Heavy Civil Estimating Learning Module for CM 314

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In the past, through engagement with students that have gone through the Heavy Civil class, it has been found that student understanding of typical heavy civil operations is subpar. Through an updated course module that focuses on estimating the four major operations, Earthwork, Underground, Asphalt, and Concrete, students will gain a deeper understanding of the heavy civil field of construction. The module consists of four assignments that pertain to the previously mentioned operations. Each contain a lecture detailing typical crew compositions and cycle times, reference material and resources the student can use when completing the assignments. This new module will challenge student critical thinking skills and provide a deeper understanding of heavy civil operations.
Key Words: Estimating, Heavy Civil, Course, Templates, Production Rate

Introduction

Engagement with students that have gone through the heavy civil class at Cal Poly San Luis Obispo has shown that students have a weak understanding of the basics of heavy civil construction. Additionally, there is indication little interest in the particular field. This inspired an idea to write a short learning module that would teach the basics of heavy civil estimating to the course students. This would be accomplished by teaching several base concepts. The primary concept taught by the developed module is how to develop a production rate for an operation based on a specific crew composition. The secondary goals are teaching basic crew compositions, teaching students the practical application of different pieces of equipment and, how certain equipment must be supported with other equipment and labor. The latter two focuses of the developed module are designed to test the critical thinking and problem-solving capabilities of the students by developing crews and production rates based on the plan sets that are given to them. This new module also intended to spark or deepen an interest in heavy civil construction for the students that are going through the program.

Project Development

Given that the primary focus of the new learning module was to be heavy civil estimating, the first step in project development was to determine what scopes of work would be most beneficial for students to learn. To determine the proper scope of work to focus on in this learning module, the existing course learning plan and syllabus was first examined. Upon analysis of the existing course, the major scope of work was determined to include the operations of underground construction, earthwork, road paving, minor and major concrete work, cranes, pile driving, and trucking. After this initial narrowing of topics, the next step was to compare this scope to the ASC Region 7 Heavy Civil competition expectations for student knowledge of heavy civil estimating. The pre-problem statement provided by Granite Construction, and given to all student teams, states that it expected students have a solid understanding of earthwork, underground, paving, and concrete operations. Using the two resources of the pre-problem statement, and the existing course syllabus, it was determined that four main scopes of work would be focused on in the development of the new learning module. These four scopes include the operations of underground construction, earthwork, asphalt paving, and concrete work. The topic of trucking was also decided to be addressed as it is a support function to many of the core four operations. The concepts of trucking are ingrained in the asphalt paving assignment.

Figure 1. cut/fill map for the earthwork assignment

Once the scopes of work were determined for the learning module, the next step in the development of this project would be developing the assignments that accompany each of these topics. It was determined that the best way for students to grasp these concepts would be to provide a set of plans that clearly outline the work that follows one of the specific operations that the project is to cover. To accomplish this, several different plan sets were evaluated and reviewed in order to determine how well they would apply to the coursework. The ultimate goal was to find one plan set that very clearly included these operations, was easily digestible for students that may not have experience reading

civil drawings, and yet was complex enough of a project to challenge the critical thinking of the students. No plan set that was available fit this criteria so it was determined that each operation for the module would have its own unique plan set. The plan sets for the module were provided by the ASC Reno Heavy Civil Team and included previous problems and plan sets that were utilized on prior competitions.

Once the plan sets for each of the four topics were determined, the final step in the design of the assignments was to develop several templates and calculators that the class could utilize to aid in the estimating process. The main template developed is a Microsoft Excel document that is modeled after the bid breakdown sheets in the estimating software Heavy Bid. This template allows the students to input crew information, production rates, unit costs, and man-hours all in one organized sheet that auto populates total cost, total man-hours, and total durations based upon the data that is entered. This template would be the main deliverable for each assignment as it showcases all the critical concepts that the module is teaching. Several additional Microsoft Excel sheets were also created to be utilized by the class. These templates include scraper haul calculators, trucking calculators, crew composition examples, material weight conversions, and trucking capacities.

