Strategy to incorporate BIM curriculum in Planning and Scheduling classes

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Abstract
Architect-Engineer-Construction (AEC) employers have begun expecting that construction program graduates have a working knowledge of Building Information Modeling (BIM). This paper is an attempt to adopt this new skill-set in educational institutions along with the fundamental techniques of Planning and Scheduling already being taught. To incorporate the BIM curriculum pertaining to the class topics, it was determined essential to introduce students to project scheduling and simulation software. Though a wide variety of tools are now available and used in the industry, P6 scheduling software and Synchro simulation tools were opted based on user conform level, easy access and availability for education institutions. A 3D model scenario along with a schedule from a project was used to create a simpler scenario for academic purpose. The project was introduced to the students and the task of creating a meaningful schedule in P6 was assigned. The students were provided with specific assignments and tutorials to help them navigate through P6 and aide in creating their schedules during the lab sessions. To continue the implementation, students have guest speakers from industry who discussed and showed them the real time implementation of schedules and how they should manage schedule changes, updates and other important considerations to address. The strategy to incorporate BIM curriculum into this important topic for Project Managers is finalized with a 3D Synchro model and students are asked to go through a tutorial that would make them to better understand the link of a previously generated P6 schedule to the model and to develop a 4D simulation.

Keywords: Curriculum Development, Planning and Scheduling, BIM, Construction Education, Primavera, Synchro

Introduction and background for the Planning and Scheduling class

Project Planning and Scheduling course is a study of the fundamentals and techniques of Planning and Scheduling for construction projects. Topics include bar charts, critical path method using arrow and node networks, precedence networks, cost-time trade-offs, PERT, resource leveling and management, updating schedules during construction, introduction and practice to project controls and intermediate level of computerized scheduling in Primavera (P6) version R8.2. BIM is introduced later in the semester through a visualization tool helping students to understand even better scheduling techniques.

Just before the mid semester, students are introduced to the use of computerized scheduling techniques using P6 to develop, monitor and update project schedules. This implementation focuses on hands-on learning approach through a combination of lecture and laboratory sessions. The practical realities of planning and scheduling construction projects are reinforced during the weekly class supported by a variety of guest lecturers including construction project managers, engineers and/or CEOs of local industry companies. The lectures provide examples of how scheduling techniques has been put into practice across the project lifecycle, starting from design, preconstruction, construction and fabrication, coordination and commissioning. During

the lab session, students use structured tutorials, supplemented with videos, to implement scheduling skills like in real-world case scenarios. Group work is always encouraged and submission of small assignments is required periodically to assess the students' software learning curve. The customized tutorials provide a step-by-step guide to the software, allowing for self-paced learning and providing easy access for future reference. Also, industry professionals deliver their materials, advising students on best practices, the day-to-day challenges they face, and the importance of the skills within their practice on the jobsite. By implementing a visualization tool, students have the chance to identify the sources and impact of changes and interruptions on the schedule and to compare and contrast the appropriateness of scheduling techniques for varying construction operations.

To incorporate the BIM curriculum pertaining to the class topics, Synchro software is employed. A schedule from a simplified project scenario is deployed into a schedule visualization and analysis procedure and presented to the class. The paper will present sample tutorials of the curriculum throughout the semester. It will also describe how the content was developed, and how industry input was vital to further develop on the real-life, practical skills. A framework for creating and incorporating more BIM related content in the coursework to address industry needs will be discussed and recommended for further development.

Primavera tool used in the Planning and Scheduling class

Any new integrative concept can be taught in several ways, i.e. as an elective, stand-alone class or it may be a part of different courses into an advanced degree program. Construction Management programs accredited by the American Council for Construction Education (ACCE) do not have specific requirements for BIM classes or a specific industry requirement that would make a BIM class mandatory in programs as such, making it difficult to offer a stand-alone class that teaches such tools and processes. However, some programs consider offering content and topics to allow for "Computer Applications" development in the construction curriculum. This provides the opportunity to include BIM applications in classes that teach subjects directly related to a BIM functionality, such as - Construction Estimating, Construction Planning and Scheduling, Project Management, Building Materials and Systems, Contract Documents, etc. This integration may be undertaken by faculty as an iterative process, beginning with basic software programs related to the main subject. Thus, continuing the support for including BIM applications in the respective Construction Management classes. This is specifically the case with Primavera Software, where BIM applications may be used and can be integrated for better understanding and visualization of a project schedule into a Project Planning and Scheduling class. Therefore, a real-world case scenario of a project schedule can be better understood on the job-site and executed in a more efficient way.

