

BIM LABORATORY EXERCISES FOR A MEP SYSTEMS COURSE IN A CONSTRUCTION SCIENCE AND MANAGEMENT PROGRAM

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SUMMARY: Recognizing the need of Construction Science and Management students to be proficient with the latest information technology developments in the architecture, engineering and construction (AEC) industry, the curriculum at the Construction Science and Management (CSM) program at the University of Texas at San Antonio was modified to include Building Information Modeling (BIM) courses. Starting with the 2014-2015 academic year BIM courses became part of the degree requirements. One of the courses requiring BIM is the Mechanical, Electrical and Plumbing (MEP) Systems course. This paper focuses on the BIM based laboratory exercises developed for the MEP Systems course, the specific topics covered, and the organization of the course as it was modified to accommodate the inclusion of BIM. The differences with previous offerings of the course without the BIM component are described in the paper. It also discusses the perceived benefits and disadvantages of using BIM as part of the teaching process, as well as the difficulties and drawbacks encountered while using the software. In addition to presenting the instructor experiences, the paper also discusses the results and observations stemming from student surveys and evaluations. The student surveys were used specifically to assess the effectiveness of the BIM exercise in presenting the MEP topics. Additionally, the surveys provided student opinions and suggestions on how to improve the BIM component of the course, whereas the course evaluations only provided general feedback on the instructor teaching and course delivery. Lastly, the paper discusses future additions, changes and improvements to the course laboratory BIM exercises, as well as other changes to the course organization and topics covered that might be to ease the inclusion of BIM into the classroom.

KEYWORDS: BIM, MEP Systems, Laboratory Exercises, Course Development.

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1. INTRODUCTION

Starting with the 2014-2015 academic year, the curriculum of the Construction Science and Management (CSM) program at the University of Texas at San Antonio includes Building Information Modeling (BIM) courses as part of the degree requirements. The inclusion of BIM into the curriculum responds to current technology trends in the construction industry (Azhar, Khalfan, and Maqsood 2012), feedback from the program’s Industry Advisory Council, as well as the CSM department goal of graduating well rounded students that are proficient with the software technology and tools currently being used in the construction industry, such as BIM, quantity take-off (QTO) and estimating software, and scheduling software, among other computer programs (Reginato 2010).

Under the newer catalogue, BIM is covered primarily in three courses. First, BIM software packages and fundamental concepts are introduced in a dedicated course during the fall semester of the junior year, then students are further exposed to specific aspects of BIM in the laboratory exercises of the program’s Mechanical, Electrical and Plumbing (MEP) Systems course. Finally, students are required to use BIM as part of the program’s final capstone project course during their senior year. **FIG. 1** shows the current required CSM course sequence flowchart starting from the sophomore year, without showing the business course requirements of the program. The first year of the program consists of the base core courses required by the state of Texas and accreditation agencies, such as sciences, mathematics, and humanities/social sciences classes. Other ACCE accredited schools have started introducing BIM into their curriculums, for example Purdue University (Sah and Cory 2008) developed introductory BIM courses that might include some MEP system modeling as part of the course term project; and Colorado State (Clevenger and Ozbek 2010) replaced an existing CAD course with a BIM based courses, and started the development of stand-alone BIM modules to be incorporated into upper level core courses, however specific BIM laboratory exercises focusing solely on MEP systems have not been reported in the literature so far, to the authors’ knowledge.

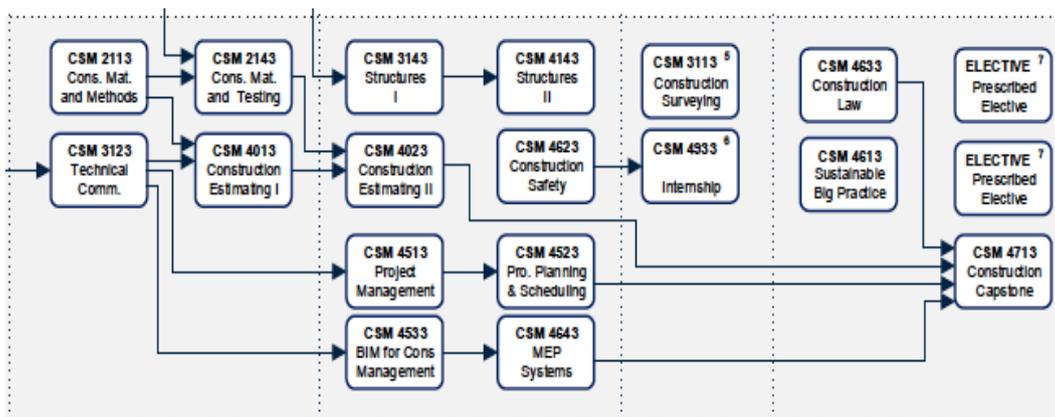


FIG. 1: 2014-2015 UTSA Catalogue CSM Program Sequence Course Structure

The Mechanical, Electrical, and Plumbing Systems (MEP) course in the Construction Science Department at the University of Texas at San Antonio (UTSA) is structured as a 3-credit hour (2-2-3) course consisting of two hours of lecture per week, and a single two-hour laboratory session per week. The MEP course goals and objectives are:

- Develop an understanding of the design principles of mechanical, electrical and plumbing systems.
- Develop an understanding of the principles, materials, and equipment used in plumbing/drainage, building electrical systems, HVAC, and fire protection and suppression systems.
- Read and interpret electrical, mechanical, plumbing and fire protection building construction plans and specifications.
- Conduct basic sizing and layout of MEP systems based on the building specifications, loads and demands.

The first two objectives are covered primarily through the lecture presentations, textbook and hand-out readings, and supplemental audio-visual materials posted on the course Blackboard Learn[®] webpage. The last two, more practical, objectives are covered primarily through the course laboratory exercises. Starting with the Fall 2014 semester, Building Information Modeling became an essential part of the course laboratory component, as part of the department initiative to include BIM proficiency and knowledge in the program's graduates skillset.

