

# Visualizing Construction: A Course in Digital Graphics for Construction Management Students

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Constructors must effectively communicate with every party involved in the construction project, visually, orally, in writing, and graphically. In the course of executing their work, contractors use drawings, specifications, and other graphic documents extensively. As building designs have become more complex and consequently buildings have become more difficult to build, and with increasing popularity of the design-build project delivery system, communicating as effectively as possible among the design/build team is imperative. Technological advancements in both hardware and software are providing powerful digital graphics tools capable of assisting constructors in this communication. Computer graphics applications are being increasingly adopted by more construction companies. Therefore, the ability to use digital graphics for visualization and communication is becoming an important skill for constructors and hence for construction management students. In response to this need, a course taught in an ACCE accredited construction management undergraduate program traditionally a CAD course, has been redesigned to incorporate many modern forms of graphic communication appropriate for construction, including simple drawing tools, digital photography, animation, video, 2d CAD, and 3d sketching applications. This paper presents the development and implementation of a digital graphics course for construction management students and some of its benefits.

**Keywords:** Digital Visualization, Digital Graphics, Information Technology, Construction Education

## Introduction

Communication is at the heart of any collaborative human activity and building is no exception. Imagine trying to construct even a small building without communicating with someone. In the course of a single day on a construction jobsite, there are thousands of communications necessary for coordinating activities among designers, trades workers, suppliers, owners, and construction managers. Construction managers are responsible for understanding shop drawings, as-built drawings, and for producing temporary structures drawings, graphs and charts, and site utilization plans. In many cases, use of digital visualization tools can greatly assist a project manager in understanding and communicating about a project. "...In the construction industry, because professionals involved in building design must communicate particularly complex ideas, they typically do so through graphics. Therefore constructors ... must have a thorough understanding of graphics commonly used in construction projects" (Bisharat, 2004). There is strong indication that use of digital graphics by constructors to communicate about construction is on the rise. Thirty of thirty-three constructors polled in a recent survey by the authors indicated that they employ digital graphics applications within their companies. Digital graphic applications have been adopted to visualize not only design but also construction and operation of a building, and to exchange information among parties involved in the construction process. As a communication tool, digital visualization allows people to understand buildings better and more quickly (Sawyer, 2006). For example, capturing digital images on construction sites for

project documentation and evidence of potential legal issues; developing site utilization plans to organize the sequence of construction activities; sketching small details or highlighting digital construction plans for RFIs or change orders; creating 3-dimensional models to demonstrate projects to clients. The recent and rapid growth of interest in Building Information Modeling (BIM) within the building professions further suggests that constructors will need to be increasingly skilled with digital graphics.

Digital visualization has become one of the key information technologies of the last decades (Martini, 1998). Recent developments in information technology have provided increasingly powerful and complex visual communication media. These include modern digital forms of photography, animation, and video recording. Each of these media provides exponentially more information but requires more time and skill to extract meaning from the robust information embedded in them. Modern digital photography provides realistic capture of an actual scene. Photographs are used to report job progress, problems, and as-built conditions at a specific point in time. Animations, built from a sequence of changing images, are useful in illustration of construction processes or progress of activities over time, or to provide training. Digital videos create realistic recordings of processes or techniques in action. They are the most lifelike of communication media, combining moving photo images with the added dimension of sound. The common format of all modern digital communication media allows for easy blending of information from a variety of sources. Examples are annotated portable document files (pdf), photographic images with overlaid text and dimensions, and overlaid voice commentary on video or animation sequences.

With the growing use of graphic communication on construction projects and the advancements in digital graphic technology, the ability to use applications of digital visualization programs has become one of the important skill sets for construction management students. The plethora of visual digital media has the potential to provide more precise information about more complex buildings. Although these sophisticated tools are designed to be more intuitive to use, they are sufficiently complex to require training and practice. It is reasonable that the more familiar construction graduates are with these new software tools, the more likely they are to find a productive use for them in the construction industry. Therefore, faculty members at a four year ACCE accredited construction management program completely redesigned their CAD-based course to incorporate a wider range of relevant graphic tools.

