AC 2012-3029: BIMING CONSTRUCTION ENGINEERING CURRICULA

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BIMing Construction Engineering Curricula

Abstract

Building Information Modeling (BIM) has been used by various construction engineering (ConE) programs to fulfill the Body of Knowledge (BOK) requirements, such as cost estimating, construction scheduling and control, project administration, and contract documents. Currently a number of BIM software packages are available to ConE educators. However, guidance to select an appropriate BIM software and an understanding of how this software can be used to instruct aforementioned requirements are minimal to nonexistent. This paper seeks to address these challenges by developing a BIM model using Autodesk Revit. Then 4D simulations and clash detection are performed. How to conduct cost estimating, the 5th dimension of the BIM model, is recommended. This paper outlines strengths and limitations of software packages used in this study, and presents a suggested work flow for a future BIM course. By providing a template to integrate BIM into an existing course or implement a standalone BIM course within construction engineering curricula, this paper should have great potential to directly benefit ConE educators throughout the country.

Introduction

Building Information Modeling (BIM) has been widely used by today's architecture, engineering, and construction (AEC) industry to address energy conservation, sustainability, and environmental compliance of construction projects from inception to disposal [1]. Consequently, there is an increasing demand for ConE and Construction Management (CM) students who are competent in the BIM technology. Many institutes have already provided accessible trainings to meet this need. A recent survey [2] regarding the current status of BIM within the AEC education in the U.S. indicated that, among 101 respondent programs, 51% were Accreditation Board for Engineering and Technology (ABET) accredited engineering programs; 44% of these engineering programs offer BIM courses; other programs that have not adopted BIM believe that they will be incorporating BIM into their curricula with a year (43%) or two (44%).

Recent studies have indicated numerous ways and the corresponding advantages and challenges of incorporating BIM into ConE curricula. Johnson and Genderson [3] viewed one of the challenges as the complexity of the relatively new software tools. Salazar et al. [4] described how BIM models were developed using Autodesk Revit [5] and how BIM was integrated into their

ConE curriculum. At Brigham Young University, students learned how to use Autodesk Revit products and Sketch-up to complete course work [6]. In a recent study, procedures of using both Autodesk Revit and Vico Virtual Construction Software Suite [7] to fulfill specific body of knowledge (BOK) for the ConE education were presented [8].

However, there are few studies conducted to investigate how one BIM solution can fulfill ConE BOK. This is a significant constraint hindering the use and adoption of the BIM technology in ConE curricula.

To address this issue, this paper is to answer the following main research questions:

1. What are the limitations of most widely used BIM software packages?
2. How to use the selected BIM software package(s) to fulfill specific body of knowledge (BOK) for the ConE education?

Methodology

In this study, a BIM model is developed using the selected BIM software package, and then procedures of fulfilling ConE BOK are presented. Finally, conclusions and recommendations are provided.

BIM Solutions

A surveyed of all members of the Associated Schools of Construction plurality showed that the majority of respondents used Autodesk Revit in BIM education, others used Graphisoft ArchiCAD, Bentley Architecture and VectorWorks Architect [9]. To better disseminate the findings of this research, Autodesk Revit product, including Revit Architecture/Structure/MEP, and Autodesk Navisworks are selected as the BIM solution used in this study.

Introduction of the BIM Software Packages

Autodesk Revit (**Rev**ise **I**ns**t**antly) family includes Revit Architecture, Revit Structure, and Revit MEP (**M**echanical, **E**lectrical and **P**lumbing). Revit Architecture is one of the best known BIM software in architectural design. Besides the modeling capacity, Revit MEP also provides built-in tools for building systems design and analysis. Revit can interface with other software through DWG, DWF, DXF, IFC, and gbXML files.

Autodesk Navisworks [10] can import modeling file (DWG, DXF, IFC, gbXML, etc.) from numerous BIM software packages, run construction sequencing simulation (4D scheduling simulation) and real-time navigation, perform clash detection, and generate photorealistic visualization.

Construction Scheduling Solution

Microsoft Project [11] was chosen as the construction scheduling software because it is available to most institutes, and its native file can be imported into Navisworks to generate 4D simulation.

