue package II** | |
| Weather Issue | Heavy rain affects the construction process for 2 weeks. |
| Payment Issue | Owner delayed payment to the contractor for 60 days. |
| Quality Control | Efflorescence happens in the exterior brick wall. |
| **Issue package III** | |
| Clash Detection | HVAC and Structure clash is found in third floor. |
| Clash Detection | HVAC duct conflict with Steel column with criteria 2". |
| Scope Change | Owner change scope by adding bridge linking to an existing building. |

During the issues solving, teams are successfully using BIM techniques as a common language platform and IPD principles as basic rules. In each report, teams summarize the principles that they used for coordination and cooperation and those that they failed at. For each party, their responsibilities for issues are numerated. Most issues are solved within the requirement of party guides, even though there are still teams that are using traditional fingers point way.

## 5. COURSE EVALUATION AND RESULTS

The evaluations are conducted anonymously. Instructors receive a summary report of the multiple choice responses and text copies of written comments. The evaluation is divided into three parts: general course feedback; whether course objectives have been met; and additional comments. In response to each question in the first and second parts, students choose one of the following: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, (5) strongly agree. General course feedback part contains ten questions in Table 3 and course objective questions are shown in Table 4.

Table 3 General Course Information for Course Evaluation

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | (1) | | | | (5) | A detailed online course syllabus was provided at the beginning. (1=no, 5=yes) |
| 2 | (1) | | | | (5) | Grading policy was stated in detail at the beginning of the course. (1=no, 5=yes) |
| 3 | (1) | (2) | (3) | (4) | (5) | The course was effectively organized to promote the learning objectives. |
| 4 | (1) | (2) | (3) | (4) | (5) | Instructor demonstrated mastery of course material. |
| 5 | (1) | (2) | (3) | (4) | (5) | The lecture Instructor was helpful and answered questions outside of class. |
| 6 | (1) | (2) | (3) | (4) | (5) | Feedback on assignments was provided in a timely manner. |
| 7 | (1) | (2) | (3) | (4) | (5) | Textbook/lab manual/material provides quality support for course curriculum. |
| 8 | (1) | (2) | (3) | (4) | (5) | The difficulty of the course was appropriate or as I expected. |
| 9 | (1) | (2) | (3) | (4) | (5) | My work in this course was evaluated fairly. |
| 10 | (1) | (2) | (3) | (4) | (5) | Value was added to my education. |

Table 4 Course Objectives for Course Evaluation

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | (1) | (2) | (3) | (4) | (5) | I understand the concept of (3D) and (4D) Building information models (BIM). |
| 12 | (1) | (2) | (3) | (4) | (5) | I can integrate the schedule to the BIM model using Primavera P6 and Navisworks. |
| 13 | (1) | (2) | (3) | (4) | (5) | I understand the concept of simulation, cost estimating, scheduling, procurement and information technology. |
| 14 | (1) | (2) | (3) | (4) | (5) | I understand the process of Project bidding and project handling. |

Evaluation results are summarized in table 5.

Table 5 Course Evaluation Results Summary

| | Questions | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Count | 28 | 28 | 28 | 28 | 27 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| Mean | **5.00** | **4.71** | **4.79** | **4.79** | **4.93** | **4.64** | **4.57** | **4.79** | **4.79** | **4.79** | **4.64** | **4.79** | **4.79** | **4.86** |
| STD | **0.00** | **1.07** | **0.58** | **0.8** | **0.27** | **0.97** | **0.76** | **0.8** | **0.8** | **0.8** | **0.5** | **0.43** | **0.43** | **0.36** |

For the third part, some comments from students include:

1. Overall, the class was great. We learned how to prepare bids and schedules and develop a 4D model using the latest technology.
2. I believe that the course was a great start for better understanding BIM and IPD that was used during the semester.
3. The course was overall really helpful to understand the change and advancement in construction industry.
4. The series of three courses may be made dependent each other. For instance we have used 3d model in both of the courses Construction Modeling Techniques and Information Management. Although the usage of the models in each course is different I think it will be useful to import the construction process and the design process in a same model in each courses.
5. Enjoyed the class thoroughly and learnt a lot this semester, especially BIM/IPD implementation.
6. TA provided valuable insights to the material based on her doctoral research. DDC commissioner and Company practitioners all provided valuable real world application of the ideas, methods & strategies taught in the course.
7. Everything is very useful for the future career.

Evaluation results indicate that the course format was a success. The course will contribute further to a better and more comprehensive BIM program that will advance the department’s goal to be a leader in the development of the future of construction education.

## 6. CONCLUSIONS

This paper has provided an integral project course in the Polytechnic Institute of New York University. A number of universities around the world are offering courses on various applications of BIM. Such courses often focus on design domains and software products. New mechanism of curricular integration for BIM educational opportunities were discussed which include three modules from the BIM techniques to incorporate BIM and IPD. To implement BIM efficiently, one has to consider the real projects and the issues that most likely occur during the construction. Using BIM to solve complex and sophisticated problems will naturally lead to its use in collaborative settings in project delivery system.

BIM is being gradually and systematically introduced at many academic universities and research institutions to cater to the requirements from the A/E/C industry and to facilitate project delivery system. The integrated project course may be used in universities at other places as well. Assessment and course evaluations from the industry and from students showed positive results towards the BIM education in terms of its perceived benefits and further improvement of BIM education.

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