7700 ARLINGTON BLVD.
FALLS CHURCH, VA

SENIOR THESIS FINAL REPORT

CHRISTIE SMITH

CONSTRUCTION MANAGEMENT

2012 CAPSTONE PROJECT

ADVISOR: JAMES FAUST

SUBMITTED: 4/4/2012

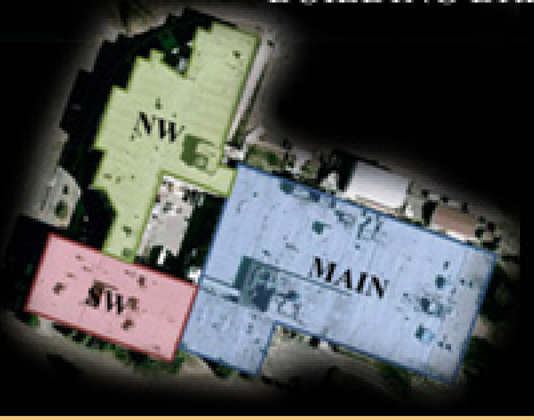
7700 Arlington Blvd. | Falls Church, VA

Rendering Courtesy of Gensler

PROJECT OVERVIEW

Owner |	GBA Associates LP
Owner's Rep |	Kramer Consulting
Architect |	Gensler
Engineer |	GHT Limited
General Contractor |	James G. Davis Construction
Total Square Feet |	684,651
Total Project Bid Cost |	$52,691,347
Dates of Construction |	1/20/10 - 5/1/12
Project Delivery Method |	CM at Risk

BUILDING BREAKDOWN



Northwest Building
| 267,436 SF
| 4 stories
Southwest Building
| 159,005 SF
| 4 stories
Main Building
| 258,209 SF
| 2 stories

ARCHITECTURAL FEATURES

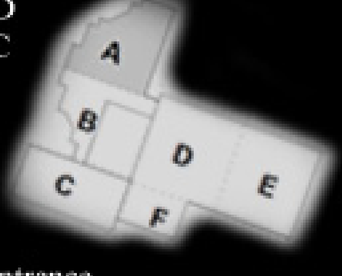
3 buildings on a 43.63 acre site
4 story atrium connecting the buildings
New home to the Defense Health Headquarters
Original buildings built between the 1950s & 1980s
Typical office building
Precast panels on entire facade
Glazed aluminum curtain wall around entrance
Courtyard in the middle of all 3 buildings

MECHANICAL & ELECTRICAL SYSTEM

Mechanical System (Separate units for each builidng)
| All-air rooftop cooling system that distributes air to different spaces through low-pressure ductwork and ceiling diffusers
| Closed-loop water source heat pump system
| Chilled water/hot water system with central VAV air handling units
| A direct digital control system will be used to monitor and control the three HVAC systems
Electrical System
| The electrical system for all three buildings will consist of a 480/277V, 3-phase, 4-wire, 4A system

SCOPE OF WORK

Demolition of 90% of the current interior partitions
Demolition of a third story above segment D
Demolition of a penthouse above segment C
Replacement of all windows
A re-skin of the 4th floor
Construction of new core elements
Anti-terrorism/force protection
Coating the existing brick façade
Construction of a new canopy at the main entrance
Renovation of mechanical and electrical systems in segments A and B
New mechanical and electrical systems in segments C, D, E and F



STRUCTURAL SYSTEM

Progressive Collapse System
| Around perimeter of Northwest and Southwest buildings
| System consists of W24X103 steel beams with varying W24X103 & W24X131 kickers
| 8 different types of HSS columns
Seismic Bracing Enchancement
| Northwest | HSS8X8X3/8
| Southwest | HSS6X6X1/4 & HSS6X6X3/8
| Main | HSS6X6X3/8 & HSS7X7X3/8
Blast Proof Facade
| H-Frame system around entire facade

Table of Contents

1.0 Executive Summary

Senior Thesis Final Report is intended to identify four analyses that will be utilized on 7700 Arlington Blvd. Each analysis either addresses all or some of four investigation areas; Critical Issues Research, Value Engineering Analysis, Constructability Review, and/or Schedule Reduction. The expected outcome and overall theme for the four analyses is defining and creating more efficient means to construction collaboration.

Analysis #1 | Simplifying the Integrated Project Delivery Approach

Material procurement was a challenge for this project and it involved detailed coordination amongst trades in order to reach project start-up. Additional time and money were required to achieve the necessary material due to the type of project delivery method used for 7700 Arlington Blvd. The goal of this analysis was to create a way to improve showing an owner, contractor, and architect how to implement an integrated project delivery approach on a project through the use of a process map. The map shows the different levels of coordination and communication throughout the entire project lifetime and the map will be a way to streamline the process for all parties involved throughout a project.

Analysis #2 | New Mechanical System in the Northwest Building

The Northwest Building was the only building that did not receive a new mechanical system due to the owner's budget. Therefore, the goal for this analysis was to create a TRACE 700 model for the Northwest Building that collected data for a comparison between a water source heat pump system and a VAV system. The same VAV system that was used in the Southwest Building was utilized in the TRACE 700 model. Based on the owner's goals, the VAV system would have been chosen because it costs $6,393,552.88, takes 8-10 months to install, and lasts 25 years. Two breadths can be extracted from this analysis; ***Breadth #1*** being the ***TRACE 700 analyses*** and ***Breadth #2*** being two ***raised platform designs*** for the additional roof top units if the VAV system were to be installed in the Northwest Building.

Analysis #3 | Creating a Short Interval Production Schedule

There were many coordination issues that occurred on 7700 Arlington Blvd. due to the complex schedule. There was not enough time allotted for demolition, which directly impacted the structural steel erection schedule. The goal for this analysis was to create an efficient SIP Schedule that could be utilized in the field for the demolition and structural system aspect of the project. As a result a new phasing plan was created to achieve an overall reduction of 11 weeks and a general condition's savings of $438,535.90.

Analysis #4 | BIM Implementation into the Field

Due to the coordination issues that happened with this project, the utilization of BIM in the field could have possibly prevented certain issues. Continuing with the same issue as in Analysis #3, the goal for this analysis is to look at the influence of flow diagrams and process charts for use in the field. A high-tech work station that incorporates the use of an Apple iPad as well as the use of BIMsight technology was explored to figure out the applicability for workers in the field. The use of the work station and BIMsight technology will increase collaboration on the jobsite as well as create safer working conditions due to the availability of the station to get the correct information.

2.0 Acknowledgments

I would like to thank the following people for their help and support throughout the development of my senior thesis project.

Academic Acknowledgments

Dr. Craig Dubler

Dr. Robert Leicht

Mr. James Faust

Professor Robert Holland

Professor Kevin Parfitt

Industry Acknowledgments

James G. Davis Construction Corporation

Mr. Bill Moyer

Mrs. Julie Kirkwood

Mr. Tyler Moyer

Mr. Jonathan Dougherty

Gensler

GBA Associates LP

GHT Limited

James Cummings

WE Bowers

Dave O'Donnell

PACE Industry Members

Personal Acknowledgments

My family and friends

3.0 Project Overview

3.1 Project Introduction

7700 Arlington Boulevard is comprised of three buildings with a four story atrium in the middle and will be the new home to the Defense Health Headquarters (DHHQ). The three buildings were originally built between the 1950s to the 1980s. The Northwest Building is four stories tall with a height of 47 feet and a gross square footage of 267,436 SF. The Southwest Building is four stories tall with a height of 43 feet 10 inches and a gross square footage of 159,005 SF. The Main Building is two stories tall with a height of 31 feet 10 inches and a gross square footage of 258,209 SF. Overall, the architecture of 7700 Arlington Boulevard looks like a typical office building.

Since this structure was pre-existing, the overall scope of work at the time documents were given to perform the Senior Thesis Project includes all of the following:

- Demolition of 90% of the current interior partitions
- Demolition of a third story above segment D
- Demolition of a penthouse above segment C
- Replacement of all windows
- A re-skin of the 4th floor
- Construction of new core elements
- Anti-terrorism/force protection (progressive collapse steel and façade hardening)
- Coating the existing brick façade
- Construction of a new canopy at the main entrance
- Renovation of mechanical and electrical systems in segments A and B
- New mechanical and electrical systems in segments C, D, E and F

The project was awarded to James G. Davis Construction Corporation on July 12, 2010 after about six months of evaluating the solicitation from offer (SFO) which is where an agency, in this case DHHQ, posts all their requirements for a space they would like to occupy. It is a public posting where different property owners will send in a bid in an attempt to meet the owner's requirements and costs. Three months later, Davis Construction mobilized on the construction site.

Since there are three buildings on this jobsite, a lot of coordination had to be done in order to evaluate the correct sequence for the job. The 2-phase construction sequence, shown in Figure 1, was developed because Raytheon will still be occupying the space during the beginning of construction and DHHQ will be moving into the space as construction approaches completion. The square foot breakdown results with Phase I being 525,645 SF and Phase II being 159,005 SF.

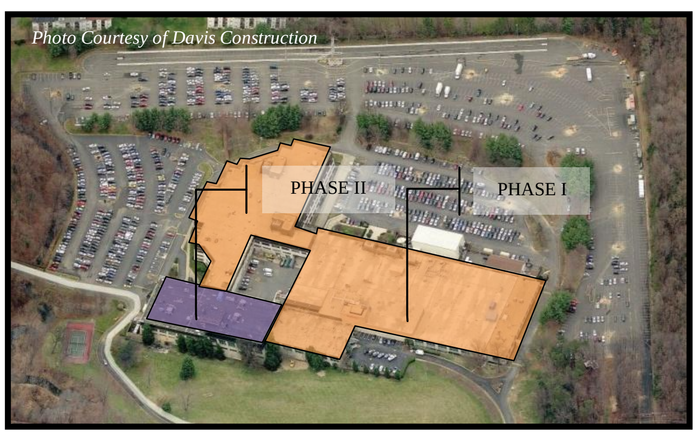


Figure 1 | 2-Phase Construction Sequence

3.2 Project Location

7700 Arlington Blvd. is located in Falls Church, Virginia. The two major roads that surround the building are Route 495 (The Capital Beltway) and Route 50 (Arlington Blvd.). The main entrance into the site is off of Route 50 and since this is an already existing structure there is plenty of space to store equipment, trailers, and other construction items for the duration of construction. This site was originally home to Raytheon, a company that specializes in defense, homeland security and other government markets.[7] Demolition and construction will be going on prior to Raytheon vacating the building. The picture below shows the existing site and the roads that surround it.

Figure 2 | Aerial View of Project Location

Figure 3 | Close-up Aerial View of Site

[7] Raytheon Company. (2011) *"Raytheon Company: Customer Success is Our Mission."* Accessed: 22 September 2011. <http://www.raytheon.com/ourcompany/>.

3.3 Client Information

GBA Associates Limited Partnership is the owner responsible for the new 7700 Arlington Blvd. site. DHHQ (Defense Health Headquarters) is going to be the tenants of this new space. The reason they are building this facility is because the Defense Base Closure and Realignment Commission (BRAC) recommended that the Department of Defense relocate all facilities to be in accordance with BRAC BP 198. BRAC BP 198 is where a bunch of government buildings must be realigned in order to support certain threats. For example, 7700 Arlington Blvd. will have a blast proof façade, a progressive collapse system and more in order to comply with the BRAC Commission's recommendations.[5]

Schedule is one of the driving factors for this project because the building must be in accordance to BRAC BP 198 by September 15 of this year. Unfortunately, the entire project was to be completed within six months which eventually became unattainable due to designing issues on the tenant side. The project started on January 1, 2010 and will be completed at the beginning of May 2012. Even though they did not hit their target date, they will still be considered to be in accordance to BRAC BP 198.

Since this is a government project there is cost issues associated with the job. The government will only be able to give a certain amount to this project. According to Davis Construction, the budget is going well and looks like it will be on par with the bid if the rest of construction continues as planned. In the beginning though, the government had to cut out a good chunk of what they had planned in order to reach their budget. Unfortunately, some aspects of the job were sacrificed in order to get what was needed to comply with BRAC BP 198.

In all government jobs as well as Davis' jobs, safety is of the upmost importance. All codes and regulations have been followed on this job to ensure a safe and working building. GBA Associates Limited Partnership and Davis Construction have worked closely together to ensure there are no huge interruptions with the site logistics. Since this is a large site there is no excuse for unsafe work environments involving material, equipment, and most of all the workers.

A detailed 2-phase sequencing process has been developed for 7700 Arlington Blvd. This includes the Main Building and Northwest Building in the first phase and the Southwest Building in the second phase. The reason the construction is being sequenced in this manner is because the Main Building and Northwest Building will be turned over to GBA Associates Limited Partnership in order to comply with the September 15, 2011 deadline. The Southwest Building will be turned over on May 1, 2012 which will be the completion of the entire building including the tenant work.

Through heavy communication and coordination between GBA Associates Limited Partnership and Davis, 7700 Arlington Blvd. will be a high quality building that will help ensure the safety of all those that will occupy it due to its complex systems inside and out.

---

[5] GBA Associates LP. (2011) *"7700 Arlington Blvd.."* Accessed: 22 September 2011. <http://7700arlingtonblvd.com/dhhq.html>.

3.4 Project Delivery System

The project delivery system for 7700 Arlington Blvd. is CM at Risk. The contract type for the general contractor services with Davis Construction is a Guaranteed Maximum Price. Due to the complexity of the project there had to be constant communication between every player on the job. There was a lot of research done to find out what the existing conditions were during the design phase of construction. Raytheon's high security did not allow for any onsite research which proved to force more communication and coordination amongst all trades. In this case, most of the subcontractors like the glass and glazing contractor were considered to be design-assist due to the tightness of the construction schedule and how much information was necessary to design something new on an existing structure. The delivery methods and contract types make sense for this type of project due to the size. All the subcontractors held by Davis Construction are lump sum contracts which help Davis Construction achieve the best price possible for their bid. Refer to Figure 4 for the project organizational chart.

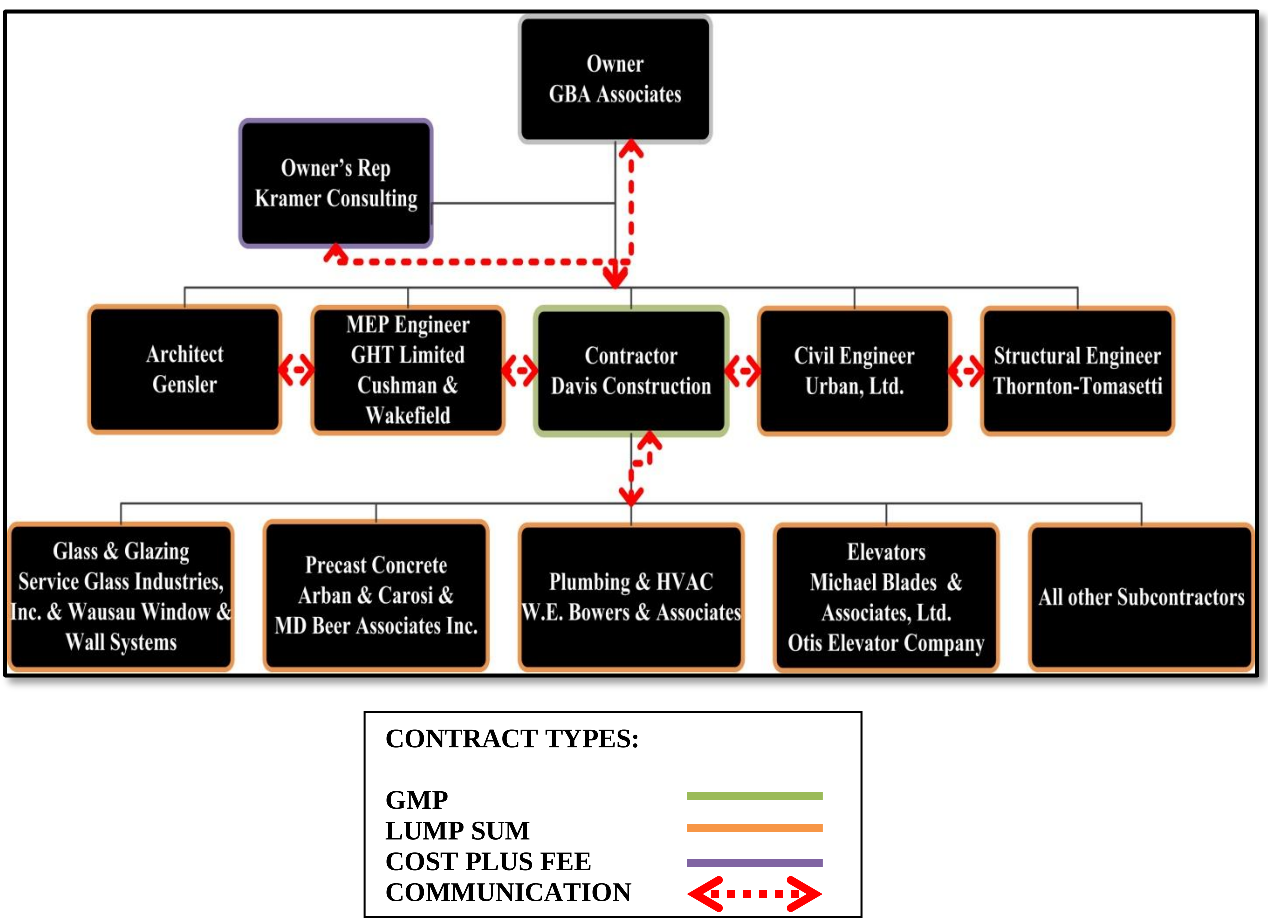


Figure 4 | 7700 Arlington Blvd. Organizational Chart

3.5 Project Team Staffing Plan

Since this project is very large, Davis Construction knew they had to provide a staff that could get the job done on time and under budget. 7700 Arlington Blvd. required virtual construction for the façade, progressive collapse, and other systems which meant they needed to hire well trained employee(s) that understood certain programs. The field staff is relatively large due to there being three existing buildings on the site. The diagram below illustrates the staffing for Davis on and off the construction site.

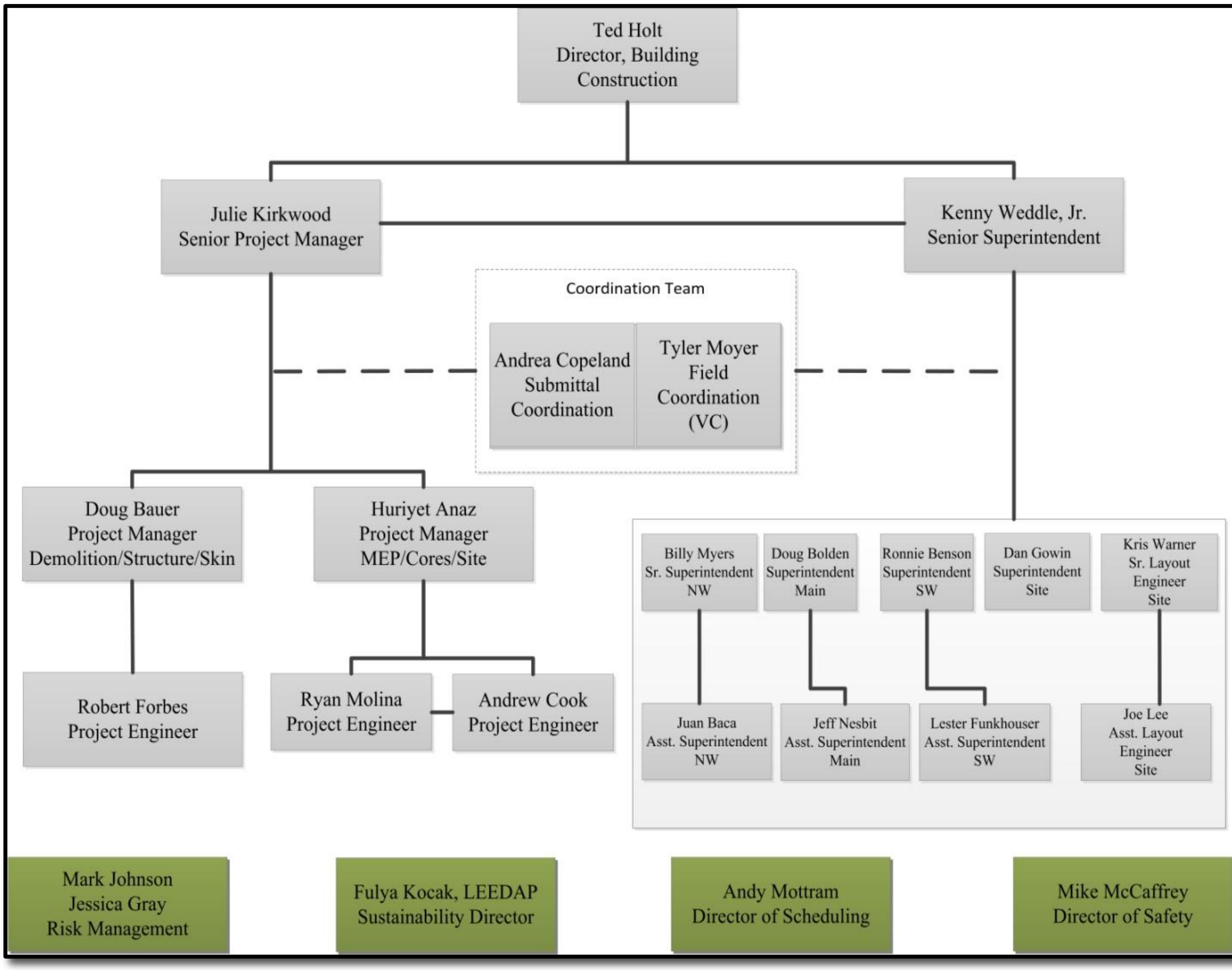


Figure 5 | Davis Construction Staffing Chart

Ted Holt is the director for this project followed by Julie Kirkwood and Kenny Weddle. Julie is in charge of managing the overall job while Kenny is responsible for all the on-site superintendents. Since the job required a lot of BIM modeling coordination, Andrea Copeland and Tyler Moyer were hired to orchestrate that part of the project. There are also four main people in the Rockville office that help keep the job running smoothly since Davis Construction is doing both the base building and tenant work. Overall, Davis Construction has a well-rounded staff for a challenging project.

4.0 Design and Construction Overview

4.1 Building Systems

4.1.1 Demolition

Since 7700 Arlington Blvd. is an already existing structure, there will be certain systems demolished for this project. The main materials that will be demolished include the removal of the building façade, louvers & windows, elevator structure, interior stairs, existing penthouse structure, cafeteria, antenna room, and the existing parapet for the entire perimeter of the Main Building which is shown in the picture to the right. In addition to these materials being removed, two mechanical systems will be removed, the entire electrical & lighting system, and the plumbing and fire protection systems will be demolished.

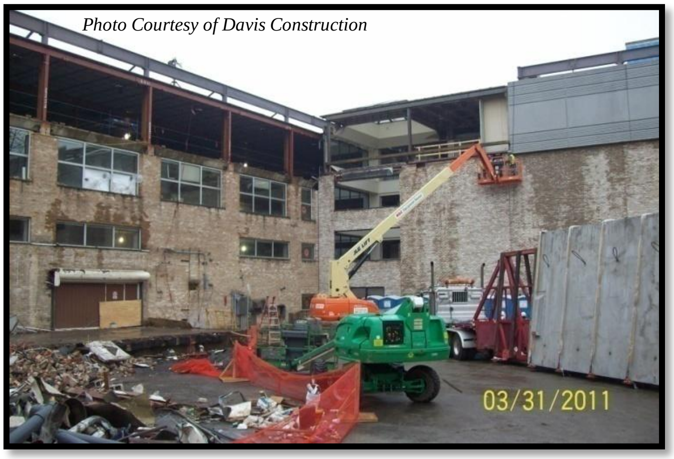


Figure 6 | Demolition of Existing Parapet for Perimeter of Main Building

The initial demolition includes the removal of asbestos and lead-based paint and lead-containing components. Removal of HVAC duct insulation, cementitious panels, textured ceiling material, boiler exhaust duct, elevator doors, and many other pieces will be removed due to asbestos from the premises in order to ensure a safe work environment. If any lead-based paint and/or lead-containing components are found they will be removed to OSHA regulations. Areas that could contain lead include electrical conduit, structural I-beams and columns, glazed ceramic wall tiles, interior door lintels, freight elevator doors, and more materials.

There are a few selective structural elements that need to be demolished. The existing fourth floor exterior wall assembly in the Northwest and Southwest Buildings, along with the Northwest Building roof assembly to the surface of the structural substrate will be removed. All interior partitions and associated doors and frames will need to be demolished unless otherwise noted on drawings. Other items that will be demolished include all existing ceilings and all floor finishes.

4.1.2 Structural Steel System

Since this is an existing structure and each building was built at separate times the structural system in each building varies. The Main Building structural system is primarily composed of concrete. The structural steel in the Main Building includes steel columns that extend up from the upper level slab and support a steel beam and girder framed roof. The cafeteria roof framing will be demolished and replaced with a new steel frame and gypsum roof similar to the already existing roof. A steel framed roof is the primary structural system in the Southwest Building. There are steel pile sections that extend from the fourth floor to the roof. The roof consists of a metal deck on bar joists and steel girders. The roof live load capacity is limited to 30 psf and is not able to accommodate concentrated loads. Lastly, there is no prominent existing structural steel within the Northwest Building.

In the renovation, different structural systems will be installed to help support the structure if ever under certain threats. A progressive collapse system will be implemented around the perimeter of the Northwest and the Southwest Building. This system consists of W24x103 steel beams with varying W24x103 and W24x131 kickers. Kickers are used to support the progressive collapse system. The steel columns that run from the roof to the foundation include eight different types of HSS columns.

Seismic bracing enhancement is another part of the structural system that was renovated. In the Northwest Building HSS 8x8x3/8 braced frames were used to support the structure while in the Southwest Building HSS 6x6x61/4 and HSS 6x6x3/8 braced frames were used. HSS 6x6x3/8 and HSS7x7x3/8 were the primary seismic bracing for the Main Building.

Figure 7 | Installed Seismic Bracing

Another part of the new structural system that will be installed to help support the building against any threats is the blast proof façade. The building will incorporate an H-frame system around the entire façade. HSS 5x2x1/4" steel beams at a 16'-6" max span or HSS 5x3x1/4" steel beams at a 18'-6" max span will be used to connect to already existing columns to make up the H-frame system.

4.1.3 Cast in Place Concrete

Concrete spread footings with concrete basement walls and concrete flat slabs at the upper floor level are used in the Main Building. The columns have capitals and drop panels that extend out approximately 1/6 of the adjacent span dimension from the column centerlines. For the Southwest Building, the foundations are spread footings that occur in a crawl space beneath the ground floor. All the floors are cast in place concrete two-way flat slabs and have beams at the building perimeter. All floors including the ground level are designed to support 100 psf. The majority of the Northwest Building is founded on spread footings, with a portion of the building including the lobby atrium area supported on a mat foundation. The ground floor level consists of a 6" concrete slab on grade, which should be capable of supporting larger uniform loads. The 2nd through 4th floors and the roof are all framed with two-way flat slabs and drop panels at the columns. The slabs are design for 125 psf, at the floors, and 30 psf at the roof.