In the initial implementation of the course, the lecture components and order of topics covered were not modified from previous approaches. On the other hand, the laboratory topics were arranged to follow the lecture subjects: electrical systems, followed by plumbing and fire protection, and ending with HVAC systems and building science fundamentals. However, starting with the Fall 2015, the topics of the course were rearranged to mimic the more conventional construction sequencing of the MEP systems followed traditionally in the construction industry: first mechanical systems and building science concepts, followed by plumbing and fire protection, and finalizing with electrical power and lighting systems.

In both semesters Fall 2014 and 2015, students enrolled in the course were sophomores to seniors majoring in the Construction Science and Management (CSM) Bachelor program. The majority of students enrolled in the MEP course had either completed the program's first construction estimating course, or were enrolled in it concurrently with the MEP class. Prior to the Fall 2014 semester, the introductory course to Building Information Modeling was not a requirement of the program, so proficiency with BIM was not required nor expected from the students taking the MEP course. However, the introductory BIM course is now a requirement of the CSM program, and a pre-requisite for the MEP course, for any student enrolled in the CSM program under the newer UTSA Course Catalogue.

2. LABORATORY STRUCTURE

2.1 Laboratory Format without BIM Exercises

The laboratory sessions of the MEP course are organized as two-hour long sessions in a computer laboratory setting. Personal computing work stations running Microsoft Windows[®] operating system are provided in the room for each student in the class. The computers contain the software packages used in the course, as well as other construction software packages used in the other construction management courses in the department.

Prior to the inclusion and use of BIM, the laboratory exercises focused on the following practical construction management areas:

- Plan reading and interpretation
- Material quantity takeoffs (QTO)
- Basic system sizing
- Basic material and labor estimating
- Fundamental principles calculations

Specialized construction software package used in the course was limited to On Screen TakeOff[®] (OST), published by OnCenter Software, Inc. ("On Screen Takeoff 3.8.1 User Guide" 2010), which was used to complete the QTO exercises, for each of the MEP systems covered in the course. A detailed description of the development of the OST based laboratory exercises was presented by the author in a previous education conference and is available in the conference proceedings (Palomera-Arias 2014).

2.2 Laboratory Format with BIM Exercises

The laboratory exercises developed in the Fall 2014 semester, and modified for the Fall 2015 semester, were designed to introduce and develop practical knowledge required from construction management students (Koontz, Alter, and Lafayette 1996; Korman and Huey-King 2014) in the following areas as they apply to the most common MEP subsystems present in vertical construction:

- Plan reading and interpretation
- Material quantity takeoffs (QTO)
- Basic system sizing

- System modeling and layout
- Fundamental principles calculations

The main difference between this list and the list presented in the previous subsection, is the substitution of the estimating component of the laboratory with the system modeling and layout using Revit®.

Two software packages were used in the new format laboratory: OST and Revit 2014® (Revit) published by Autodesk, Inc. (Bokmiller, Whitbread, and Hristov 2013). OST was used to perform the material QTO during some of the non-BIM related exercises. Revit was the only BIM software package used during the course, and it was required to perform the system modeling and layout exercises for the various MEP subsystems covered in the course.

During the Fall 2014 semester, there were a total of ten laboratory exercises; while in the Fall 2015 the number of laboratory exercises was expanded to twelve. The exercises were designed to cover the five areas discussed. The order of the laboratories, as mentioned previously, closely followed the topics covered in the lecture component of the course at the time of the offering. 1 lists the laboratory topics initially developed for the course in 2014, and the specific areas covered in each, while Table 2 shows the updated Fall 2015 list, with the topics covered, and the new order as to follow the most recent lecture topic's sequence.

TABLE 1: Fall 2014 Laboratory Exercises Focus (Legend: •-explicit focus; ○-implicit focus).

Laboratory Description	Plan Reading	QTO	Sizing	BIM	Principles
Lab 1: Introduction to OST® and Revit®		•		•	
Lab 2: Electric Power and Loads					•
Lab 3: Power Distribution Systems	○	•		•	
Lab 4: Lighting Systems	○	•		•	
Lab 5: Electrical System Sizing			•		
Lab 6: Plumbing Plans and Pipe Sizing	•	•	•		•
Lab 7: Plumbing Layout	○			•	
Lab 8: Fire Suppression Layout	○			•	
Lab 9: HVAC Forced Air Systems Layout	○			•	
Lab 10: Heating and Cooling Loads			•		•

TABLE 2: Fall 2015 Laboratory Exercises Focus (Legend: •-explicit focus; ○-implicit focus).

Laboratory Description	Plan Reading	QTO	Sizing	BIM	Principles
Lab 1 Introduction to BIM and OST		•		•	
Lab 2 Building Thermal Loads			•		•
Lab 3 Mechanical Systems Layout	○			•	
Lab 4 Mechanical Systems QTO's	•	•			
Lab 5 Plumbing Systems Layout	○			•	
Lab 6 Plumbing Systems QTO's	•	•			
Lab 7 Plumbing Systems Sizing	○		•		•
Lab 8 Fire Protection Layout	○			•	
Lab 9 Electric Power and Loads			•		•
Lab 10 Electric Power Distribution	○			•	
Lab 11 Electrical Lighting Systems	○			•	
Lab 12 Electrical Systems QTO's	•	•	•		

A total of six exercises were created, both semesters, focused on using BIM for MEP system modeling and layout, while the rest of exercises focused on developing the other practical construction management skills. These skills are: plan reading, quantity take-offs (QTO), and basic system load calculations and sizing. Load calculations and system sizing exercises were performed in the laboratory using table and equation based methods and calculations, that could be performed by hand or using a spreadsheet program such as Microsoft's Excel®.

All laboratory instructions, hand-outs and supporting materials, were delivered using the Blackboard Learn® course management system. Similarly, students were required to submit a Portable Document Format (PDF) or MS Word® file of their work using Blackboard. In the case of BIM exercises, the Revit® model file (.rvt) or a PDF file showing specific views of the model were required for the submission.

