
Technical Assignment 2

Cost and Methods
Analysis

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AE 481W – Senior Thesis

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Executive Summary

The Washington Christian Academy (WCA) Flagship and Gymnasium Buildings are part of a phased construction project located in Olney, MD; Montgomery County. These two initial buildings will serve as the base for a growing religious education campus. This technical report analyzes the schedule, site, and costs of the project in more detail than Technical Assignment 1. Below are summarizations of the key findings from each section.

A. Detailed Project Schedule: The approximately 200 item schedule shows the phasing and structural sequences of the Flagship Building and Gymnasium. As the schedule proves, a delay in the start of the project has left little time for any further delays or unforeseen problems. The project has a strict completion deadline which will allow the owner enough time to prepare and be functional for the 2008-2009 school year. The logical sequencing of the project is intended to maximize productivity.

B. Site Layout Planning: A 60 acre site is large enough for generally conflict-free site layout planning. There is room for one-way traffic flow through the site which allows for faster deliveries and easier maneuverability of machines and equipment. Additionally, the site plan shows that there is room for two steel staging areas, which makes the crane picks more efficient and safer. The crane selected for the project was a 42 ton mobile crane. Two site plans are included to show the entire site (60 acres) and show the more detailed site planning for the area cleared for the Flagship Building and Gymnasium.

C. Assemblies Estimate: The built-up roof system was chosen for the assemblies estimate. Six parts of the roof assembly estimated a total cost of \$224,917. Of this cost, it was interestingly found that 54.5% of the cost was installation, and only 45.5% was material. This nearly balanced cost ratio is not typical in the larger CSI divisions (steel, masonry, etc.). The unit cost of the roof assembly is approximately \$8.24 per square foot.

D. Detailed Structural System Estimate: This estimate was created by performing takeoffs and using *R.S. Means* data. The total Structural System cost was estimated at \$1,106,689. The estimate is made up of three main CSI Divisions: concrete, masonry, and steel. The cost was found through unit prices generally by the lineal foot, square foot, or cubic yard of material. Material, labor, and equipment costs make up the following percentages of the cost: 58.7%, 35.8%, and 5.3% respectively.

E. General Conditions Estimate: Through assumptions, class notes, and information from the general contractor, a General Conditions Estimate was formed. The final cost of the general conditions was \$1,743,744. This accounts for approximately 9% of the total project cost. The project duration used for calculations was 17 months (73.7 weeks). The durations were obtained from section A. Detailed Project Schedule.

A. Detailed Project Schedule

Please see the Detailed Project Schedule in Appendix A

A.1 Overview

As addressed in Technical Assignment 1, this project is classified as design-build even though the schedule does not reflect the fast track process that typically coincides with a design-build project. The Washington Christian Academy (WCA) Flagship Building and Gymnasium site was undeveloped prior to breaking ground for the school. Therefore, neither demolition nor school release dates constrained the schedule. In other words, construction was not limited to only the summer months as it most likely would have been on the current WCA site in Silver Spring, MD. The Washington Christian Academy is able to function normally in their current facility while the construction of the new facility is underway. The largest constraint on the project is that the school must be completed and open for the 2008 school year.

This opening date constraint should have been no problem according to the contract schedule. Upon review of the schedule in Appendix A, a large gap in time can be noticed between October 30, 2006 (Building Permit) and January 25, 2007 (NTP, mobilization). The reason for the almost 3 month delay was obtaining the necessary permits for construction. During this lapse, valuable time was wasted. To compensate for this delay, many activity durations have been shortened. The more rigorous schedule will allow the project to still meet the necessary completion date. As it is scheduled now, the tenant will be able to move-in in mid July, 2008. There is very little tolerance for any more substantial project delays.

A.2 Sequencing

In general terms, the sequencing of the project is by floor, not by phases or sections. The structural system of the building requires the building to be built from the bottom up, floor by floor. The foundations of both buildings will begin construction at the same time. Tradesmen will work between the two buildings sequentially, creating less down time and increasing efficiency. An example of the sequence after foundation completion is as follows:

Time	Activity			
T1	Floor 1 Superstructure	Gym Superstructure		
T2	Floor 2 Superstructure	Floor 1 MEP Rough-In	Gym MEP Rough-In	
T3	Floor 3 Superstructure	Floor 2 MEP Rough-In	Floor 1 Interior	Gym Interior
T4	Roof Superstructure	Floor 3 MEP Rough-In	Floor 2 Interior	Floor 1 Finishes

This sequencing continues until the buildings are complete. This sequence should maximize the productivity of the subcontractors, as well as the use of the crane and concrete pump. Once the crane is on site, it should be used to its maximum capabilities every day in order to avoid losing money on the lack of productivity.

