

**AC 2009-1111: DEVELOPING A WORKABLE CONSTRUCTION-MANAGEMENT  
TECHNOLOGY SENIOR CAPSTONE PROJECT AT THE UNIVERSITY OF  
MAINE**

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# **Developing a Workable Construction Management Technology Senior Capstone Project at the University of Maine**

## **Abstract**

Creating a meaningful capstone experience in a construction education program is often a challenge. Most of these programs do not offer significant design courses or foster creation of a project from concept through the design cycle to actual construction completion. A capstone experience in construction management is best developed from the design stage through to the preconstruction phases. Our construction capstone focuses on having students work within four aspects of preconstruction typical for a project. Students are divided into working groups to form a contractor team. An actual unit price bid project is used that the teams bid, schedule, calculate layout, and decide the best effective methods for construction.

Industry plays a significant role in the capstone course. Guest speakers come to class and discuss various aspects of construction including project management, material selection, and regulation. Public sector owners contribute plan and specification sets and come to the class to give an overview of the class project as in a typical prebid meeting. These owners come to the last class and judge the teams as to the practicality of individual team means and methods. This paper discusses the set up of the course that we use at the University of Maine. It defines the aspects of the preconstruction process that is used and discusses some aspects of the outside speaker program.

## Introduction

The Construction Management Technology (CMT) program at the University of Maine is a four year ABET accredited program that offers students a combination of business management, construction, and applied civil engineering courses. Upon graduation, CMT students are prepared to take active roles in managing and supervising construction projects.

Through a combination of course work, summer job experiences, and professional interactions, students form a set of working skills that they bring to potential employers. Often in the educational setting, the student gets overwhelmed in the myriad of varied courses not really understanding how these courses fit into the bigger picture. To complete a student's education, a capstone course is used to encapsulate all of these seemingly different classes and experiences to show students the interaction needed to solve modern construction problems. Students are challenged to participate in a construction project using the skills that they have gained in their educational experience.

Students in the CMT program are not trained as designers, but rather as constructors that will take design plans and specifications to effectively complete a project. In the educational arena, we train our students to be problem solvers that will use their ingenuity (1) to come to a solution. We encourage students to be able to work independently, to be creative, cooperate with team members, and to manage their time to meet a deadline. (2)

## Course Design

Since simulating an actual working project is difficult in the classroom situation, we concentrate on developing the capstone experience from the bid stage through the preconstruction phase. Our goal is to simulate the needed development that a contractor does from the time of identifying a project to the point of the preconstruction meeting. We have developed a four part, one semester capstone course that takes students through the preconstruction process using their overall skills. CET 458 Senior Capstone is designed such that students meet within project groups to complete typical aspects of an actual construction project as a contractor would do. Additionally, the course is also created as a time to bring in outside speakers to discuss various supplemental topics of interest to practicing construction professionals. In an earlier paper about the UMaine capstone project, the author discussed a four part project using self-selected teams. These four parts consisted of developing a business plan, preparing a bid estimate, developing a schedule, and resolving a legal claim. (3) After 2 years of the format, the author revised the capstone course to better simulate preconstruction operations and to better utilize guest speakers for relevant management topics. The business plan was eliminated because many graduating seniors will not be part of this aspect of the company development as they start their respective careers. Resolution of the legal claim was eliminated because many aspects of a claim need to be experienced and documented to have relevance. Students wouldn't have enough background to be able to understand the claim process and to use their skills in refuting the claim.

In developing the capstone project, the CMT program at the University of Maine uses ABET criteria to determine the set of educational goals used to create the course exercises and syllabus. We apply several of the ABET criteria within the course:

- a. Demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools of their discipline,
- b. Apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology,
- d. Apply creativity in the design of systems, components, or processes appropriate to program objectives,
- e. Function effectively on teams
- f. Identify, analyze, and solve technical problems,
- g. Communicate effectively,
- i. Understand professional, ethical, and social responsibilities (4)

On the first class of the semester, students are divided into teams. The teams are chosen through a lottery system whereby each student is given a number. Random numbers are drawn to form the teams. This random number selection process creates teams of individuals that may or may not have normally come together. As in real life, teams are formed through chance rather than by ongoing friendships. The random teams are then assigned to meet to decide how they will proceed, divide out work, and schedule work meetings as the various aspect of the project unfold.