There is no major cast in place concrete activities being performed on this job since no slabs or structural systems will be demoed. Minor concrete work will need to be done if existing holes in the slab need to be filled.

4.1.4 MEP Systems

Mechanical System

The mechanical system is designed to satisfy the requirements of meeting LEED CI Silver certification as well as provide the appropriate level of comfort for the future tenants of the building. There are three basic air conditioning systems throughout all the buildings, with the Main Building system utilizing an all-air rooftop cooling system, which distributes air to different spaces through low-pressure ductwork and ceiling diffusers. The return air will be sent back to central duct risers, which are through a ceiling plenum.

The Northwest Building system is a closed-loop water source heat pump system. There are interior and perimeter zones for this system with the interior zone having large heat pump air-handling units in mechanical rooms on each floor. The perimeter zone has individual heat pump units located in each office along the perimeter. A roof top unit is home to the closed-loop hydronic circulation system where it houses pumps, boilers, and cooling towers.

The Southwest Building system is a chilled water/hot water system with central VAV air handling units. Low-pressure ductwork and ceiling diffusers will be used again to distribute the air throughout the building. Increased ventilation is provided for each system type by roof mounted preconditioning outside air units or by integrated heat wheels. A direct digital control system will be used to monitor and control the three HVAC systems.

There are two types of fire suppression systems that will be used throughout each building and they are a wet-pipe sprinkler system and a dry-pipe sprinkler system.

Electrical System

The electrical system for all three buildings will consist of a 480/277V, 3-phase, 4-wire, 4000A system. A 15000kVA pad-mounted outdoors transformer that belongs to the electric utility company is also incorporated into the buildings' electrical system. Three generators will help back-up the electricity for this project.

4.1.5 LEED Rating

7700 Arlington Blvd. will feature a vegetation roof in certain areas of the roof for the building. The HVAC system will be protected in order to ensure good filtration as well as certain materials will be used during construction like sealants or caulks. Another LEED aspect will be scheduling certain finishes together in order to reduce the absorption of volatile organic compounds by absorptive materials. A few more items that help with LEED points are housekeeping, pathway interruption, and monitoring which includes progress photos. The base building will not qualify for any LEED certifications, but the tenant side will meet LEED silver certification since the tenants are a branch of the government.

4.2 Local Conditions

****Reference Appendix A for the Existing Conditions Site Plan***

7700 Arlington Blvd. sits on approximately 43.63 acres with an existing gross floor area of 684,651 square feet. The Northwest Building is four stories tall with a height of 47 feet and a gross square footage of 267,436 SF. The Southwest Building is four stories tall with a height of 43 feet 10 inches and a gross square footage of 159,005 SF. The Main Building is two stories tall with a height of 31 feet 10 inches and a gross square footage of 258,209 SF. Parking outside the building includes 29 handicapped spots, 4 van handicapped spots, and 1811 regular parking spots. There are plenty of parking spots for construction employees during the project as well as lay down areas for material. Below are a few pictures that show the existing building and site conditions, including parking. Refer to Appendix A for the Existing Conditions Site Plan which shows all the utility lines and other site items.

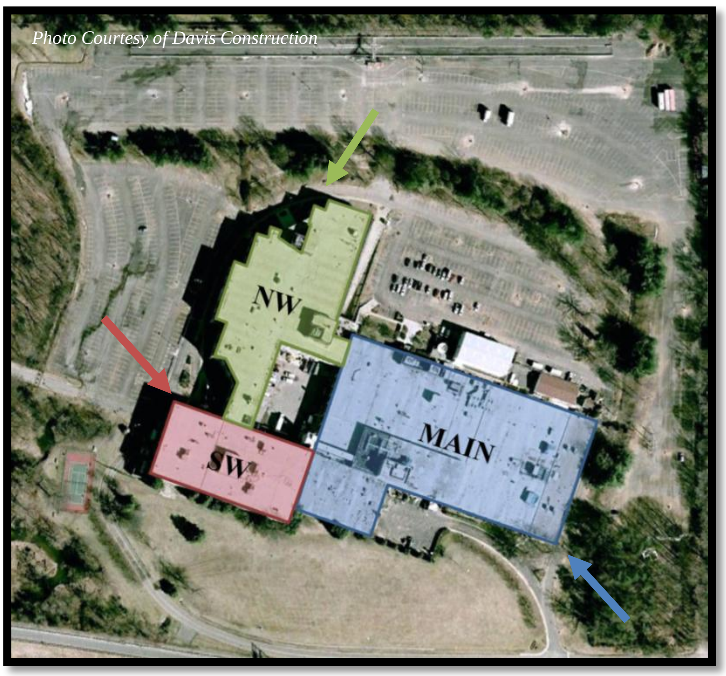


Figure 8 | Existing 7700 Arlington Blvd. Site

Figure 9 | (Left to Right): Northwest Building (green arrow), Southwest Building (red arrow),

and Main Building (blue arrow)

The landscaping is another area of the existing site that needs to be taken into consideration. Preservation of the trees will take place for this construction project. A few main species of trees that will be preserved include; tsuga canedensis (hemlock spruce), acer saccharum (sugar maple), and acer rubrum (red maple)

Even though there is an already existing structure, it is still a good idea to take a look at the types of soils located in the area. The six types of soils found on and around the site include; mixed alluvial (1A,A+), glenville (10B), manor (21D,E), elioak (24C), fairfax (sil) (32C), and glenelg (55B). Mixed alluvial has poor foundation support while manor, elioak, Fairfax, and glenelg have severe erodability. Below is a picture showing the different soil types on and around the construction site.

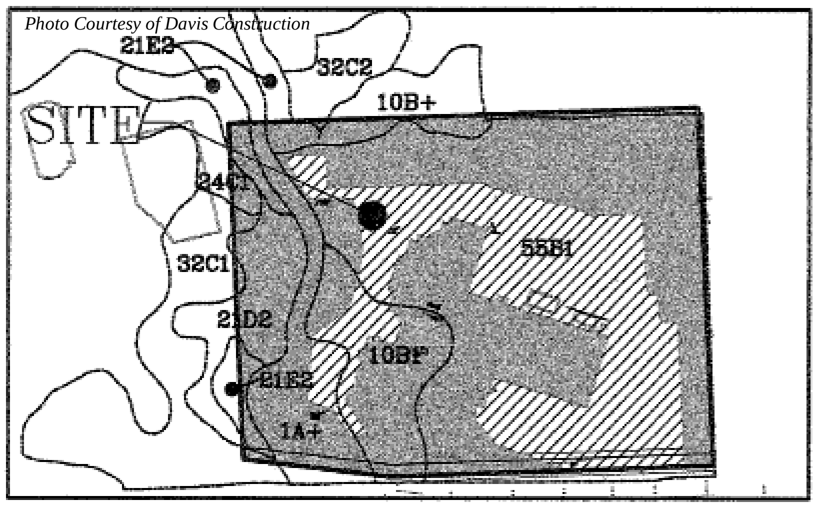


Figure 10 | Soil Types

There is no specific preferred method of construction in this area because each building on the site is made of steel and/or concrete. Every building is different and unique in its own way due to the time they were built. Also, since this building is a government building it will need to be LEED Silver Certified which means that there will be recycling on the site. Dumpsters will be placed where easy access can be obtained. One dumpster for example will be placed in the corner of the Southwest Building and the Main Building due to the ease of access in and out of the site. Davis Construction will coordinate all waste removal for the duration of the project.

4.3 Detailed Project Schedule

Reference Appendix B for the Detailed Project Schedule

The preconstruction for this job was broken down into the major components due to the complexity of the existing structure and the fact that no one was allowed into the building until Raytheon moved out. The designer, contractor, and subcontractor for each main component communicated to make the design as efficient and as cheap as possible since the budget for the renovation was not as much as everyone would have liked it to be. The first phase which is to include the Northwest Building and Main Building is to begin November 2010 and end July 2011. The second phase which is to include the Annex (or Southwest) Building is to begin January 2011 and end May 2012. The sequence within each phase begins with

Raytheon vacating the building, followed by the demolition, structure, façade/roof, building core/shell infrastructure, elevators, and tenant work. There will also be site improvements that will take about four months to complete. Refer to Appendix B for the Detailed Project Schedule.

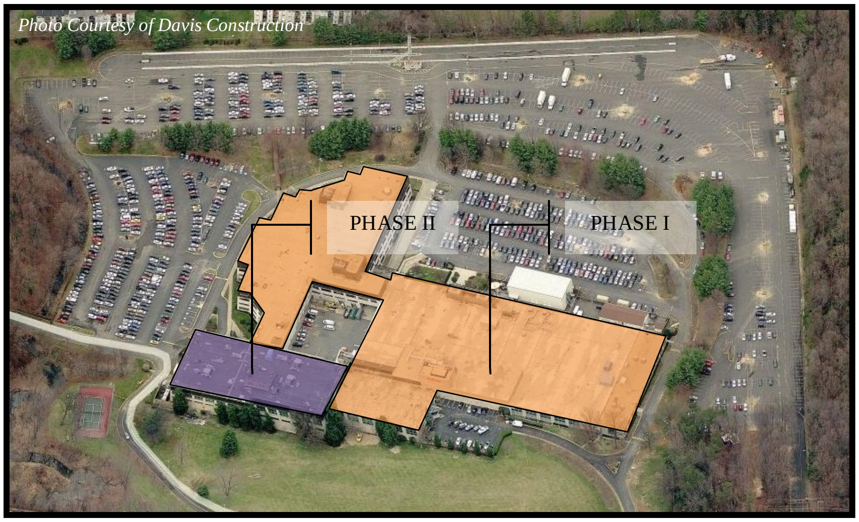


Figure 11 | 2-phase Construction Sequence

Table 1 below is a detailed schedule breakdown for final completion and inspections for each phase of construction. Staying on schedule is crucial for the success of this project because if these completion dates are not hit than a good deal of money will be wasted.

Table 1 | Final Completion & Inspections Breakdown for Phase I & II

Task Name	Start Date	Finish Date
Base Bldg Systems Start-up & Commissioning – Main	4/22/11	6/17/11
Base Bldg Final Inspections – Main	6/20/11	7/1/11
Base Bldg Final Inspections Completed – Main	7/1/11	7/1/11
Base Bldg Systems Start-up & Commissioning – NW	3/23/11	5/17/11
Base Bldg Final Inspections – NW	5/18/11	6/1/11
Base Bldg Final Inspections Completed – NW	6/1/11	6/1/11
Base Bldg Systems Start-up & Commissioning – SW	10/20/11	12/23/11
Base Bldg Final Inspections – SW	12/27/11	1/17/12
Base Bldg Final Inspections Completed – SW	1/17/12	1/17/12
Tenant Improvements Complete – Main & NW	5/2/11	7/29/11
Tenant Improvements Complete - SW	12/27/11	5/1/12

4.4 Site Layout Planning

***Reference Appendix C for the Site Plans of Site Layout Planning**

This job will have three different site layout plans, but because this is a renovation project the site plans will be a little different than if it was new construction. The most beneficial way to show what will be going on in the site is to show the major site logistics. The first site layout is of initial mobilization logistics. The last two site layouts will show phase one and two of construction. Refer to Appendix C for the three different site layout plans for 7700 Arlington Blvd.

The way that each logistics plan is laid out is pretty reasonable due to the fact that it is such a large site. There is a lot of room to house all the material and different pieces of equipment for the job site. By implementing an initial mobilization logistics plan, Davis was able to have everything prepared ahead of time. Once Raytheon moved out of the building, Davis Construction was able to start construction. For the first two site plans, Raytheon was redirected to use different entrances and exits to the site. The normal entrance is now the construction employee and delivery entrance and exit. The first phase utilized as much of the building perimeter as possible in order to place precast panels and install the progressive collapse system. The disturbance zone is placed in a way that it does not disturb the deliveries coming into the site. In addition, the construction storage and lay down area is placed in the most convenient spot for all the truck deliveries. Phase two is similar to the first site plan because DHHQ will be occupying the space while the Southwest Building is being complete. This is the only plan where some rearranging could have been done in order to utilize the area by the Southwest Building better. Overall, the site layout plans were done well, especially due to the fact that this was an already existing structure and most of the work will be complete on the inside more so than the outside.

4.5 General Conditions Estimate

***Reference Appendix D for the General Conditions Estimate**

The General Conditions estimate, provided by Davis Construction, consists of the following elements:

- Personnel
- Jobsite Operations
- Safety, Clean Up, Health
- Permits, Insurance, Bonds
- Punch List & Close Out

Table 2 outlines what it costs in total, per day, and per week for the General Conditions for 7700 Arlington Blvd. The total cost is $3,293,004.80 which is approximately 6.25% of the total construction cost.

Table 2 | General Conditions Summary			
	Total	**$ / Day**	**$ / Week**
General Conditions	**$3,293,004.80**	**$7,973.38**	**$39,866.9**

Each category is broken down in Table 3 and Figure 12 to show what makes up the total General Conditions Estimate. Personnel makes up about 84% of the total cost with Safety, Clean up, and Health making up the next biggest percent at 9%.

Table 3 | 7700 Arlington Blvd. General Conditions Breakdown Estimate Summary	
Category	**Total Cost**
Personnel	$2,752,775.20
Jobsite Operations	$185,750.00
Safety, Clean up, Health	$298,479.60
Permits, Insurance, Bonds	$17,000.00
Punch List & Close Out	$39,000.00
General Conditions Total Estimate	**$3,293,004.80**

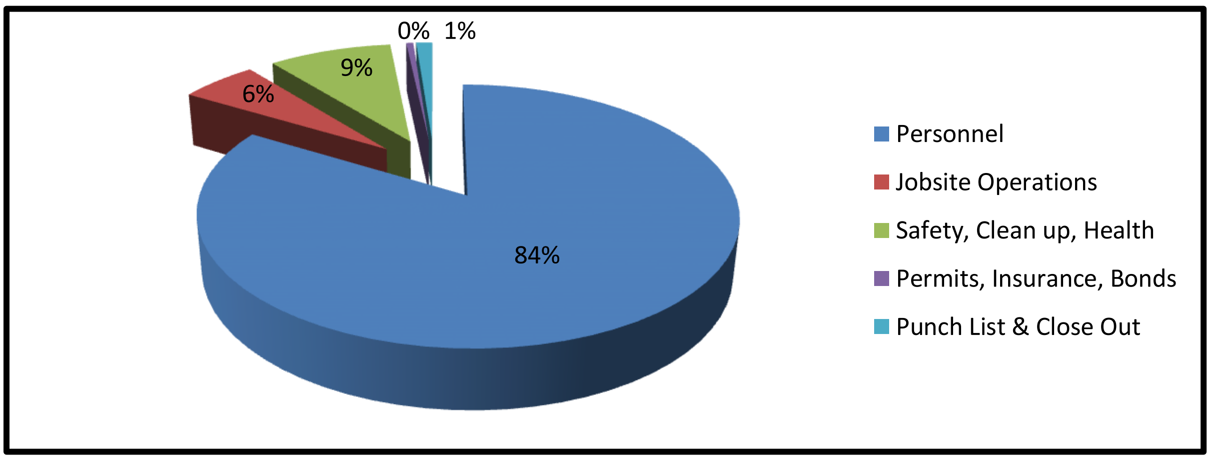


Figure 12 | General Conditions Breakdown Estimate Summary

There were quite a few items within the General Conditions Estimate that Davis Construction included directly into the job costs. The items that were charged directly to the job are outlined in Table 4.

Table 4 | 7700 Arlington Blvd. General Conditions Job Cost Items

Category	Item
Jobsite Operations	Travel Expenses
	Owner Office Expense / Trailer Rental
	Owner Office Cleaning (weekly)
	Field Office Set Up & Relocation
	Field Office Trailer Rental – Field Staff
	Field Office Trailer Rental – Office Staff
	Trailer Rental – Delivery & Removal
	Construction Signage
	Construction Site Fence
	Temporary Power – Consumption
	Temporary Power – Installation
	Temporary Water / Sanitary Supply
	Temporary Heat
	Temporary Lighting
	Winter Protection – Labor & Material
	Scaffolding
	Scissors / Telescoping Lift
	Minor Tools & Equipment
	Major Tools & Equipment
	Protection of Existing Conditions – Labor & Material
	Protect Work in Place – Labor & Material
	Temporary Partitions – Labor & Material
Safety, Clean up, Health	Final Clean – Parking Areas & Buildings
	Trash Chute – Erect, Dismantle, & Rental
	Misc. Fire Protection
	Respiratory Protection
	Guard Rails & Toe Boards – Labor & Material
	Floor Opening Protection – Labor & Material
Permits, Insurance, Bonds	Misc. Trade Permits
	Wall Check
	Pollution Control Liability Insurance
	Builders Risk Insurance
	Davis Construction Bond

It is clear that if the General Conditions were to account for all these items that the total cost would increase by an immense amount. Davis Construction could have carried the job cost items as a General Conditions cost; however, they decided to carry them as a job cost of the work for this estimate. This way the money is distributed into the appropriate areas instead of having every item in the General Conditions Estimate. If there are any drastic changes with the schedule for the project, the General Conditions Estimate and the items listed in Table 4 will be directly affected and costs will increase. This is because most costs incur on a weekly or monthly basis.

4.6 Detailed Progressive Collapse Steel System Estimate

****Reference Appendix E for the Detailed Structural System Estimate***

Since this project is a renovation there was already a structural system in place that would remain. Additional structural systems will be added to the building because it is a government building and the need for certain protection has to be addressed. The structural system that was analyzed for this part of the technical assignment was the Progressive Collapse Steel System. This system will be installed on the perimeter of the Northwest and Southwest Buildings. The breakdown of the Progressive Collapse Steel System includes structural members like HSS columns, W beams, Channels, Kickers, and more. Each part of this system was broken down and estimated using the *2011 RS Means Facilities Construction Cost Data* book. Table 5 shows the overall estimate pricing with Segment A and Segment B being the Northwest Building and Segment C being the Southwest Building. Appendix E shows a detailed breakdown of each segment for the Progressive Collapse Steel System.[9]

Table 5 | Progressive Collapse Steel Overall Estimate Pricing	
Segment A & B Total Estimate Pricing	**$589,407.73**
Segment C Total Estimate Pricing	**$364,277.09**
Overall Total System Estimate Pricing	**$953,684.82**
Overall Total System Estimate Pricing (including 0.92 location factor)	**$877,390.03**

Table 6 shows the comparison between the actual cost of the Progressive Collapse Steel System and the estimated cost. Due to detailed structural construction documents, the detailed estimate was within 8.3% or $79,624.97 of the actual cost for the system. There is most likely a few items missing since RS Means does not include every little detail for a system like this, but overall the estimate turned out better than expected.

Table 6 | Progressive Collapse Steel Actual vs. Estimated Cost Comparison				
	Actual		**Estimated**	
System	**Total**	**$/SF**	**Total**	**$/SF**
Progressive Collapse Steel	**$957,015.00**	**$2.24**	**$877,390.03**	**$2.05**

Figure 13 shows the Progressive Collapse Steel System installed in the Northwest and Southwest Buildings.

Progressive Collapse Steel System

Figure 13 | Progressive Collapse Steel System Installed

[9] RSMeans. (2010) *"RS Means Facilities Construction Cost Data, 2011."* 26th Annual Edition.

Below in Table 7 and Figure 14 is the breakdown by CSI Masterformat Divisions for the Progressive Collapse Steel System. The steel columns and steel beams make up most of the estimate for this particular system. 10% waste was included in the concrete footings due to any items that were missed between the translation of RS Means and the construction documents. 5% waste was used for the kickers because on-site cutting would potentially have to be done if they were shipped in longer lengths than needed for installation.

Table 7 | Progressive Collapse Steel Estimate Summary by CSI Masterformat Divisions

CSI Masterformat Division	Unit Cost	Unit	Quantity	Total Cost
033053 Cast-In-Place Concrete Footings (includes 10% waste)	$445.00	CY	13.68	**$6089.38**
050523 Anchor Bolts	$55.50	SET	109	**$6,049.50**
051223 Steel Columns	$1,027.93	EA	396.0	**$407,060.00**
051223 Steel Beams	$154.47	LF	2,526.4	**$390,258.18**
051223 Column Plates	$2.08	LB	19,513.81	**$40,577.25**
051223 Angle Framing (includes 5% waste)	$44.24	LF	798	**$35,301.00**
051223 Channel Framing	$64.15	LF	1,065.5	**$68,349.51**
			Total	**$953,684.82**

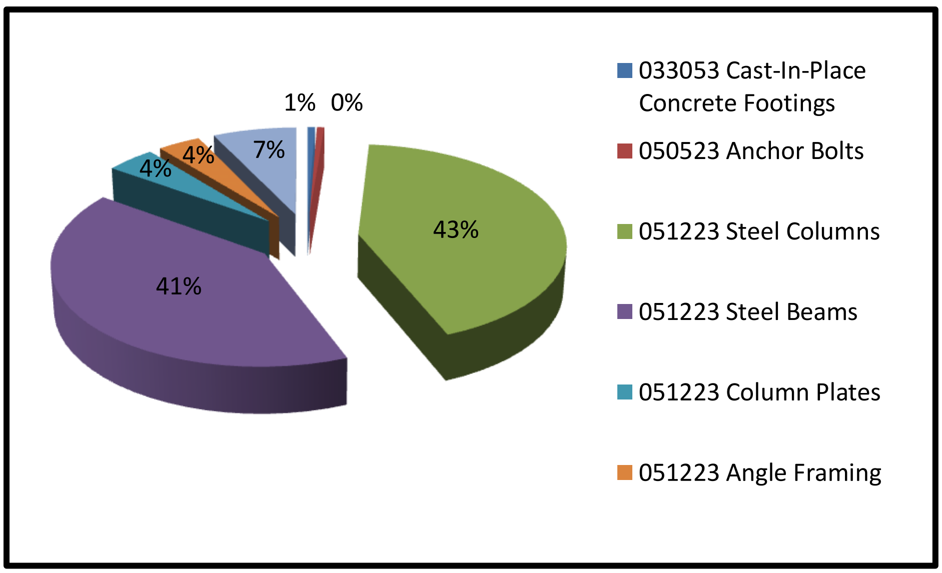


Figure 14 | CSI Masterformat Division Breakdown

In order to produce as accurate of an estimate as possible interpolation was done to get certain pricing for some steel beams. Refer to Appendix E for pricing calculations. Also, since not every HSS column was in RS Means the closest category was used in order to do the pricing. The biggest size in RS Means was used for the kickers to account for the quality and price of this system. Overall, different assumptions were made in order to get the best estimate for such a complex system. Refer to Appendix E for more assumptions that were made for this estimate.

4.7 Building Information Modeling Use Evaluation

****Reference Appendix F for the BIM Use Evaluation***

The first part to implementing BIM into any project is to define and rank the different goals for the project. The major goals for 7700 Arlington Blvd. include reducing the project schedule duration, reducing the project cost, increasing the overall quality of the project, and identifying concerns with the 2-phase construction sequence. Efficient design documentation, field conflict elimination, increase in project productivity levels, and construction tracking are other project goals that were taken into consideration. From outlining the BIM goals, which are shown in Appendix F under the BIM Goals Worksheet, different BIM uses were defined. The uses that were considered to be the most relevant and useful for this project were Design Authoring, 3D Coordination, 4D Modeling, Construction System Design, and Record Modeling.

To clearly understand each BIM use for this project each use is defined below. The definitions are from the *BIM Project Execution Planning Guide*. The reason for doing is to clearly organize the BIM uses when analyzing the BIM Use Analysis Worksheet and Process Map which can be found in Appendix F. Only the BIM uses that were utilized on the project are defined and thoroughly analyzed.[4]

- Design Authoring – "A process in which 3D software is used to develop a Building Information Model based on criteria that is important to the translation of the building's design."

- 3D Coordination – "A process in which Clash Detection software is used during the coordination process to determine field conflicts by comparing 3D models of building systems."

- 4D Modeling – "A process in which a 4D model is utilized to effectively plan the phased occupancy in a renovation, retrofit, addition, or to show the construction sequence and space requirements on a building site."

- Construction System Design – "A process in which 3D System Design Software is used to design and analyze the construction of a complex building system in order to increase planning."

- Record Modeling – "A process used to depict an accurate representation of the physical conditions, environment, and assets of a facility."

For 7700 Arlington Blvd., the Design Authoring use has a reasonable amount of value to the project with the responsible parties to include the Architect, MEP Engineer, Structural Engineer, and Civil Engineer. Each party has a good capability rating as well as self-value. The Design Authoring takes place at the beginning of the schematic design phase, design development phase, and construction documents phase. The reason for doing this is to ensure that the appropriate designs are being implemented into the project efficiently. Coordination between trades for different complex systems took place through each phase of construction and issues were resolved by using 3D software.

[4] CIC Research Program at Penn State. (2010) *"BIM Project Execution Planning Guide."* Version 2.0.

3D Coordination on the job is the most critical BIM use for 7700 Arlington Blvd. because by detecting clashes prior to installation, everyone involved in the project is able to save time and money. Saving time and money is important on every job, but in this case there was a demand for DHHQ to move into a new building and they did not have these resources readily available. The responsible parties involved with 3D Coordination include the Architect, MEP Engineer, Structural Engineer, and Contractor. Each play a vital role when it comes down to making sure the project runs smoothly. Ultimately, the contractor is responsible for the coordination between trades. For this job, weekly meetings are held where updated models are put through clash detection. Once the models are combined and clash detection software is run, everyone at the table must resolve the issue. After the issue is taken care of and the meeting is adjourned, Davis Construction and each subcontractor will go back to his/her office and update the model for the next week's meeting. 3D Coordination is done through the schematic design phase, design development phase, and construction documents phase. It is important for this coordination to be a part of each phase because there will inevitably be errors and clash detection can catch most, if not all the issues prior to installation.

Following 3D Coordination is 4D Modeling which is another vital BIM use for this project because it involves thorough analysis in order to help with the construction sequence. The main player for this use is the Contractor because they are the ones responsible for making sure the project is done on time. Not only is 4D Modeling beneficial to the Contractor, but it is extremely beneficial to the owner due to the fact that the schedule could be decreased by a decent percentage through the use of 4D Modeling. For 7700 Arlington Blvd., 4D Modeling was used in the schematic design phase, design development phase, and construction documents phase in order to develop an appropriate construction sequence as well as stay on par with the 3D Coordination. It is important, especially for this project to keep everything updated because time and money are so important to the owner. Where 4D Modeling came into play the most was with the new structural systems that were being installed. These systems include the blast proof façade, seismic bracing, and the progressive collapse system. Being able to sequence these systems in the appropriate manner took the BIM coordinator for Davis Construction a lot of time and effort to ensure the most logical sequence would be performed.

Construction System Design was implemented in the design development phase in order to help ease any type of confusion with the complex structural systems. The idea behind the Construction System Design BIM use is to build a 3D mock-up of some system or a part of a building in order to eliminate certain construction issues and any other errors. This use is another way to not only help the Architect and Contractor, but the Owner as well due to the fact that there is the potential for the team to save the Owner once again, time and money. In order to fully understand this BIM use there will need to be training for the Architect especially if they will be the ones designing these mock-ups.