Construction Cost Estimating Solution

RSMeans CostWorks is an online cost estimating tool [12]. Construction costs estimated by CostWorks can be adjusted for localities based on the latest RSMeans online cost data. This tool is chosen for this study because of its good feedback from students, and also the fact that it is free for use for 7 days.

The Body of Knowledge (BOK) for ConE Education

In their study, Hildreth and Gehrig [13] identified the following four principal knowledge areas and their subsets of knowledge and skills to define the ConE BOK:

I. The knowledge and skills associated with **cost estimating** include:
    a. understanding the requirements of the work based on the drawings and specifications;
    b. estimating work quantities;

c. evaluating and selecting appropriate construction means and methods;
d. estimating labor and equipment rates;
e. designing field operations and estimating rates of production;
f. estimating indirect and overhead costs; and
g. preparing a bid estimate.

II. The knowledge and skills associated with **construction scheduling and control** include:
a. understanding and preparing various types of construction schedules;
b. developing a work breakdown structure and list of schedule activities;
c. planning an appropriate sequence activities for a logical project work flow;
d. estimating activity durations;
e. applying appropriate methods to allocate and level schedule resources; and
f. analyzing a project schedule and reporting project status.

III. The knowledge and skills associated with **project administration** include:
a. understanding project delivery processes;
b. applying principles of construction law and ethics;
c. understanding contractor licensing requirements and procedures;
d. understanding lien and labor laws as applied to construction;
e. identifying appropriate construction codes and regulations;
f. developing quality control programs and plans;
g. performing economic analyses and developing cash flow projections; and
h. managing risks on a construction project.

IV. The knowledge and skills associated with **contract documents** include:
a. understanding the elements of a construction contract;
b. understanding payment, performance, and bid bonds;
c. preparing construction contract documents;
d. developing safety programs and plans; and
e. developing procurement documents for construction materials and services.

The following sections show how the chosen software packages can meet these BOK requirements.

1. Cost Estimating

This section describes how proposed BIM solution can fulfill Subsets I (b) and I (g) of BOK requirements -- cost estimating.

Step 1: Developing the BIM model of the Case Study Building

The case study building selected for this research is a 2,800 S.F., 1-story Branch Bank. Figures 1 and 2 show the floor plan and the isometric view of the building. Revit Architecture was used to develop the BIM model.

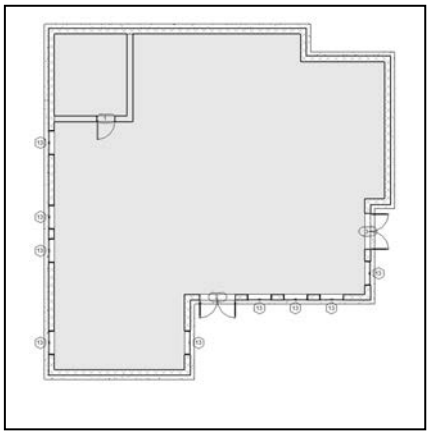

Figure 1. Floor Plan

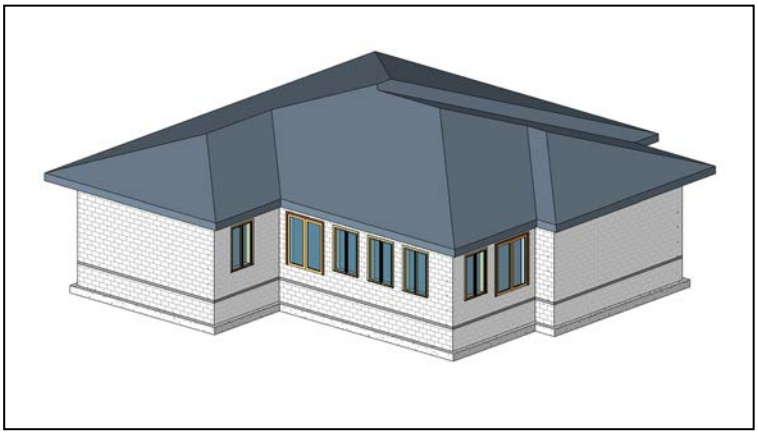

Figure 2. Isometric View

Step 2: Conducting quantity takeoffs in Autodesk Revit Architecture

Quantities of building components, including areas and volumes, can be easily obtained from Revit once the BIM model has been developed (Figure 3 and 4). The process can be completed in a matter of a few minutes and the results are more accurate compared to tedious and time consuming manual calculations or using 2D quantity take-off software.