A.3 Schedule Assumptions

The following assumptions were made in the creation of the project schedule.

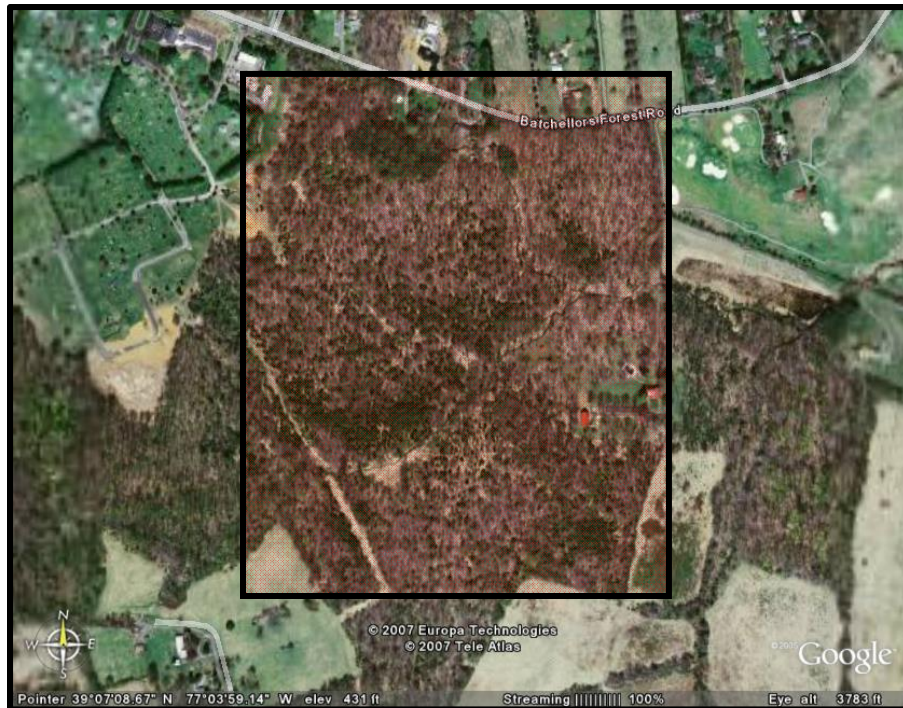
- **Activity Durations:** Great effort was made to make the activity durations accurate. With limited experience on creating schedules, some of these durations were knowledgeable guesses.
- **Floor Sequencing:** Activities on each floor occur in the same order as the previous floor.
- **Overall Project:** The Flagship Building and Gymnasium can be under construction at the same time.
- **Inspections:** Inspections that need to occur during construction are not listed as activity items. For instance, if the sprinkler system needs to be checked before the ceiling is hung, that inspection time is not included.
- **Delays:** No weather or any other delay “buffers” were accounted for.
- **Move-In:** The tenant may move in while punch list items are still being remedied.

B. Site Layout Planning

Please see the two Site Layout Planning Drawings (S.1 & S.2) in Appendix B

B.1 Overview

- **Address:** 16227 Batchellors Forest Road, Olney, Maryland 20832
- **County:** Montgomery
- **Site Size:** 60 acres; 26 of the 60 acres are reserved for forest retention



The *Google Earth* aerial photograph above shows the vast 60 acre site (roughly highlighted in the red box). Only a portion of this site will be developed for the WCA Flagship Building and Gymnasium construction. The rest of the site will be developed over the next decade and will eventually become an entire WCA campus. A full 60 acre site plan can be seen in Appendix B (S.1), with the site perimeter and preserved forests shown. The second site plan (S.2) shows the planning and layout for the superstructure phase of the project.