The last BIM use that was not necessarily used on 7700 Arlington, but could greatly benefit from would be Record Modeling. The benefit to using Record Modeling is to help in the future if say DHHQ would ever decide to renovate again in certain areas. By having a model already created, it would reduce the amount of time spent trying to figure out what is in the building. This was a huge issue with 7700 Arlington Blvd. because no one was allowed into the building before Raytheon vacated the space. If a Record Model was already created than the Architect and Contractor would not have had to wait to get some of the information that they needed due to having a Record Model. There would need to be training for the Facility Managers of the building in order to make sure the Record Model is kept up to date for any future renovations, but overall it would have been a smart thing to do to help aid this project.

Overall, each BIM use is appropriate for this type of job because the most important aspect of this project is coordination amongst everyone involved. 3D Coordination and 4D Modeling were implemented exceptionally well on 7700 Arlington Blvd. and as a result the construction sequence ran nice and smooth. The other three BIM uses could have been utilized more throughout the project, but all in all the BIM coordinator for Davis Construction encompassed the main issues for this job.

Figure 15 shows a 4D Model of 7700 Arlington Blvd. The progressive collapse system is highlighted in red on the Northwest and Southwest Buildings. This model is used for clash detection as well as construction sequencing and has proved to be a valuable resource for this job.

Figure 15 | 7700 Arlington Blvd. 4D Model | Photo Courtesy of Davis Construction

4.8 LEED Evaluation

****Reference Appendix G for the LEED Scorecard***

The following analysis is based off of all assumptions because the tenant information was not released for review and information and; therefore, will not reflect Davis Construction. The only information that is known from the DHHQ main website is that the tenant improvements will meet LEED Silver Commercial Interiors Standards. Instead of doing the LEED Scorecard for New Construction and Major Renovations, the LEED Scorecard for Commercial Interiors has been completed. Refer to Appendix G for the LEED Scorecard.[5]

The requirement for obtaining LEED Silver for Commercial Interiors is between 50-59 points. Therefore, the LEED Scorecard was filled out to reflect a LEED Silver rating. Table 8 summarizes the LEED Scorecard showing the possible points in each category followed by the points that could potentially be obtained for 7700 Arlington Blvd.[14]

Table 8 | LEED 2009 for Commercial Interiors

Project Checklist	Possible Points	Points Obtained
Sustainable Sites	21	10
Water Efficiency	11	6
Energy and Atmosphere	37	16
Materials and Resources	14	5
Indoor Environmental Quality	17	16
Innovation and Design Process	6	1
Regional Priority Credits	4	0
Total	**110**	**54**

Sustainable Sites is the first category within the LEED Scorecard that was analyzed with four subcategories that could obtain points. Everything in this category has to deal with alternative transportation to 7700 Arlington Blvd. Public transportation access, bicycle storage and changing rooms, as well as parking availability are all valid points for this type of project. There is a major highway right next to the site as well as residential developments in the vicinity, and there is existing parking that will remain. The goal for this part of the LEED system is to reduce the amount of pollution and land development impacts from automobile use.

The second category is Water Efficiency and the employment of using less water throughout the building. The main areas that will use less water include the toilets, urinals, restroom faucets, pre-rinse spray valves, as well as other items that require a heavy amount of water usage. The reason that reducing water is so important to DHHQ is that it not only decreases the water bill but also reduces the burden on municipal water supplies and wastewater systems. Many projects employ these items into their buildings nowadays because it is a rather inexpensive way to reduce water consumption and still help the environment.

Energy and Atmosphere is the next category and it encompasses quite a few different LEED credits. In order to become LEED certified for Commercial Interiors there are certain required credits. This category happens to have three which are, fundamental commissioning of building energy systems, minimum energy performance, and fundamental refrigerant management. The idea is that if these three requirements are not satisfied than it would not make sense to have any of the other categories within

[5] GBA Associates LP. (2011) *"7700 Arlington Blvd.."* Accessed: 22 September 2011.
[14] U.S. Green Building Council. (2011) *"U.S. Green Building Council."* Accessed: 17 October 2011. <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220>.

Energy and Atmosphere. The commissioning for both the base building and tenant work are extremely detailed which is beneficial for the government because they want their space to be designed and constructed accurately. The rest of the categories focus on optimizing energy performance by using light controls, occupancy sensors, zoning controls for HVAC, and ENERGY STAR appliances throughout the building. The assumption is made that each office will have different sensors to personalize the space for when he/she is in the room. Also, in the cafeteria and/or lunch break rooms there will be energy efficient appliances to reduce excessive energy use. Overall, this category is responsible for a large percentage of the LEED rating for Commercial Interiors and if done properly can save the tenants money and help the environment immensely.

Materials and Resources is the fourth category in which LEED credits can be obtained and in this case credits can be easily obtained during construction. The easiest way to summarize the points that could be obtained in this category is that if Davis Construction does their part during construction and pays particular attention to recycling and reusing then not only is waste being diverted from landfills, but it helps out the owner too. Since this is a government building, the idea would be that DHHQ would occupy the space for a minimum of 10 years in order to conserve resources, reduce waste and reduce the impacts moving has on the environment. Also, another huge factor that comes into play during construction is where the different materials are being shipped from. Points are awarded if materials and products are manufactured regionally and with 7700 Arlington Blvd. being located in such a populated and growing area, there should be plenty of opportunities to receive local products for the project.

The next biggest points category for 7700 Arlington Blvd. is the Indoor Environmental Quality. The comfort and well-being of the occupants is based on this category because if he/she is not comfortable in the space then there will inevitably be a decrease in productivity. Multiplying that by a whole building of occupants is not what a company like DHHQ would like. The two minimum requirements that contribute to the well-being of others are minimum indoor air quality performance and environmental tobacco smoke control. The other categories chosen for this project includes items like increase ventilation, low-emitting materials, controllability of systems, thermal comfort, and daylight and views. By choosing adhesives, sealants, paints, and other finishes with low volatile organic compounds there is a reduction in the amount of indoor air contaminants which can be harmful to the occupant's comfort level.

Innovation and Design Process is the last category where points can be earned. This category earned one point for having a LEED Accredited Profession on the project. Davis Construction has plenty of LEED Accredited Professionals and will definitely have one to be a part of the tenant work for 7700 Arlington Blvd.

After assuming all the LEED credits for this project, all in all it turned out seemingly appropriate for what the interiors might actually turn out to be. Granted there will be some aspects that are different, but overall by using the LEED Scorecard for Commercial Interiors it proved to be useful and educational.

5.0 Simplifying the Integrated Project Delivery Approach

Reference Appendix H for the IPD Process Map

5.1 Problem Identification

7700 Arlington Blvd. utilized a CM @ Risk project delivery method with a GMP contract. At the beginning of the project material procurement was a challenge due to the budget and time allotted. The initial planning involved time and money from all ends to ensure the quality of expensive materials. Davis Construction was in charge of organizing the design professionals and specialty contractors during the material procurement process. For example, the steel contractor had to develop an economical design for the progressive collapse steel system for the three building complex. They worked closely with Davis Construction to ensure the materials would be on site prior to the system's installation. After attending the PACE conference in fall 2011, many industry members expressed an interest in figuring a way to simplify the integrated project delivery approach in order to fully utilize the method in future viable projects.

5.2 Research Goal

The goal of this analysis is to create a way to show an owner, contractor, and architect how to implement an integrated project delivery approach on a project more efficiently. In order to do this, one process map will be created of an integrated project delivery approach to show the different levels of coordination and communication throughout the entire project lifetime.

5.3 Research Steps

- Contact Davis Construction to receive an IPD contract
- Analyze AIA Contract Documents and AIA IPD Guide
- Perform a detailed analysis on all given information
- Design a process map for fully simplifying the IPD approach
- Analyze and document how to use the process map
- Suggest different strategies to use IPD on 7700 Arlington Blvd.
- Explain any conclusions and recommendations that were made from the analysis

5.4 Background Information

5.4.1 Integrated Project Delivery Definition

The first definition of IPD came about in 2007 when the AIA California Council developed the AIA Guide for Integrated Project Delivery.[16] The following page contains the definition that was created and the one takeaway from this definition is that when using IPD on a project all parties involved must communicate effectively throughout the life of the project in order to fully utilize IPD.

[16] Wikipedia, . "Integrated project delivery." . Wikimedia Foundation, Inc.,, 01 12 2011. Web. 17 Mar 2012. <http://en.wikipedia.org/wiki/Integrated_project_delivery>.

"Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction."[2]

5.4.2 Why IPD

In the figure below, the Macleamy Curve illustrates that the earlier decisions are made, the cheaper changes will be in the later project phases. Also, the IPD team has a greater ability to change and impact different costs earlier than if a traditional design process were used. This curve is important to understand because it clearly shows why projects should utilize the IPD design process.

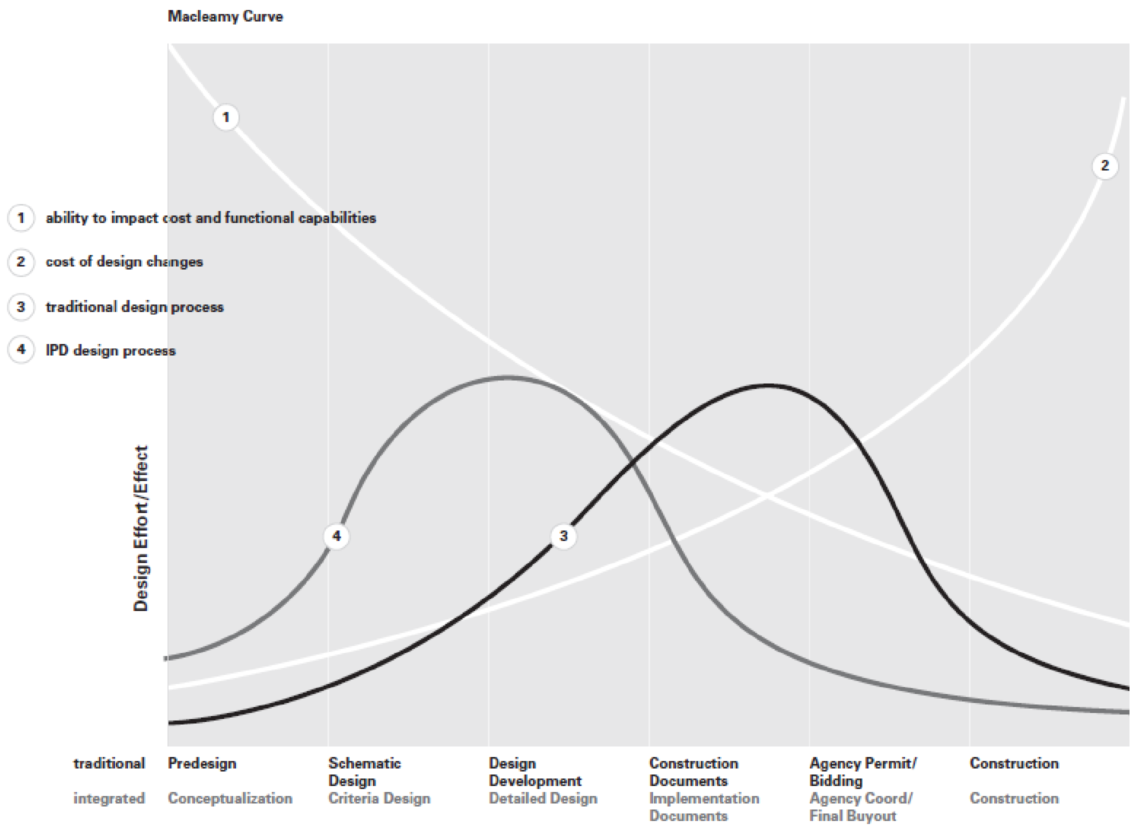


Figure 16 | Macleamy Curve[2]

The next diagram is also from the AIA Guide for Integrated Project Delivery and is just as important to understand as the Macleamy Curve. The main concept is the shifts of when different project resolutions occur and when different project players get involved. In a traditional design process, contractors do not get involved until the beginning of construction. In an integrated design process, the contractor gets

[2] AIA. "Integrated Project Delivery: A Guide." Version 1. The American Institute of Architects, 2007. Print.

involved during the conceptualization phase, allowing for construction coordination with the owner and architect from the birth of the project. This could be looked at as a positive or negative quality from an architect's perspective because the architect no long has the time to completely develop the "feel" of the building due to the contractor's involvement. On the other side though, the architect is now able to utilize the contractor to design a practical building that still incorporates the quality of the architecture. Also, for an owner who wants to be involved in the entire process, an integrated project environment would be beneficial. The owner can see the process evolve as well as become educated on how to manage their facility once built.

In addition to the project players, project issues are outlined on the Traditional Delivery vs. Integrated Delivery Diagram in Figure 17. What is the issue, how does it get resolved, who resolves it, and the solution are the four aspects addressed when an issue is developed. Fewer changes happen later in the integrated design process which avoids the high costs associated with making changes once construction has begun. The difference between a traditional design process and an integrated design process is that the what, how, and who should be addressed together throughout all the design phases in the integrated design process. That way, by the time construction starts there will be limited problems and when a problem occurs, the owner, contractor, and architect resolve it together.[2]

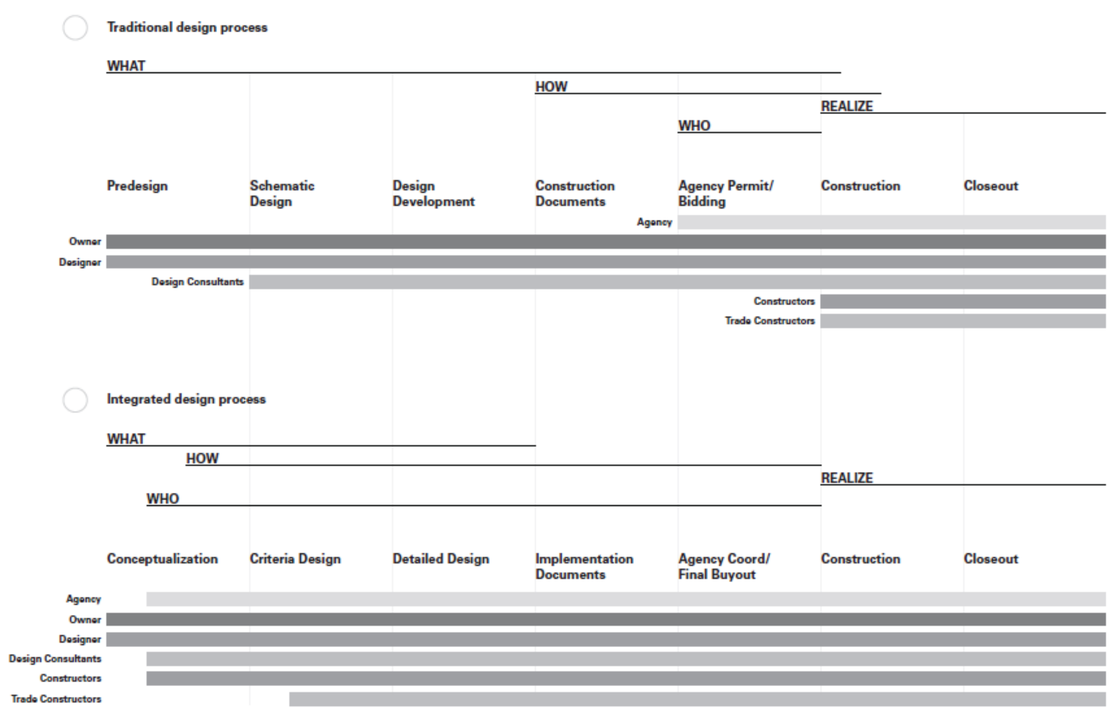


Figure 17 | Traditional Delivery Method vs. Integrated Delivery Method[2]

[2] AIA. 2007.

5.5 Davis Construction's Opinion about IPD

At the PACE conference, many contractors emphasized the challenges that come about from using an IPD approach. The critical point that most contractors explained was that they would try to use IPD and it would eventually turn into a Design-Build delivery approach. Therefore, IPD was not actually being used on many projects. The process map that was created will be a way to simplify and enforce the IPD approach. During the creation of the process map, interview questions were sent to the Executive Vice President of Davis Construction, Bill Moyer, to get his opinion and view on the utilization of the map and the IPD approach in general. The three main questions that were sent include:

1. *Would a process map outlining the different responsibilities of the major parties involved in an Integrated Project Delivery approach be useful for a project? If so, what would you find beneficial about it? If not, what would you like to see be implemented in order to make an IPD project successful?*
2. *What do you think is the biggest challenge in implementing the Integrated Project Delivery approach?*
3. *Have you ever been involved in an IPD project? If so, what was the most valuable lesson you learned throughout the project life? If not, would you like to be involved in one and why?*

Bill Moyer believes that a process map would be a valuable tool for project teams to use "as a facilitator to function in an IPD environment". He thinks that the IPD approach is not the real challenge, but the real issue is with the "contracting mechanics". Davis Construction has not had the opportunity to implement an IPD approach on any of their jobs, but they do use collaboration with an entire project team to engage in active Preconstruction Services and Programming with their CM at Risk/GMP Agreements. The reason for not having used IPD on any projects yet is because there is a major hurdle of the evaluation and assignment of risk and reward amongst the Owner, Contractor, and Architect. The risk that is associated with this type of delivery method is that if there were something to go wrong, someone has to take responsibility. Usually, on an IPD project this risk and reward is determined early enough that there is a clear understanding throughout the entire project lifetime. Overall, Bill Moyer did say that Davis Construction will continue to look for the right opportunity to use an IPD approach.

5.6 A Guide to the IPD Process Map

The process map is based upon the 2008 AIA Contract Document A295, *General Conditions of the Contract for Integrated Project Delivery*, because the contract outlines what each party is responsible for throughout each phase of the project.[1] Once an Owner, Contractor, and Architect agree to work on a project in a collaborative work environment, there are certain responsibilities that must be followed through each phase of the project in order for the integrated process to be successful. The process map is a way to streamline each member's responsibilities on an individual and team basis. The 2007 version of the AIA Guide for Integrated Project Delivery was also used in conjunction with the AIA Contract

[1] AIA. "AIA Document A295 - 2008." *General Conditions of the Contract for Integrated Project Delivery*. The American Institute of Architects, 2008. Print.

Document in order to complete the process map.[2] By using these two AIA documents, the process map will exemplify how to efficiently communicate and coordinate with one another throughout an entire project lifetime. Also, it should be noted that these documents are from an architect's perspective based on the fact that the American Institute of Architects created them.

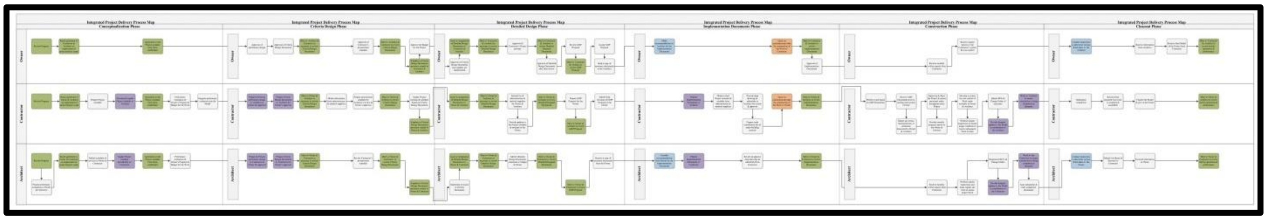


Figure 18 | IPD Process Map

The image above shows the process map in its entirety and will be explained by each phase of construction. The green represents communication between all parties, the purple represents communication between the Contractor and Architect, the blue represents communication between the Owner and Architect, and the orange represents communication between the Owner and Contractor. Also, note that this process map has been created to summarize and set a standard for what the AIA Contract Document says. There are clauses and if statements for different scenarios that have not been included into the map to avoid making the map too complex. Please refer to Appendix H for the IPD Process Map.

5.6.1 Conceptualization

According to the AIA Guide for Integrated Project Delivery as well as the AIA Contract Document, the conceptualization phase, "begins to determine WHAT is to be built, WHO will build it, and HOW it will be built".[2] As the map shows in green, during this phase there are three critical times when the Owner, Contractor, and Architect must be in collaboration with the project details. The first is to review the program that the Owner has furnished and then they have to come to an agreement on the scope of the project. Following that agreement, the next time all parties must collaborate is when an agreement must be reached for the time limits on the project schedule.

This phase of construction is when the main organizational structure will be developed regarding communication levels amongst team members as well as certain responsibilities that each team member will hold. Other significant outcomes that were addressed in the AIA Guide for Integrated Project Delivery include; cost structure development, and the creation of the Building Information Model.

Throughout the entire Conceptualization Phase, the owner is in constant communication with the Contractor and Architect. The Contractor must prepare the project schedule with periodic updates with the Architect prior to sharing it with the Owner. They must also perform a preliminary evaluation of the Owner's Program & Budget for the Work and the Contractor will then implement the evaluation into the model. According to the AIA Contract Document, the preliminary evaluation will take into consideration "cost information, constructability, and procurement and construction scheduling issues".[1] Some

[1] AIA. 2008.
[2] AIA. 2007.

responsibilities of the Architect include presenting the preliminary evaluation, which defines the concept of the design, to the Owner and Contractor and submitting a schedule of services to the other parties. Part of the responsibility of the Architect is to provide alternative solutions to the design and include any environmental capabilities into the design for the preliminary evaluation. Once the preliminary evaluation is integrated into the model, the next phase of the project will commence.

5.6.2 Criteria Design

During the Criteria Design Phase, the project begins to grow and each party starts to assume more responsibility. In the beginning of this phase, the purple on the process map shows that the Contractor and Architect must create the preliminary design and present it to the Owner. Once the Owner approves the preliminary design the Contractor and Architect will work together to develop the criteria design documents which will then be presented to the Owner. These documents consist of drawings, a site plan, and other documents. The documents will get reviewed by all the parties right after they are presented to the owner and they will also get reviewed at the end of the Criteria Design Phase which is directly after the development of the procurement schedule.

Individual responsibilities for the Contractor include obtaining information from the subcontractors and material suppliers. This information, according to the AIA Contract Document is in “regard to proposed systems or products, including material procurement scheduling, product data sheets, life cycle and energy efficiency data, cost data necessary to validate estimates and schedules for their scopes of work, tolerances, and prefabrication opportunities”.[1] From that, the Contractor must prepare a procurement schedule as well as update the project estimate and schedule. Also, the Contractor must have continuous updates to the model for the project based on all the feedback throughout each phase. The Owner and Architect’s responsibilities either stem off of what the Contractor submits or they are based on collaboration between parties. At the end of this phase, the Owner must approve the budget based on the documents received thus far.

From the AIA Guide for Integrated Project Delivery, the following aspects of the project are finalized during this phase: Scope; Form, adjacencies and spatial relationships; Selection and initial design of major building systems; Cost estimate; and Schedule.[2] Other critical Team decisions that need to occur during this phase include planning for site utilization and public and private utilities. The three parties must incorporate value engineering at every stage of review and the key building systems must be designed within the Criteria Design Documents.

5.6.3 Detailed Design

As defined in the AIA Guide for Integrated Project Delivery, “The Detailed Design Phase concludes the WHAT phase of the project.”[2] This is important to understand because compared to a traditional delivery approach; this phase is far more significant and detailed.

At the beginning of this phase the criteria design documents must be approved by the Owner because then it is the responsibility of the Architect to prepare the detailed design documents in consultation with the

[1] AIA. 2008.
[2] AIA. 2007.

Owner and Contractor. From there, the team must meet as often as needed to review the detailed design documents which these meetings should also continue to incorporate value engineering. During this time period, the Contractor will prepare a list of the subcontractors and material suppliers that have been selected for the project and provide updates to the project schedule and estimate. Meanwhile, the Architect will update the detailed design documents and submit them to be consistent with the Owner's budget. The team will meet again to review the documents and once they have been approved by the Owner, the Contractor will prepare the GMP proposal. A final collaborative meeting will be held to review the GMP proposal and once any updates are done by the Contractor, the Owner will approve the proposal. This allows for the Implementation Document Phase to begin which is the final phase before construction.

5.6.4 Implementation Documents

The Implementation Document Phase is to figure out how the work will be completed. The goal is to not change any of the designs already completed, it is to, "complete the determination and documentation of how the design intent will be implemented".[2]

The Contractor and Architect will start this phase by preparing the implementation documents. The AIA Contract Document states that during the preparation of the implementation documents, "The Architect shall consider the Contractor's recommendations for substitutions, and shall incorporate that information, as well as cost or product data, into the implementation documents".[1] Before the team meets to review the documents, the Contractor must obtain a final project schedule and estimate from the subcontractors and material suppliers. Shop drawings and submittals must then be sent to the Architect for review and approval as well as the contractor must prepare trade coordination for all the major building systems. Per the contract, the Owner and Contractor must agree on a commencement date for construction. This commencement date will most likely be discussed in prior phases, but this is when the date gets put in writing.[1] Finally, everyone will meet to review the implementation documents which once finalized will get approved by the owner.

From the AIA Guide for Integrated Project Delivery, the Owner is also responsible for the establishment of the user appeals process and the model must be finalized by the Architect for construction.[2] At the end of this phase, construction should be ready to go and most of the design issues should have been handled. The AIA Guide considers two phases prior to construction, Agency Review and Buyout, but since the AIA Contract Document does not include these phases, the map reflects the AIA Contract Document.

5.6.5 Construction

Under an IPD approach, by the time construction begins it should be, "primarily a quality control and cost monitoring function".[2] The AIA Contract Document goes into detail for requirements regarding taxes, warranty, permits, working conditions, cleaning, change orders, payments, and many more items. It does not go into detail regarding the responsibilities of the Owner, Contractor, and Architect as did in the other

---

[1] AIA. 2008.
[2] AIA. 2007.

phases. In order to continue the process map, as much as possible was picked out of both the AIA Guide and Contract Document.

During this phase, the Contractor must perform the work based on the GMP documents and they must report any errors, inconsistencies, or omissions to the Owner and Architect. Throughout construction, the Contractor will supervise and direct work and ensure personnel safety throughout the whole project. Monthly progress reports will be completed and sent to the Owner and Architect and a system for cost control will be made available to both, Owner and Architect. Routine inspections will be performed to ensure that work is being completed accurately and the Architect will respond to any RFI's and/or Change Orders that the Contractor sends. By the end of the Construction Phase the Contractor and Architect will work together to provide frequent updates to the model and they will also work together to ensure that construction is being completed as designed. Lastly, by the end of construction, the Architect will issue substantial and final completion documents.

5.6.6 Closeout

The Closeout Phase is the final step before the project is deemed complete. During this phase, the Owner and Architect will conduct on-site inspections to determine various finish dates. The Architect will then submit the Certificate of Payment to the Contractor and the Contractor will then receive final payment once all work has been completed. In addition to final payment, the model will be finalized, which should reflect the As-Built Conditions and then sent to the Owner. Various documents will also be given to the Owner at the end of the Closeout Phase. All three parties will meet within a year of final completion to review the facility operations and performance to ensure the facility meets the requirements established in the Program set on Day 1.