### **Course Development**

The course (named CIT2 in the curriculum) is the second in a series of junior level Construction Information Technology courses offered in the program. Its prerequisite, CIT1, covers elements of digital computations utilizing Excel and Access, while CIT2 focuses on applications of digital graphics. During the stage of initial design of CIT2, an overall course purpose was established: "...to explore, discover, create and manage digital visualization appropriate for the construction industry". Based on different types of digital media addressed, course topics were divided into four major sections, including image editing and management, 2-dimensional drawing, 3-dimensional modeling and video capture and editing. Class size and meeting format were chosen to optimize learning for students. Typical class sizes are between 15 and 20 students in

each section, which meets in one of the department's computer labs for two 2-hour sessions per week. To provide students sufficient practice time in this hands-on computer course, each class meeting generally consists of instructor's lecture and demonstration during the first hour, and hands-on guided instruction using exercises in the second hour.

The rapid evolution of application software and the approach taken to teach the material in the context of construction has necessitated the creation of unique study and tutorial materials for the course. Students are issued a custom packet of exercises and assignments for all course material, with the exception of SketchUp, which is presented in the form of interactive tutorials available online from Google SketchUp's website. Course materials are improved and upgraded continuously as new software capabilities are released and new construction examples emerge from practitioners. The tutorial provides a guide and notes of course material, freeing student's attention for hands-on learning and practice.

### *A Few Words about BIM*

Building Information Modeling, BIM, though an extremely important emerging topic, incorporates not only graphics, but scheduling, estimating, and other project management information. The graphics course reviewed in this paper is introduced to juniors before computer estimating, scheduling, and project management have been covered in the curriculum. Because of the comprehensive scope of BIM, the department is planning a separate BIM course, positioned at the capstone level and incorporating all of the information types contained in BIM, including cost, time, and others. Graphics skills learned by students in this course will be reinforced and extended in the BIM course.

### *Digital Images*

The objective of this section is to present basic techniques of capturing, storing, managing and editing digital images. An overview of digital image capture using cameras and scanners and some fundamental photography skills are also covered. Digital image editing and file management software applications are taught in this section, including MS Windows Explorer, Windows Picture and Fax Viewer, Microsoft Office Picture Manager and Adobe Photoshop CS.

The following features of digital image editing and managing are covered in three classes:

1. Capturing images with digital cameras and scanners at various resolutions.
2. Viewing, sorting and printing images.
3. Naming and assigning properties to image files.
4. Adjusting brightness, contrast, and color balance of an image.
5. Annotating images with text, dimensions or other graphics.
6. Resizing and Compressing Images.
7. Converting image file formats.
8. Cropping and Combining images.

A series of exercises and homework were created for this section. The following example shows a course exercise requiring students to use Adobe Photoshop to straighten and crop a scanned image, and then add a text label. See figure 1 for original photo and its solution.



Figure 1: A digital image editing exercise and student's solution.

### *2-D Digital Drawings*

In a recent survey, the authors received responses from a selected audience of 33 software users from the construction industry in the Southeast US to share information on their use of graphic applications in their companies. In regard to choices of computer applications for creation of 2-dimensional graphics, the standard drawing tools in MS Office Excel, Word and PowerPoint are used by more than 80% of the respondents; AutoCAD is used by the same percentage of construction companies; MS Visio is selected by more than 40% of respondents, with other CAD applications including DataCAD, and Bentley Microstation used by 31% of the respondents. The uses of these applications include developing flow charts and conceptual diagrams, making PowerPoint illustrations, extracting distances and areas, creating templates for building layout, producing construction site utilization plans, developing erosion control plans and temporary structures sketches, checking accuracy of architectural drawings, and obtaining counts, areas, and volumes for quantity take-offs.

To give students the capability of creating and editing basic 2-dimensional digital drawings, several digital graphics applications broadly utilized in the construction industry are introduced in the class, including: the latest versions of Microsoft Excel, Word and PowerPoint for their built-in drawing tools, AutoCAD as a widely used elemental drawing creation program, and Microsoft Visio as a component drawing application.

### *Simple Drawing Tools*

As the most common office software suite, with its own built-in drawing functions, Microsoft Office is capable of producing basic 2d graphics to meet the graphic communication needs of a construction company, such as a sketch for an RFI or daily log, or a drawing for design of a temporary structure. Construction specific exercises and assignments have been developed for this section of the course. The example assignment in figure 2 is constructed of geometric shapes of different colors and weights, snapped to a square grid. Entities are grouped as a single object; their properties set so they do not resize and move with cells. Dimensions are a grouped set of lines and text, which can be altered with the input table shown.