B.2 Site Layout Planning Analysis

- **Temporary Facilities:**
 - **Trailers:** The two trailers on site serve as field offices for the general contractor (Forrester Construction) and the owner (Washington Christian Academy). The double-wide trailer is large enough to accommodate the entire WCA project team. This is important to the success and coordination of the project. The trailer is equipped with electricity and utilities from the nearby temporary transformer and with water from the

existing utilities on the neighboring site. The trailers' locations are at the front of the site for easy monitoring of deliveries and visitors.

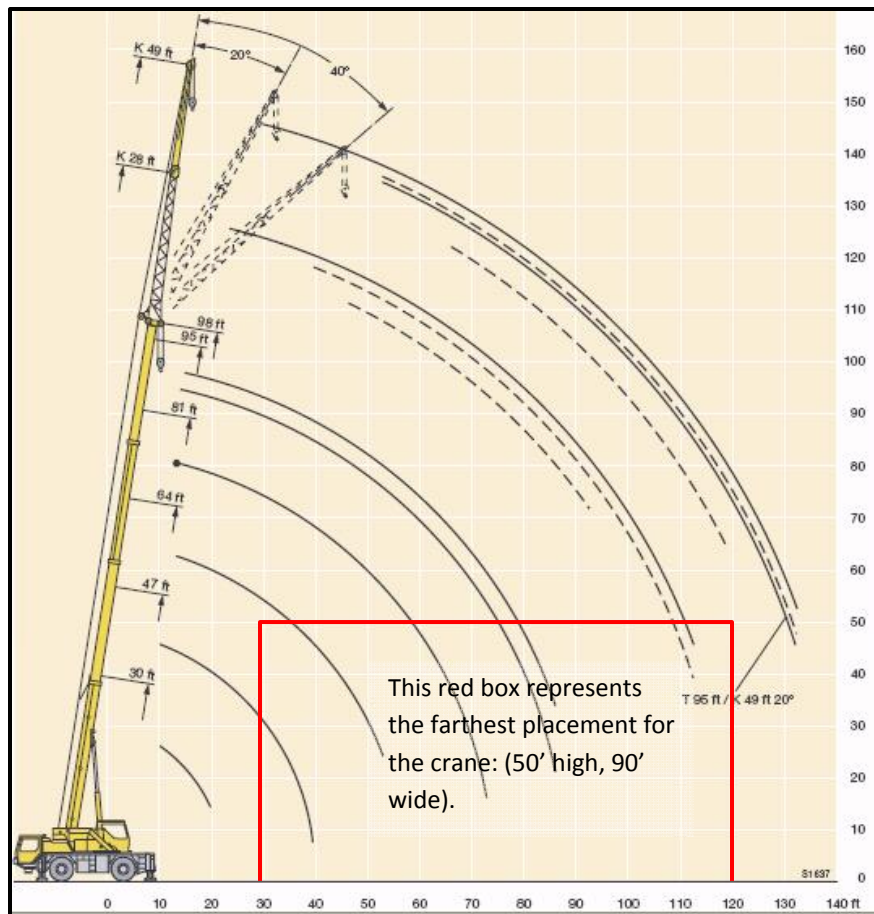
- Portable Toilets: Four portable toilets are located in a convenient location for the construction workers and management. There are three for men and one for women.
- Construction Fence: The fence runs around the needed area for this construction project, not the entire site. A natural barrier is created by the trees. The fence still surrounds the construction areas and prohibits pedestrians and vehicles from access.
- Dumpsters: There are two locations for the dumpsters. One on the north side of the Flagship Building and the other on the south side near the Gymnasium. This is to alleviate long travel distances to discard waste. Additionally, there are two dumpsters in each location because one is for general waste and the other is for masonry only and recycling purposes. The dumpsters are located near the traffic routes for easy trash removal.
- **Traffic:**
 - Entrance: The only entrance to the site is off of Batchellors Forest Road. There is no traffic light; however traffic on this road is light enough that turning on to the site should not be a problem. The existing paved entrance road outside the site boundary was used as a rear entrance for the neighboring cemetery. During construction, it will be used solely for the WCA project.
 - Personal Automobiles: The subcontractors, management, owners, and visitors may continue on the entrance road to the parking lot created temporarily for the project. After completion, this lot will be demolished. The lot is out of harms way from the crane and other construction activities.
 - Deliveries and Equipment: The site is large enough to allow the most efficient traffic pattern; one-way. Material delivery trucks, garbage trucks, and equipment will never have to turn around on the site in order to exit. The circular path is large enough for most vehicles to turn, yet small enough to create efficient route times. There are two routes by the Gym in case the crane is working overhead. This alternate route allows trucks to continue moving while the crane is in use.
- **Designated Areas:**
 - Steel Laydown: This large site lends itself nicely to storage areas. There is plenty of room to have two steel staging areas. These areas were selected to make delivery easy and crane placement efficient. A forklift can easily fit near these two areas to unload the steel delivery trucks.
 - Excavated Soil: The excavated soil is permitted to be reused for backfill and for the athletic fields. Therefore, storing it on site is more cost efficient than having it removed and then brought back.
 - Mock-Up: This area is near the owner's trailer and is relatively far from daily construction activities. Façade mock-ups and other needed scaled mock-ups can be built in a safe zone.
 - Storm Water Management Pond: This is located slightly down grade from the buildings.