5.7 Implementing the IPD Process Map with Technology

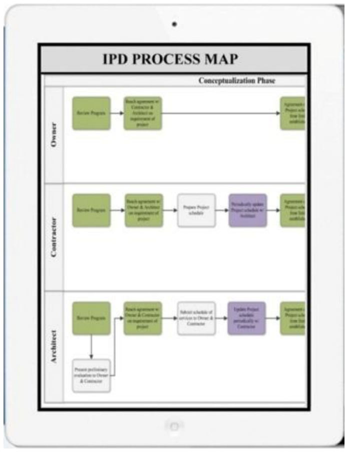


Figure 19 | IPD Process Map on the Apple iPad

Since technology is an ever improving industry, industry members in construction have started to take advantage of this benefit. The newest and biggest improvement in the construction industry has been the implementation of tablets on jobsites. Workers are finally able to take what has been produced on a computer and are able to compare it better to what has been constructed out on the actual project. Due to this ever changing industry, it is important to keep up with the new ideas and find new ways to implement them.

The IPD process map was created to simplify and standardize the AIA Contract Document with the intention of using it with a tablet during meetings and in the field. Since the map is fairly large, the idea is to be able to use a tablet to fully utilize the IPD Process Map. During a team meeting, each individual would be able to open the map on his/her tablet. The image to the left shows what the process map would look like on an Apple iPad. The individual using the tablet has the capability to scroll left and right as well as zoom in and out to see the entire map. Also, the map that is uploaded onto the tablets would be a shared document. That way the entire team will be able to edit and write down notes pertaining to the project they are on and they will all be able to see each other's notes. During a meeting, if the Owner feels the need to write information down, the Owner can click on the block within the process map that he/she wishes to open.

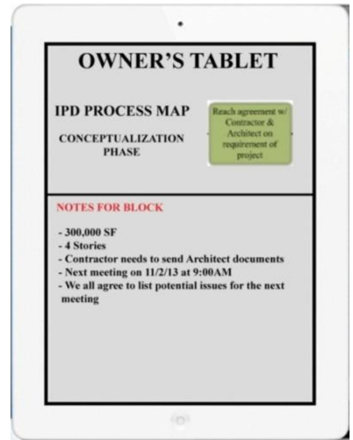


Figure 20 | Window for Individual Block within the Process Map

From there a new window will pop up, which will look like the next image on the right. This is the window that notes and other team obligations will be developed and shared amongst the whole team. It is a way to organize thoughts and keep the project moving in the right direction. Each block within the Process Map has this capability as well as each team member in the meeting. Utilizing technology is an important part of the construction industry, so by using models in the field and now documents in meetings, the overall idea is to create a more efficient means to construction collaboration.

5.8 Implementing IPD into 7700 Arlington Blvd.

Since 7700 Arlington Blvd. used a CM at Risk project delivery method with a GMP contract, the only hurdle as Bill Moyer stated would be figuring out the shared risk and reward amongst the parties. The project used collaboration with the Preconstruction, especially with the Progressive Collapse System, but if the Owner, Contractor, and Architect would have come together from the very beginning of the project, using the IPD approach could have been even more beneficial than CM at Risk. Time and money were the main focus on 7700 Arlington Blvd., so through the use of the IPD Process Map, each team member could have figured out, in detail, which risks of the project each member would take and how the reward would be distributed. By using the map, team members are forced to communicate and collaborate, which by the nature of this job using an IPD approach would have been beneficial. Overall, more education on IPD is necessary, but is a great idea for this type of project since collaboration was already implemented from the very beginning.

5.9 IPD Case Study (AIA)

In 2010, AIA put together a document that included different case studies that utilized the IPD approach.[3] The Autodesk Inc. AEC Solutions Division Headquarters in Waltham, Massachusetts is a prime example of what happens when IPD is used on a project effectively. This project was a 55,000 square foot, three-story building fit-out that included offices, a gallery, conference rooms, etc. LEED Platinum for Commercial Interiors and an eight and one half month schedule were the two main goals for this project. The Owner was Autodesk Inc., the Contractor was Tocci Building Companies, and the Architect was KlingStubbins. All parties involved were willing to abide by the "true" IPD agreement and the contract established an Incentive Compensation Layer that put the Contractor and Architect's profit at risk. Basically, if the Contractor and Architect were to perform above and beyond, then they could receive up to 20% bonus, but if they performed below average then they could risk 20% of their profit. The custom wood paneling in the atrium of the building is one example where the Contractor and Architect went beyond their contractual duties and gave the Owner an iconic design as seen in Figure 21.

[3] AIA. "Integrated Project Delivery: Case Studies." The American Institute of Architects, 2010. Print.

Figure 21 | Custom Wood Paneling in atrium space[3]

In the beginning of the project, the Architect was hesitant but willing to try something new and as for the contractor, Tocci was able to move money around within the budget if necessary. This allowed for early procurement time and cost sensitive material and services. Another advantage that the Contractor had was its connections within the geographical area to get permitting done faster than normal. A BIM execution plan was utilized on this project to determine who modeled what and when. Overall, the project was extremely successful and some of the lessons learned are listed below:

- "The first step should be a scoping exercise taken to the level of conceptual design, in which everyone works at cost until a deep understanding of the project and a level of comfort around the program and budget is achieved by all parties."[3]
- Eliminate the contingency (this created a form of discomfort due to the "team's obligation to design to the target cost")[3]
- Interoperability of the different systems was a challenge[3]

Another case study that was presented in the AIA document was the Walter Cronkite School of Journalism at Arizona State University.[3] The project was a 230,000 square foot, six-story building consisting of classrooms, offices, retail area on the ground floor, as well as many other unique rooms. The Owner was the City of Phoenix, the Design Architect was Ehrlich Architects, the Executive Architect was HDR Architecture, and the Contractor was Sundt Construction.

The Architects and Contractor jointly served as one team for this project and the project had to follow the City of Phoenix's design-build contract. Regardless of this contractual duty, the project players introduced many IPD qualities on a non-contractual basis in order to get the job done. Everyone from all parties was able to collaborate to decide how to spend the funds for maximum gain and weekly meetings would be held to go over the budget, design, model, etc. in order to capitalize on as much as possible for the project. The BIM model helped throughout the whole project because it eliminated some of the mundane tasks that have to be done on a traditional delivery method.

Overall, the project was successful, but there were some lessons learned on this project. One of the most important lessons that industry members must overcome with using the IPD approach is the trust that must be put into other individuals from other companies. It is hard to get rid of old habits and in order to form a project team that works well together, time is needed prior to project start-up to get use to everybody and gain that trust. Also, another lesson that was learned on this project was with the functionality of the model. Not every company was using the same program and that caused more headaches than necessary. Training and education is important for the IPD approach because of the in-depth modeling that must be done early on in a project's life. Lastly, owners must change their level of commitment within their own project because the more responsibility an owner takes on, the lower the risk will be for everyone else to get their work done.

[3] AIA. 2010.

This case study was a great way to show that trust is the number one quality that must be overcome in order for the IPD approach to fully work. Granted there are many other qualities that must be achieved after that, but once trust is gained throughout different companies then the right teams can form to complete a project successfully. Furthermore, the Autodesk Headquarters was an excellent way to show what happens when the integrated design process is done right. Both projects had issues with the complex models that had to be created, but overtime, through training and different educational programs this hump will be overcome.

5.10 Recommendations and Conclusions

The IPD Process Map was created to show where the different coordination and communication levels are on a project. The idea is to prove that through using an integrated project delivery approach, higher levels of commitment must be made and everyone must rely on one another throughout the life of a project. Also, since implementing IPD successfully on projects is not an easy task, the process map will be a way to standardize the process.

By analyzing the AIA Contract Document and the AIA Guide for IPD, the main concepts and requirements were extracted from each and utilized on the map. The map may not be a way to solve the hurdle of who shares the risk and reward when working in a collaborative work environment, but it definitely tries to alleviate some of the stress and burden that is put on teams during a project's life. If the map is implemented and used in coordination with technology, meetings will run smoother and the team will have an efficient means to complete work together. Referencing the case studies described in this analysis, it is easy to see that using an IPD approach on projects can be highly beneficial and can save everyone time and money if done correctly.

5.11 MAE Requirement

The integrated BAE/MAE requirement for the senior thesis project was met by incorporating course topics from two classes, **AE 570: Production Management in Construction & AE 598D: Legal Aspects of the Engineering and the Construction Process**, into the first analysis: **Integrated Project Delivery Approach.**

AE 570: Production Management in Construction was a course that explored the use of production management to efficiently manage the delivery processes of capital facility projects. In this class, topics such as improving performance, measuring performance, mapping project delivery, building projects of value were all utilized for the development the first analysis. Learning how to develop a process map that could illustrate information properly was the main concept that was used for this analysis.

AE 598D: Legal Aspects of the Engineering and the Construction Process was a course that explored three basic legal doctrines, contractual relations between parties, analysis of construction contract clauses, contract performance, and professional practice problems. The concepts of these lessons were utilized to create the process map for the first analysis by analyzing and documenting the AIA Contract Document and AIA Guide to IPD.

6.0 New Mechanical System in the Northwest Building

Reference Appendix I for the TRACE 700 Data Sheets

6.1 Problem Identification

Since this building is a renovation, some of the systems are to remain due to the owner's budget. The Northwest Building is to keep the control system and mechanical system that already exists with minor improvements. Due to the unforeseen ceiling conditions, a mistake was made by the general contractor with the control system, resulting in time and money lost. Even though there was a mistake made on the jobsite, the owner will benefit from the loss of the control system because a new control system will be implemented and tied in with the other two buildings. This was a sizeable constructability challenge and a learning lesson for all parties involved.

6.2 Research Goal

The overall goal for the analysis is to compare and contrast the idea of implementing two new mechanical systems in the Northwest Building. Since the Southwest Building is fairly similar to the Northwest Building, the same VAV system for the Southwest Building will be placed into the Northwest Building. Also, since a water source heat pump system exists in the Northwest Building, a new system of the same type is going to be looked into. The idea is too show the owner through a basic Trace Model that one system is more beneficial than the other and that even though their budget was not substantial a new mechanical system in an existing building has a variety of benefits.

6.3 Research Steps

- Research and analyze the existing mechanical system in the Northwest Building
- Research and analyze the new mechanical system installed in the Southwest Building
- Build TRACE 700 Model and collect data
- Compare and contrast a VAV system with a water source heat pump system
- Perform cost and schedule analysis
- Design two different raised platforms that will hold a 32000lb roof top unit on the Northwest Building
- Summarize results and draw conclusions on the outcomes developed

6.4 Background Information

As stated earlier in the report the Northwest Building system is a closed-loop water source heat pump system. There are interior and perimeter zones for this system with the interior zone having large heat pump air-handling units in mechanical rooms on each floor. The perimeter zone has individual heat pump units located in each office along the perimeter. A roof top unit is home to the closed-loop hydronic circulation system where it houses pumps, boilers, and cooling towers.

The Southwest Building system is a chilled water/hot water system with central VAV air handling units. Low-pressure ductwork and ceiling diffusers will be used again to distribute the air throughout the building. Increased ventilation is provided for each system type by roof mounted preconditioning outside air units or by integrated heat wheels.

Based on interview questions sent to the engineers for the project, the main reason for keeping the water source heat pump system in the Northwest Building was a “first cost” driven decision. The owner decided to replace only the inoperative water source heat pump equipment. Also, one initial idea for this analysis was to consider connecting the Northwest and Southwest Building mechanical systems together for maintenance reasons and to be able to control both systems at the same time. Unfortunately, the engineers stated that this was not feasible due to the intervening atrium space and differing floor to floor ceiling heights. All in all, implementing the VAV system used in the Southwest Building into the Northwest Building is certainly feasible and the following sections will describe the differences between this system and a water source heat pump system.

6.5 Mechanical System Definitions

6.5.1 Water Source Heat Pump System

By definition, a water source heat pump system is a heat recovery system. A document published by WattMaster Controls provided valuable information on these systems. Buildings that have both heating and cooling loads as in the case of 7700 Arlington Blvd. are good examples. This is because in the winter months, the interior zones require more cooling while the exterior zones require more heating. The image below shows a typical water source heat pump system. Normally, they have a high initial capital cost and offer more versatility throughout the building. Also, maintenance on water source heat pump systems is generally painless, but they can be more costly than conventional air side systems. One other negative aspect about the system is that it can create noise in areas where people will be located due to the compressor and fan. [15]

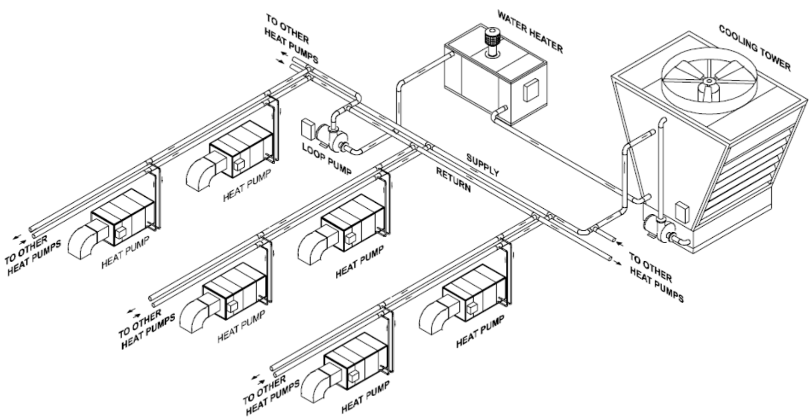


Figure 22 | Typical Water Source Heat Pump System[15]

[15]WattMaster Controls, ."WHP - Water Source Heat Pump Design, Installation & Operations Manual." .WattMaster Controls, Inc., Copyright 2004. Web. 28 Mar 2012.

6.5.2 VAV System

"A VAV system is a type of heating, ventilating, and/or air-conditioning system that in its simplest form incorporates one supply duct."[17] One advantage to this system is the control of fans in order to reduce energy levels. Another benefit is that dehumidification is greater with VAV systems than it is with CAV systems. The image to the right shows the flow of a VAV system. These systems are also economical to install and to operate.

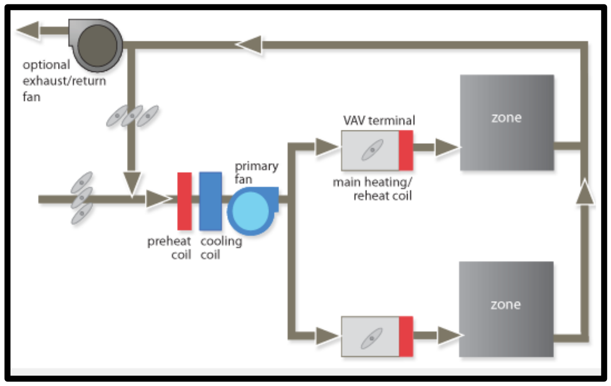


Figure 23 | Typical Flow Diagram of a VAV System

6.6 TRACE 700 Analyses

TRACE 700 was used to design two scenarios for the Northwest Building to find certain system outputs for a feasibility study. Due to limited experience with TRACE 700, the models were designed to be simple enough to compare. Breaking the systems into great detail would allow too much room for errors to occur. With that in mind, the building was broken into four zones, one floor per zone. Also, each wall was inputted with the appropriate direction and a 30% wall percentage with the rest being covered with windows. After the general information was inputted, each system had to be inserted into the program, which will be discussed further in the following sections.

6.6.1 Water Source Heat Pump System

Since there was limited information on the existing water source heat pump in the Northwest Building, the data inputted into TRACE 700 came from a fellow Architectural Engineering Student, Brian Sampson, who produced a step by step document for designing a water source heat pump in TRACE 700.[10] This document was helpful in standardizing a procedure and data inputs to be carried over to the other model for the VAV system. The Systems Checksums and Energy Consumption Summary data sheets that were calculated can be found in Appendix I. A summary chart of the valuable information can be found in the table below.

Table 9 | Water Source Heat Pump System Calculations

	Floor (ft^2)	ft^2/ton	Primary Heating (kBtu/yr)	Primary Cooling (kBtu/yr	Auxiliary (kBtu/yr)	Total Source Energy (kBtu/yr)	Building Energy Consumption (kBtu/ft^2)
WSHP System	267,289	545.50	48,331	4,283,341	5,010,683	9,342,355	34.95

[17] Wikipedia, . "Variable Air Volume." *Wikipedia*. Wikimedia Foundation, Inc., 30 11 2011. Web. 28 Mar 2012. <http://en.wikipedia.org/wiki/Variable_air_volume>.
[10] Sampson, Brian. "Set Up Ground Source Heat Pumps In Trane Trace." 2012. Print.

System performance should be between 350 ft^2/ton and 500 ft^2/ton, with the latter being pretty high. The water source heat pump's performance is 545.50 ft^2/ton, which is too high for 7700 Arlington Blvd., but this could be from the fact that what was inputted into the model was generic, lacking highly detailed information. The TRACE 700 model did not separate each floor into two separate zones. In information provided by the engineers on the project, they specified an exterior and interior zone throughout the building. This means that the exterior zone is subject to a heating and cooling load, while the interior zone is subject to only a cooling load. In a water source heat pump system, it transfers the rejected heat from the interior zone through the use of water to the exterior zone. This reduces the heat consumption, which results in the use of fewer utilities.

The total energy consumed in the building is equal to 9,342,355 kBtu/yr which amounts to 34.95 kBtu/ft^2. Based on the Major Fuel Energy Intensity table below, from the 2003 Commercial Buildings Energy Consumption Survey, 34.95 kBtu/ft^2 is around 10kBtu/ft^2 lower than the average kBtu/ft^2 the year the building was constructed.[13] This means that there is less energy being consumed per square foot of area with this system. The number would potentially increase with more detailed information, but because this is a broad analysis, the amount of energy consumed is not far off of the average.

Table 10 | Major Fuel Energy Intensity (thousand Btu/square foot)[13]

Major Fuel Energy Intensity	Space Heating	Cooling	Ventilation	Total
Building Floorspace				
200,001 to 500,000	38.2	7.8	7.4	53.4
Principal Building Activity				
Office Avg.	32.8	8.9	5.2	46.9
Year Constructed				
1980 to 1989	28.8	9.8	6.6	45.2

[13]U.S. Department of Energy. "Table E2A. Major Fuel Consumption (Btu) Intensities by End Use for All Buildings." 2003. Print.

6.6.2 VAV System

When the VAV system was inputted into TRACE 700, its performance amounted to 455.63 ft^2/ton, which according to the general rule of thumb; the system is performing at a good standard. The table below outlines the values that were calculated using the program. The total energy consumed in the building is equal to 9,708,246 kBtu/yr which amounts to 36.32 kBtu/ft^2. Based on the Major Fuel Energy Intensity table shown in the previous page, this number is more than 10kBtu/ft^2 than the average kBtu/ft^2 the year the building was constructed. This means that there is less energy being consumed per square foot of area with this system. The analysis is broad, which means that the number would potentially increase with more detailed information.

Table 11 | VAV System Calculations

	Floor (ft^2)	ft^2/ton	Primary Heating (kBtu/yr)	Primary Cooling (kBtu/yr)	Auxiliary (kBtu/yr)	Total Source Energy (kBtu/yr)	Building Energy Consumption (kBtu/ft^2)
VAV System	267,289	455.63	95,138	4,958,626	4,654,482	9,708,246	36.32

6.6.3 System Choice Based on TRACE 700 Data

Based on the two TRACE 700 models, the system that performs better is the water source heat pump because it consumes less energy, which ultimately takes less energy to heat and cool the building than the VAV system. Energy consumption is not the deciding factor when an owner is choosing a system. The owner needs to look at the pay back periods of both systems and determine which one is more reasonable. This is where a cost and schedule analysis is beneficial because the project team can show the owner several different options if necessary. One cost analysis that would have to be looked into is the units that would have to be installed on the roof for both mechanical systems. Since a water source heat pump is already installed in the Northwest Building the owner would most likely need to refurbish what exists on the roof. If the owner were to choose a VAV system, two roof top units would have to be installed on the roof. Since the Northwest Building is mostly a concrete structure, a new raised platform was designed in the case that the owner wanted this system. The next section goes into full detail of two design choices for the raised platform.

6.7 Raised Platform Design

The individual roof top units that are to be installed in the Southwest Building weigh 36,000lbs each. The units sit on a steel structural system which was designed in the renovation to properly hold each unit. Each RTU is mounted on a raised platform and set on a factory curb to concentrate the load that is being applied to the floor below.

With the scenario of the VAV system being implemented into the Northwest Building, two RTUs will need to be installed. The Northwest Building is composed of concrete unlike the Southwest Building which is mostly steel. Calculations were performed to design a new raised platform for the units to sit on the Northwest Building's roof and will be described in the following paragraphs.

The platform used on the Southwest Building is a 60'x22' structure and the new design will be for a 66'x22' platform as shown in Figure 24 and Figure 26. The reason for the increase in size is to allow for the platform to sit directly on the 18"x18" concrete columns below. This will distribute the load as a point load onto the columns for easier calculation of extra support by the structural engineers. Two designs were developed so that a cost analysis could be performed and the most efficient platform could be chosen.

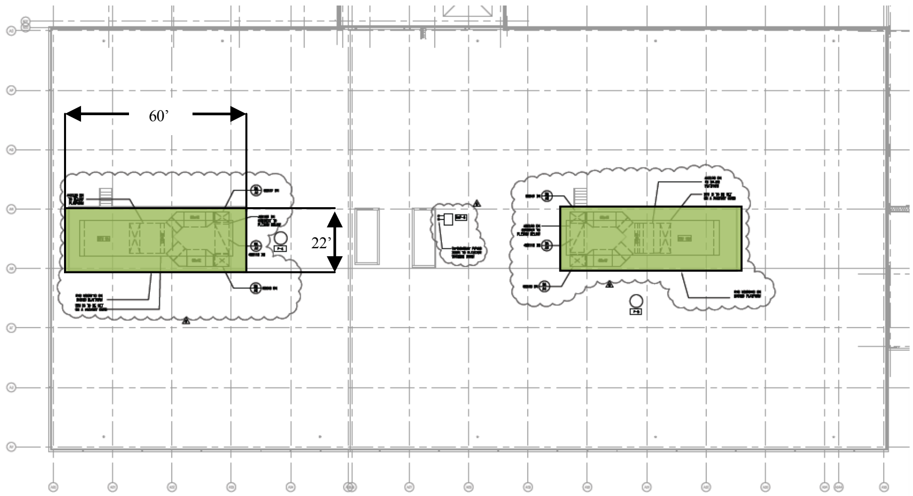


Figure 24 | VAV System's RTUs on Southwest Building

The image to the right shows the raised platform highlighted in orange that was installed on the Southwest Building. This design was specifically designed to sit on top of the steel deck roof with steel beams and columns below the RTU. The unit itself is fairly large, so designing a platform that is efficient and cost effective is important to consider for the Northwest Building.

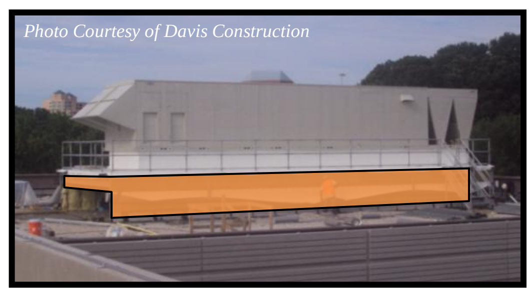


Figure 25 | Raised Platform for RTU

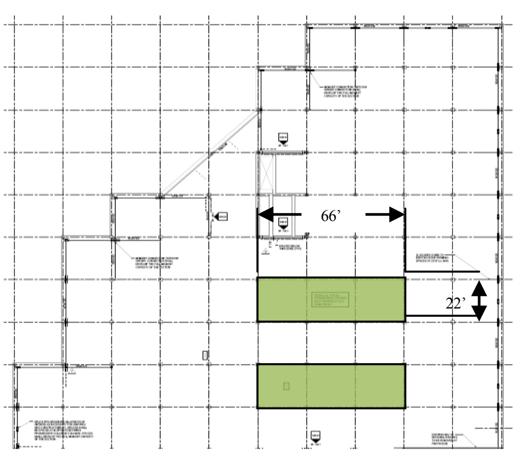


Figure 26 | RTU Placement on Northwest Building

Since the units are centralized on the roof of the Southwest Building, the same concept was used for the Northwest Building. Each RTU was placed in a central location on the roof to allow for maximum efficiency with the mechanical system. Figure 26 shows where the mechanical units will be placed. The raised platform will be 66 feet by 22 feet and will house the unit which is approximately 52 feet by 22 feet. For the sake of each design, the load calculations assumed the load would be equally distributed throughout the entire platform.

6.6.1 Design #1

****Reference Appendix J for the Raised Platform Design #1***

The goal for the first design was to use as few beams as possible because the overall manufacturing time would be shorter and the design would be more efficient. After going through the calculations the raised platform system uses four beams in total. Design #1 consists of (2) W16x40 laterally braced to (2) W21x55. Although, since the W21x55 beam is 66' long there will have to be (6) of those beams used to erect the raised platform based on transportation capabilities. The dotted line in Figure 27 shows the outline of where the catwalk will extend to for maintenance of the mechanical units. Overall, the deflection was the greatest because the beams extend 66 feet and flexure and shear met the design requirements by quite a bit. Refer to Appendix J to see the complete design of the first design.

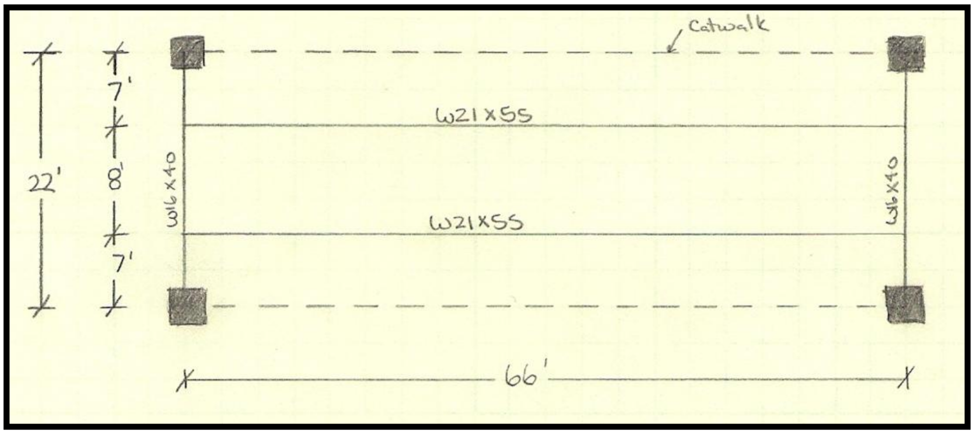


Figure 27 | Raised Platform Design #1

The next step is to complete a cost analysis for this design and since the platform was simplified to calculate beams only, the analysis will reflect beams only. This will allow for an easy comparison between the two designed systems. RS Means 2012 Building Construction Cost Data was used to determine the cost of the beams as well as linear interpolation to get more precise values for members not listed in the cost data.[9]

Table 12 | Raised Platform Design #1									
Beams									
Description	**Quantity**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total Incl O&P**	**Total Bare Cost**	**Total Cost Incl O & P**
W21x55	132	LF	$75.88	$3.71	$1.54	$81.12	$91.21	**$10,707.84**	**$12,039.72**
W16x40	44	LF	$55.00	$3.38	$1.87	$60.25	$68.50	**$2,651.00**	**$3,014.00**
							Total	**$13,358.84**	**$15,053.72**

Based on the cost data, the raised platform for the first design, including overhead and profit, will cost $15,053.72. When the location factor is added for Falls Church, Virginia the system totals **$13,849.42**.