Multiple scheduling tools such as Primavera, MS Project, Suretrack, etc. are now available and used in the construction industry. Primavera was opted for the curriculum due to its advanced features in scheduling, high industry usage and its interoperability with all kind of BIM tools. Primavera has also a long history for its development - a series of versions that were adding great features and functionality - making it a very powerful scheduling tool.

Tutorials development in P6, R8.2 for project schedules to illustrate software functionality in project samples

In order to ease the learning of Primavera P6, version R8.2, a couple of tutorials were developed along with an instructional micro-project example directly applied into the software to exemplify its schedule manipulation and utility. The tutorials objectives are three-fold in nature:

- Develop deeper understanding of P6 software features and functionalities
- Understanding how important it is to develop a valid schedule for later 3D visualization and modeling
- Retaining knowledge for post-graduation times

The tutorials are created to progress the knowledge and understandings of the software as students advance on their learning curves in this class. The assignment was designed as a semester long project and the tutorials were meant to help them navigate the software and prepare their schedule in P6. A hypothetical project scope was presented to students with some logic of activities, constraints and available resources. The idea is to help students visualize what activities to create, how much time to assign for the activities, what would be a logical sequence etc., thereby combining all the concepts taught in the class. It was made clear to the students from the beginning that they were not expected to be "Primavera" experts, but they would benefit from the working knowledge of the Primavera at least to an advanced-beginner level or an intermediate level user in this class.

There are mainly four graphic tutorials with specific instructions and illustrations that students are encouraged to go through during the lab sessions in order to become familiar with the software and perform hands-on practice exercises presented in their assignments. The tutorials were created to explain the concepts and software features in a graphical manner. They are self-guided and self-explanatory:

- Tutorial 1: Navigating the Project Management module in P6 (excerpt in figure 1)
- Tutorial 2: Creating a new Project (create a brand new project, navigate the Projects window, view and modify information on the project details tabs, importing and exporting files, etc.)
- Tutorial 3: Creating a work-breakdown structure (WBS), implementations, multiple levels on WBS hierarchy, assigning responsible managers to WBS elements (figure 2)
- Tutorial 4: Adding and assigning activities to the project; manipulation of activity data

The students are encouraged to go through them in groups of 2-3 individuals and helping each-other in their respective teams.