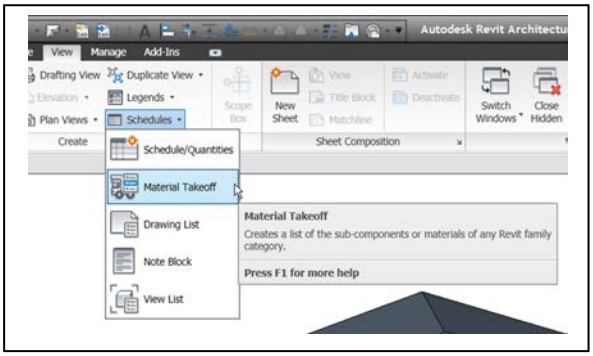

Figure 3. Quantity Takeoff in Revit

Wall Schedule 2

Assembly Cod	Description	Length	Area	Volume
B2010		42' - 0"	658 SF	631.01 CF
B2010		4' - 8"	72 SF	68.59 CF
B2010		14' - 0"	214 SF	205.58 CF
B2010		24' - 0"	368 SF	352.45 CF
B2010		3' - 4"	51 SF	49.01 CF
B2010		16' - 0"	179 SF	171.01 CF
B2010		30' - 0"	346 SF	330.24 CF
B2010		12' - 8"	170 SF	162.74 CF
B2010		22' - 8"	347 SF	332.87 CF
B2010		57' - 4"	768 SF	734.86 CF
B2010	InteriorWalls	14' - 8 15/16"	247 SF	246.75 CF
B2010	InteriorWalls	13' - 0 15/16"	213 SF	212.57 CF

Figure 4. Wall Quantities

Step 3: Estimating construction costs via RSMeans CostWorks

Once the quantities are obtained, they can be entered into RSMeans CostWorks to calculate construction costs (Figure 5). RSMeans provides comprehensive and accurate, up-to-date cost data that are localized to users' geographic region.

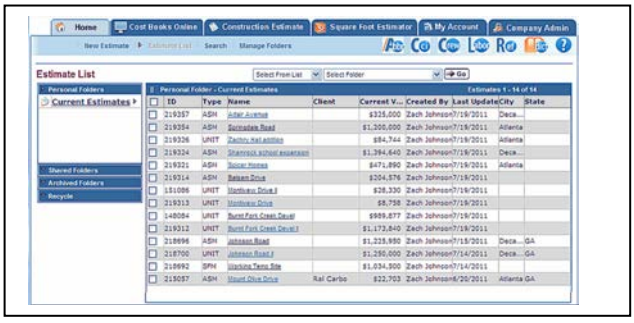

Figure 5. RSMeans CostWorks
Image courtesy of *www.reedconstructiondata.com/*

2. Construction Scheduling and Control

This section demonstrates how to fulfill Subsets II (a, b, c, d, and f) BOK requirements -- construction scheduling and control.

Step 1: Importing the BIM model into Autodesk Navisworks

Revit files (.rvt) need to be exported to NWC files that can be opened directly by Navisworks. The screenshot below (Figure 6) shows the case study building in Navisworks.