[9] RSMeans. 2010.

6.6.2 Design #2

***Reference Appendix J for the Raised Platform Design #2**

The goal for the second design was to use the smallest beams possible. After going through the calculations, the raised platform system uses seven beams in total. Design #2 consists of (5) W10x12 laterally braced to (2) W30x90. Although, since the W30x90 beam is 66' long there will have to be (6) of those beams used to erect the raised platform based on transportation capabilities. The dotted line in Figure 28 shows the outline of where the catwalk will extend to for maintenance of the mechanical units. Overall, deflection, flexure, and shear were checked to design each beam. Refer to Appendix J to see the complete design of the second design.

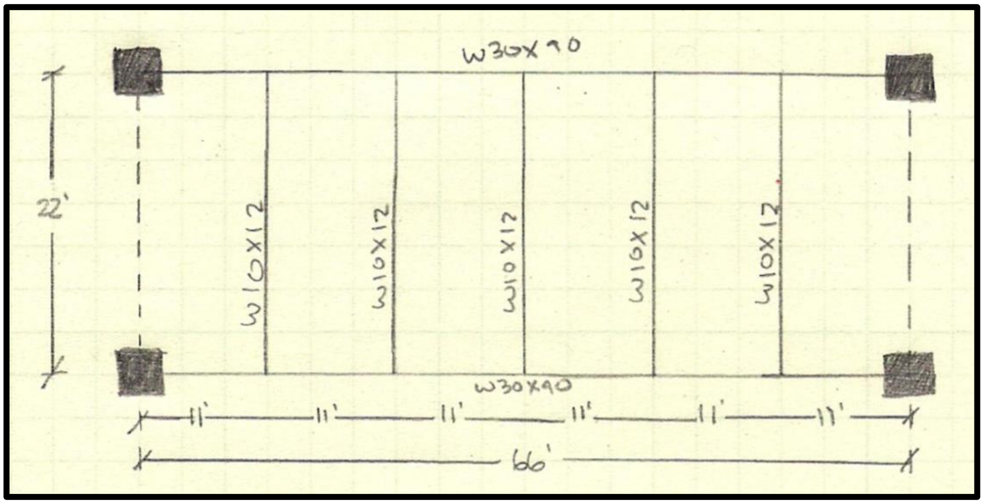


Figure 28 | Raised Platform Design #2

The next step is to complete a cost analysis for this design and since the platform was simplified to calculate beams only, the analysis will reflect beams only. This will allow for an easy comparison between the two designed systems. RS Means 2012 Building Construction Cost Data was used to determine the cost of the beams.[9]

Table 13 | Raised Platform Design #2									
Beams									
Description	**Quantity**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total Incl O&P**	**Total Bare Cost**	**Total Cost Incl O & P**
W10x12	110	LF	$66.00	$4.91	$2.72	$73.63	$84.00	**$8,099.3**	**$9,240.00**
W30x90	132	LF	$136.00	$3.25	$1.35	$140.60	$157.00	**$18,559.20**	**$20,724.00**
							Total	**$26,658.50**	**$29,964.00**

Based on the cost data, the raised platform for the second design, including overhead and profit, will cost $29,964.00. When the location factor is added for Falls Church, Virginia the system totals **$27,566.88**.

[9] RSMeans. 2010.

6.6.3 Design Choice

Based on the two designs, Design #1 is recommended for the raised platform. The platform costs $13,717.46 less than the second design and it will take less time to install eight beams versus eleven. The platform will most likely be designed off site at a manufacturing plant and be trucked in. It will then be hoisted into position, which makes the overall design and idea efficient and requires the least amount of effort.

6.6.4 Other Factors to Consider with Designs

After each design was calculated, StructurePoint, specifically spColumn was used to analyze the capacity of the existing columns. The interaction diagram below shows the available loading conditions that the column can withstand. Figure 29 shows the interaction diagram for an 18"x18" concrete column with (4) #9 bars and #4 ties at 18" on center. The direct axial loads will be between 6 & 8 kips which when plotted on the interaction diagram, the column capacity will be able to hold the load with little effort. The red line represents where the loads of the raised platform fall on the interaction diagram.

Design #1 is recommended, which means that 8 kips will be the load applied to the columns. There will be other loads that would need to be added by a structural engineer to ensure the stability of the columns. These loads include; the roof loads; service loads; snow loads; loads underneath the columns; self-weight of steel beams, etc., which according to the interaction diagram should not exceed approximately 790 kips.

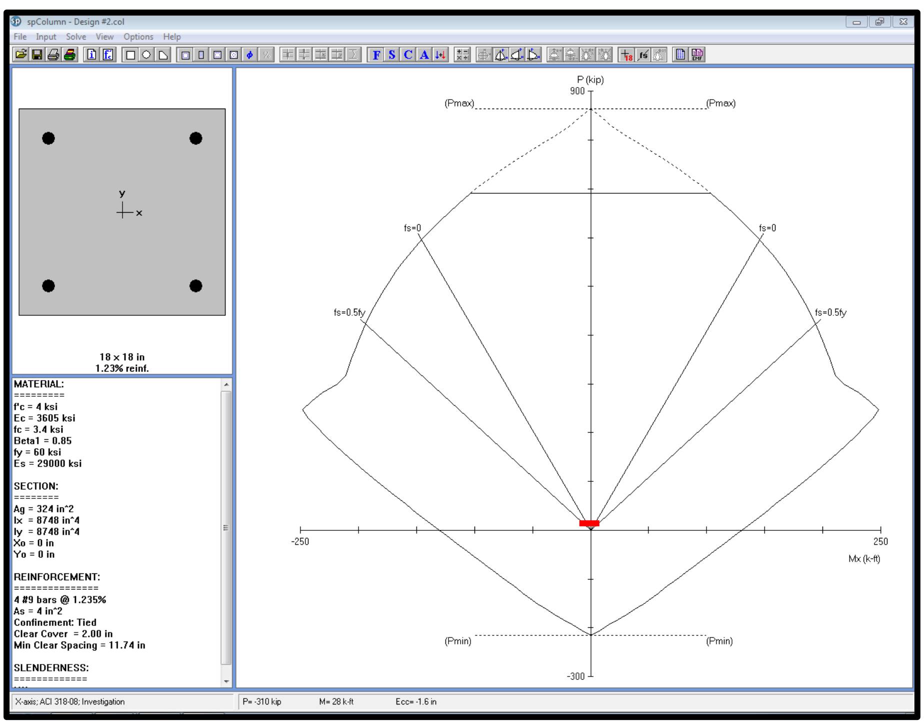


Figure 29 | Interaction Diagram from StructurePoint

6.8 Cost & Schedule Analysis

The cost and schedule data analyzed for this part of the analysis was provided by Dave O'Donnell from WE Bowers, who was the mechanical subcontractor for 7700 Arlington Blvd. The systems do not vary drastically in price per square foot, construction duration, and the life of the system which will be further described below.

For the water source heat pump system it will cost $28.00 per square foot to fully fit out the system, which also includes the tenant work. Since the building is approximately 267,289 square feet, it will cost $7,484,092.00, but when the location factor is added in the system will cost **$6,885,364.64**. The water source heat pump system will take 10 to 12 months to construct and once installed the life is anywhere from 20 to 25 years. Compared to the original construction schedule, it will take three to four times longer to install this system, but this is because the mechanical system exists and only refurbishing is being completed.

The VAV system costs around $26.00 per square foot to completely install and this includes the tenant work as well. That means for the size of the building it will cost $6,949,514.00 and once the location factor is added in it will cost around **$6,393,552.88**. This number will also include the $13,849.42 for the raised platform designed in the previous section. The VAV system will take anywhere from 8 to 10 months to fully install and the system will last around 25 years. The VAV system that is being installed in the Southwest Building which is around 147,000 square feet, will take around four months to install. Therefore, eight months to install the system in the Northwest Building is verifiable through simple ratio calculations.

Between the two systems, it will cost 7.14% more for the water source heat pump and it will take approximately two months longer to install, but each system's life is about the same. It depends on what the owner's goals are for the building and with the owner's number one priority being cost for 7700 Arlington Blvd., than they should choose the VAV system. If the owner's goal was for building efficiency than the water source heat pump system performs a little better than the VAV system. The decision of choosing a mechanical system comes down to ultimately what the owner wants to pay for. In the original project, the owner decided to keep the existing water source heat pump due to budget constraints and based on the analyses performed this makes sense especially when money and time comes into the situation. If the owner's budget was larger than the recommendation could be argued that either system would be a viable option for 7700 Arlington Blvd.

6.9 Recommendations and Conclusions

Through the process of creating two TRACE 700 models and designing two raised platforms for the Northwest Building, a thorough mechanical analysis was performed in order to choose the appropriate system. By comparing and contrasting a water source heat pump system and a VAV system, the expected outcome was that one system would perform better than the other as well as cost less than the other. The water source heat pump system was more efficient than the VAV system, but costs more and takes longer to install.

Based on the owner's goals the system that would have been chosen if a new mechanical system was installed in the Northwest Building would be the VAV system. The two main reasons are that it costs $6,393,552.88 and it takes 8-10 months to install, which is less than the other system's cost and installation time. Time and money were the top two priorities for the owner and the VAV system's performance is 9,708,246 kBtu/yr, which is only 365,891 kBtu/yr less than water source heat pump system.

7.0 Creating a Short Interval Production Schedule

7.1 Problem Identification

There are many areas throughout the project from the initial design phase to construction that have been challenging for the design team. The problem is coordination is a large part of the day to day tasks and 7700 Arlington Blvd. has a complex schedule. There seems to be many areas of the job that have repetitive work, but have schedule lags for one reason or another. The time allotted for the demolition was not enough and impacted the structural erection aspect of 7700 Arlington Blvd. The project team had to create a new plan as to how they were going to keep the schedule on time, as well as get the demolition and structural systems installed. The plan that was created ended up being extremely successful, but costly because most crews worked double shifts in order to complete the work.

7.2 Research Goal

The goal of this analysis is to create a Short Interval Production Schedule (SIPS) that can be utilized in the field for the demolition and structural system aspect of 7700 Arlington Blvd. Another goal is to create a plan that better suits this type of project and a plan, eliminating the possibility of running a double shift and creating an unsafe work environment by having multiple trades in one area. Overall, the SIP schedule created should reduce the construction schedule and reduce general condition costs.

7.3 Research Steps

- Obtain information from Davis Construction
- Analyze and document the sequence of work for demolition and structural steel
- Develop a repetitive sequence for demolition and structural steel
- Create the SIP Schedule
- Analyze the SIP Schedule
- Perform schedule analysis
- Perform cost analysis
- Implement SIP Schedule into Analysis #4

7.4 Background Information

Figure 30: Roof top Air Handling Units

James G. Davis wrote an RFI asking about dunnage for the huge air handling units on the roof. Little did they know that this was going to open a can of worms because the architect and engineer came back saying there was no dunnage in the design as well as the appropriate acoustical requirements. It is great that this issue was caught, but the issue came too late in the project. Not only did a design have to be done, but other trades were impacted immensely in order to keep the job on schedule. Figure 30 is one of the air handling units once installed.

The plan was to build the Main Building top down, but because of the change they were forced to re-sequence the construction. Since each air handling unit was right over the core of the building, the tradesmen were forced to work first around the perimeter of the building. The owner's number one goal on the project was schedule followed by cost, so with having that in mind the general contractor's team had to make a few changes throughout the project. The demolition portion of the project ended up taking longer than expected which impacted the steel installation. In order to accelerate the schedule and avoid the core of the building, the project team came up with a plan to do both at the same time. Double shifts were utilized during the plan in order to keep construction on schedule.

A twenty foot perimeter was demoed and abatement had to be done as well in order to core drill the holes for the progressive collapse steel system. In order to keep the steel moving, the core drilling crew had to drill a hole for the columns in each floor before they moved to the next section. For example in the figure to the right, the illustration shows the basic idea of what the team had to do. They started with hole number one and worked their way up to hole number three and repeated this process for each section so that the steel column could be placed and the schedule could stay on track. By having to remove the core drilling machine and move it from floor to floor instead of drilling a few holes on one floor and then move to the next, it obviously had an impact on the cost. The cost information for this technique was not available at the time of communication with the project manager and therefore assumptions will be made and stated during this analysis.

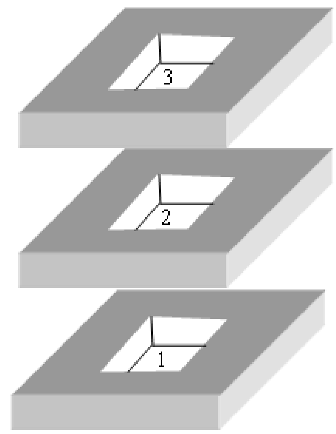


Figure 31 | Core Drill Sequencing Diagram

Figure 32 | Installation of Progressive Collapse Steel System

To the left is one picture of a steel column for the progressive collapse steel system being installed into 7700 Arlington Blvd.

7.5 Types of Short Interval Production Schedules

For this analysis a short interval production schedule will be developed in order to show the possibility of decreasing the demolition and structural steel activity durations, reduce overtime work, eliminate the safety issue of having too many tradesmen in one area, and overall make the construction process more efficient. In the fall of 2011, Hensel Phelps Construction Co. spoke to the, AE 570: Production Management in Construction, class about the different kinds of SIP schedules in the construction industry. Traditional and non-traditional are the two kinds of SIP schedules and each are used in different circumstances.

7.5.1 Traditional Short Interval Production Schedule

A traditional SIP schedule normally deals with one process or only a few contractors and it is mostly to help level manpower and material usage. The activities that are implemented in this type of schedule are usually assembly line work. Unlike the non-traditional SIP schedule, the traditional SIP schedule does not maintain consistent time segments. The image below is a typical traditional SIP schedule for a structural slab forming operation. The image lists the activities in the left hand column and the days in the top row. Each block within the activities and days represents when the activity will be done and how many man hours it is going to take.[11]

SHORT INTERVAL PRODUCTION SCHEDULE

STRUCTURAL SLAB FORMING OPERATION

ACTIVITY	DAY 1		DAY 2		DAY 3		DAY 4		DAY 5		DAY 6		DAY 7		TOTAL MHRS
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	
Layout	4														16
Move Shoring to Area	4														16
Shake out shoring	4	4													32
Erect Shoring		9	9	9	9	9									180
Set/Grade U Heads				4	4	4	2								56
Move Stringers/Beams to Area			2												8
Install Safety Static Lines							3								12
Set/Clip Stringers							6	6	4						64
Set Beams							2	7	6	6					84
Install Plywood Staging Area									3						12
Stage Plywood										2					8
Install Plywood Deck										5	9	9			92
Install Handrail											2				8
Layout Edge Forms/Blkouts											2				8
Install Edge Forms												4	2		24
Install Bulkheads													5		20
Form Blockouts													5		20
Install Embeds														5	20
Caulk Joints													1	1	8
Cleanup														7	28
Manpower Toals	12	13	11	13	13	13	13	13	13	13	13	13	13	13	716
Equip Totals (Crane Hrs)	5	0	5	0	0	0	0	0	1	1.5	0	2	0	4	18.5

Hensel Phelps Construction Co.

Figure 33 | Traditional Short Interval Production Schedule Example[9]

7.5.2 Non-Traditional Short Interval Production Schedule

A non-traditional SIP schedule deals with many trades and many activities that take place in one area. This analysis will be based on this type of schedule due to the amount of trades and activities. Only two trades and their activities will be shown on the schedule, but there is the opportunity that other trades could be incorporated into the schedule if desirable. As stated before, this type of schedule has consistent incremental schedule blocks and it takes on an assembly line mentality. A non-traditional SIP schedule is

[11] Sandeen, Jeff, and Shane Fisher. "Introduction to Short Interval Production Schedules." AE 570 . PSU, State College. 27 October 2011. Lecture.

also more concerned with getting an activity completely done in an area before the next one starts. All these requirements resembled will be implemented into the 7700 Arlington Blvd. SIP schedule. Figure 34 is an example of a non-traditional SIP schedule from the Pentagon Renovation that Hensel Phelps Construction Co. completed. Each number represents a group of activities and the top row corresponds to the date, while the left vertical column corresponds to the areas that have been broken up. Looking at the number one activity on the schedule, the first area (block 1) will be completed the week of January 9th. This first block is used to figure out if there are any errors with the sequencing and small adjustments will usually be performed in order to become comfortable with the schedule.[11]

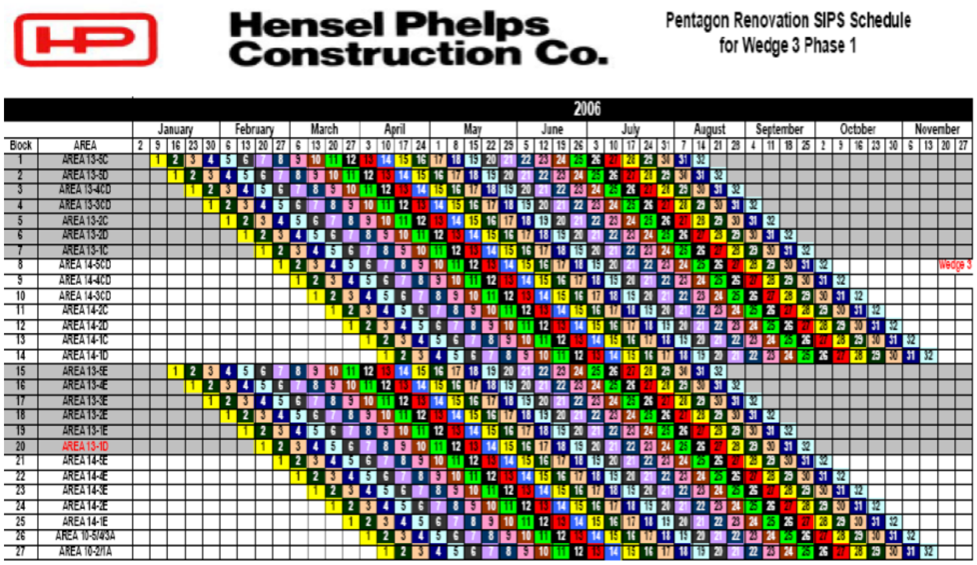


Figure 34 | Non-Traditional Short Interval Production Schedule Example[9]

7.6 Short Interval Production Schedule for 7700 Arlington Blvd.

The first step to developing the SIP schedule is to draw the sequence that the project team used on site. In the picture to the right the blue represents the perimeter of the building that the demolition and structural contractor followed while the green represents the core of the building that was not allowed to be touched until cleared to do so. The direction of the crews is assumed for illustration purposes. The Northwest and Southwest Building are the two buildings that have a progressive collapse steel system while the Main

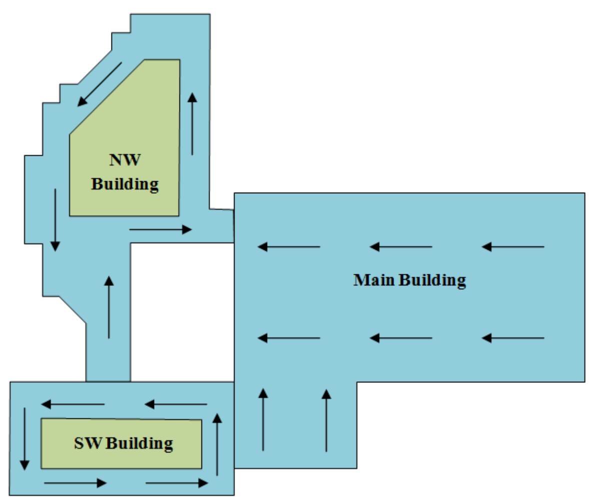


Figure 35 | Original Construction Sequence

[11] Sandeen, Jeff, and Shane Fisher. "Introduction to Short Interval Production Schedules." AE 570 . PSU, State College. 27 October 2011. Lecture.

Building does not. The Main Building entails the installation of seismic bracing and structural support for the MEP rooftop equipment. The plan shown is meant to give a simple illustration that would be repeated on each floor.

Developing a SIP schedule is feasible for this project because most activities are on the critical path and since time is the most important factor to the owner, reducing the overall critical path is important. Demolition and the Structure are the first activities (as shown in the diagram) on the critical path, therefore; making them the most important activites to start off on the "right foot". With these factors known, a new sequence will be developed to implement in the SIP schedule.

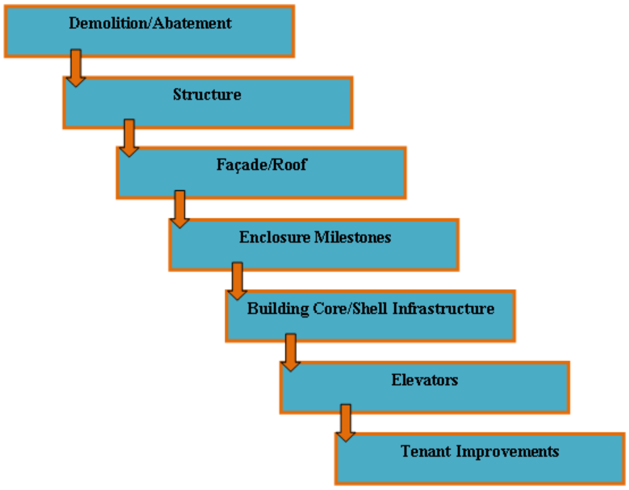


Figure 36 | Critical Path for 7700 Arlington Blvd.

Demolition, Core Drill, FRP Footings for Progressive Collapse, FRP Columns & Beams for Progressive Collapse, Strengthening/Hardening, Seismic Bracing, Erect Steel for Progressive Collapse, and Detail Steel for Progressive Collapse are the eight activites that will be utilized in the schedule. For this analysis, all the demolition is considered to be one activity to avoid any confusion on exterior demolition versus interior demolition. Also, the Strengthening/Hardening activity is time alloted for the strengthening of the footings, columns, and beams and will have no crews installing anything during this time. In order to reduce the schedule even further, the seismic bracing activity will utilize double the amount of workers to complete the work within the one week period that is scheduled while the demolition will have two crews and two weeks to complete the work.

The new sequence incorporates 17 different areas; six in the Northwest Building, six in the Main Building, and five in the Southwest Building. Each area, which includes all floors, is developed to maximize the time to get work completed for every activity. For example, M3 includes the first and second floor of the Main Building while NW5 includes the first through fourth floor of the Northwest Building. It was calculated that every activity would take an average of one week to be completed for each area. After gathering all this information, an excel sheet was created to show the SIP schedule. This schedule, which is shown

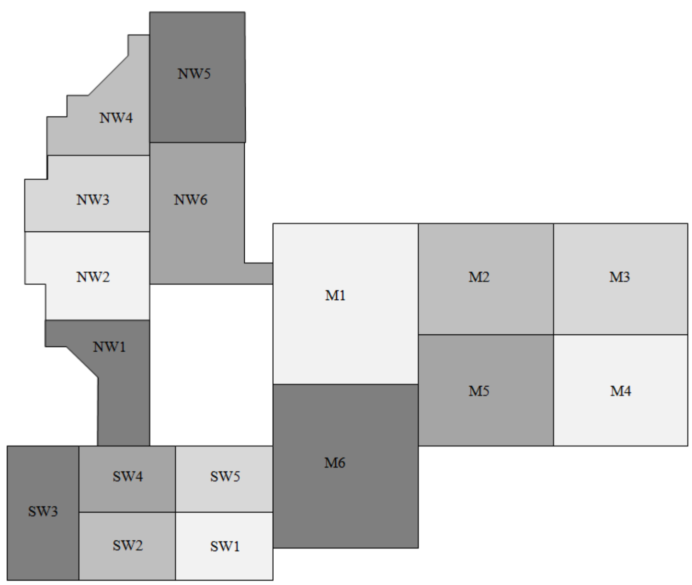


Figure 37 | New Sequencing Plan for 7700 Arlington Blvd. with Original Phasing

below begins with demolition in the Northwest Building. The Northwest Building and Main Building are part of Phase One and the Southwest Building is Phase Two. Demolition is two weeks long for each area because in the original project, demolition was not completed fast enough before the steel had to be erected. Also, the gap where the Main Building is shown reflects the fact that there will be no progressive collapse system installed in the building.

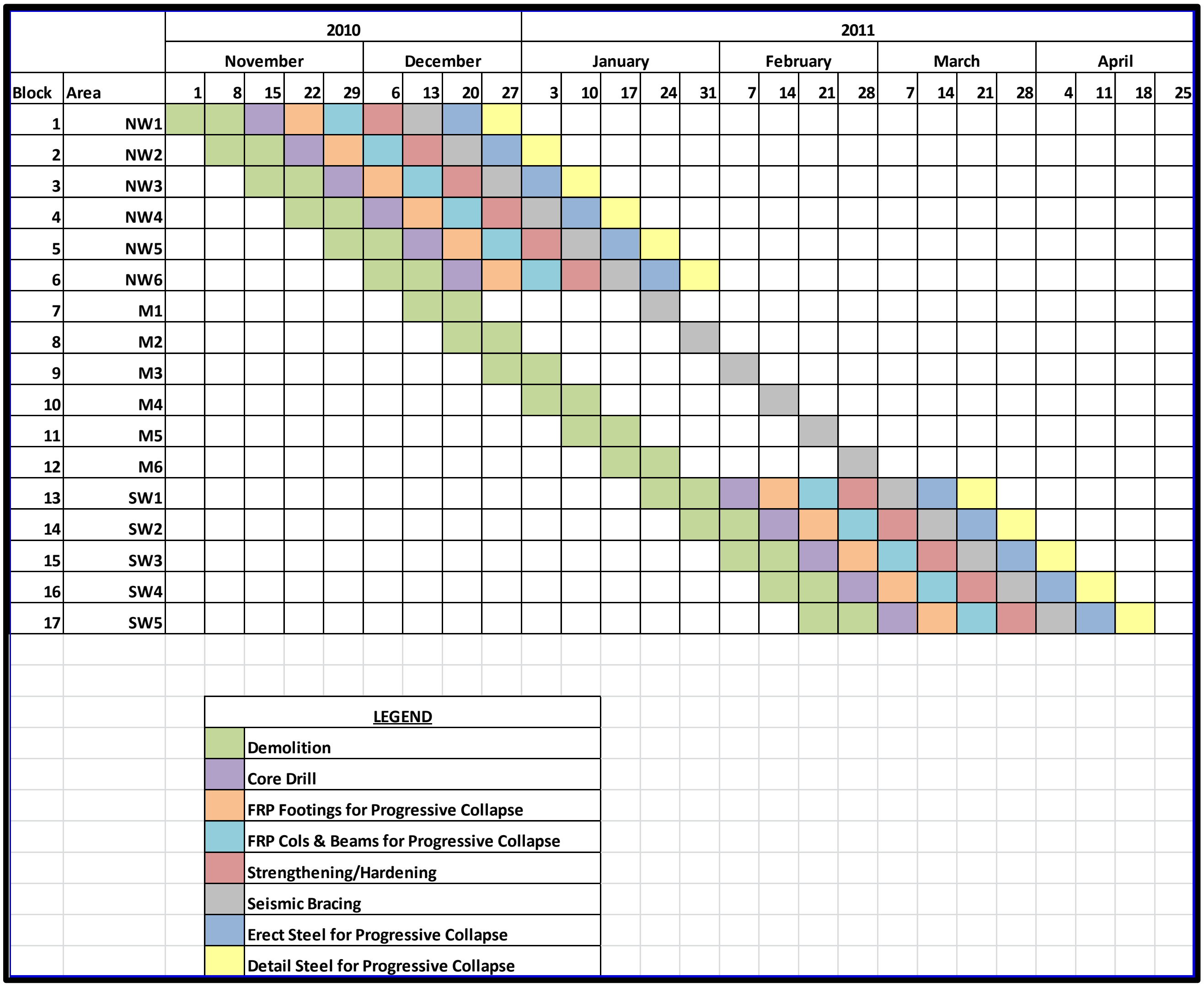


Figure 38 | 7700 Arlington Blvd. SIP Schedule with Original Phasing

The benefit of creating this schedule is that from resequencing two activites, nine weeks was shaved off the orginial schedule. Everything was calculated so that the same amount of work needed would be incorporated in the SIP schedule. By implementing a linear relationship between all the activites there is no overlap between activities. This aliveates the possibility of having different crews on top of each other in order to meet the schedule deadline. In the original schedule, the progressive collapse system for the Northwest Building was sequenced in this similar nature, but since the demolition was overlapping, problems arised. Further comparision between schedules will be discussed in the next section.