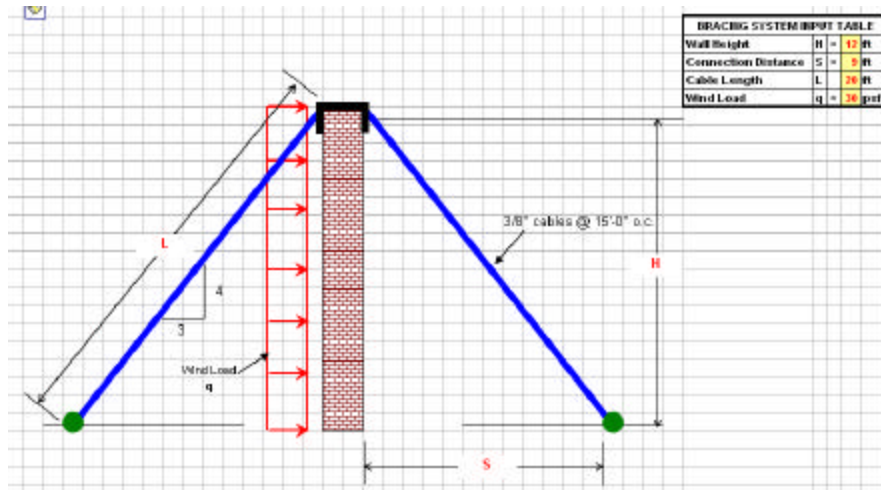


Figure 2: A wall bracing system sketched in MS Office Excel as a class assignment

Following is a list of features of MS Office drawing tools covered in two classes in this course.

1. MS Office Excel and Word:
  - Using drafting aids: setting up grid and snapping to grid and shapes.
  - Creating basic drawing entities: line, oval, rectangle or other shapes.
  - Editing drawing entities with color, line type and weight, and fill patterns.
  - Grouping and ordering of drawing entities.
  - Moving, copying and rotating entities and groups.
  - Creating dimensions with corresponding dimension text.
2. MS Office PowerPoint:
  - Creating basic drawing entities: line, oval, rectangle or other shapes.
  - Developing animations using custom animations and motion paths.

### Autodesk AutoCAD

The CIT2 course has its roots in AutoCAD, and was originally a 15 week course in AutoCAD mastery. AutoCAD remains the most difficult application for most students in the course, and its primary features take more than one third of class meeting time (10 lectures) to be covered. The comprehensive written tutorial discussed earlier covers 2-dimensional drafting in AutoCAD using original construction related exercises. Figure 3 is an example from the tutorial showing a property layout plan in AutoCAD, which makes use of survey angle measure.

Below is a list of major AutoCAD functions covered in this course:

1. Basic draw and modify commands:
  - Creating basic drawing entities: line, arc, circle, polygon, and polyline, etc.
  - Creating annotations: dimension and text.
  - Modifying a drawing entity, such as moving, copying, scaling, rotating, etc.
  - Viewing a drawing: zooming and panning.
  - Drawing with precision using data entry, and object inference and snap.

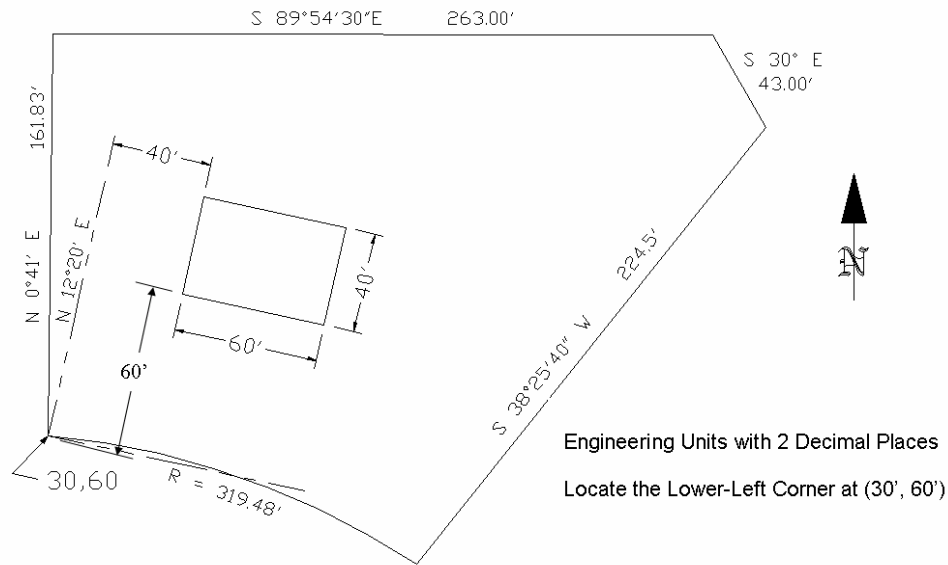


Figure 3: A building layout plan created in AutoCAD 2007 as a class assignment.