- Crane:

- The crane was selected on three main criteria: mobility, lifting capacity, and placement radius.
- The following mobile crane was selected:
 - LTM 1030-2.1
 - 42 ton max capacity at 10' radius
 - 148' max lifting height
 - 132' max radius (approx. 120' used in site plan)



Crane information and photographs from http://www.liebherr.com/at/en/57534_57537.asp



The above picture demonstrates the placement reach of the crane. The most difficult placement for the crane will be at 50' high and 90' away. The diagram indicates that this mobile crane is more than capable. The heaviest pick will be a 30' W 18x97 (97 plf x 30' = 2910 lbs → 1.45 tons). Therefore, the crane capacity is more than adequate. The mobility of the crane will allow for easy transport to and from site. Additionally, the crane will be able to move between the three locations necessary to erect the Flagship Building and Gymnasium (see the three locations on the Detailed Site Plan).

C. Assemblies Estimate

C.1 Overview and Assumptions

The assemblies estimate below is for the Flagship Building's roof system. The estimate is broken down into six categories based on the roof composition. The information for the estimate was gathered from the roof plan and specifications, and the cost data was retrieved from *R.S. Means Assemblies Cost Data*. For reference, this table and the data sheets are located in Appendix C.

Washington Christian Academy									
Roof Assemblies Estimate									
<i>A roof assembly estimate prepared by Casey Mowery</i>									
Item	Qty.	Unit	Mat.	Mat. Cost	Inst.	Inst. Cost	Total	Total Cost	
Base Flashing	350	lf	8.45	\$ 2,957.50	13.75	\$ 4,812.50	22.2	\$ 7,770.00	
Flashing	27,300	sf	0.90	\$ 24,570.00	2.98	\$ 81,354.00	3.88	\$ 105,924.00	
Roof Deck Rigid									
Insulation	25,850	sf	2.12	\$ 54,802.00	0.43	\$ 11,115.50	2.55	\$ 65,917.50	
Shingle	1,450	sf	0.79	\$ 1,145.50	1.35	\$ 1,957.50	2.14	\$ 3,103.00	
Built Up Roof	25,850	sf	0.96	\$ 24,816.00	1.28	\$ 33,088.00	2.24	\$ 57,904.00	
Roof Hatch	4	ea	785.00	\$ 3,140.00	179	\$ 716.00	964	\$ 3,856.00	
				\$ 111,431		\$ 133,044		\$ 244,475	
		Location		0.92		0.92		0.92	
		Grand Totals		\$ 102,517		\$ 122,400		\$ 224,917	

The material accounts for 45.5% of the total cost of the roof assembly. This inherently indicates that the installation accounts for 54.5% of the total cost. At first this seems intriguing because usually detailed estimates yield that the material costs the most, and this assemblies estimate proves the contrary. After review, this system does not include many of the expensive construction materials such as steel or masonry. Also, the multiple layers of installation and the fact that workers are working at high elevations could result in the emphasis of installation costs. The overall square foot estimate for the roof system is approximately \$8.24 per sf.