The main issue with the SIP schedule is that the progressive collapse crew will have to demobilize for seven weeks before the second phase begins. This technically does not make this schedule a Non-Traditional Short Interval Production Schedule because there is a big gap within the schedule. In order to resolve this issue, a new phasing plan is proposed to get this work completed. The Demolition and Structure would be completed early enough that it would not interfere with occupancy. The Northwest and Southwest Building would be the new Phase One and the Main Building would be the new Phase Two. This creates a better work flow throughout the building and it saves even more time than the sequencing plan with the original phasing. The images below show how the flow of work would change if the project were to be sequenced differently. The new sequencing plan with the new phasing shows how work would start at NW1 and flow around the entire building and finish with M6, which is part of the new Phase Two.

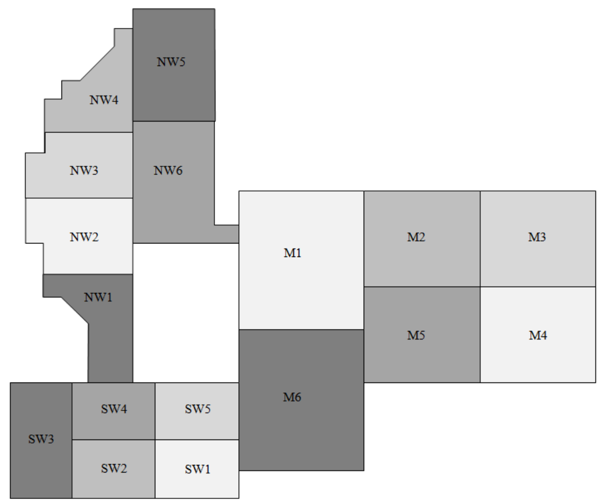


Figure 39 | New Sequencing Plan with New Phasing (left) & New Sequencing Plan with Original Phasing (right)

Since it would be inefficient to have the progressive collapse crew demobilize, a new SIP schedule was created to effectively utilize each crew's time. The image of the SIP schedule is on the next page and it clearly utilizes a Non-Traditional Short Interval Production Schedule for the first phase of construction. At the end of Phase One, the progressive collapse crew will demoblize and the demolition and seismic crews will continue onto Phase Two. This flow of sequencing saves two weeks of construction from the SIP schedule that was created for the original phasing. This also will have a direct impact on the general conditions cost and will be discussed in the following sections.

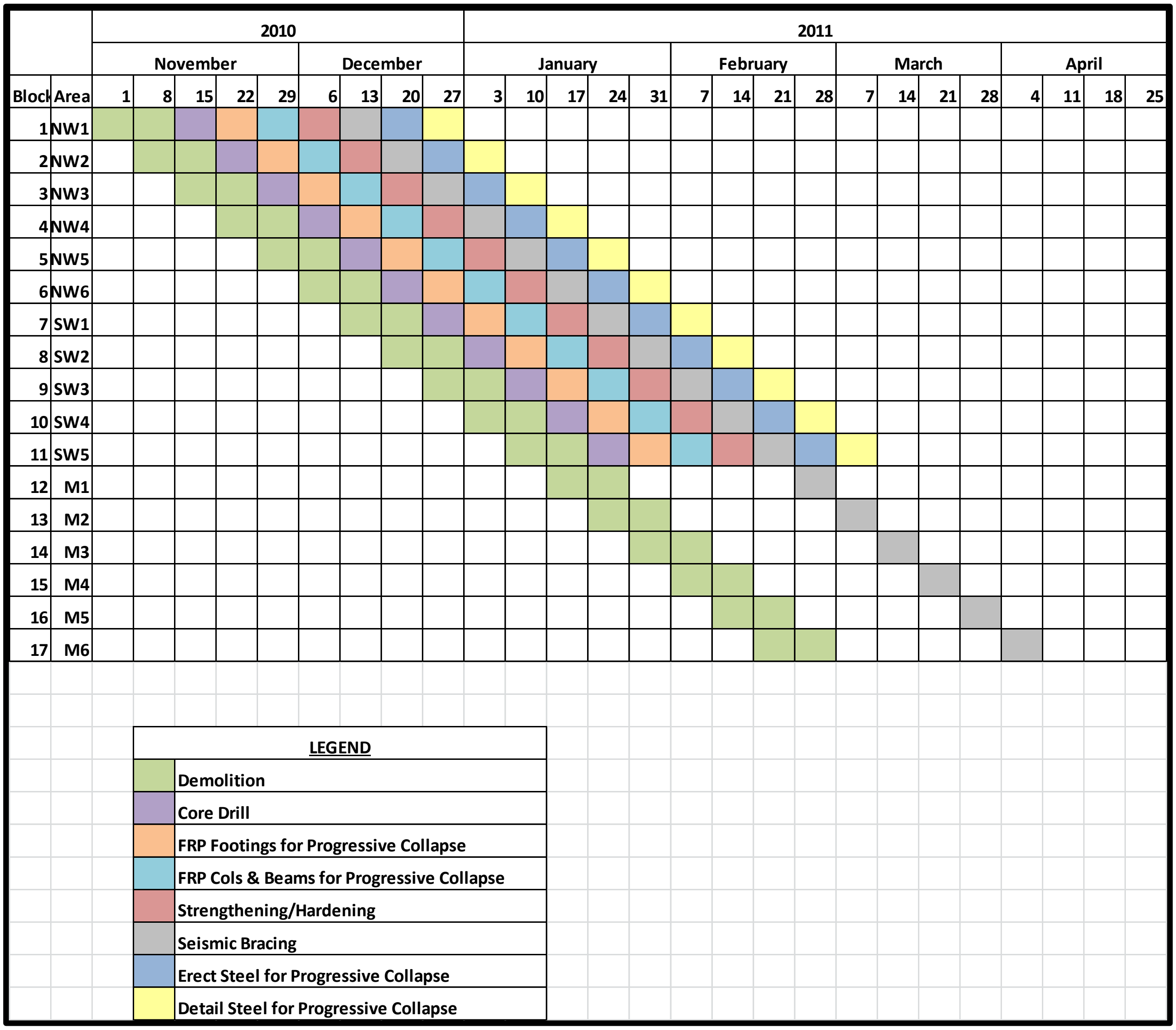


Figure 40 | 7700 Arlington Blvd. SIP Schedule with New Phasing

7.7 Schedule Analysis

To fully understand how the SIP schedule was created Table 14 shows how each activity duration was calculated. Remember that the demolition crew is doubled and has two weeks in each area and the seismic crew is also doubled in order to condense the work into week increments. Since the original schedule did not breakdown the Southwest Building into the different progressive collapse activities, a ratio using the Northwest Building was applied to figure out the SIP durations. By using the SIP schedule and applying a linear relationship to the activites, there is approximately a 45 day savings. Since these activities are on the critical path, the extra savings could be used for the other items on the critical path.

Table 14 | SIP Schedule Calculations with Original Phasing				
Task Name	**Original Duration (total days)**	**SIPS Sequence (# of areas)**	**SIPS Duration (days)**	**SIPS Duration (weeks)**
NW Building	***72***	***6***	***70***	***14***
- Demolition	61	6	35	7
- Structure	69	6	60	12
Core Drill	31	6	30	6
FRP Ftgs for Prog Collapse	32	6	30	6
FRP Cols & Beams for Prog Collapse	32	6	30	6
Seismic Bracing	49	6	30	6
Erect Steel for Prog Collapse	36	6	30	6
Detail Steel for Prog Collapse	36	6	30	6
Main Building	***62***	***6***	***60***	***12***
- Demolition	62	6	35	7
- Structure	46	6	30	6
Seismic Bracing	60	6	30	6
SW Building	***86***	***5***	***65***	***13***
- Demolition	64	5	30	6
- Structure	50	5	55	11
Core Drill	22	5	25	5
FRP Ftgs for Prog Collapse	23	5	25	5
FRP Cols & Beams for Prog Collapse	23	5	25	5
Seismic Bracing	46	5	25	5
Erect Steel for Prog Collapse	26	5	25	5
Detail Steel for Prog Collapse	26	5	25	5
Total	**170**	**17**	**125**	**25**

The next table and image are a schedule analysis comparing the original schedule's start and finish dates of the two critical path activities to the SIP schedule's new start and finish dates for the original phasing and to the SIP schedule's new start and finish dates for the new phasing. The SIP schedule's start date for the Northwest Building is the same as the orignal schedule. Looking at the table and image, it is apparent that by utilizing two crews for demolition, the schedule is greatly reduced. The idea behind using two crews is that in the original project, double shifts were employed in order to get work done. By having double the crews from the beginning there is a bigger upfront cost, but there could be less risk in work getting behind. Overall, there is a nine week savings from the original finish date to the new SIP schedule finish date for the original phasing and when compared to the total original days of work there is a 45 day savings. Since this project is time sensitive, having nine weeks of savings would be extremely benefical to the owner.

The new SIP schedule with the changed phases incorporates the same duration as shown in the table above, but because the Southwest Building was switched with the Main Building, two more weeks were shaved off the schedule. This is because the progressive collapse crews demobilize after the first phase. That means when compared to the total original days of work there is a 55 day savings. The schedule analysis table and image in Table 15 show how the dates would change with the new phasing plan when compared to the original schedule and the SIP schedule with the original phasing implemented.

Table 15 | Schedule Analysis						
	Original Schedule		**SIP Schedule**		**SIP Schedule New**	
Task Name	**Start**	**Finish**	**Start**	**Finish**	**Start**	**Finish**
Phase I – 500,000 SF						
NW Building						
- Demolition	11/1/10	1/24/11	11/1/10	12/17/10	11/1/10	12/17/10
- Structure	11/4/10	2/8/11	11/15/10	2/4/11	11/15/10	2/4/11
Main Building						
- Demolition	1/3/11	3/29/11	12/13/10	1/28/11	12/13/10	1/21/11
- Structure	1/24/11	3/28/11	1/24/11	3/4/11	12/27/11	3/11/11
Phase II – 147,000 SF						
SW Building						
- Demolition	2/28/11	5/26/11	1/24/11	3/4/11	1/17/11	3/4/11
- Structure	4/19/11	**6/27/11**	2/7/11	**4/22/11**	2/28/11	**4/8/11**
Total Schedule Reduction			**9 Weeks**		**11 Weeks**	

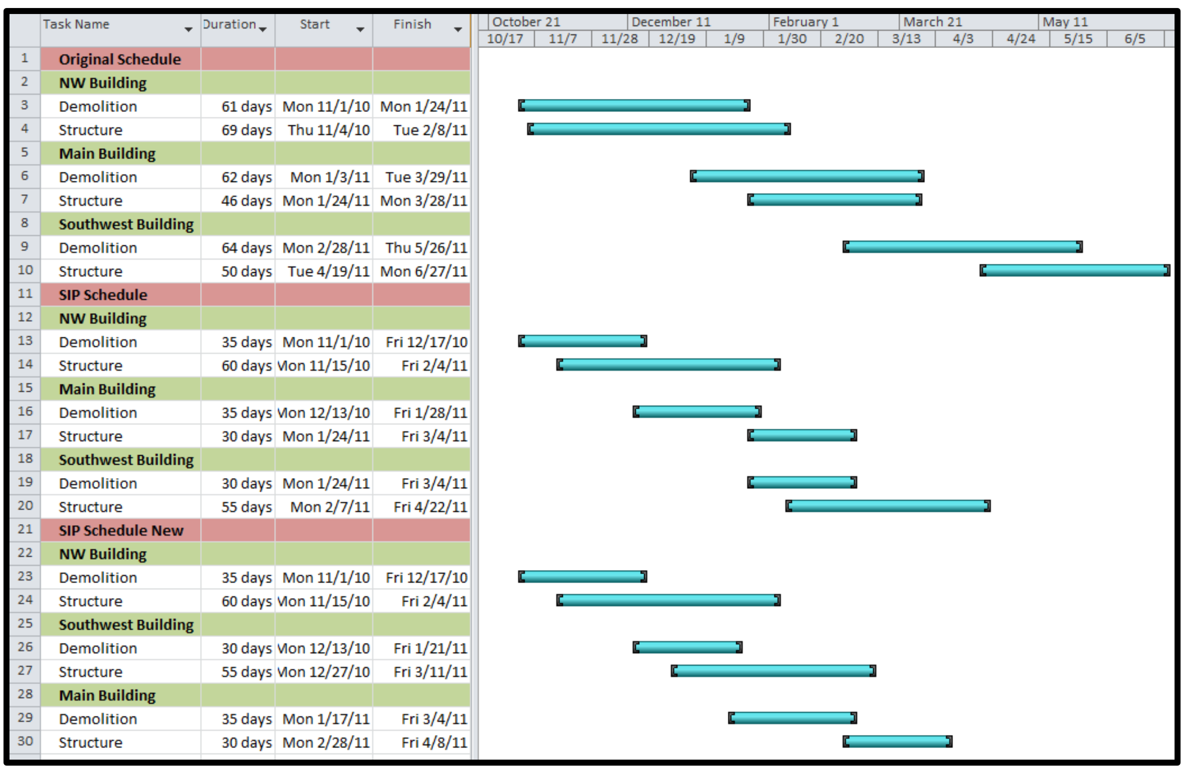


Figure 41 | Schedule Analysis

In the SIP schedule, assumptions were made that the crews would be able to reduce some of their work by a couple days in order to meet the week increment requirements. It is a feasible analysis because the new schedule implies a reptitive nature to the project that workers will get use to quickly. By having this repetitive nature, workers will become more efficient over time and this theory is directly applied to 7700 Arlington Blvd.

7.8 Cost Analysis

Table 16 shows a summary of the general conditions by breaking it down to the amount spent per day and per week. Eliminating nine weeks of construction based on the SIP schedule with the original phasing, would have a direct savings of **$358,802.10** which makes the total general conditions equal to **$2,934,202.70**. Eliminating eleven weeks of construction based on the SIP schedule with the new phasing, would have a direct savings of **$438,535.90** which makes the general conditions equal to **$2,854,468.90**. Therefore, it would be beneficial to use either SIP schedule to reduce the construction duration, but to save on overall efficiency, time, and money, the SIP schedule with the new phases should be utilized.

Table 16 | General Conditions Summary

	Total	$ / Day	$ / Week
General Conditions	$3,293,004.80	$7,973.38	$39,866.9

7.9 Recommendations and Conclusions

As shown in the schedule and cost analysis, utilizing the short interval production schedule with the new phasing for items on the critical path instead of the original schedule proves to be a good alternative. By reducing the schedule eleven weeks, there is a direct general conditions cost savings of $438,535.90. To implement the schedule effectively, good project management teams will have to teach others how it works and keep subcontractors on track at all times. Inevitably, there will be a learning curve in the beginning, but by using a non-traditional SIP schedule, that curve should be reduced as the project progresses.

The expected outcome for this analysis was to reduce the overall project schedule as well as implement a new lean process to create a safer work environment and incorporate with different BIM technologies. It is believed that all of the expected outcomes will be accomplished with the use of the short interval production schedule. The next analysis will further break down the concept of the SIP schedule and create a way to implement it into the field through the use of new technologies. Furthermore, creating a sequence that is effective and efficient is crucial on a project like 7700 Arlington Blvd. because delaying a critical path activity will only put pressure on the rest of the project. This alternative to scheduling provides a huge reduction in time and since the owner is concerned mostly with time, a SIP schedule would be greatly beneficial.

7.10 MAE Requirement

The integrated BAE/MAE requirement for the senior thesis project was met by incorporating course topics from one class, **AE 570: Production Management in Construction**, into the third analysis: **Creating a Short Interval Production Schedule**.

AE 570: Production Management in Construction was a course that explored the use of production management to efficiently manage the delivery processes of capital facility projects. In this class, topics such as improving performance, mapping project delivery, building projects of value, production sequencing planning, and short interval production schedules were all utilized for the development of the third analysis. The guest lecture by Hensel Phelps Construction Co. was the topic that was widely used in the development of the SIP schedule for 7700 Arlington Blvd.

8.0 BIM Implementation into the Field

****Reference Appendix K for the Big Picture Flow Diagram***

8.1 Problem Identification

Since there were a large amount of coordination issues on 7700 Arlington Blvd., improving performance through the use of technology in the field could have possibly prevented some of the larger issues that they encountered. The same problem described in Analysis #3 pertains to this analysis, which there was not enough time allotted for the demolition to complete what was necessary in order for the structural steel crew to begin their installation. The schedule was the owner's top priority on this project, but meeting the schedule was pricy with the amount of work that had to be re-sequenced. Through the use of flow diagrams and detailed process charts, the sequencing of work could have been broken down far enough to ensure activities would stay on track.

8.2 Research Goal

Developing flow diagrams and detailed process charts, which can be tied into the SIP schedule in order to reduce the schedule and make the sequence of the demolition crew and structural crew easier, is one goal for this analysis. The overall goal is to create a physical station that can be placed on job sites and will house a tablet to give workers access to the necessary information, such as the SIP schedule, flow diagrams, and process charts. These stations and a software program, BIMsight, will be implemented to better help the contractor coordinate with the other trades on a daily basis.

8.3 Research Steps

- Complete Analysis #3
- Create big picture flow diagrams (use areas developed from the SIP schedule)
- Create detailed flow diagrams
- Create process charts
- Develop physical station in SketchUp
- Research programs and what will be loaded onto the tablets
- Research potential issues with station
- Create images to use in technology
- Discuss how technology can be used in the field through the use of BIMsight
- Summarize results and analyze the effectiveness of this method

8.4 Background Information

The Short Interval Production Schedule with the new phasing in the previous analysis will be the basis for this analysis. The reason for using the latter schedule is because it best resembles a Non-Traditional SIPS and the progressive collapse crew will not have to demobilize in the middle of construction. Since there were coordination issues early on in the job, this analysis will focus on a practical way to value engineer this project.

A SIP schedule has become an efficient way to keep work moving at a consistent rate. The project teams on 7700 Arlington Blvd. worked together during preconstruction in order to ensure that the progressive collapse system was correct and that the material would be delivered to the site far in advance. If the teams would have taken it one step further and implemented a SIP schedule for the structure during the preconstruction phase, everyone would have had a better understanding of the work flow from the start of construction.

8.5 Flow Diagram & Process Charts for 7700 Arlington Blvd.

8.5.1 Big Picture Flow Diagram

The first aspect of this analysis is to break down the SIP schedule developed with the new phasing into images showing the sequence of work for 23 weeks. Each week is represented as one image and can be found in Appendix K. The images below show the sequence of construction as well as a legend that will directly correlate in the big picture flow diagram. One benefit of showing the SIP schedule on the actual project is the fact that it can be utilized in the field through the use of technology, which will be discussed in a later section.

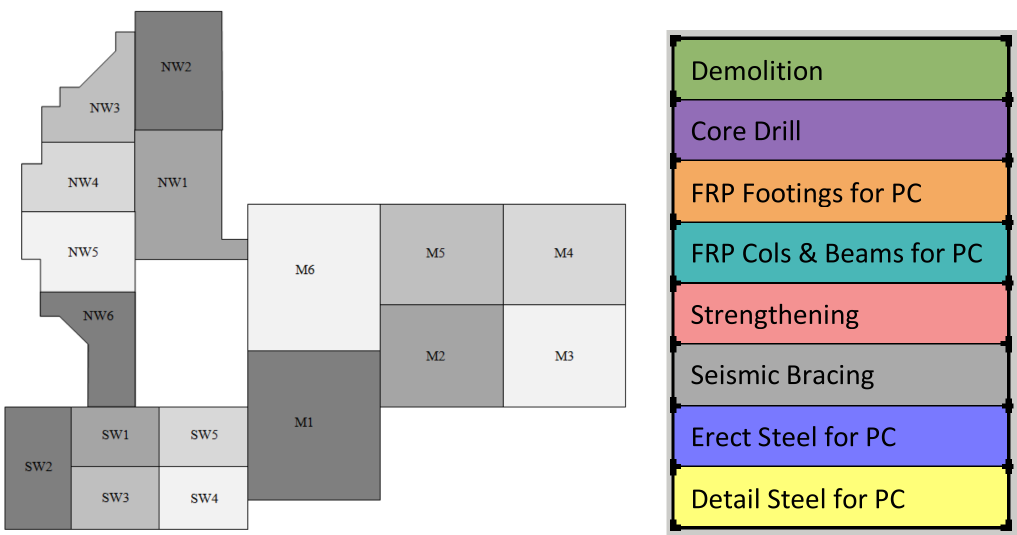


Figure 42 | New Sequencing Plan with New Phasing (left) & Legend for Images in Appendix K (right)

8.5.2 Detailed Flow Diagram

Value Engineering is an important aspect to consider on all types of projects, but unfortunately for 7700 Arlington Blvd., there was limited value engineering done. There are many factors that play into why value engineering was not utilized with the main reason being that this project was stripped to its bare bones from the very beginning. There was little room to make improvements with the budget that was allocated. The most important goal for the owner was making sure the project was done on time due to BRAC BP 198 which is the reason why they are building this facility. The Defense Base Closure and

Realignment Commission (BRAC) recommended that the Department of Defense relocate all facilities to be in accordance with BRAC BP 198 in order to support certain threats.

By utilizing the SIP schedule for the demolition and structure, the project teams and workers will be able to clearly see what area their crew should be in and when. The SIP schedule created decreased construction by 11 weeks and saved $438,535.90 in general condition costs. This in itself is a way to value engineer a project, but because this is a large project, a more detailed analysis would prove to be beneficial. The idea is that a few flow diagrams be created in order to show one specific activity throughout each area. The following images represent the erection of the progressive collapse system, which is the activity highlighted in a deep blue on the SIP schedule. The Southwest Building is the building used in the following images, but the same procedure that will be discussed can be applied to the other two buildings and all the different activities could be shown if desired. For the sake of time and length of the analysis, one activity and one building was analyzed.

There are a few main reasons to break the schedule down to this extent. The first reason is to gain an efficient means to the sequence of construction. The further the schedule is broken down, the faster construction could potentially be performed. Creating these diagrams and charts is not meant to be complicated or time consuming, but they are meant to make everyone’s life on the jobsite easier. Another reason for a detailed flow diagram is that the images are capable of being implemented into technology, which will help the workers when there is any confusion on where they should be. The same goes for any process charts that are created to go along with the flow diagrams. Everything created should have technology capabilities because otherwise the results will not be thoroughly effective.

The progressive collapse system is designed to be directly behind each column in the Southwest Building. Each assembly that will go behind the columns consists of a base plate, channels for each floor and a cap plate. This activity also includes the movement of material, crane lifts, and assembly placement. All the detailing is the last activity in the SIP schedule and it is separate from the erection activity due to time constraints.

Figure 43 shows the Southwest Building separated into five different areas (SW1, SW2, etc.) and it also shows the progressive collapse system in yellow with the appropriate description on each assembly. There are a total of 44 progressive collapse assemblies that must be installed in a total of 5 weeks. To keep it consistent, five areas were created within one area, allowing one day per designated erection.

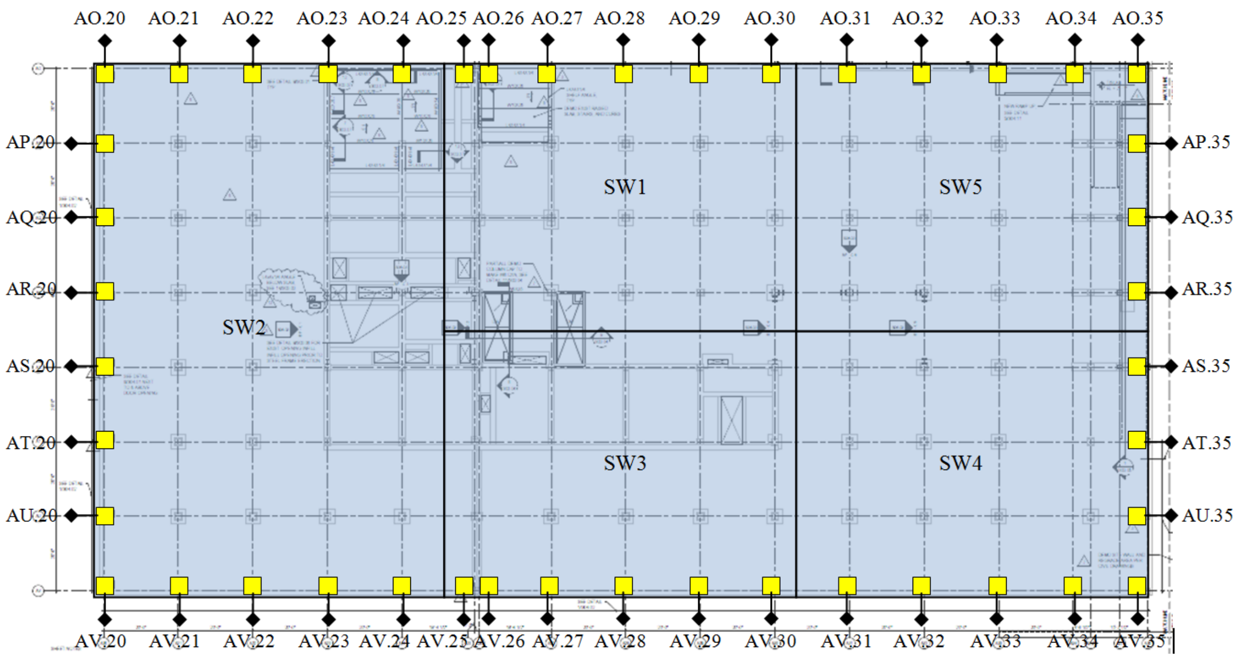


Figure 43 | Overview of Erection of Progressive Collapse Flow Diagram

The five areas that were created within one area are displayed in the next five images. Each assembly is grouped together by color to designate one day's worth of work. For example, the red in SW1.1 represents the part of the progressive collapse system that will get installed on day one of section SW1. Day two is represented in orange, day three is represented in blue, day four is represented in purple, and day five is represented in green. This trend continues into the process charts to keep everything consistent. Color coordinating is an effective method when trying to keep several items organized. Since this is only one activity within one building, there could be approximately 40 more images to represent the rest of the activities within the Southwest Building.