DESCRIPTION		Quantity	Units	Hours	Labor Unit Cost	Equipment Unit Cost	Material Unit Cost	Labor	Equipment	Subs	Materials	Total
BID ITEM	16" Cast In Drilled Hole Concrete Pile							**4,504.08**	**3,922.20**		**7,574.63**	**16,000.91**
	Item Quantity	88.00	LF									
	Item direct unit cost	181.83	LF									
Material Buy Out Package												
	Rebar #6 - Vertical	380.00	LF				$ 0.84				$ 319.20	$ 319.20
	Rebar #6 - Spiral	7000.00	LF				$ 0.84				$ 5,880.00	$ 5,880.00
	Concrete	5.00	CY				$ 150.00				$ 750.00	$ 750.00
						Tax Rate:	9.00%				Tax	$ 625.43
	Notes: 10% Waste Factor										Section total	**$ 7,574.63**
Work Package #1												
Operation 2.1	Drill Piles											
	Operation Quantity	5.00	CY									
	Operation Duration	1.00	Days									
	Labor Man Hours	16.00	Hours									
	Productivity:	5.00	Units / Day									
	Productivity:	0.63	Units / Hr									
	Unit Cost:	309.04	$/Unit									
Laborer		1.00		8.00	$ 27.30			$ 218.40				$ 218.40
Equip Operator/ Foremen		1.00		8.00	$ 37.60			$ 300.80				$ 300.80
Continuous Flight Auger, CM-50		1.00		8.00		$ 128.25			$ 1,026.00			$ 1,026.00
	Notes: Assume Soil is good and doesn't need Slurry mix										Section total	**$ 1,545.20**
	Assume Soil can be reused on site											

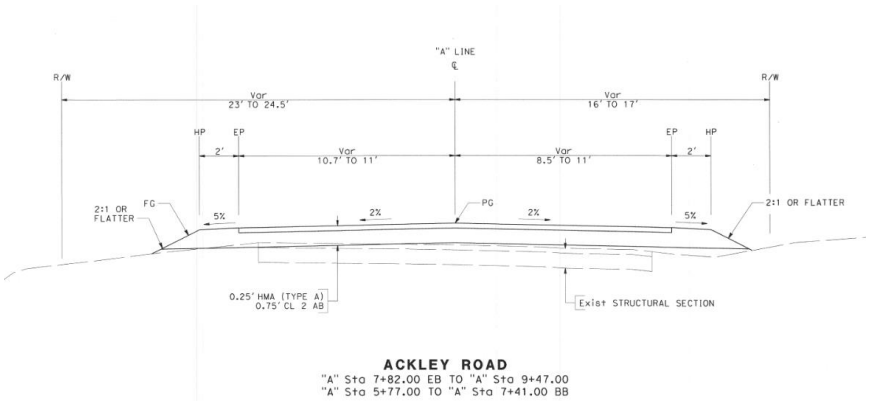
Figure 2. Example of Master Estimate Template

Classroom Application

After development of the module was complete, it was determined the best course of action would be to teach the module in the class to serve as a trial run. This was decided to be the best course of action as it would allow for effectiveness of this estimating module to be evaluated and adjusted to optimize learning objectives. Four class times were set aside for the new module to be taught alongside the existing course. Each assignment was to be given after the main course had touched on the topic. For example, after the professor had discussed excavators, trench safety, and underground construction the underground estimating assignment would be given.

The first assignment taught was the underground estimating portion of the module. As this was the introduction for the students to estimating, the goal of this first was lecture was familiarize students with the templates and the thought process of estimating crews and production rates. During this lecture, the class was introduced to the concept of cycle times, shown how to effectively use the master estimating template, and get them familiar with other estimating resources that they were given such as the CAT handbook and the crew examples handout that were created for the module. The students worked together with the lecturer to develop and fill out the master template.

The second assignment, concrete, was focused on estimating minor concrete for a roadway improvement. This included sidewalk, curb and gutter, and driveways. This assignment was designed to be their first attempt at filling out the template without guidance from the lecturer to ensure they had a solid grasp of the base concepts of crew composition and production rates. The lecture simply included an overview of the plan sheets with the students to ensure they understood what they were looking at before they undertook their individual estimates.