The course work for the semester is divided into four parts: bidding the project, scheduling the project, establishing temporary support structures and construction layout, and presenting means and methods for construction. Students are assigned readings in a construction management textbook for self study on personnel and management topics. Though the topics have varied, most class time is devoted to presentations from outside speakers that address relevant information for the modern construction project. During the 2009 spring semester, topics included 3D surveying through scanning, construction accounting, synthetic drainage and modular bridges, field construction management, ethics and professionalism, federal regulation, and construction project management. Several cooperating companies included the Maine Department of Transportation, Cianbro, Sargent's Corporation, CBB Construction, Contech Products, Kiewit, Bancroft Construction, Gilbane, and the Federal Highway Administration.

#### Part 1 – The Bid

Under the first part of the project, teams are given plans and specifications for a contemporary capital improvement project from public sector infrastructure work. We partner with the Maine Department of Transportation who provides plan sets for projects selected by the CMT faculty. The projects are chosen for structure and level of difficulty. The project is common to all student teams and the objective is to have individual teams act as independent competitors.

In the first part, the team develops an estimate for the project. A set of parameters is given for the deliverables along with a completion date. The team has approximately 3 weeks to complete the estimate following standard protocols developed in the specifications of the owner, the Maine Department of Transportation. Two experienced project engineers who worked on the subject project come to the class to discuss the project with students as would be done in a prebid meeting. Students are provided plans and specifications one week in advance of the prebid meeting to review the plans and ask questions normally associated with bidding the project.

Deliverables for this exercise include the needed bonds and supplemental materials requested within the bid documents. Teams are also required to provide a contractor’s project book that shows all assumptions, calculations, and other supporting information to support the estimate.

The instructor for the class has developed a grading rubric to analyze key areas of the information including organization and completeness of the deliverables. The grading rubric is shown as Figure 1. The instructor determines if the team is “responsive” and whether they have ultimately followed the standard protocols of a bid process. This exercise also helps the respective team develop a learning curve for working with one another. Because of the random team selection process, team members have not necessarily worked with some of their respective team mates. The teams are expected to structure themselves to complete the tasks needed for the bid. As in real applications, team leaders and followers tend to emerge.

**CET 458 Estimate Evaluation Sheet**  
Spring 2009

Names of Team Members \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Criteria	1	2	3	4	5	Total
<b>BID REQUIREMENTS</b>						
Bid Bonds						
Completed MDOT Bid Sheets						
Bid submittal package						
<b>SUPPORTING DOCUMENTS</b>						
Quantity Comp Sheets						
Errors and Omissions						
Assumptions: Reasonability, Clarity						
Estimate Sheets: ie, cross sections						
Other supporting information.						
Overall Presentation: Put together with reasonable care and organization.						
Demonstration of Knowledge of Estimating and use of basic concepts						
	Total					

Comments: \_\_\_\_\_

Figure 1 – Estimate Evaluation Rubric

Each team bid is based on the responsiveness of the bid and the supporting contractor’s estimate book. Though the students have had a course in estimating and bidding, most groups are weak in developing a responsive bid and a complete contractor’s book. Teams are scored on a 50 point basis with an individual team grade given for the exercise. All team members get the same grade for the estimate. Under ABET criteria, the evaluation of this exercise demonstrates student learning per items a, b, e, and g. The author has observed that communications between team members is poor in the estimate exercise as team members determine a working order.

## Part 2 – The Schedule

Under the second part of the course work, students take their respective estimate and develop a schedule for the project. They need to develop an understanding of the larger project under a work breakdown structure. The student teams are given parameters for the scheduling exercise that include limitations on resources. Teams need to demonstrate how the use of limited resources will affect the schedule. The teams also have to provide support information to show

what assumptions were used to prepare the schedule. Deliverables for this exercise include a discernable Primavera P3 schedule as would be presented to a public sector owner during a preconstruction meeting. A support book as would be kept on record in a contractor's office is also required.