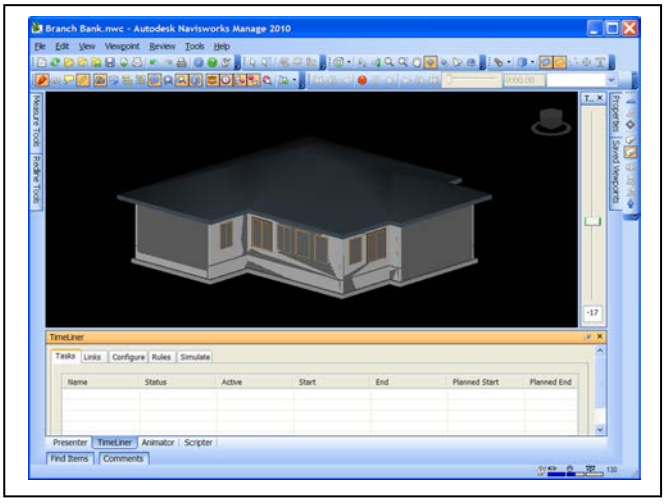

Figure 6. Imported BIM model in Navisworks

Step 2: Developing a construction schedule using Microsoft Project (Figure 7)

Navisworks can import construction schedule files from various software programs, including Microsoft Project and Primavera. Microsoft Project was used in this study because many institutes have Microsoft site licensed products, but not Oracle Primavera.

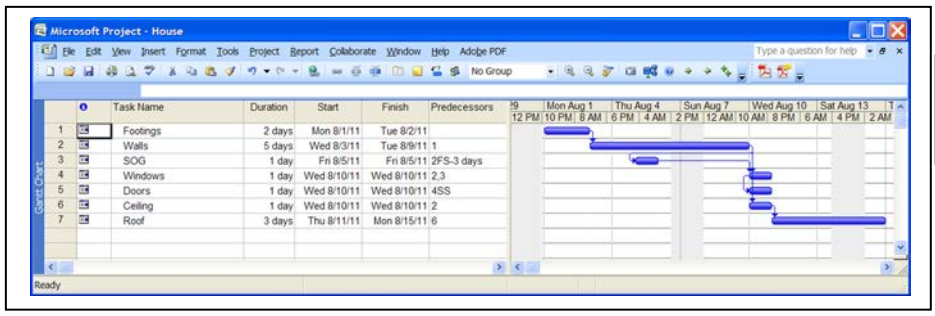

Figure 7. Construction Schedule

Step 3: Generating a 4D simulation in Autodesk Navisworks

After the Microsoft Project file was imported into Navisworks, the link between construction tasks and their corresponding BIM components was established, and then a 4D construction simulation was generated (Figure 8).

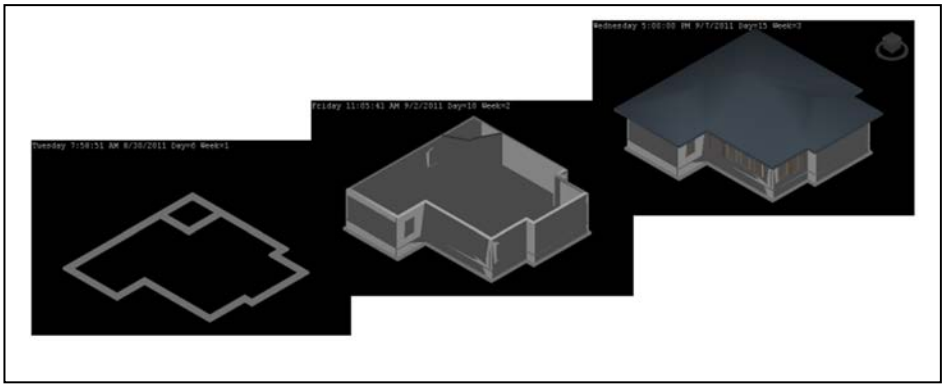

Figure 8. 4D Construction Simulation

3. Project Administration

BOK requirement Subset III (h): managing risks on a construction project can be achieved using Autodesk Navisworks' clash detection function.

Clash detection can be conducted to locate physical conflicts between building components (Figure 9), especially between MEP and structural elements. This allows AEC professionals to manage these risks before the project is physically built. As a result, the number of Request for Information (RFI) and change orders can be reduced significantly.