3. BIM EXERCISES FORMAT

As shown previously a total of six BIM exercises were developed for the course. The first exercise was intended as an introduction to the software packages that would be used in the course. In addition, the first exercise provided an introduction to the main 3D model of the building (FIG. 2) that would be used throughout the semester for all BIM problems. The building used and presented to students (West St. Video) is a single-story, open-floor plan retail building with two small rooms and a single bathroom. It contains full plumbing, including storm drainage, rooftop HVAC with ductwork, automatic fire sprinkler system, and a full electrical power and lighting system with a single electrical panel. A full set of digital plans for the building is available, including architectural and structural plans, at a scale of an eighth of an inch to a foot ($1/8''=1'$) in an US 11x17 page size (FIG. 3).

The Revit® architectural and structural base model provided was developed by the instructor based on the architectural and structural plans contained in the building plan set provided to students. The model was then distributed to students using Blackboard® to allow them to add the MEP systems to the building. The West St. Video building was chosen for the course because it contains most of the systems covered in the course at a relatively low complexity level, thus allowing students to concentrate on developing the MEP systems BIM modeling skills without being distracted by the complexity of the system modeled.

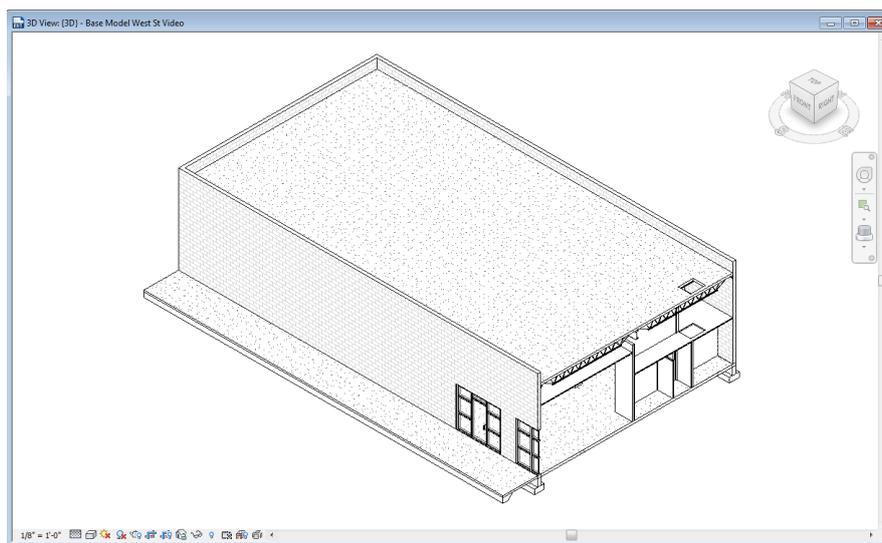


FIG. 2: 3D View of the West St. Video Building Base Revit® Model Used in BIM Exercises.

After the introductory BIM and OST laboratory, the remainder BIM based exercises focused on the various MEP subsystems covered in the course, specifically mechanical systems, plumbing systems, fire suppression systems, and electrical power and lighting systems. The exercises were structured as step-by-step instructions that guided students through the process of setting up the Revit workspace to work with each of the MEP systems covered, and the mechanics of placing the corresponding components into the provided BIM model in order to create a three-dimensional model using the two-dimensional plans provided. In order to simplify the model setup, students added the MEP systems to the base Revit architectural model, rather than linking an external architectural model into an MEP specific file created using one of Revit's stock project templates. Also, since the students were using an existing plan set to create the BIM MEP models, they were not required to size or verify the design of the components specified in the plans. The following subsections describe the BIM exercises for each of the MEP subsystems covered in the laboratory, and provide examples of both the floor plan used by the students and the resulting BIM models.

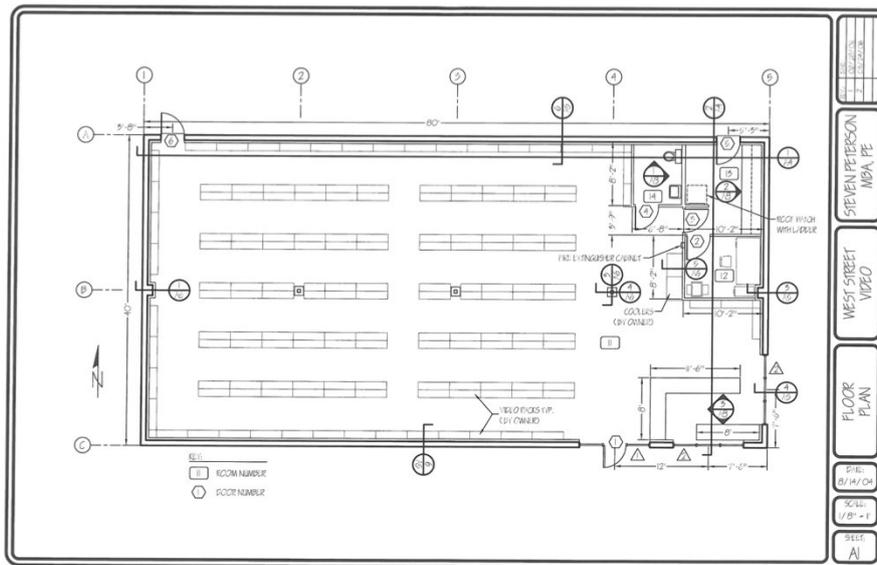


FIG. 3: Sample Architectural Plan Provided for the West St. Video Building.

3.1 Mechanical System Exercise

The mechanical system specified in the West St. Video construction documents consists of a forced air HVAC system, made up of two Roof Top Units (RTU) feeding supply ductwork connected to square ceiling diffusers, and using a non-ducted return plenum space (It was noted to the students that using non-ducted return plenum is no longer an accepted practice)

Creating the BIM model of this system consists of the following steps:

- Create a floor plan view and a 3D view, changing the discipline to “mechanical” and adjusting the view extents to show ductwork and equipment placed above the drop ceiling and roof.
- Define the routing preferences for rectangular and round ducts, and load the required duct fitting families into the project, as indicated in Table 3.
- Load families for mechanical equipment and terminals as specified in the project plans.
- Place diffusers and return grills in reflected ceiling plan view according to the plans provided.
- Create supply and return ductwork systems on the mechanical floor plan as shown in the mechanical floor plan provided. Place the ductwork above the drop ceiling level and below the roof joists.
- Place the two RTU above the roof, modify their duct connections to match existing building ductwork, and connect the units to the appropriate ductwork system.
- Cap open ducts and insulate ductwork as specified in the plan set.