A rubric for evaluating the scheduling aspect of the project is shown as Figure 2. In this rubric, students must demonstrate important items for a construction schedule that at least include the critical path, resource constraints, and logic order of the tasks that have been described.

**CET 458 Schedule Evaluation Sheet**  
Spring 2009

Names of Team Members \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Criteria	1	2	3	4	5	Total
Primavera Print						
Logical sequencing of schedule						
Clarity of Print						
Reasonable durations						
Assumptions: Reasonability, Clarity						
Transmittal Letter: Convey information properly						
Overall Presentation: Put together with reasonable care and organization.						
Integration of Estimating						
Demonstration of Knowledge of scheduling and use of basic concepts						
Quality Points: Bonus						

Comments: \_\_\_\_\_

Figure 2 – Schedule Evaluation Rubric

Each team is evaluated on the logic and clarity of their printed schedule. Both bar chart and PERT depictions are required to show the logic that has been instituted into the schedule. The supporting information that contains assumptions and supplemental materials is also judged to see how it is used in the scheduling process. The evaluation looks at integration of the estimating information from part 1 into the schedule. This information is the foundation for durations and logic to the work breakdown structures of the schedule. Students develop clear logical schedules using the software but often lack the supporting information that demonstrates the assumptions used in creating the logic. It is noted that assumptions from the estimating part are not all integrated into the schedule. Scheduling demonstrates the team's understanding as to how a project will be constructed. In developing a schedule, ABET goals met are within a, c, e, f, and g.

### Part 3 – Temporary Structures and Layout

Part of actual construction work is to develop temporary structures and layout incidental to doing the work associated with construction. A CMT structures professor reviews the design plans and develops a scenario for student teams to analyze. This exercise consists of sizing steel members used for a temporary support structure considering temporary construction loading. The problem is based on not only the calculation, but the assumptions used to create the temporary structure. The professor evaluates the designed solutions more on the stated

assumptions and calculation process than the actual sizing of the temporary supports. Teams submit one design and the professor grades the solution based on the written solution given. Teams are required to use the current steel manual and structural design codes for full credit. Lack of assumptions and proper code application result in lower credit. A CMT surveying professor develops a layout scenario for the project associated with the construction survey. Students submit a team solution to determine where the construction baseline is best implemented given geometric site constrictions. Accuracy is evaluated on how the project is laid out and for the assumptions that are presented. Full credit is awarded to those who can state all of the considerations such as traffic control that a small contractor needs in laying out the site. Partial credit is awarded based on the level accuracy provided. These exercises demonstrate the ABET criteria of a, b, d, e, and f.

#### Part 4 – Means and Methods

The last part of the project is to develop the scheme for construction methods that would be used by the contractor team to build the project. The teams are required to do a presentation on the construction means and methods that are proposed. As is done in a preconstruction meeting, the owner is given the opportunity to know how the contractor plans to build the project. Actual representatives that were involved in the project are brought in as outside judges to ask questions about the methods presented. They fill out a rubric as shown in Figure 4. Students from the other teams are also part of the judging process and fill out evaluation rubrics for the presentation of the individual teams as shown in Figure 5. The individual members of the teams fill out an evaluation of their team as in Figure 6 and an evaluation of their presentation as in Figure 7. This 360° evaluation gives teams a broad evaluation of what others think of the respective methods that are proposed. As in actual practice, several reviews may be made of methods before actual construction takes place.

CET 458  
Senior Capstone  
Spring 2008

Group Evaluation Sheet

Team Members \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Contractor Name \_\_\_\_\_

Please rate the presentation based on 1 as low and 5 as high.

Characteristic	1	2	3	4	5	Total
1. Each member of the group contributed to the presentation.						
2. The aspects of the project construction make sense.						
3. The group worked together in the presentation.						
4. Graphics and other visual aspects were complete.						
5. Safety was identified.						
6. Quality issues were addressed.						
7. The project sequencing was logical.						
8. The estimate and schedule were adequately tied into the methods addressed.						
9. The approach showed unique efforts.						
10. The team adequately addressed questions and other aspects of the project.						

1. Items that were well developed.  
 2. Items that need improvement.  
 3. Concerns or other observations.  
 4. Miscellaneous.