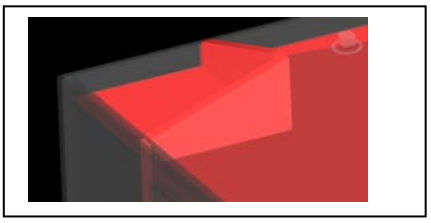

Figure 9. Clash Detection in Autodesk Navisworks

Since none of Revit products can perform cash flow analysis, it is suggested to use Vico suite to fulfill BOK requirement Subset III (g): performing economic analyses and developing cash flow projections (Figure 10).

Figure 10. Cash Flow Analysis in Vico 5D Presenter (picture courtesy of Vico Software)

4. Contract Documents (Subsets IV (c and e): preparing construction and procurement documents)

A BIM model contains almost all important building information. Therefore, it can be used to generate construction documents (Figure 11).

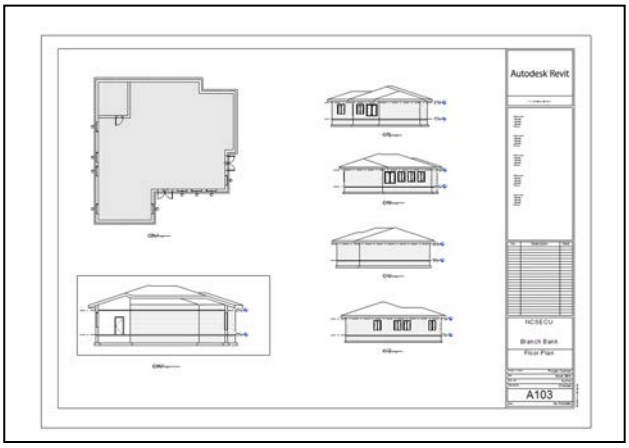

Figure 11. Construction Document generated by Autodesk Revit Architecture

Suggested Work Flow

Based on the findings from previous sections, a work flow (Figure 12) of a future BIM course is proposed.