TABLE 3: Duct Fitting Families Required in West St. Video Mechanical Project Duct Routing Preferences.

Routing Fitting Type	Rectangular Duct	Round Duct
Elbow	Rectangular Elbow-Mitered-Transition	Round Elbow-Mitered
Preferred Junction	Tap	Tap
Junction	Rectangular Takeoff	Round Takeoff-Shoe
Cross	Rectangular Cross	Round Cross-Conical
Transition	None	Round Transition-Length
Transition Rect-Round	None	None
Transition Rect-Oval	None	None
Transition Oval-Round	None	None
Union	Rectangular Union	Round Union
Cap	Rectangular Endcap	Round Endcap

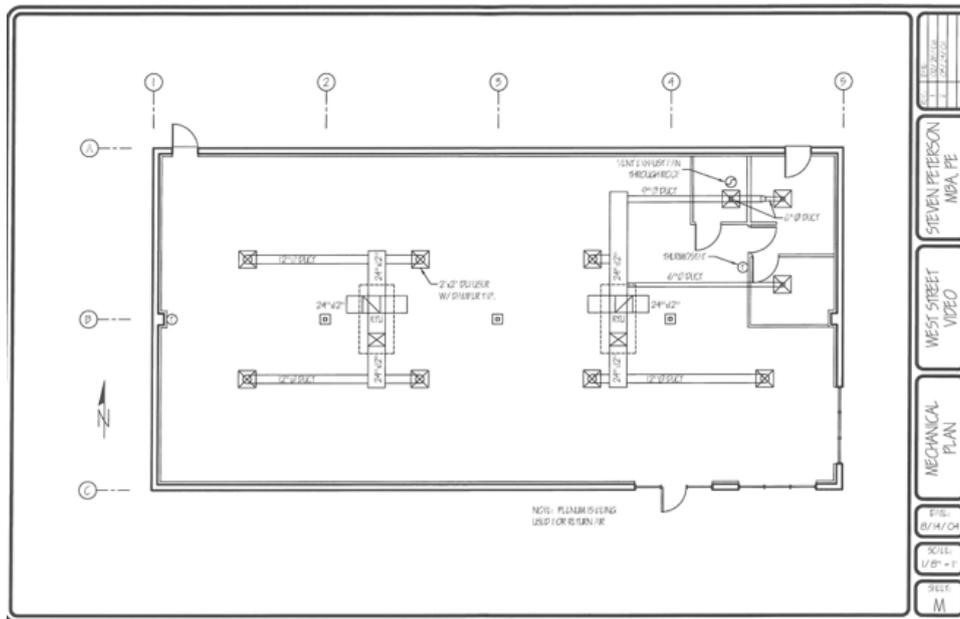


FIG. 4: West St. Video Mechanical Plan.

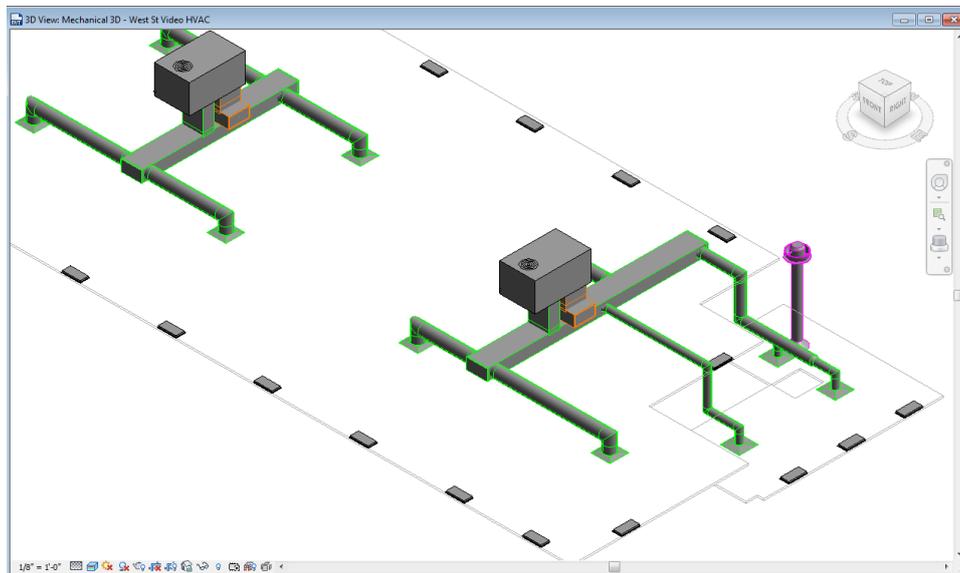


FIG. 5: West St. Video Mechanical Revit Model.

FIG. 4 shows the mechanical floor plan used during the exercise, while FIG. 5 shows the corresponding Revit model created by following the steps outlined in the laboratory hand-out. The image shows a screen shot of the 3D view in the Revit workspace. The exercise focused mainly on the modeling and layout of the forced air system without entering equipment capacities, nor diffusers and grills specified airflow rates.

3.2 Plumbing and Fire Suppression Systems Exercises

Two piping related exercises were developed. The first exercise involved the modeling of the plumbing system in the building with the exception of the gas piping supplying the RTU's. The plumbing system consists of a single half-bathroom, and the storm drainage system. FIG. 6 shows the plumbing details sheet available in the plumbing plans of the West St. Video Building. This sheet shows an enlarged plan of the bathroom. FIG. 7 presents the Revit workspace showing a tiled arrangement of the 3D view and the plumbing floor plan view of the completed plumbing model.