2. Drafting settings and aids:

- Setting up drawing limits, units, scales, snap and grid, and coordinate systems.
- Creating and using drawing templates.
- Using layers to organize graphics entities.
- Creating, inserting, and editing blocks.
- Combining drawings and externally referencing drawings.

3. Inquiry commands:

- Obtaining point locations, distances, and areas from a drawing.
- Obtaining and editing entity properties from a drawing.

4. Output:

- Plotting.
- Multiple formats of outputs from a drawing, for instance, a JPEG image.

*Microsoft Office Visio*

Producing a Visio diagram involves selecting appropriate shapes from a built-in shape library, and placing them in proper locations within the drafting space with necessary modifications. This drag-and-drop approach makes Visio extremely easy to learn for people with limited drafting experience. Visio is the application that is learned most quickly by students in this course. In Visio, associated shapes are grouped and stored in stencils such as walls, fixtures, landscape features, etc. All shapes have built in labels that can be activated and most come with data-connected attribute properties, which can be easily edited. With such advantages and a relatively low cost, MS Visio has been adopted by construction companies for creation of flowcharts, site plans, floor plans, timelines, schedules, etc.

As part of the course materials, several step-by-step tutorials were created for students to quickly master MS Visio. Figure 4 shows the assignment of a site utilization plan for a small

construction project. Students first create sheet layout with border, title block, north arrow, and scale on a background page. Then the building footprint, materials storage and job trailer areas that are made of basic rectangles with text labels are placed on a foreground page. Gravel access road is created by joining three rectangles. Security gate, landscape plantings, vehicles and parking spaces are dragged from appropriate stencils and placed on the drawing.

Main features in Visio covered by three lectures of this course include:

1. Drafting aids and page setup, including: snap and glue; drawing units and scales; foreground page and background page.
2. Basic drawing tools using drag and drop shapes from stencils
3. Editing tools such as move, copy, rotate and changing shape properties.
4. Use of data-connected drawing entities, such as door/window schedule.
5. Importing and exporting from and to AutoCAD drawings or other digital image formats.

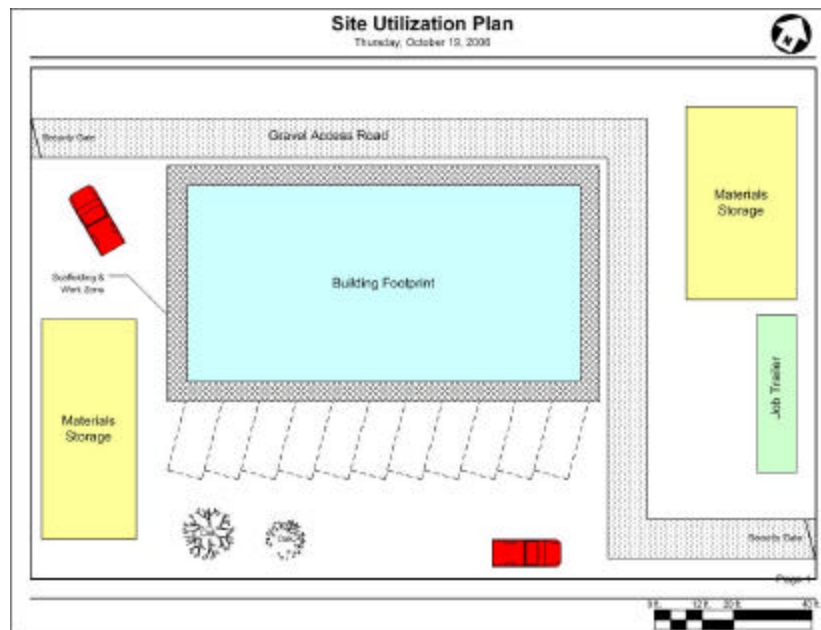


Figure 4: A site utilization plan created in MS Office Visio as a class exercise.

### 3D Digital Models

More contractors have started taking advantage of creating and using 3-dimensional models for visualizing, controlling and managing construction projects. In the survey of graphics usage conducted by the authors, 55% of the 33 respondents indicated that their companies used some type of 3D software. Recent advancements in building information modeling (BIM) seem to be the future of the building design and construction industries. 25% of survey respondents indicated that their companies currently made use of BIM.