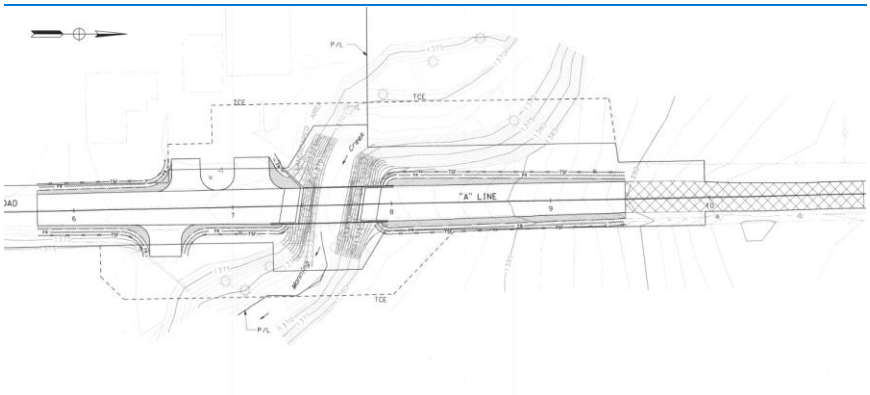


Figure 3. Road Section And Plan from Assignment 3

Assignment three, asphalt base and asphalt paving, was taught two weeks after the concrete assignment was assigned. Similar to the first lecture, this section was not assigned and taught until after the students had conducted their paving lectures from the core class. Assignment three was similar in scope to the others, however along with the completed master estimate template the students were to turn in a trucking take-off for the asphalt base and asphalt concrete for the operation. The lecture for this section of the module contained a plan reading exercise with a question and answer section to test student learning as well as a demonstration on how to effectively utilize the trucking take- off calculator. The calculator allows students to determine the total number of trucks

needed as well as the total price of material and trucking while also allowing comparison to different suppliers.

Truck Takeoff - (Supplier 1)		
Take Off Information		
Operation Quantity	9858	Tons
Total Operation Hours	56	Hr
Load Capacity	18	Tons
Cycle Time		
Trip Time	20	Min
Load	5	Min
Haul		Min
Dump	15	Min
Haul		Min
Total Roundtrip	40	Min
Truck Roundtrip	0.666666667	
Loads/Truck per Hour	1.5	
Total Number of Loads needed	548	
Loads needed Per Hour	9.785714286	
# of Trucks Needed	7	
Price/Unit	$ 9.50	
Total Material Price	$ 93,651.00	
Trucking cost/HR	$ 95.00	
Total Trucking Cost	$ 37,240.00	
TOTAL PRICE (Material + Trucking)	$ 130,891.00	

Truck Takeoff - (Supplier 2)		
Take Off Information		
Operation Quantity	9858	Tons
Total Operation Hours	56	Hr
Load Capacity	18	Tons
Cycle Time		
Trip Time	45	Min
Load	5	Min
Haul		Min
Dump	15	Min
Haul		Min
Total Roundtrip	65	Min
Truck Roundtrip	1.083333333	
Loads/Truck per Hour	0.923076923	
Total Number of Loads needed	548	
Loads needed Per Hour	9.785714286	
# of Trucks Needed	11	
Price/Unit	$ 8.65	
Total Material Price	$ 85,271.70	
Trucking cost/HR	$ 95.00	
Total Trucking Cost	$ 58,520.00	
TOTAL PRICE (Material + Trucking)	$ 143,791.70	

Truck Takeoff - (Supplier 3)		
Take Off Information		
Operation Quantity	9858	Tons
Total Operation Hours	56	Hr
Load Capacity	18	Tons
Cycle Time		
Trip Time	30	Min
Load	5	Min
Haul		Min
Dump	15	Min
Haul		Min
Total Roundtrip	50	Min
Truck Roundtrip	0.833333333	
Loads/Truck per Hour	1.2	
Total Number of Loads needed	548	
Loads needed Per Hour	9.785714286	
# of Trucks Needed	9	
Price/Unit	$ 9.10	
Total Material Price	$ 89,707.80	
Trucking cost/HR	$ 95.00	
Total Trucking Cost	$ 47,880.00	
TOTAL PRICE (Material + Trucking)	$137,587.80	

Figure 4. Trucking Take Off Calculator

The fourth and final lecture was on earthwork. This lecture was modeled, to include the plan reading section with accompanying question and answer. To increase academic rigor, a new calculator was provided to the students to aid in the estimating of scraper hauls. The developed calculator took haul lengths, speeds, machine capacity, total machines, shift length, and efficiency factors and gave the students an overall daily production rate based on these variables. By this point in the lecture series, the students had a firm grasp on all the templates and estimating techniques that were taught in the previous assignments. Because of this, the assignment included the master bid template, their scraper haul calculator for each cut to fill, and a trucking take off for all of the excess cut in the project.