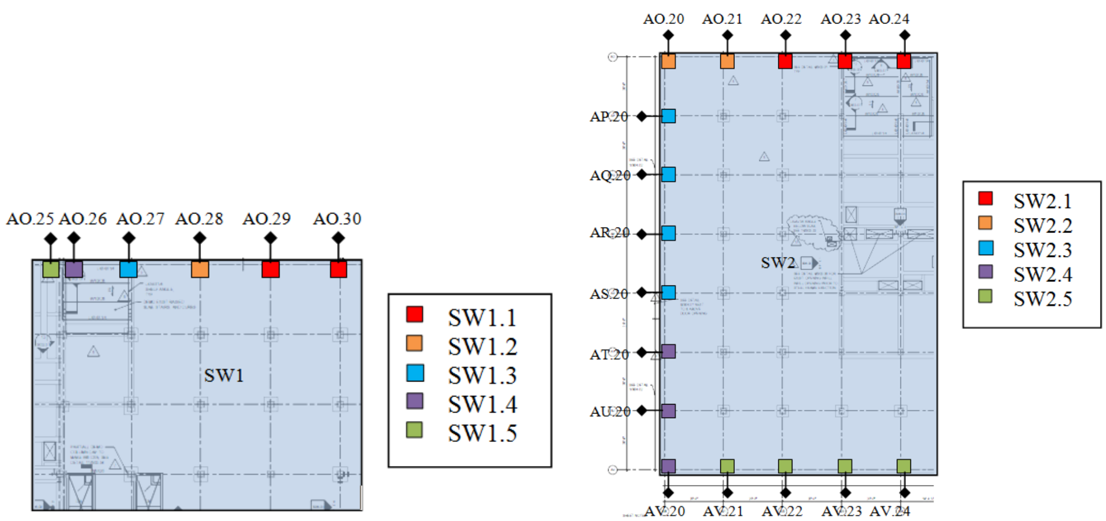


Figure 44 | SW1 & SW2 Flow Diagrams for the Progressive Collapse Steel Erection

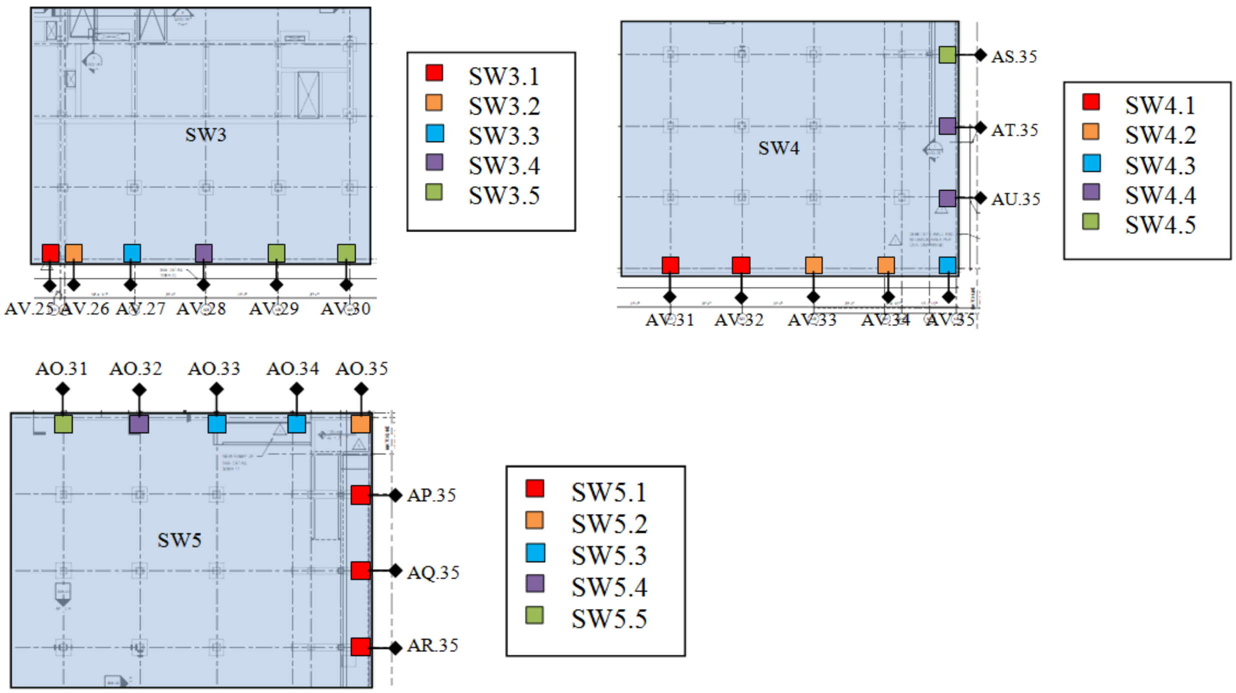


Figure 45 | SW3, SW4 & SW5 Flow Diagrams for the Progressive Collapse Steel Erection

Since there is a good amount of tedious work involved in creating all the flow diagrams and process charts, the contractor will be responsible for getting the other subcontractors involved. The contractor will first be responsible for creating the SIP schedule for the project. Once the schedule is created, it will be sent to each subcontractor involved with the SIP schedule. In this particular situation, the steel subcontractor would be responsible for compiling the data necessary to create the diagrams and charts. Once they are completed, the subcontractor will send the information back to the contractor, who will then compile all the data into one working document. There will be several meetings held at the beginning, middle, and end of the SIP schedule process to ensure that there is no confusion once construction commences. The main idea behind getting everyone to coordinate and communicate on this level is to establish individual goals and group goals that can be implemented during construction. For example, the progressive collapse system is one of the most important systems being installed, but if the structural contractor is not in coordination with the demolition contractor, then overlapping crews and frequent delays will most likely occur.

The flow diagrams and process charts should be created at the same time in order to coordinate when an assembly should be installed and how long it should take to install that assembly. The next section goes into more detail about the process charts that directly relate to the flow diagrams in this section.

8.5.3 Detailed Process Charts

If each section has the capability to be divided up evenly, then the process chart looks exactly like a SIP schedule except on a smaller scale. Figure 46 shows the detailed process chart for the steel erection activity in the Southwest Building.

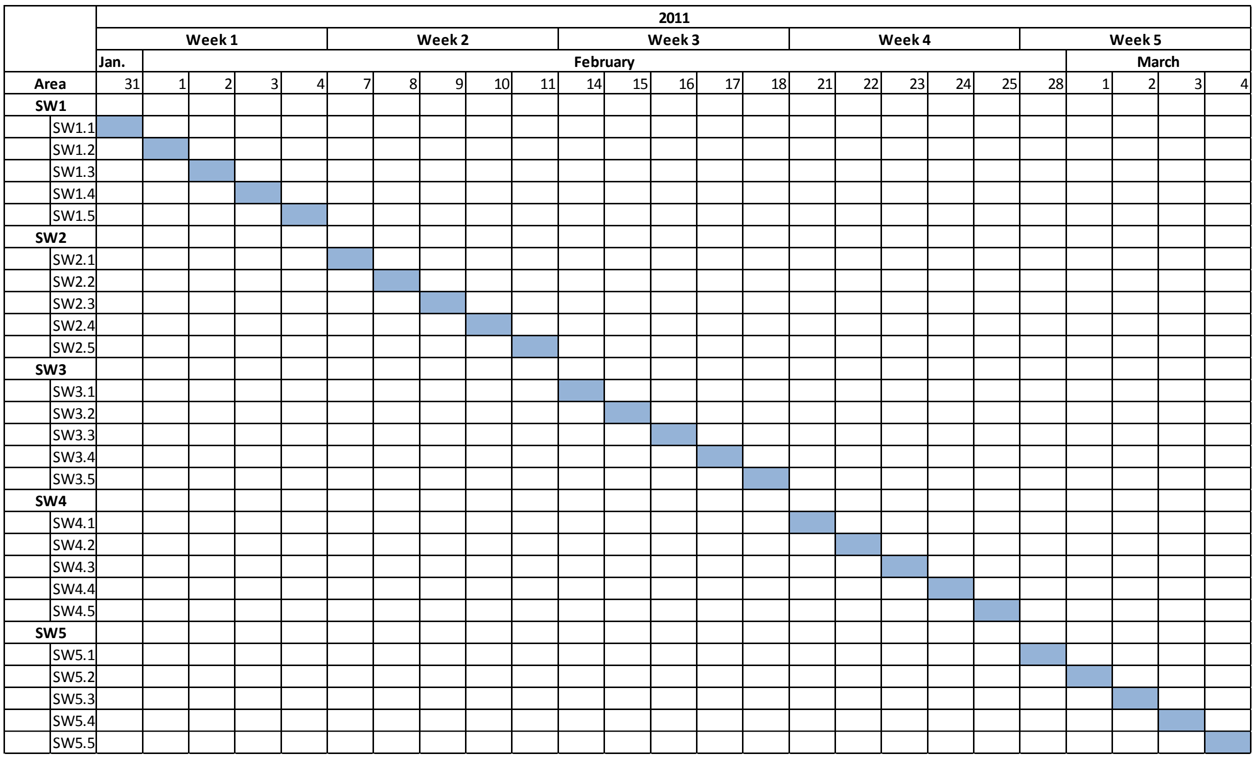


Figure 46 | Detailed Process Chart for Steel Erection Activity in the Southwest Building

As a steel contractor, this process chart is the initial formation of how the work will be divided in each area. It is not necessary to evenly distribute the work within each area, but this was done so that the concept would be easier to understand.

After, the initial process chart is created; each area within a bigger area (i.e. SW1.1) will be broken down into a separate process chart. These process charts can be found on the following pages. Breaking down each activity to this level of detail is important when implementing the SIP schedule because coordination is the key to success. If everyone knows where they are supposed to be and when, then all the planning is worth it. Also, by breaking it down to the hours spent on each assembly allows the project manager of that trade to easily access the work flow and it allows the workers to fully understand what has to get done each day.

Referencing SW1.1, there are two progressive collapse assemblies that must be erected on January 31, 2011. Each assembly must be completed in four hours, while every other day has eight hours to complete one assembly. The reason that there are more some days is because of the area in which they are to be installed. Some areas will inevitably be harder to place, such as corners of the buildings.

SW1		Jan. 31	Feb. 1	Feb. 2	Feb. 3	Feb. 4
		Time (hrs)				
SW1.1	AO.30	4				
	AO.29	4				
SW1.2	AO.28		8			
SW1.3	AO.27			8		
SW1.4	AO.26				8	
SW1.5	AO.25					8

SW2		Feb. 7	Feb. 8	Feb. 9	Feb. 10	Feb. 11
		Time (hrs)				
SW2.1	AO.24	2.67				
	AO.23	2.67				
	AO.22	2.67				
SW2.2	AO.21		4			
	AO.20		4			
SW2.3	AP.20			2		
	AQ.20			2		
	AR.20			2		
	AS.20			2		
SW2.4	AT.20				2.67	
	AU.20				2.67	
	AV.20				2.67	
SW2.5	AV.21					2
	AV.22					2
	AV.23					2
	AV.24					2

SW3		Feb. 14	Feb. 15	Feb. 16	Feb. 17	Feb. 18
		Time (hrs)				
SW3.1	AV.25	8				
SW3.2	AV.26		8			
SW3.3	AV.27			8		
SW3.4	AV.28				8	
SW3.5	AV.29					4
	AV.30					4

Figure 47 | Detailed Area Process Charts

SW4		Feb. 21	Feb. 22	Feb. 23	Feb. 24	Feb. 25
		Time (hrs)				
SW4.1	AV.31	4				
	AV.32	4				
SW4.2	AV.33		4			
	AV.34		4			
SW4.3	AV.35			8		
SW4.4	AU.35				4	
	AT.35				4	
SW4.5	AS.35					8

SW5		Feb. 28	Mar. 1	Mar. 2	Mar. 3	Mar. 4
		Time (hrs)				
SW5.1	AR.35	2.67				
	AQ.35	2.67				
	AP.35	2.67				
SW5.2	AQ.35		8			
SW5.3	AQ.34			4		
	AQ.33			4		
SW5.4	AQ.32				8	
SW5.5	AQ.31					8

Figure 48 | Detailed Area Process Charts

Overall, taking a SIP schedule and developing flow diagrams and process charts to a level that most people would not think to do is beneficial for various reasons. Coordination, communication, value of work, efficiency, is all contributory benefits for developing detailed diagrams and charts.

8.6 Implementing the Flow Diagrams & Process Charts into Technology

Due to the fact that these flow diagrams and process charts can be largely beneficial, they have the potential to make a huge impact out on a construction site. With the idea that they are meant to be used on a daily basis, having to print out paper copies all the time would prove to be impossible. Therefore, by taking these diagrams and charts and implementing them into an Apple iPad, they will have the capability to be updated whenever necessary. Construction foremans, labor workers, project managers, and others will be able to access the Apple iPad through Hi-Tech work stations, which will be placed throughout the jobsite. Even though the diagrams and charts can be a tedious task to develop, the coordination they can create amongst trades would be well worth the investment. Whenever anyone has a question about the sequence of work, they will be able to go over to one of the stations and look up what the daily task is for his/her trade and how long he/she has to complete it.

Another way to implement the flow diagrams & process charts is through the utilization of BIMsight, a software program that was developed for the sole purpose of coordination amongst trades. The sequencing of work can be implemented into a program like BIMsight on a 3D level, showing crane placement on the building through the use of the BIM model. The program is also meant for all trades to combine their models and fix any overlapping issues. The next two sections go into more detail for the Hi-Tech Work Station and the software program designed by Tekla, BIMsight.

8.7 Hi-Tech Work Stations

The Hi-Tech Work station was created to help with coordination between trades on a jobsite. The initial thought behind the work station was that most jobs already incorporate some form of a drawing table for blue prints. These tables are placed throughout the site for workers to refer to during the installation process. Also, the other reason for this station is that a lot of companies have been creating "BIM kiosks" that have computers in them for BIM coordination on the site, but they are fairly large and inconvenient to move around. With that in mind, Apple iPads and other tablets have made an exponential growth in the construction industry for use in the field, so the idea was to incorporate a tablet into a drawing table. This way whenever there are questions about the project, a worker can refer to the drawings themselves or the tablet which can give him/her even more useful information. Figure 49 to the left shows the concept of the Hi-Tech Work Station.

Figure 49 | Hi-Tech Work Station Concept

The concept behind the use of the iPad is that the flow diagrams and process charts can be uploaded and viewed by a click of a button. In the case of using the SIP schedule, everyone has to be informed at all times as to what needs to get built and when because once one trade slacks, the rest get delayed as well. With the use of the station, each diagram and chart can be easily visible whenever necessary. For example, if an iron worker wants to look ahead as to what is going to be installed the next day, he/she can access the iPad and pull up the diagram and chart that correlate to that specific day and specific area. It is not meant for individuals to play on or use as an excuse for not doing work, it is merely a viewing device to help work progress more efficiently. Another neat feature that will be discussed in the next section is the use of BIMsight, which can be uploaded onto the tablets to show the sequence of work on a 3D BIM model. Also, cut sheets for different materials can be uploaded to the iPad which will allow for a worker to refer to them when he/she is unsure about the installation of something. The ideas and capabilities are endless with what can be done with the use of the tablet, but the main goal is for workers on the site to use it. Right now the tablets and "BIM kiosks" are meant for project management only because they edit and change the model while in the field. Since the tablets in the hi-tech work station will not have editing capabilities, it is truly only meant to see information about the project. In order to get an idea or concept to the workers fast, management can update the model, charts, diagrams, and documents to the iPad whenever necessary for them to refer to. This station is merely an aid to help coordination and efficiency increase and it allows for individuals to get excited about a new concept in construction.

Unfortunately, damage and theft have to be taken into account because people break into jobsites quite a bit. There are a few design elements as well as products to help keep the tablet protected and the work stations nice. The first element is the tool boxes that will be installed underneath the tablet the entire way down the station. There will be a keypad lock or industrial lock on the back of the tool box for maintenance purposes. Figure 50 shows what the back of the hi-tech station looks like as well as a close up view of the locked tool box that will house the tablet.

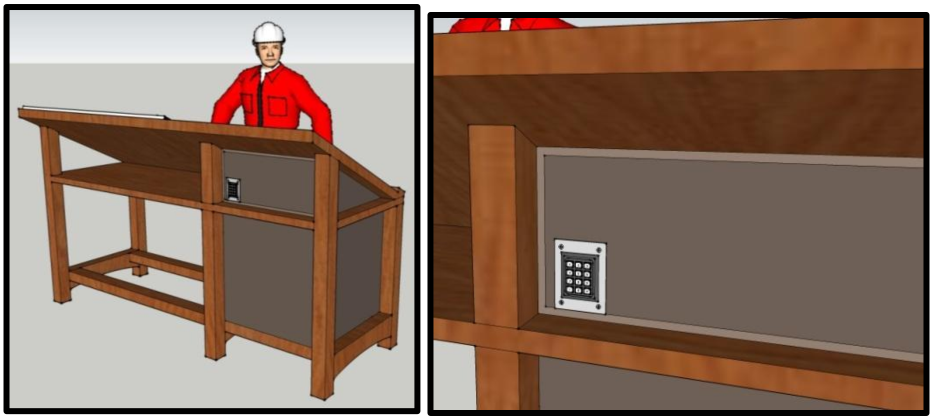


Figure 50 | Rear View of Hi-Tech Work Station

The iPad will be inset about 1/16" in the front of the work station; so that it is not sticking out and the drawings can be spread out over the entire station if necessary. The screen will be protected by an invisible shield that is indestructible, such as the brand Zagg. Also, software such as lo-jack could be utilized to protect the iPad if it ever did get stolen. This type of technology can track where the tablet is through GPS tracking and it can erase everything on the tablet if need be. There are many types of security options that can be incorporated into the hi-tech work stations and it is important to implement them because otherwise the stations will not be as successful as they can be if management is worrying about them all the time.

To fully understand the potential of the hi-tech stations, an estimate was performed to see how much one station would cost to build and implement into the site. The total estimate was around $1600, which included the cost for the iPad and security elements. The station itself, which was estimated off of the Home Depot website, was approximately $650 to build, labor not included.[6] If 7700 Arlington Blvd. were to implement one hi-tech station on each floor and in each building it would amount to 10 stations which is approximately $16,000. This amount is a little excessive because the project management team would most likely not implement this many stations due to the fact that they can be moved around. In the tool box where the iPad is held there will be an extension cord which will run down and out the bottom of the station. This will allow for the station to be plugged in to temporary power, instead of having to keep track of when the tablets run out of battery power.

Overall, the hi-tech work station is a great way to get the workers involved with what management produces for the jobsite on a day to day basis. The stations are not only affordable, but they will help increase trade coordination and keep the project organized through the use of the iPad. This has the potential to be a great investment and it takes the idea of BIM implementation into the field on a whole new level.

[6] Home Depot, . "Lumber Costs." . Homer TLC, Inc., 2011. Web. 28 Mar 2012. <http://www.homedepot.com/>.

8.8 BIMsight

Tekla Corporation is a model-based software engineering corporation specializing in model-based software products for building and construction and infrastructure management. They have created BIMsight, which, by definition from Tekla Corporation "is a professional tool for construction project collaboration." It is a way for all construction trades to combine models to eliminate clashes, share information, solve issues, and more through the use of a 3D model. Some of the collaboration features that are included in BIMsight are creating notes, sharing the notes, and sharing the aggregated project. As for the model checking capabilities, BIMsight is able to do 3D navigation, measuring, clip planes, markup, redline, automatic clash detection, save model views, object/model coloring and transparency, and finding and grouping objects from models. This product is competitive with products such as Autodesk Navisworks Freedom, Autodesk Navisworks Manage, Bentley Projectwise Navigator, Solibri and Model Checker. The great advantage to BIMsight is that it is free to download and use and it can be used with tablets that are Windows compatible. The interface for the tablets is one of the newest features with the program, so now construction professionals can bring a compatible tablet out on site to make changes to a 3D model.[12]

Continuing with the concept of implementing BIM into the field, BIMsight was explored to figure out different advantages for use on 7700 Arlington Blvd. One nice feature is how easy it is to mark up an area in a model and/or add a note to a selected item. The figure, shown below, illustrates a demo model from Tekla Corporation. The "mark" on the wall needs to be cleaned, so a project manager can easily go to this part of the model and select the desired wall to create a note. The image following the one below shows a blown up portion of the right (blue shaded) window in Figure 51.

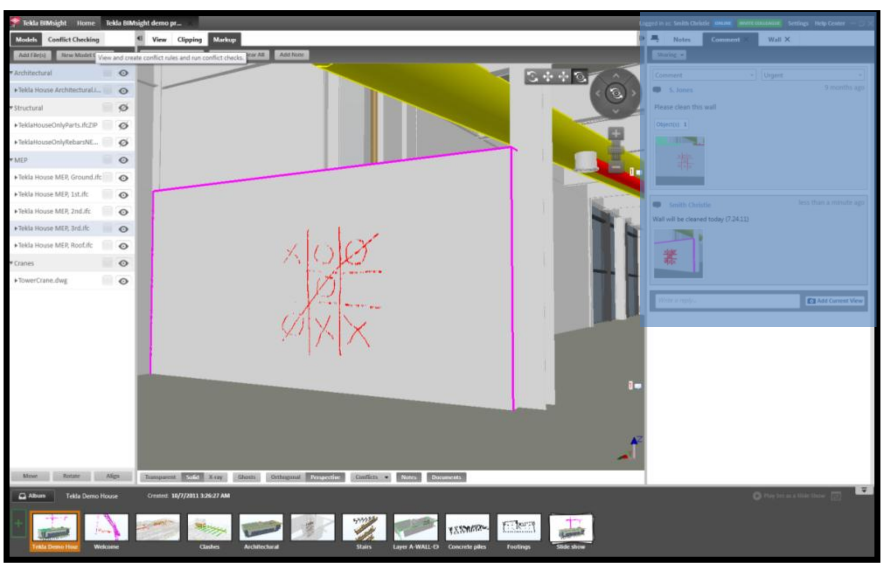


Figure 51 | Tekla BIMsight Demo Model Mark Up

[12] Tekla Corporation, . "Tekla USA." *Tekla BIMsight 1.4 takes BIM to the field with Windows tablets* . Trimble Company , 24 01 2012. Web. 28 Mar 2012. <http://www.tekla.com/us/about-us/news/pages/teklabimsight1.4.asp&xgt;.

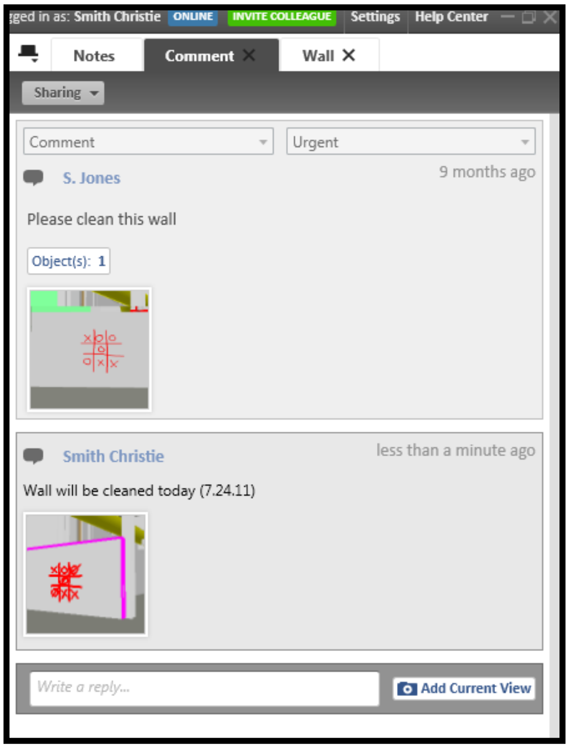


Figure 52 | Notes Column for BIMsight model

The value to creating notes is that if this were an IPD team then each team member would be able to write specific notes to one another. For example in Figure 52, S. Jones wrote a note to the team that the wall needed to be cleaned and a short while later S. Christie responded that it would be taken care of on July 24, 2011. This is a fictitious situation, but through the use of tablets on site, it would be convenient for other team members to communicate this way. Especially if the note could pop up as an alert on a worker's tablet in order for him/her to take care of the situation immediately.

The idea that is very unique which relates to an IPD environment is the fact that all the trades have to collaborate if they plan on using BIMsight in order for it to be successful. Assuming this was the case; a Revit model was transferred to an IFC file and imported into BIMsight. From there the BIMsight model can be saved in the normal format for the program, making it easier to navigate and do various coordination changes. The Revit model showed various architectural, structural, mechanical, and miscellaneous features. The full systems were not shown in detail in the Revit model, but it is assumed that if these models could be obtained that each one can be implemented into one file to perform clash detection. After learning and fully exploring BIMsight it was found that this program is extremely valuable in the sense of quality control and keeping collaboration simple. It does not have 4D capabilities, but different slideshows can be created within BIMsight.

For the purposes of this analysis where SIPS would be implemented, showing the sequence of work in certain areas is very simple. In the figures on the following page, 7700 Arlington Blvd. was utilized to show section SW4 in the Southwest Building. The first image shows where the progressive collapse assembly will be installed, which is noted in the right hand column with the date of installation specified. The inserted arrows and text box help clarify where the note is as well as where the information is formatted. The concept is that each progressive collapse assembly can be specified by creating a note for each one. That way when a team member needs to know or is curious as to the date of installation, he/she can refer to the model on a computer or tablet to get the answer. If there are any issues in that area than a reply can be created for the structural project manager to be aware of.

The second image on the next page shows the same area as the first image, but this image was clipped from a slideshow that was created to show the sequence of the progressive collapse work for SW4. The blue resembles a progressive collapse assembly already installed; therefore the image shows that four have been completed and the sequence is moving to the fifth, which is a corner column. A project manager can easily create these slideshows that can then be exported to be uploaded on the tablets in the hi-tech work stations, which were previously discussed. The benefit for doing this is that the worker's on the jobsite can refer to these slideshows whenever there is any confusion with the sequencing of work for the SIP schedule. This will allow for more efficient coordination between and amongst certain trades.