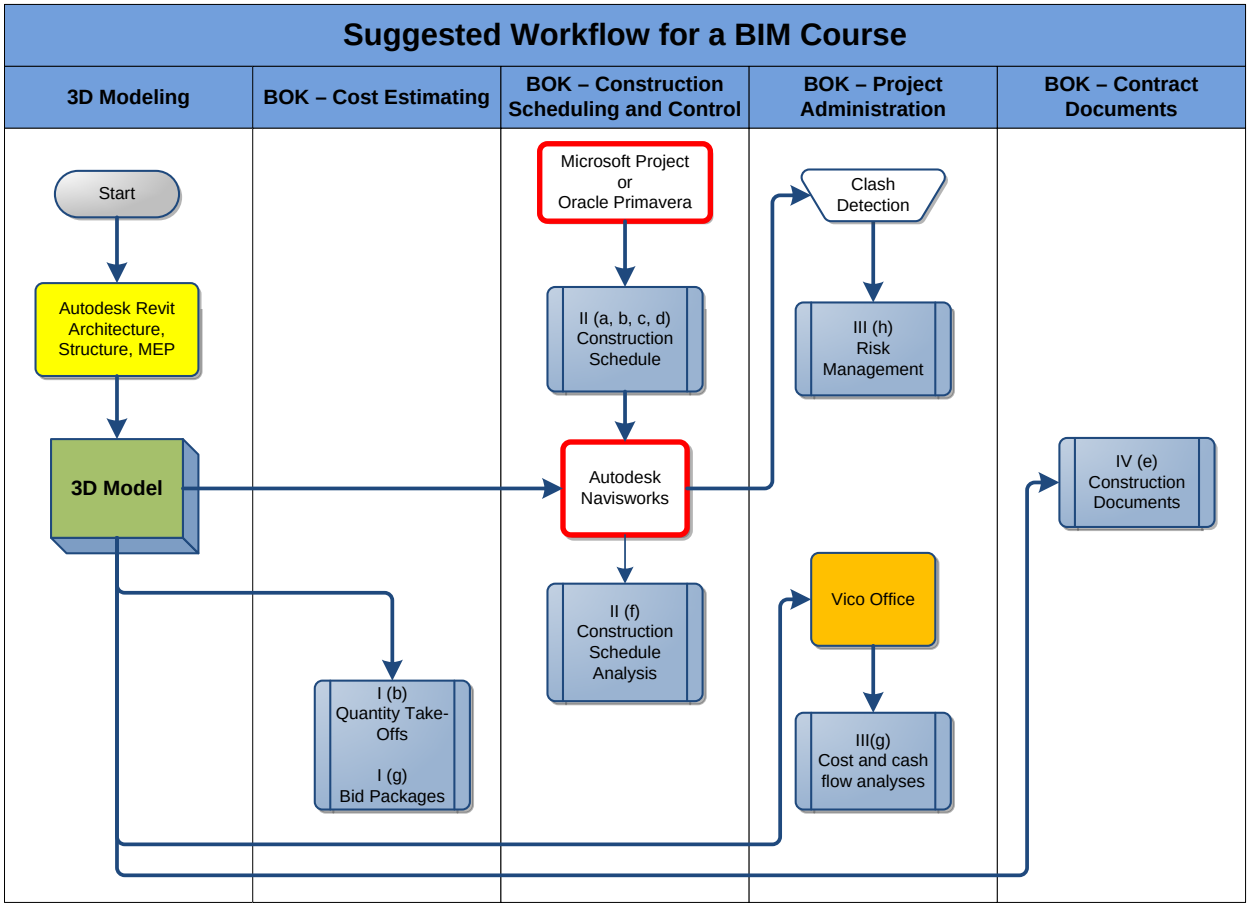

Figure 12. Proposed Work Flow for a Future BIM Course

Implementation of the Proposed Work Flow

In the Spring 2012 semester, two BIM courses, one is at the graduate level and one is at the undergraduate level, were offered to both Civil Engineering Technology and Construction Management students at University of North Carolina at Charlotte. The proposed work flow has been followed to develop syllabi and select BIM software solutions. Students learned the three Revit products and Navisworks from the instructor; meanwhile, they are working on their BIM projects whose 2D construction documents were found from isqft. Besides all the requirements

listed in the work flow, energy simulation was added to the project requirements. It is in the middle of the semester at the time of this writing, the instructor has noticed the following:

- Students are self-motivated in learning Revit Architecture/Structural/MEP and Navisworks;
- The Level of Detail (LOD) for the BIM model should be determined before students start working on their BIM projects;
- Guest lecturers from industry practitioners are particularly beneficial because they help students understand how BIM has been used on the real-world projects.
- A good textbook and a project with an appropriate level of complexity are important to help students start their first BIM project.

Conclusions and Recommendations

Similar to what happened in the AEC industry, BIM is transforming ConE education. Without fully understanding the functionalities of most commonly used BIM solutions, the acceptance and implementation of BIM in ConE education will not take place. This paper presents the proposed applications of the most commonly used BIM solution, Autodesk Revit, to fulfill the wide-accepted BOK for ConE education, such as cost estimating, construction scheduling and control, project administration, and contract documents, using Autodesk Revit products. The major findings are:

- Revit has proved to be a great 3D modeling software.
- Revit lacks the capacity to directly estimate construction costs. However, Revit can easily produce material quantities, which can then be used to estimate construction costs through the assistance of other estimating tools, such as RSMeans CostWorks.
- Importing schedule files created by Microsoft Project, Navisworks can successfully handle construction schedule analysis through 4D simulations;
- Navisworks can be used to detect potential clashes. This allows engineers to manage construction risks early during the conceptual design phase;
- Revit is able to efficiently generate various types of construction documents;
- The latest version of Vico software, Vico Office, does not have the modeling capacity. However, it can import Revit model files to perform cash flow analysis; and

- Vico Office is capable of developing location-based construction schedules and generating 4D simulations. However, in this study, the combination of Microsoft Project and Navisworks was chosen because most institutes have Microsoft and Autodesk site licenses.

The proposed procedures and the findings from this study can be easily adopted throughout the ConE academic community and should help to remove the associative barriers that hinder the rapid transformation. The movement to sustainability has been gaining momentum, with growing interest from the AEC industry. It is recommended that future research should be conducted to investigate the application of the BIM technology in energy efficient design and construction.

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