Results

Upon the completion of all four sections to the learning module, all the assignments completed by the students were graded to evaluate the success of the module. Given that there was no one right answer for these kinds of assignments, the grading rubric had to reflect the varying nature of the assignments. The rubric was based on 3 main criteria. The first criteria was to evaluate how well the templates were completed and utilized. This was due to, if the template was properly completed, it was much easier to follow the thought process of all the students. The second criteria was crew composition. If students' crews made sense in the context of the project, and showed that they had a proper understanding of the operation, they received full points. The final criteria was production rates and operation durations. Students received full points in this section as long as their productions and durations were within reason of the context of their estimated crews. Data collected from the student's grades showed that the average grade for the assignments, based upon the students that actually submitted them, was:

- Twenty-two out of twenty-five possible points for assignment one

- Twenty-one out of twenty-five possible points for assignment two
- Nineteen out of twenty-five possible points for assignment three
- Twenty out of twenty-five possible points for assignment four

All averages show a substantial understanding of the operations, with the weakest subject for students being asphalt paving and the strongest topic being underground construction. Overall the average grade per assignment was in the eighty percent range which demonstrates a better than average understanding of the material.

Conclusion

Overall, this proposed module demonstrates success. However, it does offer opportunity for improvement. While the existence of an estimating module in the heavy civil class is important, the way it is given in this proposed course module is only an entry venue toward the correct direction for this topic. Of all the items compiled and created for this module, the ones of greatest value are the templates and calculators that the students utilized to estimate the projects that they were given. These templates are tools that can be adopted to updated estimating modules for the course and updated as seen fit by the professors and students of the class. The apparent weakness in this module are the plan sets and the assignments themselves. While the data collected from the classroom application showed a firm grasp on the concepts, it would be more beneficial to the students to estimate a singular project. This would allow visualization of how an entire job is built from beginning to end. It would force students to think about the logistics of a jobsite and how to best build crews, not just for a singular operation, but for an entire job. Students would have to utilize critical thinking skills to determine crews that could be uniform throughout the job lifespan. Another addition to the module that would be beneficial to the education of the students, would be to put together a group project where teams of four to five students work to estimate the project and put together a bid package. This final project could emulate a real-life bid scenario and promote friendly competition between the students which would push them to put more effort into the project. All in all, this proposed module, noted short comings, is a success and a step in the right direction for teaching estimating concepts to the students of the heavy civil lab.

Appendix & Figures

Item Description	Unit Price	Units	Assumptions
CLASS 2 AGGREGATE BASE (FOB PLANT) - Rock Valley Aggregates	$ 15.00	TN	Source 17.5 miles from project
CLASS 2 AGGREGATE BASE (FOB PLANT) - Central Coast Aggregates	$ 10.50	TN	Source 35 miles from project
ASPHALT, CONCRETE, AND DIRT DUMP FEES -Central Coast Aggregates	$ 8.00	CY	Source 35 miles from project
TYPE A HOTMIX ASPHALT (FOB PLANT) - *Volcano Hot Plant*	$ 64.50	TN	Source 50 miles from project
TYPE A HOTMIX ASPHALT (FOB PLANT) - *Shake n Bake Hot Plant*	$ 66.00	TN	Source 45 miles from project
RSP (1/2) TON - Rock Valley Aggregates	$ 36.00	TN	Source 17.5 miles from project
RSP (1/2) TON - Central Coast Aggregates	$ 32.00	TN	Source 35 miles from project
Premium Structure Backfill - Rock Valley Aggregates	$ 15.00	TN	Source 17.5 miles from project
Permiable Material - Rock Valley Aggregates	$ 15.00	TN	Source 17.5 miles from project
Permiable Material - Central Coast Aggregates	$ 12.00	TN	Source 35 miles from project
3/4" Crushed Aggregate - Central Coast Aggregates	$ 12.00	TN	Source 35 miles from project
8'x18' Panel with 5/8" BB & Holes	$ 475.00	EA	
Bridge Forming Hardware	$ 3,500.00	LS	
4'x8' Panel with 5/8" BB & Holes	$ 105.00	EA	
12" RCP	$10.00	LF	
18" RCP	$10.00	LF	
* assume tax rate of 8.75%			