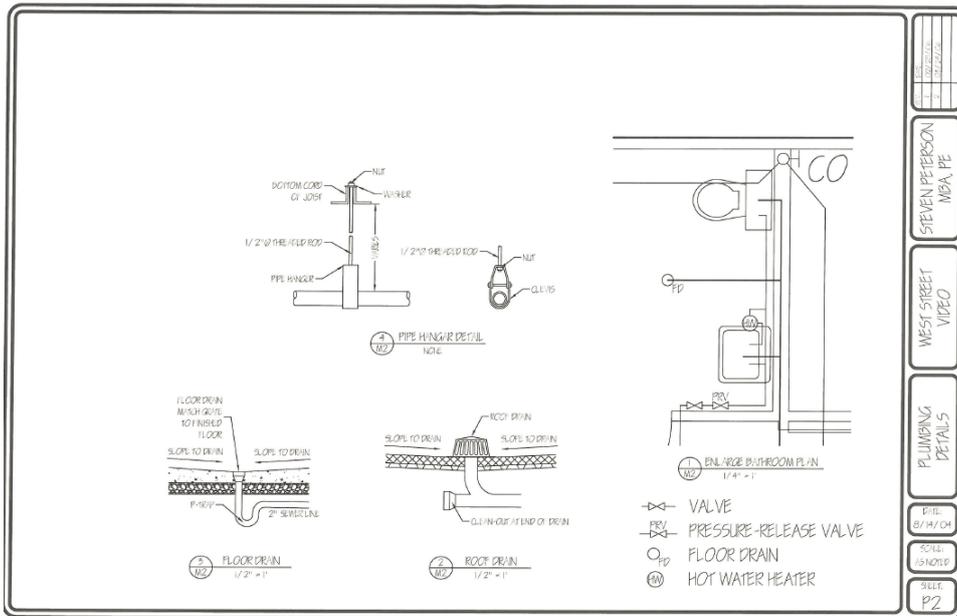


FIG. 6: West St. Video Plumbing Plan Detail Sheet

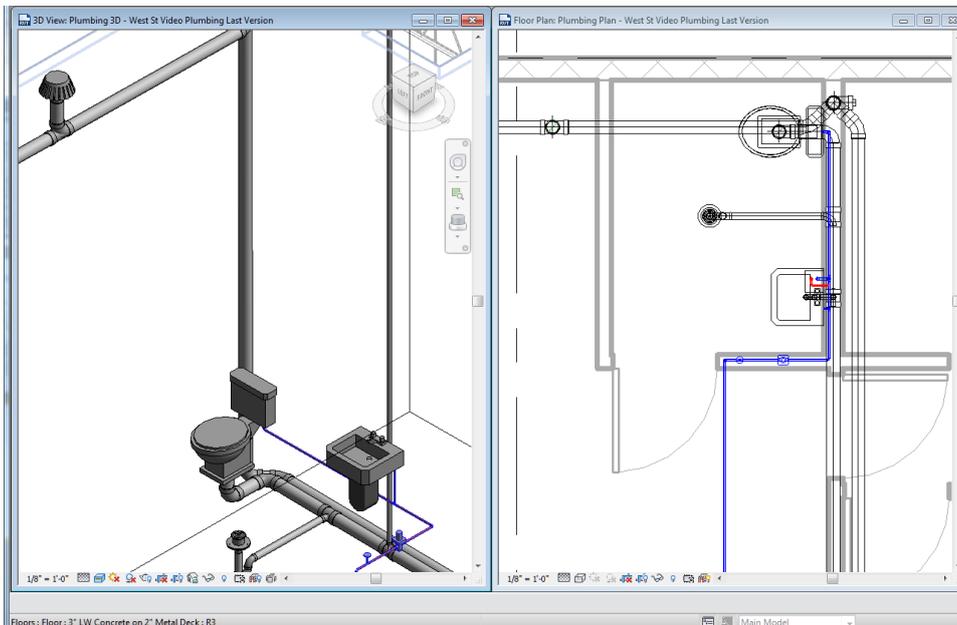


FIG. 7: West St. Video Bathroom 3D Revit Model Detail.3D and Plumbing Plan Views.

The second piping exercise focused on modeling the automatic fire sprinkler system in the building; including the sprinkler wet valve riser equipment and fire-department Siamese connection and drains. Fig. 8 shows the fire protection floor plan provided in the plan set, while FIG. 9 shows a 3D view of the resulting Revit model.

The West St. Video plumbing plans shows an under-sink instant water heater in the bathroom to provide hot water to the lavatory from the single cold water supply pipe. Because the used version of Revit in the classroom does not include that kind of water heater in its standard libraries, students needed to download a suitable “heater family” from a water heater manufacturer’s website, and load the downloaded family into the project to complete the model.

The general steps followed to build both BIM models are similar to the steps followed in the mechanical systems exercise, with the following specific changes and particularities:

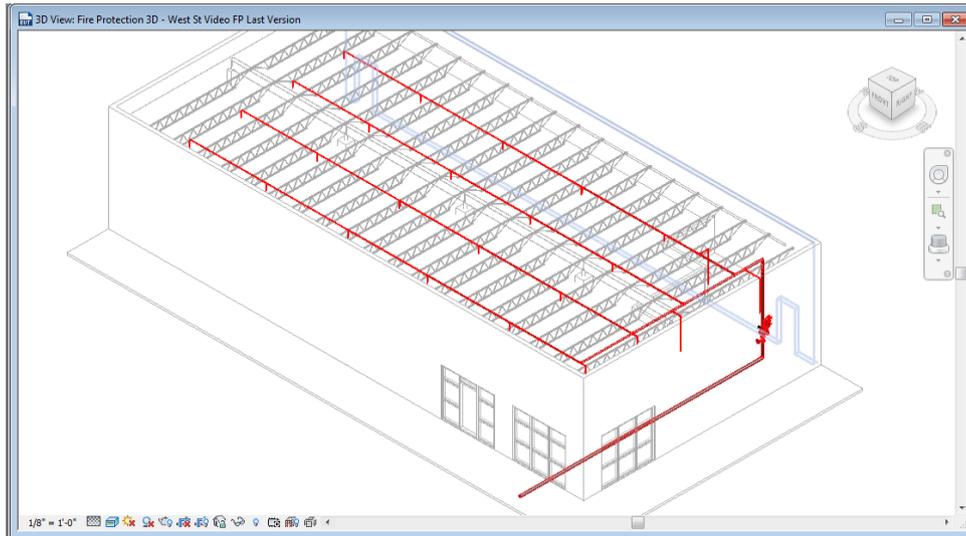


FIG. 9: West St. Video Fire Protection Revit Model 3D view.