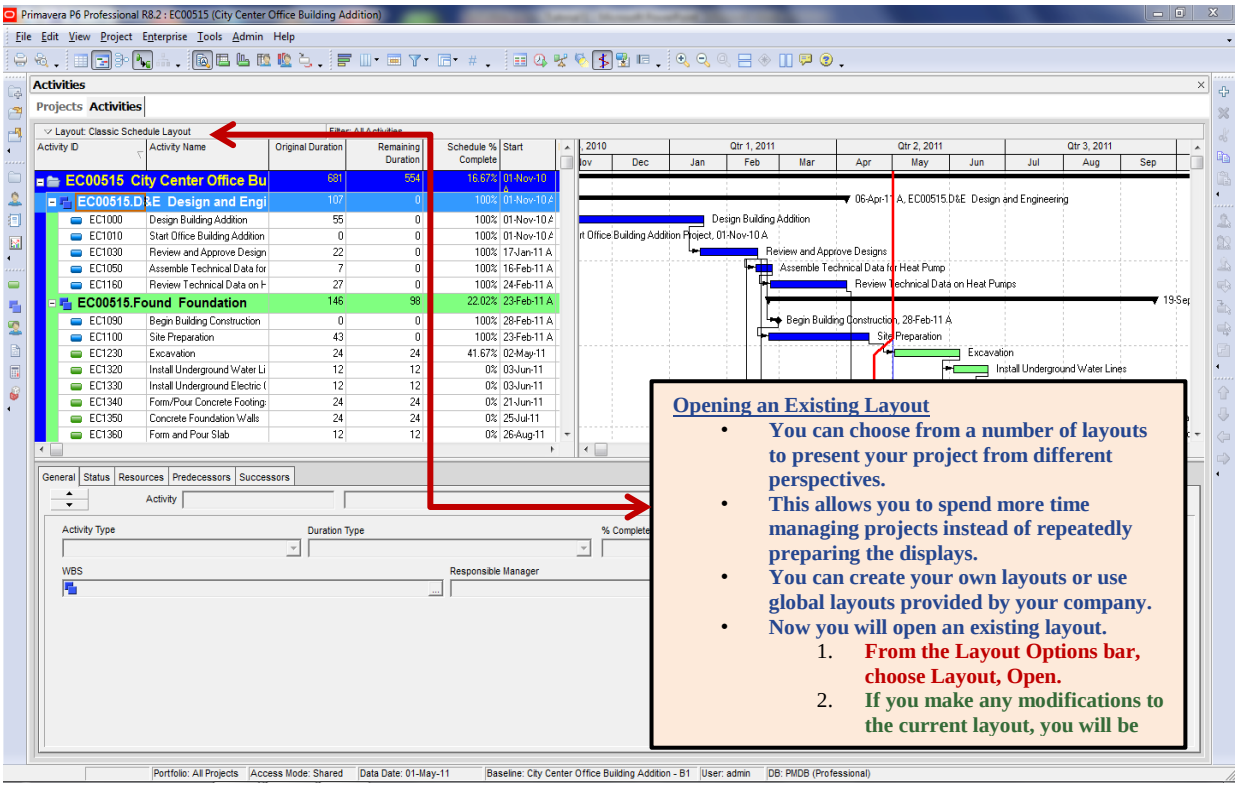

Figure 1. Excerpt of instructions from Tutorial 1

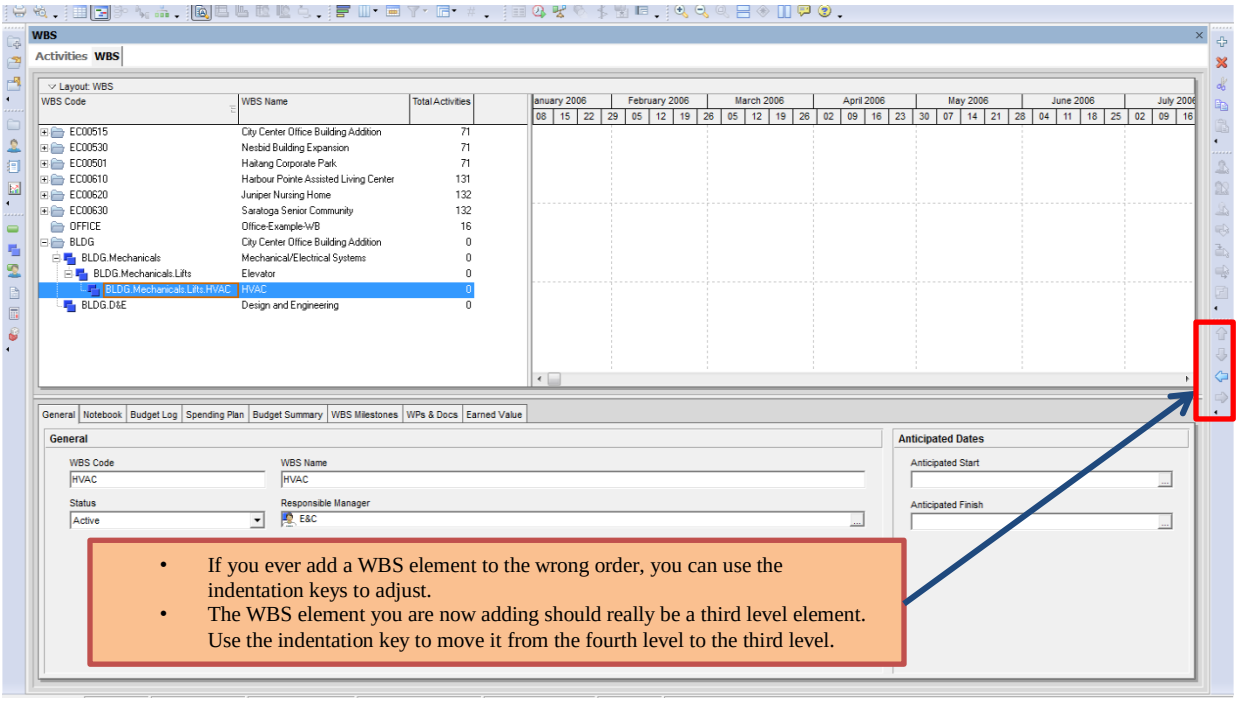

Figure 2. Excerpt of instructions from Tutorial 3

In tutorial 4, students have the opportunity to delve deeper into the software, such as changing an activity calendar assignment or adding a notebook topic to an activity. Opportunities are made available to further study the schedule and activity resource loading in the software, thus providing students with a better understanding on schedule updates and the influence of activity resources on schedules.