To familiarize students with 3D model creation and rendering within a short period of time, Google SketchUp is introduced in the course. Developed for the conceptual stages of design, Google SketchUp is an easy-to-learn but powerful 3D modeling program that enables students to



explore and communicate complex concepts in 3D, import and export various file formats, and create interactive presentations with simple tools. Through four lectures and few exercises on SketchUp, students become knowledgeable with the following concepts in 3D modeling:

1. Creating basic 2D entities from which 3D geometry is extruded.
2. Assigning color and texture to surfaces and edges in a model.
3. Manipulating a 3D model through view tools: pan, zoom and orbit.
4. Speeding drawing and minimizing effort and file size with components.
5. Casting real-time shadows.
6. Creating interactive sections from a 3D model.
7. Providing dimension & annotation.
8. Importing images and textures; exporting animations and videos.

Below is a student's SketchUp model that was used to illustrate the structure assessment of a building in his capstone thesis project (see figure 5).

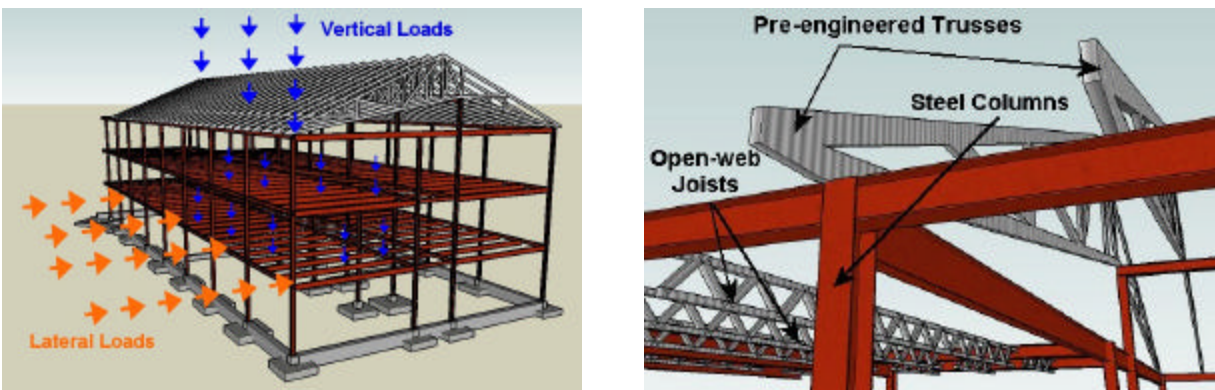


Figure 5: A 3D SketchUp model illustrating a building's structure and load assessment.

### *Digital Videos*

Since videos have been used by the construction industry for communication and enhancement of project documentation for years, it is necessary to familiarize students with capturing, editing, and managing digital videos. This includes knowledge of hardware such as camcorders and video capture cards, and software such as Microsoft Movie Maker, Camtasia Studio or Adobe Premiere. The course contains one week of introduction to digital video using a tutorial guide for students to produce a small video project. Students work with a digital video camera and discover some of the art of composing and editing captured video, and merging video with other digital media sources such as text, still images, music, and voice-over.