3.3 Electrical Power and Lighting Exercises

Electrical systems were slightly different to the mechanical and piping systems exercises as they focused mainly on generating electrical plans, electrical circuiting and power panel schedules rather than creating detailed 3D models of branch circuit conduits and wiring layouts. The two electrical related exercises are based on the two electrical plans provided in the building set: the electric lighting plan and the electric power plan (FIG. 11 and FIG. 11). A third electrical sheet contains the single line diagram for the building service entrance, and a basic panel board schedule containing circuit number description, circuit ratings, wire gauges and branch loads.

Creating the electrical BIM model of the building consists of the following steps:

- Create a floor plan view and a 3D view, changing the discipline to “electrical” and adjusting the view extents to show devices placed at higher elevations.
- Define the building electrical system and power distribution using the *Electrical Settings* dialog box. Set the building nominal voltages, and the range of acceptable working voltages.
- Load families for electrical equipment, lighting fixtures and lighting devices as needed in the project.
- Place power distribution panel, and define its distribution system membership
- Place lighting fixtures in reflected ceiling plan view according to the plans provided.
- Create electrical circuits connecting lighting fixtures to the power panel
- Load families for electrical power devices as required per the project
- Place outlets on model using the electric power plan view according to the plans provided
- Create electrical circuits connection power outlets to the power panel
- Create the power panel schedule.

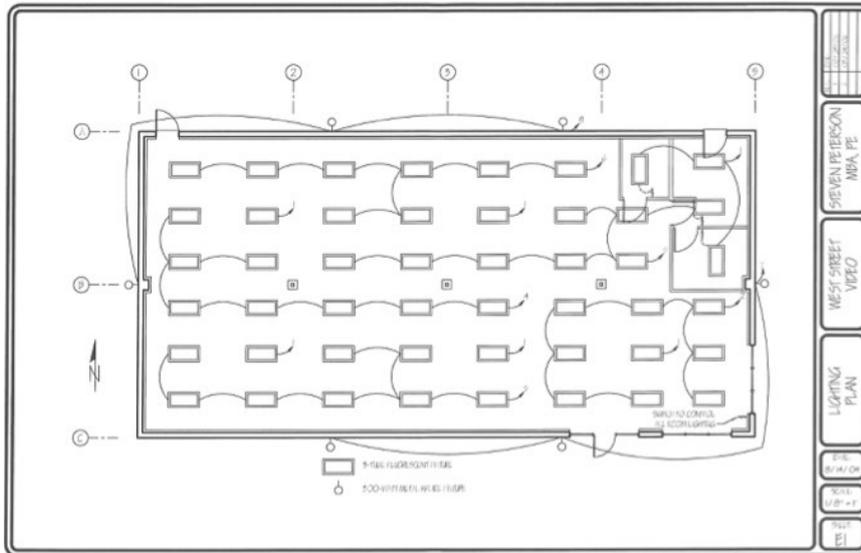


FIG. 10: West St. Video Electric Lighting Plan.

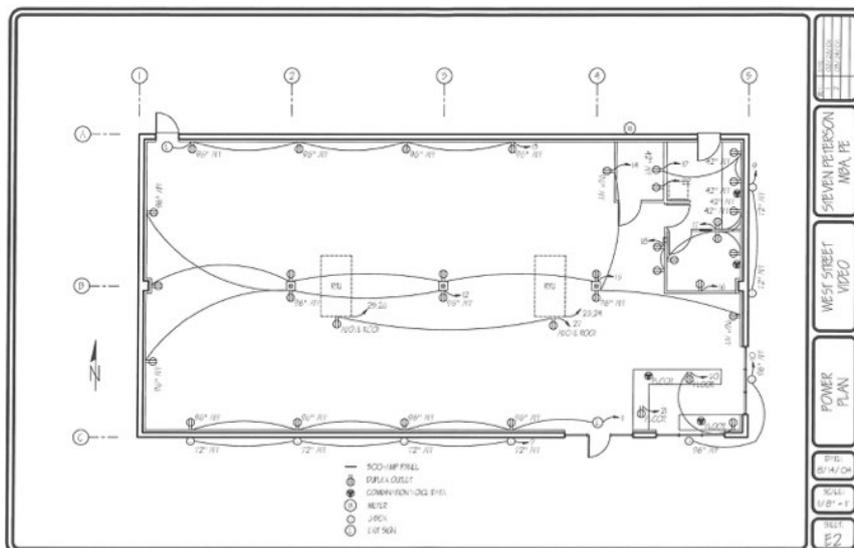


FIG. 11: West St. Video Electric Power Plan.

Devices and lighting fixtures were placed on the architectural model, but only “electrical” connections were made between devices. FIG. 12 shows a 3D view of the electrical model created in Revit including lighting, and power devices and equipment. FIG. 13 shows the Revit produced lighting electrical floor plan. Notice the lack of the electrical circuit connections between devices in the 3-dimensional view of the system that are otherwise shown in the electrical plan view.