It was observed on every class via assessments that several students fail to retain the skill as they were not using the software applications constantly and were not replicating its use for other classes or assignments. This lack of continuity was complemented with theoretical knowledge and through hands-on exercises developed for in-class use.

BIM integration into Project Planning and Scheduling class – a continuous strategy

BIM has gained significant drive in a relatively short period of time in the construction industry. Therefore, the authors are assured that there will be an increased demand for individuals with BIM skills and knowledge. Young et. al.[6] revealed that almost 50% of the industry is using BIM and its adoption will increase, expecting positive returns from the use of BIM technology. Utilizing BIM technology has major advantages for construction. It allows for an efficient construction process that saves time and money and reduces the number of RFIs and field coordination problems, compared to traditional practices. Perhaps the most important point is that the use of BIM technology improves the ability to integrate all members of project team together by communicating ideas more effectively and provides competitive advantage for innovative firms. Large companies have already realized that the BIM methodology offers the intelligent solution for the integration of the many disciplines involved in the building design process[3], one of them being project scheduling. Other academic authors are exploring areas such as integration of lean construction, sustainability, and BIM into undergraduate construction management scheduling courses[5].

Keeping up with this growing industry trend, acceptable training in BIM is needed for successful adoption. Cook states that highly skilled cross-trained staffs with both construction and IT skills are required to implement a BIM[2]. The lack of BIM practitioners as a major bottleneck to move the industry into the BIM age is identified by Hartmann & Fischer[4]. Young et.al.[6] also indicates that the lack of adequate training is the greatest challenge to adopting BIM in the construction industry. In parallel with industry, construction programs in higher education need to find a way to weight the BIM technology in their courses so that students can make themselves familiar with it before entering the construction field.

Many construction companies have created new BIM positions to make the transition from current practice to the one that integrates BIM technology into their organization. These individuals who are BIM "know-hows" are internally called with various titles such as BIM Construction Officer, BIM Coordinator, BIM Project Manager, Integrated Construction Engineer, and Virtual Construction Manager[1]. Regardless of its title, they are responsible for implementing BIM on their projects while balancing traditional operations duties. Therefore, it is certain that there is a strong need for more individuals with experience and knowledge of BIM technology and Virtual Design and Construction (VDC) practices[3]. However, there is still limited availability for BIM education since BIM is not formally acknowledged as the ACCE and ABET

accreditation criteria. In their program curricula, students might not be interested in taking more courses for BIM education as long as they are not necessary to graduate. There is a need in Construction Management programs to quickly address the adoption of BIM in their curriculum.

In near future, the authors believe that all students will embrace BIM in construction education. Based on the rapid adoption of BIM over the past few years, it will be a necessary skill for graduates to remain competitive in the job market. From a BIM point of view, the most important skills needed in the Construction Management field are:

- Ability to apply and work with a new technology
- Basic modeling and manipulation skills
- Ability to model detailed conditions in 3D
- Ability to assemble and review a clash detection model
- Ability to create 4D models using a schedule and then derive a total project estimate

BIM technology enables users to be successful in scheduling, estimating, coordination of trades, even laser scanning and many more. However, without an established workflow, the results can be inconsistent or worse than expected. There are many processes involved in BIM adoption. Fundamentally, the use of BIM requires planning and preparation to ensure successful implementation. These plans and processes change over time based on lessons learned and developments in technology. There are a wide variety of processes and steps for each virtual construction case study. Having standards in collaboration with the industry may be essential, particularly when incorporating BIM technology into Construction Management classes. This is one of the challenges to incorporate Synchro as BIM software into the Project Planning and Scheduling class.