### *Course Final Project*

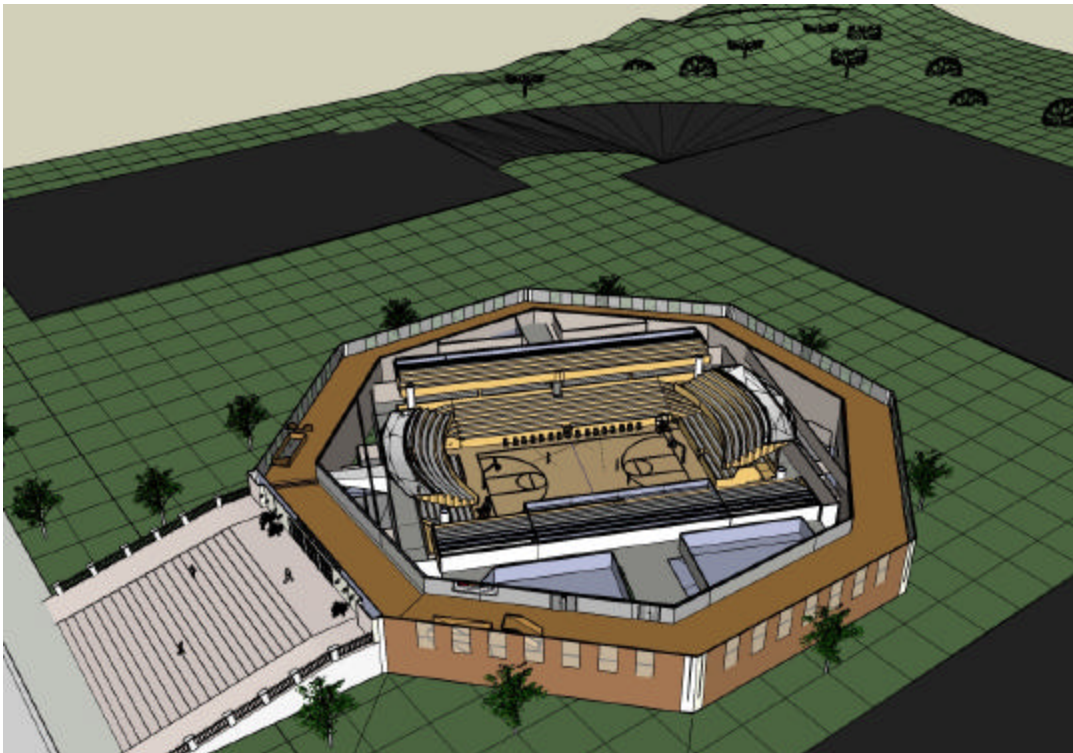
To extend students' skill and knowledge, a comprehensive final two-person group project is assigned at semester end. The two-week project involves preliminary design for a hypothetical building project on a pre-selected site, for instance, a new basketball arena on campus, an office building downtown, or company headquarters on a hilly rural site. Students are required to utilize all software applications covered in class to design, and then present their design to the



entire class. For extra credit, students are encouraged to explore new graphic applications to enhance the visualization and presentation of their design. Final project scope includes:

1. Capturing digital images of the site; assigning properties to each of digital image files.
2. Creating a comprehensive 3D conceptual model for the design in SketchUp. Appropriate advanced features such as incorporating site contours, generating sections from the model, and exporting walk-through animation should be employed.
3. Working from the 3D model, developing a set of detailed 2D design drawings using AutoCAD and MS Visio, including architectural floor plans, structural sections, and furnished room plans.
4. Presenting the design to the entire class with a formal presentation, incorporating video and animation effects.
5. Employing new software packages not used in class to enhance the visualization.

The attached image (see figure 6) is a rendering of a 3D model of a basketball arena that was designed and developed using graphic applications by a student group for class final project.



*Figure 6:* A basketball arena 3D model developed in SketchUp as a final project.

## **Conclusion**

The increasing complexity of building designs, the effectiveness of graphics for communicating complex concepts, and the ubiquity and ease of use of inexpensive hardware and software tools for producing graphics have led to a marked increase in digital graphics within the construction industry, and brought new challenge to educators in the construction management area. Through

development and implementation of a digital visualization course, the authors, have been equipping a new generation of constructors with a new generation of communication tools for visualizing construction. Students successfully completing the course possess digital visualization skills and knowledge of their appropriate use in construction.

Since the implementation of this course, incorporation of digital graphics by students has increased significantly throughout the curriculum. This is evident in increased graphic content of homework and projects. Many samples can be found in students' capstone thesis projects, which include: preliminary construction schedules developed with simple drawing tools in MS Office Excel; business organization charts and project timelines drawn in MS Visio; building structural analysis and temporary structures design demonstrated through SketchUp models (see figure 5); construction site utilization plans designed in MS Visio or AutoCAD. From a survey to the latest graduating class of Fall 2006, 100% of the graduates indicated they had made use of digital graphics applications in their capstone thesis project. The best measure of effectiveness of the course is evidence of graduates incorporating the material in their work as constructors. Instructors have first hand knowledge from recent graduates that they have introduced graphic applications to their construction companies. Instructors have collected valuable samples and ideas from real world projects through these graduates, which will be used to improve the course.

The rapid voluntary adoption by students of the course material throughout the curriculum, and its deployment by graduates into the construction industry are a testament of the appropriate content and effectiveness of the course. This outcome also indicates potential positive impact on the construction industry by new graduates skilled in using the tools of digital visualization. The authors plan to continuously improve the course by incorporating valuable feedback from students, graduates and practitioners. The next upgrade will conclude with an introduction to BIM as a preview of the more extensive BIM course now being developed to be offered in conjunction with the curriculum capstone course.

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