Figure 4 – Outside Judge Evaluation

Peer Evaluation Sheet

Team Members

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Contractor Name

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Please rate the presentation based on 1 as low and 5 as high.

Attributes of the Presentation	1	2	3	4	5	Total
The presentation was clear.						
The construction approach seemed reasonable.						
Team members all contributed to the effort.						
Presentation materials were appropriate.						
Technical Information seemed reasonable.						
Supporting information justified the approach.						
Questions were addressed adequately.						
Safety issues were appropriately addressed.						
The construction schedule seems appropriate.						
If I were an administrator, I can make a reasonable determination.						

1. Was the team neat and professional?
2. What were the strengths of the presentation?
3. What were the weaknesses of the presentation?
4. Do you have any other comments?

Figure 5 – Peer Evaluations of other teams

Group Evaluation Sheet

Team Members

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Contractor Name

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Please rate the presentation based on 1 as low and 5 as high.

Characteristic	1	2	3	4	5	Total
1. Did your team put in adequate time for each of the parts of the project?						
2. Would you rate your team's projects as Good effort?						
3. Did all members contribute to the effort?						
4. Did you feel that the capstone should include aspects about estimating a project?						
5. Did you feel that the project should include aspects about scheduling a project?						
6. Do you feel that the project should include means and methods presentation?						
Rate Team Members:						
a. _____						
b. _____						
c. _____						
d. _____						
e. _____						
f. _____						

1. Was there a member (or members) or your group that did not contribute to the overall effort? If so, who do you feel did not contribute effectively?
2. Did any member do a significant amount of work, who?
3. Any other comments about your group?

Figure 6 – Peer Evaluations of team

The evaluation process for the means and methods presentation is quite thorough. Individuals do not tend to rate peers from other teams as harshly as they do members of their own teams. Individuals readily identify those team mates whom they don't feel performs appropriately.



Outside judges ask relevant questions during the respective presentations, but don't evaluate teams too strongly on the review rubric. The multiple evaluation gives the instructor a broader perspective on the presentation of the methods for constructing the project that allows one to see what happened internal to the team, as perceived from peers, and from the outsider's view. The methods exercise demonstrates the student teams mastery of ABET criteria a, b, d, e, f, g, and i.

### The Overall Capstone

CET 458 meets once weekly in a 3 hour time frame. To supplement the management aspect associated with the construction management capstone, a series of speakers addresses the capstone students during most established meeting times. Speakers have covered a wide spectrum of topics that are part of the modern construction professional's world. These speakers have included major items from material suppliers to project managers. Speakers are chosen to address topics that may not have been discussed in the general courses offered in the curriculum. A couple of examples have included two business managers from local construction companies who as members of the Construction Financial Managers' Association discussed the difference of construction finance. A Federal Highway representative comes in and discusses the QC-QA aspects of construction material sampling. These speakers are meant to give students an overview of the respective topics often important to the duties of a construction manager. The speaker program gives students an opportunity to interact with construction professionals on a personable level. The major ABET areas addressed through the speaker program include a, b, d, f, and i.

Additionally, students are assigned reading and discussion questions from a construction management textbook. The purpose of this textbook is to expose students to some of the greater management topics that are associated with the operation of a construction company. Surprisingly, students don't get some of the business courses that could be helpful in the lines of personnel, construction accounting, and company development. The forced textbook readings tend to round the student out for understanding some of the routine office operations associated with a construction company.

### Conclusion

The CMT capstone project at the University of Maine involves using an actual infrastructure construction project to illustrate a construction project from the bid process through to preconstruction. It is enhanced by creating project teams using random team assignments. This random selection illustrates that one will likely be working with people that we don't know and can't personally select. Outside speakers are brought in to discuss current construction practice and to give students general overviews of modern construction issues. Supplemental construction management readings help a student transition their working knowledge from business course materials to the construction field. These aspects of the capstone course align with the educational goals that are outlined within ABET criteria.

Overall, student evaluations report that students generally enjoy the capstone and especially like the outside speakers who come to the classes. They also value the opportunity to work with students that they may not have associated with in the past. Several students find the varied

components of bidding, scheduling, temporary structures, construction layout, and means and methods to be comprehensive and representative of their educational experiences.

## Bibliography

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