As mentioned earlier, BIM education in Construction Management programs should mainly focus on larger industry trends and processes, not just on the software. However, a basic software understanding is also important. Therefore, for an efficient integration, the program needs to instill the following:

1. BIM development
2. BIM uses and interactions among various project stakeholders
3. Sort of BIM software – adoption of Synchro features and capabilities for Project Planning and Scheduling class
4. Basic software understanding of selected applications
5. Management skills to facilitate the BIM process
6. Understanding of the trades/systems that frequently contribute in the BIM process (if available time)

Currently, the construction industry expects Construction Management graduates to be aware of what BIM is and be exposed to the basic application and uses of the different BIM tools. This would be the main reason why construction firms have their own in-house training to meet their business necessities. Evidently, as time passes, BIM will become fully integrated into the undergraduate curriculum. This paper is an endeavor to incorporate at least partially a BIM curriculum into a Scheduling class. As the industry continues to realize more and more benefits from using the BIM technology, it is imperious that it should be required in Construction

Management curriculum. Similar to other industries, BIM will eventually become a standard for all construction businesses.

Synchro integration as a BIM tool for Planning and Scheduling class

From instructor's experience of the past semesters, surveys, assessments and conversations with the industry, it is apparent that integrating VDC activities as a central idea in construction education requires some necessary changes in existing teaching methods and philosophies. This is illustrated in Table 1 as course offerings (i.e. Project Planning and Scheduling) that should offer the inclusion of BIM and/or BIM applications and practices in the topic.

The construction schedule developed in P6 can be integrated into a 3D building model with Synchro software. Students should be capable of linking P6 schedule with a Synchro 3D model to visualize a project schedule. This way a 4D planning and scheduling is generated by adding schedule and resource data to a 3D building model. In this process, students also learn the use of BIM for scheduling and work sequencing.

Table 1. Course offerings to integrate BIM in the Construction Management program

Course name offered in the Construction program		Topics covered	Future application of these topics for understanding BIM
Year I	*Computer Concepts; Computer Applications*	- Geometric modeling to represent operations of construction equipment (i.e. a crane, etc.) - some form of 3D visualizations	Requirements for productivity, efficiency and safety
Year II	*BIM for Construction Management*	- Software applications taught in the program: Revit Architecture, Revit Structure, Navisworks, etc.	Learning BIM as a tool for future use
Year III-IV	*Project Planning & Scheduling*	- Project Scheduling methods such as Bar Charts, CPM and PERT, AOA, AON and CPM techniques; resource allocation and time/cost trade-off and analysis - Software used: Primavera P6 R8.2, Synchro for linking schedule to a model and simulations	Creating schedules, and simulating activities in a project example

Example of project schedule modeled with Synchro

Towards the end of the semester, an example is presented to the class on how a schedule is applied to a model in Synchro. The basic-intermediate level training tutorial is presented to the class and a dedicated time is allocated for a stand-alone lab session. After the skills are mastered, small groups of students are encouraged to investigate on their own more advanced capabilities of Synchro modeling. The training tutorial is self-paced and students are conducted and assisted to experience the exchange of model information in their small teams.

Importing Data is one of the most important skills explained in this session, like: Importing Schedules, Data Date, Gantt Display, Importing 3D Models, Importing DWF Model Files, 3D Resources Creation, Import the Equipment Models (figure 3). 3D views, window navigation and axis indicator (view cube) is also taught for 3D visualization and manipulation of the model.