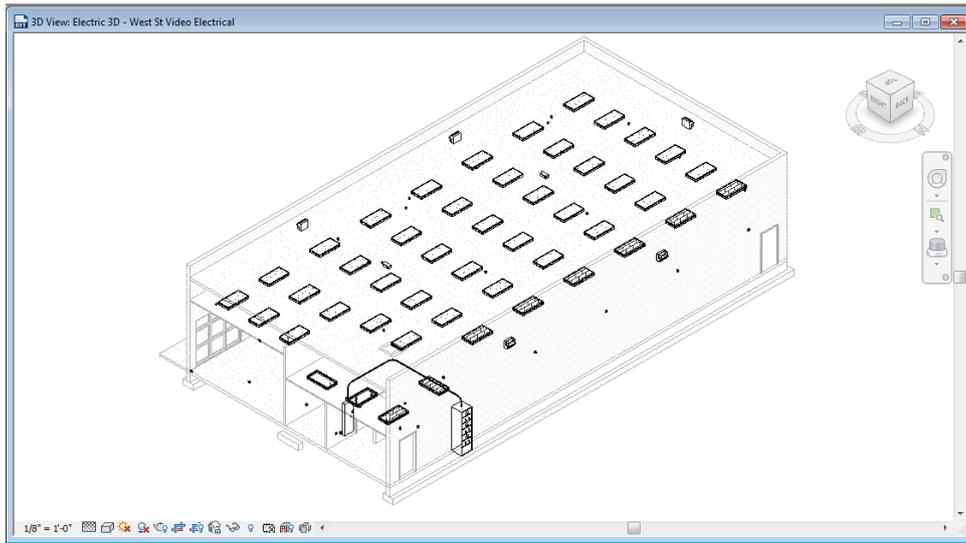


FIG. 12: Revit Electric Model 3D View Showing Lighting and Power Components.

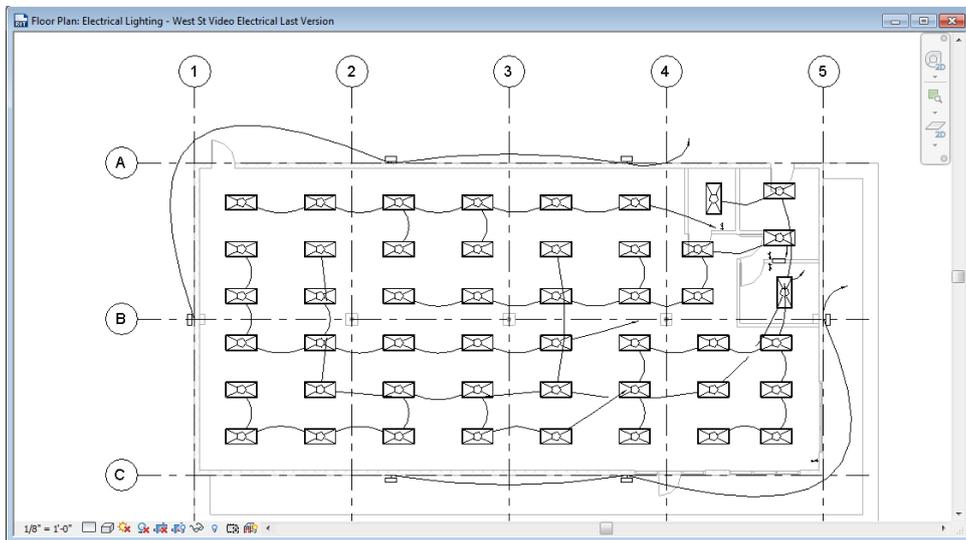


FIG. 13: Revit Produced Electric Lighting Plan.

Also, conduit is only modeled between the service entrance equipment and the power distribution panel, even though the project specifications call for branch circuit wiring using EMT conduit. Revit does not provide a straightforward method to model conduit for branch circuits using the stock electrical devices, such as receptacles or lighting fixtures. Furthermore, it is customary in the electrical construction industry to only model conduit larger than 1 inch in diameter, which limits the 3D modeling of conduit to larger electrical subsystems such as feeder conduits, conduit banks, switchgear, and electrical panels and cabinets.

4. DISCUSSION

4.1 Student Evaluation

The University of Texas at San Antonio follows a two-tier course evaluation procedure where students complete an online evaluation of the courses taken during the semester. This evaluation is used for administrative review purposes as well as assessment, and provides only a general measure of the course effectiveness and the instructors' teaching effectiveness without providing details on the individual course components.

In order to evaluate the perceived effectiveness of the BIM laboratory exercises, students were asked to complete an online survey on Blackboard® independently of the University’s online course evaluation. The supplemental evaluation was used to ask the students questions regarding the topics listed below:

- Usefulness and appropriateness of using BIM in a MEP course (TABLE 5:).
- Student proficiency with BIM software and effectiveness of laboratory problems (TABLE 6).
- Laboratory problems organization and difficulty (TABLE 7).
- And, appropriateness of the building models used in the exercises (Table 8).

A total of 30 questions were asked during the Fall 2014 and the Fall 2015 semesters. Twenty-nine questions covered the topics listed above in a multiple selection scale format. The last question allowed the students to provide written feedback on the laboratory exercises. Enrollment in the course was 35 students during the Fall 2014, and 55 students during the Fall 2015. The combined survey response rate over the two semesters was 41% resulting in the survey sample size of 37 students.

Based on the feedback received, the majority of students feel that it is a good idea to have BIM as part of the course, and that the problems were conducive to learning. They also feel that knowledge of both BIM and MEP systems are required skills in the CM profession

TABLE 5: Students Responses Regarding BIM Use in an MEP Course.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you think using Building Information Modeling, as part of the MEP System Course is a good idea?	24%	46%	22%	3%	3%
Does laboratory exercises, BIM or otherwise, should be part of the MEP course?	30%	57%	0%	14%	0%
Should an introductory BIM course be a requirement for the current MEP Course?	68%	24%	8%	0%	0%
How relevant were the BIM exercises to the CM profession?	16%	70%	14%	0%	0%
Does understanding BIM as it applies to MEP systems might help in your future CM career?	27%	68%	5%	0%	0%

TABLE 6: a) Student Perceived BIM Proficiency and b) Effectiveness of the Labs.