Assumptions:

- **Base Flashing:** Aluminum with 0.019" mil finish.
- **Flashing:** Aluminum, 0.019" specified.
- **Roof Deck Rigid Insulation:** Polyisocyanurate, 3 ½" thick.
- **Shingle:** Shingled asphalt roofing that is premium laminated multi-layered.
- **Built Up Roof:** Coated glass fiber base sheet, felt, with 1 ply mineral surfaced.
- **Roof Hatch:** 4 roof hatches with 1" fiberglass insulation.
- **Location Factor:** 0.92 average location factor. Its derivation is discussed in Section D.

D. Detailed Structural System Estimate

Please see the Detailed Structural System Estimates in Appendix D

D.1 Overview & Assumptions

The detailed estimate includes the substructure and superstructure of the Flagship Building. The structural estimate was accomplished by performing quantity takeoffs and consulting *R.S. Means* data. The following items of the structural system were estimated:

- Substructure
 - Concrete Footings & Piers
- Superstructure
 - Concrete Slabs (including Slab on Grade)
 - Welded Wire Fabric
 - Steel Beams
 - Steel Columns
 - K Series Joists
 - CMU Block Walls
 - Steel Decking

The detailed estimating process was long and tedious. In order to make the process efficient and still accurate, the following assumptions were made. Please see Appendix D.3 for the *R.S. Means* data used.

- **Concrete Footings & Piers:** According to the *R.S. Means* data, the formwork and reinforcing for the footings were included in the costs. To match *R.S. Means* information, the footings were assumed to be strip footings, and the piers were estimated per cubic yard as spread footings. A 10% waste factor was added due to the fact that concrete will inevitably have material missing, labor mistakes, or unusable material.
- **Concrete Slabs:** The Slab on Grade cost did not include finish work. Since finishing work was not structurally related, it was omitted from the estimate. The elevated slabs for the 2nd and 3rd floors did not include reinforcing. The welded wire fabric was added to the estimate to account for this reinforcing. A 10% waste factor was added for the concrete.
- **Steel Beams:** For the sake of time efficiency and repetition, floors 1, 2, and 3 were assumed to have the same structural steel members. This is a safe assumption due to the fact that the building is symmetrical and each floor serves a similar purpose. If anything, floor 1 probably has the largest steel members to support the more open areas. This results in a conservative estimate. Also, not every “W” shape was included in *R.S. Means*. Some values were interpolated.
- **Steel Columns:** Only one HSS 8x8 was listed in *R.S. Means*, therefore this quantity had to be used for all of the HSS 8x8 columns. There was no way to interpolate or assume price variations for the different final dimension. It is reasonable to assume that the price would not vary more than a few cents or tens of cents per column type. The column heights were known from the structural plans, and had to be broken down into 14’ increments based on the *R.S. Means* data.

- **K Series Joists:** The same applies to the steel joists as the steel beams. Not every K Series Joist was listed in the *R.S. Means* information. Therefore, values were interpolated and thoughtfully guessed.
- **CMU Block Walls:** The 5% reduction was assumed because the lineal length of the wall footings was used to estimate the lineal length of the walls. However, the footings extend between 6" and 1' beyond the wall's edge. The reduction accounted for the difference between the concrete footing lengths and the wall lengths. A 10% waste factor was added for wasted, damaged or cut blocks.
- **Steel Decking:** Different information was used for the slab form decking and the roof decking. The size used for the decking was the square foot size of each floor.

D.2 Estimates

The full Detailed Structural System Estimate can be seen in Appendix D.1. Below is a summary of the detailed estimate categorized by the three major CSI Divisions included in the estimate (3: Concrete, 4: Masonry, 5: Steel).

Washington Christian Academy				
Detailed Estimate Summary by CSI Division				
<i>A cost summary for Divisions 3,4,&5</i>				
Div. 3	Concrete			
	Substructure	317	CY	\$ 62,869
	Slabs	874	CY	\$ 167,062
	Total:	1191	CY	\$ 229,931
Div. 4	CMU	59346	sf	\$ 384,503
Div. 5	Steel			
	Beams	55.8	tons	\$ 150,262
	Columns	9.11	tons	\$ 21,400
	WWF	444.4	csf	\$ 14,621
	Joists	114.63	tons	\$ 290,784
	Steel Decking	67620	sf	\$ 109,481
	Total:			\$ 586,548
<i>Cost per unit for Divisions 3,4,&5</i>				
	Total	Total Cost	Cost	Per Unit
Concrete	1191 CY	\$229,931	\$ 193.00	per CY
Masonry	59346 sf	\$384,503	\$ 6.47	per sf
Steel	112060 sf	\$124,102	\$ 1.11	per sf
	179.54 tons	\$462,446	\$ 2,575.73	per ton
<i>With 0.92 Location Factor</i>				
Concrete	\$ 177.56	per CY		
Masonry	\$ 5.95	per sf		
Steel	\$ 1.02	per sf		
	\$ 2,369.67	per ton		