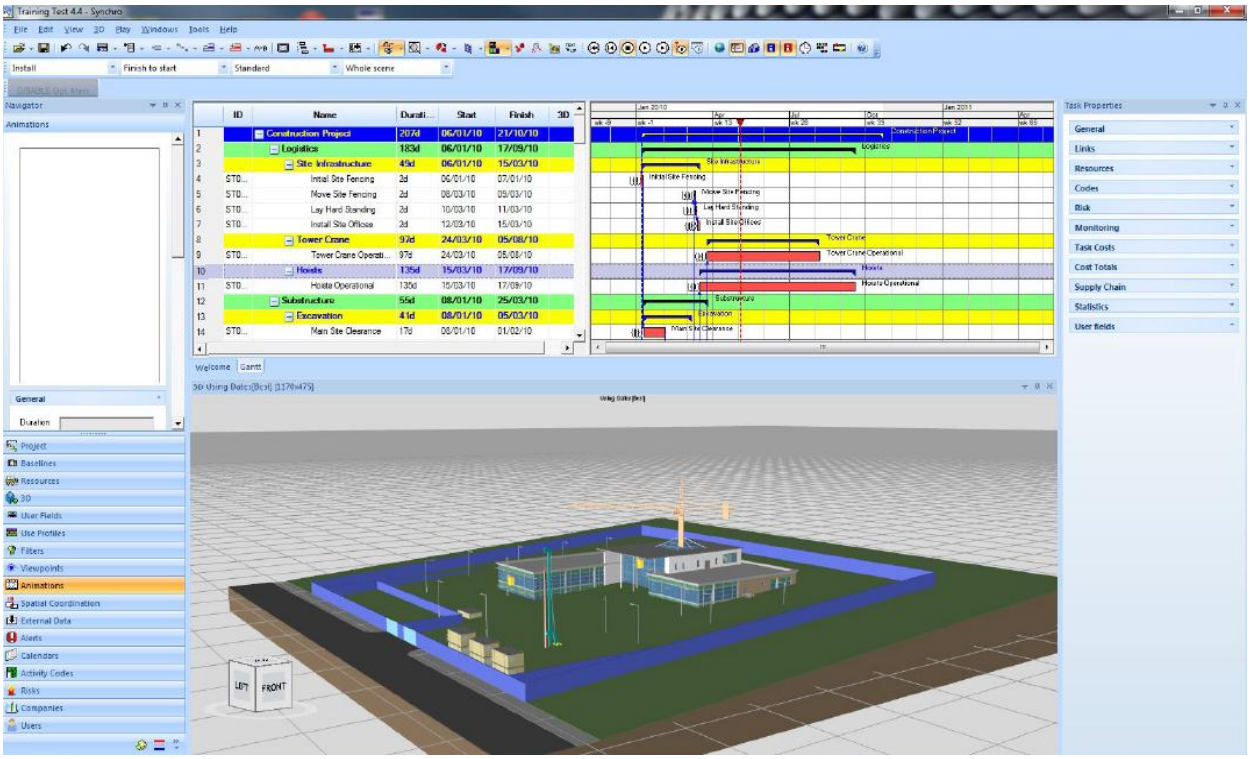

Figure 3. Importing equipment model in the 3D model

After linking 3D to the project schedule and synchronizing 3D files, another important concept presented is synchronizing the schedule and baselining. This is performed in a couple of steps:

- Explaining baselining in Synchro
- Synchronizing schedules (and the rules for synchronization)
- Basic rules for scheduling software
- Compare Baseline (using 3D views, see figure 4)
- Creating an AVI of the comparison

Figure 4 illustrates the focused time for the baseline being moved through the project in order to review how the new schedule falls behind the baseline schedule. The focused time for the baseline schedule is behind that of the new schedule as the excavation has yet to be completed compared with the updated schedule which is part way through this construction phase. The students now have the opportunity to grasp the capability of the Synchro program as project management tool equipped with great visualization features that can help Project Managers to take and adopt their daily decisions. Also, work of trades and/or subcontractors and their implications in the overall schedule can be discussed and analyzed between team members.