Question	Advanced	Average	Basic	Beginner	Clueless
At the beginning of the class, how would rate your knowledge and proficiency of BIM software?	3%	16%	14%	35%	32%
After completing the MEP class, how would rate your knowledge and proficiency of BIM software?	11%	38%	22%	24%	5%

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Did you learn something useful from the BIM exercises?	14%	86%	0%	0%	0%
Using BIM in the laboratory, does it help understand MEP systems better?	16%	46%	24%	14%	0%
Using BIM in laboratory exercises, does it help understand how MEP systems are layout/routed?	19%	68%	14%	0%	0%
Using BIM in the laboratory exercises, does it help understand what components and pieces are needed?	16%	70%	14%	0%	0%
Using BIM helps understand electrical system better?	5%	41%	54%	0%	0%
Using BIM helps understand plumbing and fire suppression systems better?	8%	73%	19%	0%	0%
Using BIM helps understand HVAC systems better?	22%	59%	19%	0%	0%

Students felt that the laboratory exercises improved their proficiency of the BIM software. They also reported that using BIM helped with their understanding of MEP system in general, with the exception of electrical system. Most students felt that using BIM did not enhance their understanding of electrical systems as much as with the other MEP subsystems.

TABLE 7: Student Responses Regarding a) Laboratory Format and b) Difficulty.

Question	A Lot More Needed	More Needed	Just Right	Little Too Much	Way Too Much
How do you feel about the number of BIM exercises done over the semester?	0%	19%	68%	14%	0%
Is one week to complete each exercise enough time?	0%	22%	68%	11%	0%

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Ignoring the software learning curve, the tasks that you were asked to complete during the BIM exercises were difficult?	5%	24%	54%	16%	0%
In regards to the BIM software used in the labs, is the software user friendly?	8%	38%	5%	38%	11%
Using REVIT is a distraction from understanding MEP systems?	3%	24%	19%	27%	27%
Does the content of the BIM exercises complement the lecture materials?	22%	41%	26%	11%	0%
Do the instructions provided in the lab handouts were easy to follow?	3%	54%	14%	24%	5%
Does the instructions provided in the labs were sufficient to complete the exercises?	11%	49%	27%	8%	5%

Table 8: Students Responses Regarding Appropriateness of Building Models Used

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you think the building model used (West St. Video Building) was a good choice?	32%	41%	27%	0%	0%
Was the other building model used (Kamp for Kids Basement) a good choice for electrical exercise? (only Fall 2014)	13%	40%	47%	0%	0%
Should the same building be used for every exercise?	46%	38%	11%	5%	0%
Do you think that adding more detail to the building models, such as furniture, finishes, doors and windows is relevant while working with MEP systems in BIM?	0%	19%	27%	43%	11%
When working with a particular MEP system, should the model not have any other MEP systems on it?	8%	16%	41%	19%	16%
When working with a particular MEP system, should the model already have all the other MEP systems on it?	8%	14%	35%	35%	8%
If the same building model is used for all the exercises, should the MEP systems be added sequentially throughout all the exercises?	46%	51%	3%	0%	0%

For the most part, students reported that the base model (West St. Video Building) used in the laboratory exercises was a good choice, and conducive to learning and understanding MEP systems. Laboratory hand-outs and problems were appropriate for the course, both in quantity and length. However, there is also room for improvement, especially on the electrical systems part of the course. Students also strongly felt that a basic BIM course is essential prior to taking the MEP course.

4.2 BIM Use Advantages

One advantage of using BIM during the MEP course is better understanding and visualization of the system layout over two dimensional plans and drawings. Students were able to visualize layout issues not evident without prior experience, or good intuition, from a collection of plans and riser diagrams, including changes in elevation, overlaps, and spacial location of components in relation to other building components such as doors, windows, ceiling, etc. Also, subsystems can be easily classified and identified, and the relative scale of the components is clear from the BIM model.

4.3 BIM Use Challenges

One of the main problems encountered using the BIM software package was the learning curve associated with the software, which was accentuated by the fact that most of the students enrolled had no previous exposure to

the software. Another caveat of the software relates to the working files size and the computer laboratory storage policies, which requires the use of external portable drives in order to allow students to work on the same project on different computers at various times during the semester, when the software is not installed on their personal laptops. Also, the instructor needs to plan accordingly to introduce the software package itself to the students, especially if it is the first time students are exposed to it.

Also, from modeling perspective, Revit® requires extensive workspace setup, such as library loadings, systems definitions, and routing preferences to name a few, which requires a considerable amount of time and effort, as well as MEP systems knowledge, before the software can be used effectively. Also, the requirement of another software package (Navisworks®), in order to run clash detection of systems in a building, requires additional class time, and possible resources, to take full advantage of the promises of BIM.

Another problem encountered while using the MEP families included with the Revit software distribution installed in the laboratory is that many of the fixtures and equipment modelled are not an accurate replica of the actual physical items in term of the location of connections, trim, and proportions. For example the standard flush tank toilet has the cold-water connection in the back of the tank as opposed to the more traditional US location at the bottom of the tank. Finally, some of the families are misclassified into the wrong type, for example, the roof drain is categorized as mechanical equipment in lieu of a plumbing fixture or accessory, which causes confusion amongst the program users.

5. CONCLUSIONS AND FUTURE WORK

Starting with the 2014-2015 academic year, the curriculum of the CSM program at UTSA encompasses BIM as part of the degree requirements. As part of this new requirement, the MEP Systems course was modified during the Fall 2014 semester to incorporate BIM as part of the laboratory exercises.

The laboratory exercises developed during the Fall 2014 semester were the first step in the ongoing process of incorporating BIM into the MEP course offered in the Construction Science Department at UTSA. During this first stage, only the basic 3D MEP systems modeling capabilities of Revit® were explored. BIM exercises were designed as step-by-step instruction that guided the students through the process of adding MEP systems into an existing architectural model, as a way to recreate an existing 2D plan set. During the Fall 2015 semester, the sequence of the topics covered in the course was modified to follow that traditional MEP system construction sequencing, and the order of the laboratory exercises was modified accordingly.

The advanced capabilities and features of the BIM software package, such as automatic quantity take off, or advanced schedule generations, to name a few, were not explored. Furthermore, clash detection of MEP systems and structural systems, which is one of the most important benefits, and drivers, for the use of BIM during design and construction of buildings, was not covered. These omissions would be the next logical additions to the laboratory exercises.

Finally, BIM laboratory exercises will be modified to link the architectural model into the MEP system model created by the student. This change better reflects how BIM models and workflows are handled in the construction industry, where the architectural model, the structural model, and the individual MEP models are created by different parties and linked together at various stages of the design and construction process.

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