- **Location Factor:** Olney, Maryland was not on the *R.S. Means* location factor list. Even though many of the trades are from Washington, D.C., the WCA is not actually in the district. Therefore, the most fair and accurate method available was to use an average.

Average for all listings in Maryland	.865
Washington, D.C.	.98
Location Factor Average:	.92

- **Time Factor:** Not used because cost data is from *R.S. Means* 2007.
- **Steel Breakdown:** The steel is broken down by square foot and ton. The square foot estimate is for reinforcing and steel deck. The sizeable structural steel members (beams, columns, and joists) are accounted by tonnage.

Appendix D.2 is a cost breakdown of the detailed estimate for the material, labor, and equipment. A summary of the breakdown is given below.

Washington Christian Academy				
Detailed Estimate Summary by Cost Breakdown Category				
<i>A cost summary for Material, Labor, & Equipment</i>				
Cost Breakdown	Initial Total	Loc. Factor	Grand Total	Percent of Total Cost
Material	\$ 706,125	0.92	\$ 649,635	58.7%
Labor	\$ 431,114	0.92	\$ 396,625	35.8%
Equipment	\$ 63,647	0.92	\$ 58,555	5.3%
Total	\$ 1,202,923	0.92	\$ 1,106,689	100.0%

These percentages seem reasonable based on experience and knowledge of these three divisions (concrete, masonry, and steel). The labor for masonry is relatively high in comparison with the other two trades, which probably brought up the labor percentage of the total cost a bit. Equipment costs are the lowest for this structural system estimate because the crane is the largest, most expensive piece of equipment and is not considered in this price. Material makes up most of the project cost, which is no surprise considering material price escalation (especially of steel). Overall, the detailed estimates in Appendices D.1 & D.2 are very similar to the contractual estimates performed for the project.

E. General Conditions Estimate

Please see the General Conditions Estimate in Appendix E

E.1 Assumptions

To complete the General Conditions Estimate, the following information was assumed. Most of the information came from the detailed project schedule and basic general conditions estimates from class notes.

- Construction Start: 2/1/07 based off of the 1/25/07 NTP/mobilization from the project schedule.
- Construction Completion: 7/1/07 based off the substantial completion for the Flagship Building from the project schedule. The reason for the slight change in dates was to create an even number of months on the project. It can be assumed that the project completion date will change as the project continues, however this estimate does not account for that.
- Duration (months): 17 months derived from the dates above.
- Duration (weeks): $\frac{52 \text{ weeks}}{\text{year}} \times \frac{1 \text{ year}}{12 \text{ months}} \times 17 \text{ months duration} = 73.7 \text{ weeks}$

This is a rough estimate. The leap year is not accounted for, but neither are holidays and other non-working days. Overall, it is a reasonable amount of time for the general conditions estimate.
- Temporary heat will only be needed on the project for 6 months.
- The warranty quantity comes from 10% of the total project cost.
- The Superintendent does not completely finish the project. Once the project is within the final weeks and activities are winding down (finishes, landscaping, punchlist), the Assistant Superintendent takes over and the Superintendent moves on to another project.
- The project time for the Project Executive, Senior Project Manager, Administrative Assistant, and IT Technician were obtained from information from Forrester Construction Company. They are merely estimates and could vary week to week. If problems were to arise on the project, these times would increase.
- Progress Photographs, schedules, reports, and meetings are included by the General Contractor with no specific charge.

E.2 Analysis

- The General Conditions cost is approximately 9% of the total project cost. This is a reasonable estimate for this size of project (around \$20 million dollars). The owner and general contractor have a good working relationship. All parties involved are striving to solve problems collectively and efficiently to avoid change orders and delays. Avoiding change orders will save the owner money, and finishing early will save everyone money.