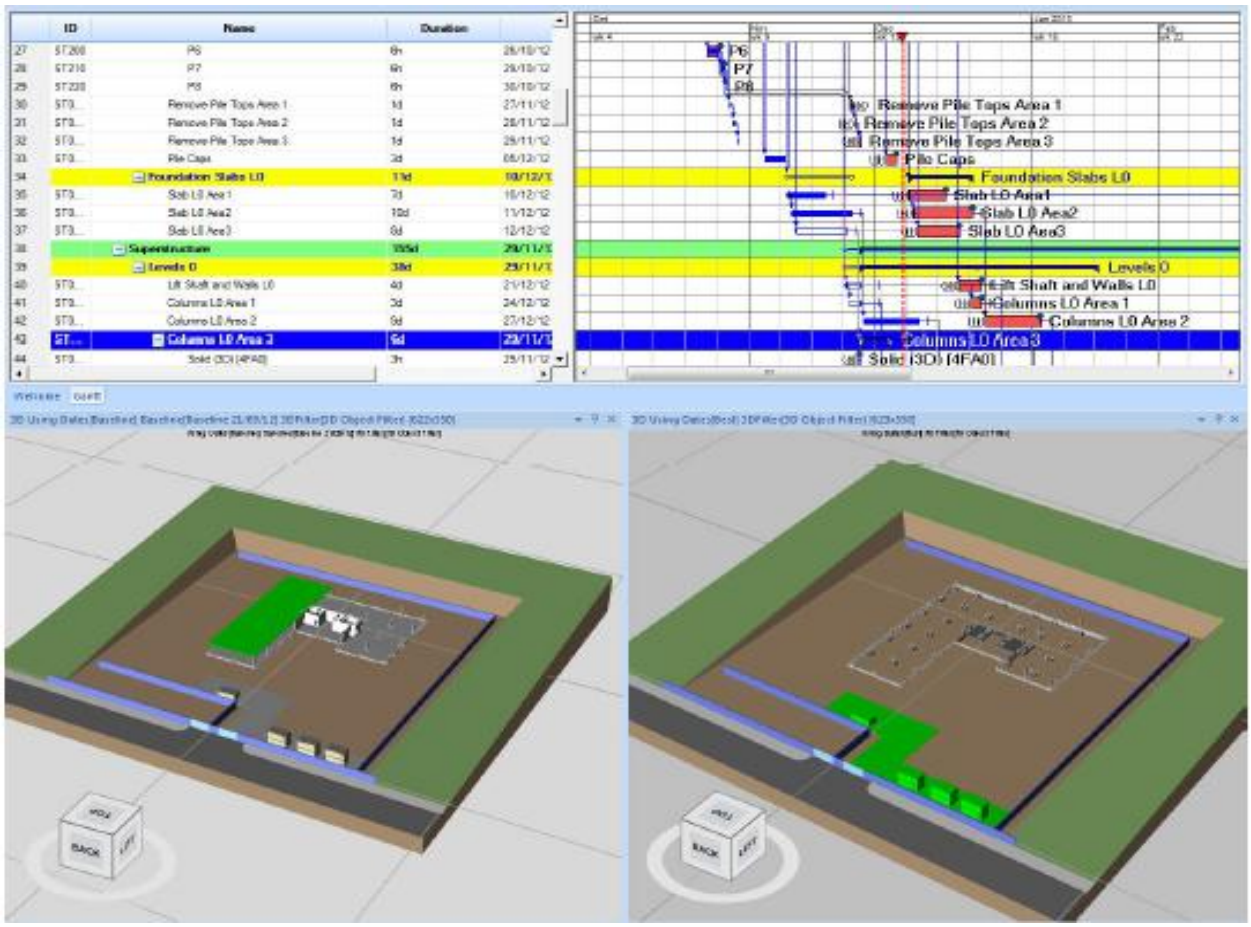

Figure 4. Comparison of baseline with updated schedule through 3D views

Discussion and conclusions

The leading instruction of this class with a few industry experts explored several areas of BIM integration and after careful considerations has determined that implementation throughout the curriculum is the most advantageous way to achieve both academic and industry expectations. The link between academia and industry is also a critical component in bringing industry guest speakers to providing students with an understanding of quintessential topics in planning and scheduling and to leading them into BIM exercises and applications. The importance of the industry lecturers is relevant when the next generations of construction professionals are not actually the BIM experts but they are capable of applying their BIM knowledge to their daily job tasks. The case scenarios in planning and scheduling through assignments, schedule creation and model visualization example help accentuate the initiative to use technology and BIM as a way of making the building process more enjoyable and learning-effective in the same time. One of the major areas that have yet to be employed into the program's curriculum is to develop even more on the BIM applications through Synchro tool in this class and other BIM software in other critical classes, like Cost Estimating, etc. A much more dedicated time to Synchro may allow for more emphasis and a better illustration of the 4D components and simulations of construction activities in the industry projects.

Nevertheless, the 15 week-semester limitation is a great impediment to extend the class content to allow for extra applications given the fact that understanding projects scheduling required a blended and slow-progressing learning of theoretical, practical, applied topics and a visualization of knowledge gained throughout this process only in the end. The importance on this crucial construction management topic and the data richness of the BIM tool is an excellent medium reflecting future field work of the project managers. In the near future, the industry input and participation in the classroom environment will be of critical significance in continuing to move the curriculum forward to reflect thoroughly or even to exceed the current state of construction and help incorporate areas that have yet to benefit from the possibilities of the new BIM applications.

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