Figure 5. Material Rates Utilized Throughout All Assignments

LOAD TO DUMP (LOADED HAUL)			
ESTIMATED LOAD TIME	70	seconds	
HAUL LENGTH (LOAD TO DUMP)	1800	feet	
TRAVEL TIME	1.5	minutes	
AVERAGE SPEED	13.6	MPH	
TOTAL TIME (LOAD TO DUMP)	**2.67**	**minutes**	
DUMP TO LOAD (EMPTY HAUL)			
ESTIMATED DUMP TIME	35	seconds	
HAUL LENGTH (DUMP TO LOAD)	1800	feet	
TRAVEL TIME	1.5	minutes	
AVERAGE SPEED	13.6	MPH	
TOTAL TIME (DUMP TO LOAD)	**2.08**	**minutes**	
SINGLE CYCLE INFO			
TOTAL HAUL LENGTH	3600	feet	
TOTAL CYCLE TIME	4.75	minutes	
AVERAGE TOTAL SPEED	8.6	MPH	
HOURLY PRODUCTION	12	cycles/hour	
SHIFT INFO			
NOMINAL SHIFT LENGTH	10.00	hours	
ESTIMATED EFFICIENCY	90%		
PRODUCTIVITY	9.00	hours/shift	
DAILY PRODUCTION	108	cycles/shift	
MACHINE AND PRODUCTION INFO			
SINGLE MACHINE CAPACITY	30	cy (bank to bank)	
HOURLY PRODUCTION	**360**	**cy**	
DAILY PRODUCTION	**3,240**	**cy**	
TOTAL MACHINES	12	each	
HOURLY PRODUCTION	**4,320**	**cy**	
DAILY PRODUCTION	**38,880**	**cy**	

Figure 6. Scraper Haul Calculator Utilized in Assignment 4

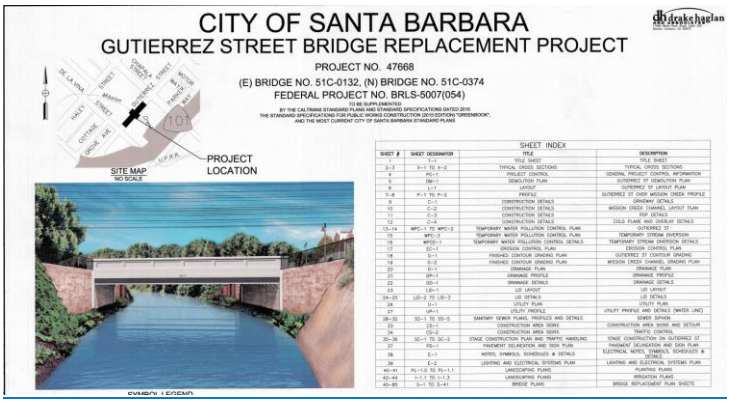


Figure 7. Cover Sheet for Plan Set utilized on Assignment 2

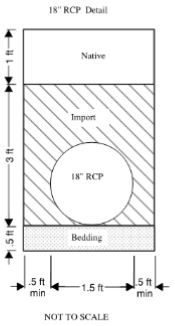
COLLEGE OF ARCHITECTURE & ENVIRONMENTAL DESIGN
CONSTRUCTION MANAGEMENT DEPARTMENT

CM 314 – Heavy Civil Lab- Estimating Lab#1

PROJECT ASSIGNMENT

You work in the estimating department at Big Yellow Iron Construction Company. Your head estimator has asked you to quickly perform a QTO and estimate for Bid Item #17-18" Reinforced Concrete Pipe. It is one continuous stretch of pipe 450 feet long. All he has given you for this estimate is the detail to the left.

1. Complete a Quantity Take Off for the detail
   a. Include quantities for: Bedding, Import, Excavation, and Export
2. Determine the operations that would fall into this scope of work
3. Determine what equipment would be best suited for each operation (Keep in mind that we don't want to mobilize and demobilize several times)
4. Determine labor needs for each operation (Crew consistency is key)
5. Now that your Crew & Equipment is determined calculate an estimated production rate for each operation (Cycle Times and Cycle Quantities)
6. Transfer this information onto the Bid Template Excel Document
7. Plug in provided labor, equipment & material rates to determine the price for bid item #17



RUBRIC:

	3	2	1
Operations	All operations make sense. None missing and no extraneous activities	Some operations missing, the order of operations is slightly out of order	List of activities needed to complete task doesn't make sense.
Crew Composition	Crew is not oversized	Crew seems slightly excessive. Mostly correct	Crew is illogical. Not enough equipment or manpower.
Operation Durations	Duration makes sense given the crew composition	Duration is slightly excessive or short, mostly makes sense.	Duration is illogical given the crew compositions
Template Filled Out Correctly	The template is filled out without any errors	The template is filled out with minimal errors	The template is filled out with excessive errors

Figure 8. Assignment 1 Assignment Sheet with Grading Rubric