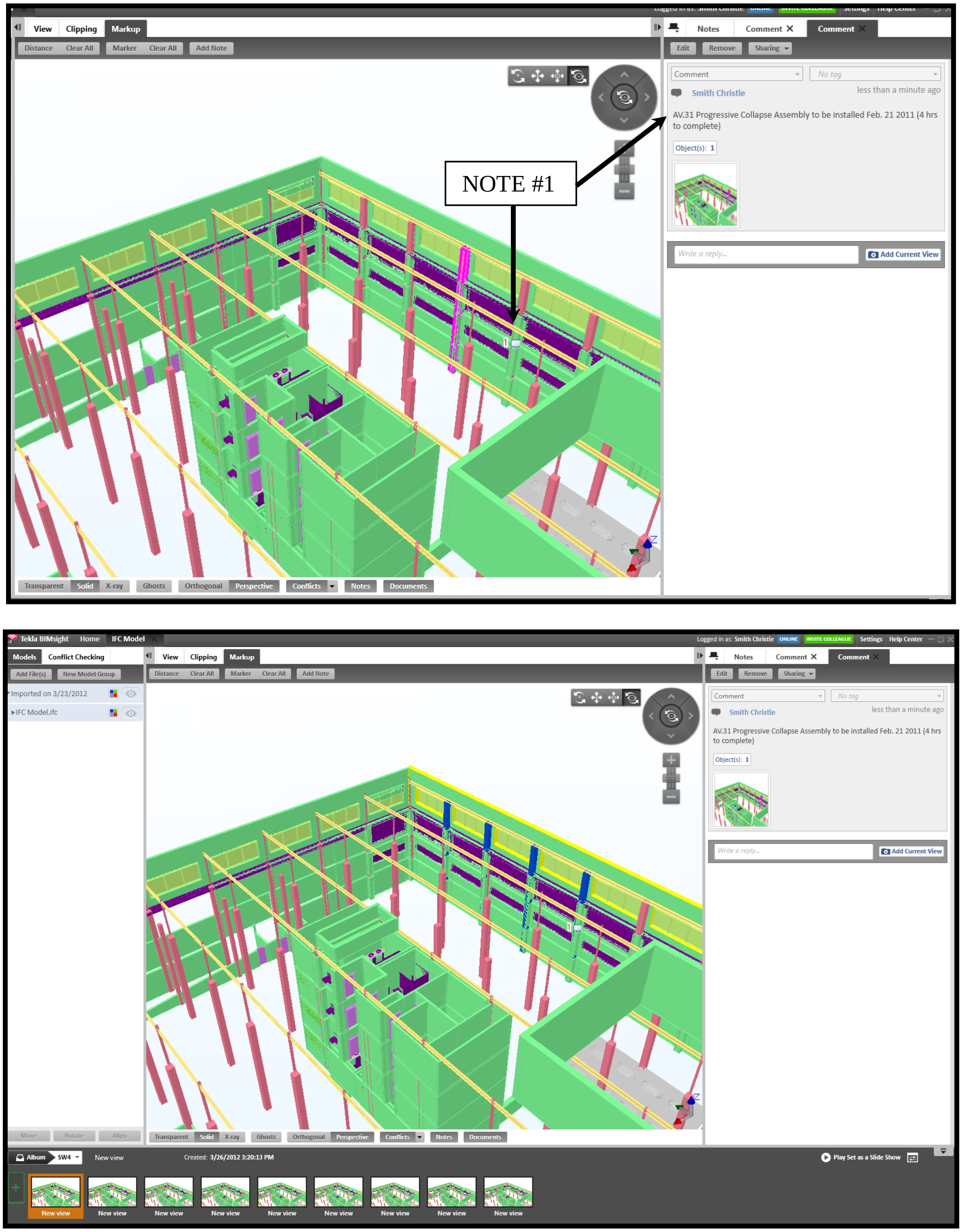


Figure 53 | 7700 Arlington Blvd. SW4 3D Sequencing Diagram

After researching various websites for different BIM technology in the field, Tekla BIMsight has proven to be a valuable tool if used properly. The fact that it is not a hard program for people to learn makes it more beneficial than some of the harder programs that project managers face on a daily basis. Through the use of tablets on site and at the hi-tech work stations, being able to create conceptual 3D sequencing plans is an appealing concept and it would be interesting to implement.[12]

8.9 Recommendations and Conclusions

The primary goal for this analysis was to find a way to implement the SIP schedule created in Analysis #3 on a more detailed level. Also, by designing a more detailed level, the other goal was to find a way to help workers on the site better understand the project sequencing through the implementation of technology. Several flow diagrams and process charts were created to detail the progressive collapse steel assemblies for the Southwest Building. These diagrams and charts thoroughly showed the progression of work within each area as well as gave basic time durations for each progressive collapse assembly. The concept of using the diagrams and charts were then used to create the idea of implementing them into a hi-tech work station. The station would be used to hold the building drawings and it would also have an iPad or some form of a tablet installed directly into the front for workers to use for viewing purpose only. Since the flow diagrams and process charts are 2D, a new program was research for 3D sequencing. Tekla BIMsight is an easy program where models from each trade can be uploaded and combined into one model in order to do clash detection and 3D sequencing. There are many other features to the program, but for the purpose of this analysis, a 3D model that could be uploaded to the hi-tech work stations was the goal.

If a project is detailed enough that there could be various coordination and collaboration issues then looking into a SIP schedule and breaking it down far enough for it to be implemented into the field through the use of technology is recommended. The hi-tech work stations have the potential to help increase efficiency on a project through continuously educating the workers on how the project is to be performed. Also, BIMsight is recommended for project managers trying to create a collaborative work environment and overall the program is a great way to wrap the 2D flow diagrams and process charts into 3D sequencing diagrams.

[12] Tekla Corporation. 2012.

9.0 Recommendations and Conclusion

Throughout the spring semester, 7700 Arlington Blvd. has been evaluated in order to find areas within the project that could be developed to be more efficient. The four analyses that were developed for the final report involved an in-depth look at four core investigation areas; critical issues research, value engineering, constructability review, and schedule reduction. The creation of an integrated project delivery process map, an analysis of a new mechanical system in the Northwest Building, the development of a short interval production schedule with a new phasing plan, and the implementation of new BIM technologies in the field were the four analyses developed for the final report and enhancement of certain areas within 7700 Arlington Blvd. The overall theme for the four analyses was defining and creating more efficient means to construction collaboration.

The first analysis was created based on one critical industry issue which was the use of an integrated project delivery team on projects. This analysis was based fully on research obtained through the 2008 AIA Contract Document A295 and the AIA Guide for Integrated Project Delivery. A process map was created to show where the different coordination and communication levels occur throughout each phase of a project. By utilizing the process map, the Owner, Contractor, and Architect will be able to alleviate some of the stress and burden of a typical project contract. It is recommended that each party looks over the map together during meetings to become highly educated on what is expected in each phase. In order to ease this process the use of a tablet with a shared document uploaded will help. Ultimately, implementing an integrated project delivery approach is based on trust and by using the process map it will help allow for others to rely on one another more efficiently.

Analysis two was a review of two plausible mechanical systems for the Northwest Building in 7700 Arlington Blvd. Since the Northwest Building was the only building not receiving a new mechanical system in the renovation due to the owner's budget, the analysis is framed around the idea that the owner would want to implement a new system. A water source heat pump system, which is the existing system and a VAV system, was analyzed in TRACE 700 to determine which system was more efficient. The water source heat pump's building performance amounted to 9,342,355 kBTU/yr which was 365,891 kBtu/yr less than the VAV system. Even though the water source heat pump was determined to be a better system, a cost and schedule analysis was performed to ultimately determine which system would be better for what the owner's wanted in 7700 Arlington Blvd. Cost information revealed that the VAV system amounted to $6,393,552.88 and the water source heat pump system amounted to $6,885,364.64. Also, on average the VAV system took 8 to 10 months to install, which was about two months less than the other system. Furthermore, two design choices were analyzed for the roof top units that would be installed with the VAV system. Based on the two designs, Design #1, which costs $13,849.42 and consists of (2) W16x40 laterally braced to (2) W21x55, is recommended for the raised platform. Overall, the recommended choice for a new mechanical system in the Northwest Building is a VAV system and this is largely based on the goals of the owners.

Schedule reduction was evaluated in analysis three by implementing a short interval production schedule for the demolition and structural steel aspect of 7700 Arlington Blvd. To solve coordination issues with these two trades the first SIP schedule created utilized a new sequence, but kept the same phasing plan. This schedule shaved nine weeks off the original schedule and saved $358,802.10 in general conditions costs. Since this schedule would not be considered a typical short interval production schedule, a new one was created by changing the phasing plan to include the Northwest and Southwest Building in phase one and the Main Building in phase two. This SIP schedule also had a new sequencing plan and ultimately reflected a non-traditional short interval production schedule much more accurately than the first one. This schedule shaved eleven weeks from the original schedule and $438,535.90 in general conditions costs. The recommendation from this analysis is through the use of a short interval production schedule, the project team can help save the owner money and time. As long as everyone in the project team understands what is involved with the schedule and all material is on time then implementing the SIP schedule with the new phasing and sequencing plan should prove to be successful.

A value engineering study was used on the fourth analysis for the development of flow diagrams and process charts to incorporate into technologies for use in the field. Big picture flow diagrams were first created to give a visual representation of the recommended SIP schedule from analysis three. The progressive collapse steel system was further analyzed to create detailed flow diagrams and process charts for the Southwest Building. Developing each diagram and chart to a worker's level was the ultimate goal for this analysis because workers should be well educated as to what the sequencing of work should be on a daily basis. In order for workers to have the accessibility of this pertinent information, hi-tech work stations were designed in Google SketchUp that incorporates a tablet for workers to view when necessary. The station would be used to hold the building drawings and it would also have a tablet, such as an iPad, installed directly into the front of the surface. A new program, Tekla BIMsight, was explored to determine the feasibility of using it in the field. It has been determined that due to the fast learning curve for the program that it would be useful for creating 3D sequencing plans of the flow diagrams and process charts. Slide shows would then be created for uses on the tablets incorporated in the hi-tech work stations to help the workers better understand how the project team wants construction to flow. It is recommended that project teams try BIMsight and incorporate it in the field because the program has a variety of beneficial uses.

Overall, each of the four analyses has attempted to help continue the improvement of the design and construction industry. The main reason that the IPD process map was created was to help project teams become more educated with the different coordination and communication levels on an IPD project. A review of a new VAV system revealed that if desired the owner would benefit from a new mechanical system in the Northwest Building. Also, through the creation of a new phasing and sequencing plan for a short interval production schedule, eleven weeks and general conditions savings could potentially be incorporated for 7700 Arlington Blvd. Lastly, the use of new work stations and a new program, BIMsight, would benefit workers by detailing sequencing plans to a level that could help everyone on the site on a daily basis. Ultimately, each analysis addressed an issue that can help define and create a more efficient means to construction collaboration within the industry.

10.0 References

[1]AIA. "AIA Document A295 - 2008." *General Conditions of the Contract for Integrated Project Delivery*. The American Institute of Architects, 2008. Print.

- The contract outlines the responsibilities of the owner, contractor, and architect for a project that incorporates the integrated project delivery method.

[2]AIA. "Integrated Project Delivery: A Guide." Version 1. The American Institute of Architects, 2007. Print.

- The guide is meant to assist users to understand the integrated project delivery from start to finish of a project.

[3]AIA. "Integrated Project Delivery: Case Studies." The American Institute of Architects, 2010. Print.

- Various case studies on successful and non-successful integrated project delivery methods are discussed in this research paper.

[4]CIC Research Program at Penn State. (2010) *"BIM Project Execution Planning Guide."* Version 2.0.

- This program is designed to help users create a BIM Project Execution Plan and can be used as a team resource to step through the procedure.

[5]GBA Associates LP. (2011) *"7700 Arlington Blvd.."* Accessed: 22 September 2011. <http://7700arlingtonblvd.com/dhhq.html>.

- 7700 Arlington Blvd.'s home page gives important information related to the building and information about the tenants.

[6]Home Depot, . "Lumber Costs." . Homer TLC, Inc., 2011. Web. 28 Mar 2012. <http://www.homedepot.com/>.

- The Home Depot website is an easily accessible website to find cost and material data for any sort of home improvement need.

[7]Raytheon Company. (2011) *"Raytheon Company: Customer Success is Our Mission."* Accessed: 22 September 2011. <http://www.raytheon.com/ourcompany/>.

- Raytheon's home page gives valuable information to the variety of defense, homeland security, and other markets that they are involved with.

[8]Reed Construction Data. (2011) *"RS Means Costworks Online Construction Cost Data."* Accessed: 22 September 2011. <https://www.meanscostworks.com/>.

- This is an online database to obtain different unit and square foot estimates for any type of project.

[9]RSMeans. (2010) *“RS Means Facilities Construction Cost Data, 2011.”* 26th Annual Edition.

- The RS Means book gives cost data for various materials and systems that can be used to perform quantity takeoffs and estimate reports.

[10]Sampson, Brian. "Set Up Ground Source Heat Pumps In Trane Trace." 2012. Print.

- This guideline helps set up a TRACE 700 model for a water source heat pump and was completed by a fellow Architectural Engineering student.

[11]Sandeen, Jeff, and Shane Fisher. "Introduction to Short Interval Production Schedules." AE 570 . PSU, State College. 27 October 2011. Lecture.

- The PowerPoint Lecture outlines what a short interval production schedule entails and projects completed by Hensel Phelps Construction that use SIPS.

[12]Tekla Corporation, . "Tekla USA." *Tekla BIMsight 1.4 takes BIM to the field with Windows tablets* . Trimble Company , 24 01 2012. Web. 28 Mar 2012. <http://www.tekla.com/us/about-us/news/pages/teklabimsight1.4.asp&xgt;.

- This article discusses the integration of BIMsight on tablets for use in the field in order to simplify certain coordination processes.

[13]U.S. Department of Energy. "Table E2A. Major Fuel Consumption (Btu) Intensities by End Use for All Buildings." 2003. Print.

- A collection of Major Fuel Energy Intensity data which is broken down for heating, cooling and other loads for various types of buildings.

[14]U.S. Green Building Council. (2011) *“U.S. Green Building Council.”* Accessed: 17 October 2011. <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220>.

- This site gives users access to a variety of LEED Scorecards that can be used to calculate the points obtained based on a project’s energy goals.

[15]WattMaster Controls, ."WHP - Water Source Heat Pump Design, Installation & Operations Manual." .WattMaster Controls, Inc., Copyright 2004. Web. 28 Mar 2012.

- A water source heat pump is defined in complete detail in the publication from general information to the sequence of operation.

[16]Wikipedia, . "Integrated project delivery." . Wikimedia Foundation, Inc.,, 01 12 2011. Web. 17 Mar 2012. <http://en.wikipedia.org/wiki/Integrated_project_delivery>.

- This site gives a short synopsis on what the history and background is on the integrated project delivery method.

[17]Wikipedia, . "Variable Air Volume." *Wikipedia*. Wikimedia Foundation, Inc., 30 11 2011. Web. 28 Mar 2012. <http://en.wikipedia.org/wiki/Variable_air_volume>.

- This site defines variable air volume and it also includes various benefits and drawbacks of using this type of system.

Appendix A

Existing Conditions Site Plan

N

LEGEND

- Parking & Staging
- Sub — Subcontractor Trailer
- GBA — GBA Trailer
- Davis Field — Davis Trailer
- Traffic Flow
- Truck Route
- Alt. Truck Route
- Gas Line
- Water Line
- Electric Line
- Sanitary Line
- Fire Hydrant
- Existing Light Fixtures
- Existing Fence
- Building Perimeter

7700 Arlington Blvd.
Falls Church, VA

Site Plan

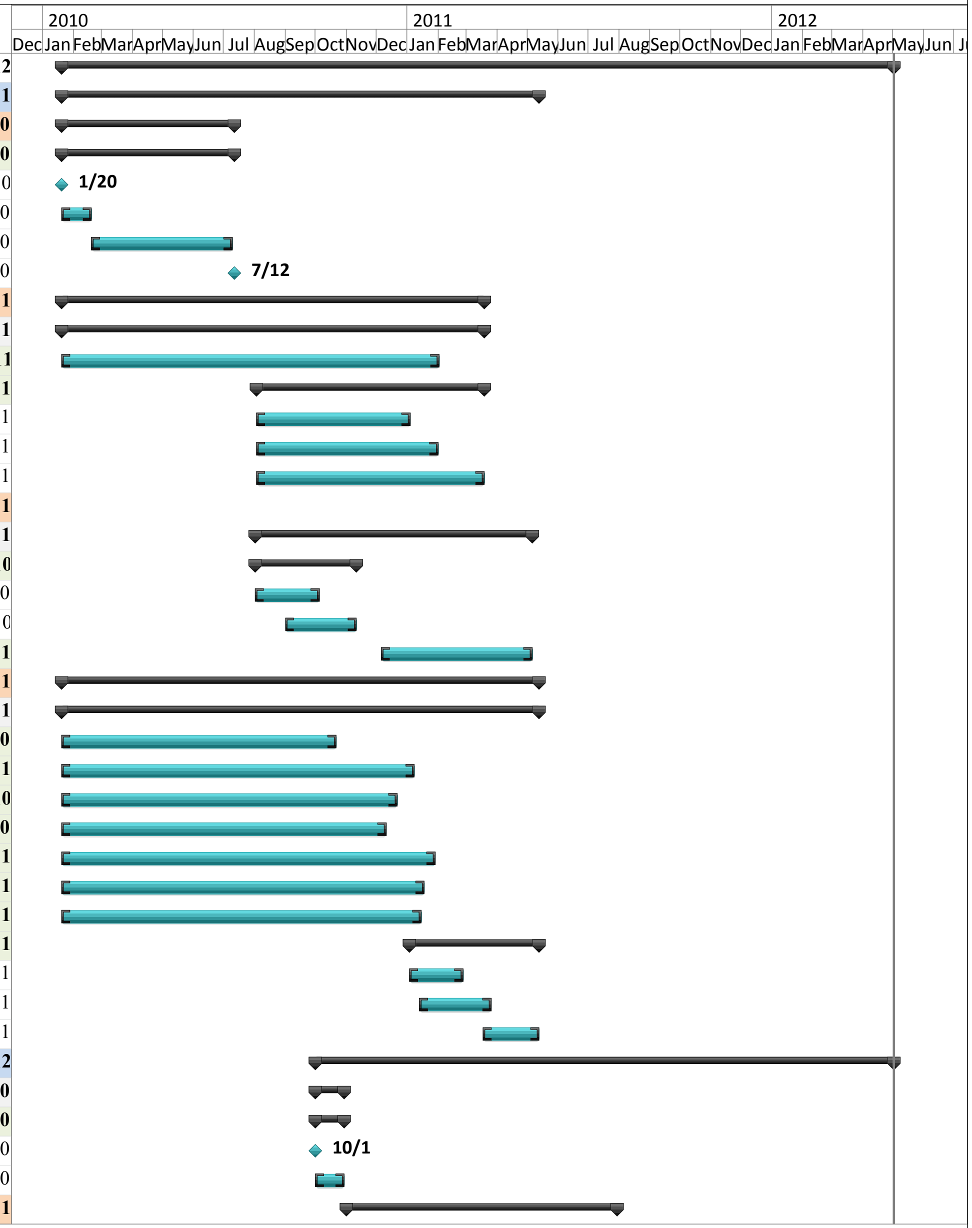
Christie Smith | 4/4/12

Scale: NTS

Appendix B

Detailed Project Schedule

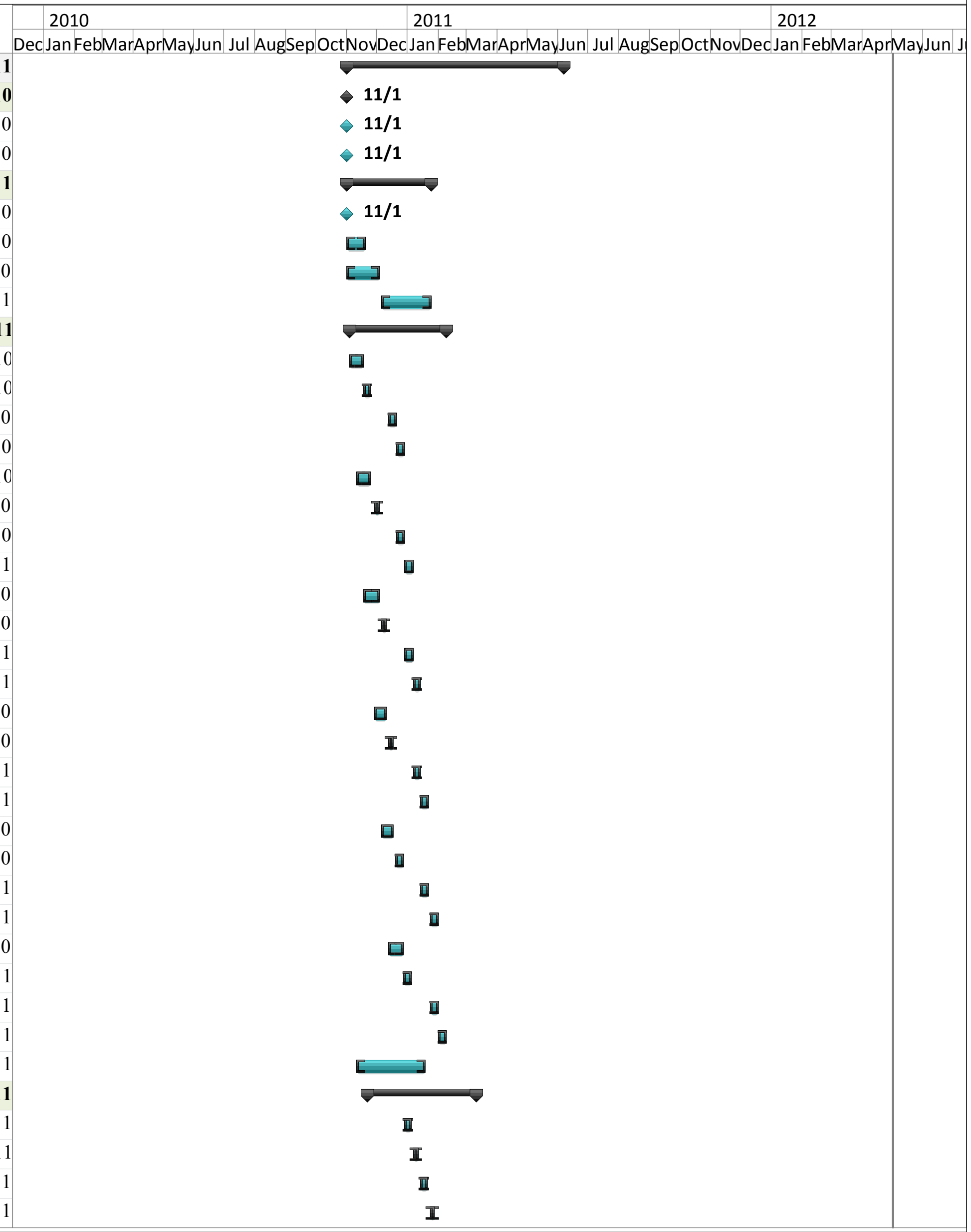
ID	Task Name	Duration	Start	Finish
1	**Schedule Summary**	**595 days**	**Wed 1/20/10**	**Tue 5/1/12**
3	**Pre-Construction**	**342 days**	**Wed 1/20/10**	**Thu 5/12/11**
4	**CMHQ SFO Release**	**123 days**	**Wed 1/20/10**	**Mon 7/12/10**
5	**General**	**123 days**	**Wed 1/20/10**	**Mon 7/12/10**
6	Re-Issue SFO	0 days	Wed 1/20/10	Wed 1/20/10
7	Prepare SFO Response	22 days	Wed 1/20/10	Thu 2/18/10
8	Evaluate SFO Responses	101 days	Fri 2/19/10	Fri 7/9/10
9	Award Contract	0 days	Mon 7/12/10	Mon 7/12/10
10	**Design**	**303 days**	**Wed 1/20/10**	**Fri 3/18/11**
11	**General**	**303 days**	**Wed 1/20/10**	**Fri 3/18/11**
12	**Base Building Procurement**	**270 days**	**Wed 1/20/10**	**Tue 2/1/11**
13	**Tenant Package**	**164 days**	**Tue 8/3/10**	**Fri 3/18/11**
14	Tenant Package Phase 1 - NW Bldg	110 days	Tue 8/3/10	Mon 1/3/11
15	Tenant Package Phase 1 - Main Bldg	130 days	Tue 8/3/10	Mon 1/31/11
16	Tenant Package Phase 2 - SW Bldg	164 days	Tue 8/3/10	Fri 3/18/11
17	**Permits**	**199 days**	**Mon 8/2/10**	**Thu 5/5/11**
18	**General**	**199 days**	**Mon 8/2/10**	**Thu 5/5/11**
19	**Base Building Procurement**	**73 days**	**Mon 8/2/10**	**Wed 11/10/10**
20	Obtain Demo Permits	46 days	Mon 8/2/10	Mon 10/4/10
21	Obtain Base Building Permits	51 days	Wed 9/1/10	Wed 11/10/10
22	**Tenant Improvements**	**109 days**	**Mon 12/6/10**	**Thu 5/5/11**
23	**Procurement**	**342 days**	**Wed 1/20/10**	**Thu 5/12/11**
24	**General**	**342 days**	**Wed 1/20/10**	**Thu 5/12/11**
25	**Demo / Abatement Procurement**	**197 days**	**Wed 1/20/10**	**Thu 10/21/10**
26	**Façade Procurement**	**253 days**	**Wed 1/20/10**	**Fri 1/7/11**
27	**Precast Procurement**	**240 days**	**Wed 1/20/10**	**Tue 12/21/10**
28	**Progressive Collapse Procurement**	**233 days**	**Wed 1/20/10**	**Fri 12/10/10**
29	**Elevator Procurement**	**268 days**	**Wed 1/20/10**	**Fri 1/28/11**
30	**Mechanical Procurement**	**259 days**	**Wed 1/20/10**	**Mon 1/17/11**
31	**Electrical Procurement**	**258 days**	**Wed 1/20/10**	**Fri 1/14/11**
32	**Tenant Package Procurement**	**94 days**	**Mon 1/3/11**	**Thu 5/12/11**
33	Tenant Package Phase 1 - NW Bldg	40 days	Mon 1/3/11	Fri 2/25/11
34	Tenant Package Phase 1 - Main Bldg	52 days	Thu 1/13/11	Fri 3/25/11
35	Tenant Package Phase 2 - SW Bldg	40 days	Fri 3/18/11	Thu 5/12/11
36	**Construction**	**413 days**	**Fri 10/1/10**	**Tue 5/1/12**
37	**General**	**21 days**	**Fri 10/1/10**	**Fri 10/29/10**
38	**General**	**21 days**	**Fri 10/1/10**	**Fri 10/29/10**
39	Mobilize on Site	0 days	Fri 10/1/10	Fri 10/1/10
40	Mobilize / Site Preparation	21 days	Fri 10/1/10	Fri 10/29/10
41	**Phase 1 - 500,000 sf**	**195 days**	**Mon 11/1/10**	**Fri 7/29/11**



7700 Arlington Blvd.
Falls Church, VA

Milestone | Project Summary | Start-only
Summary | Manual Task | Finish-only

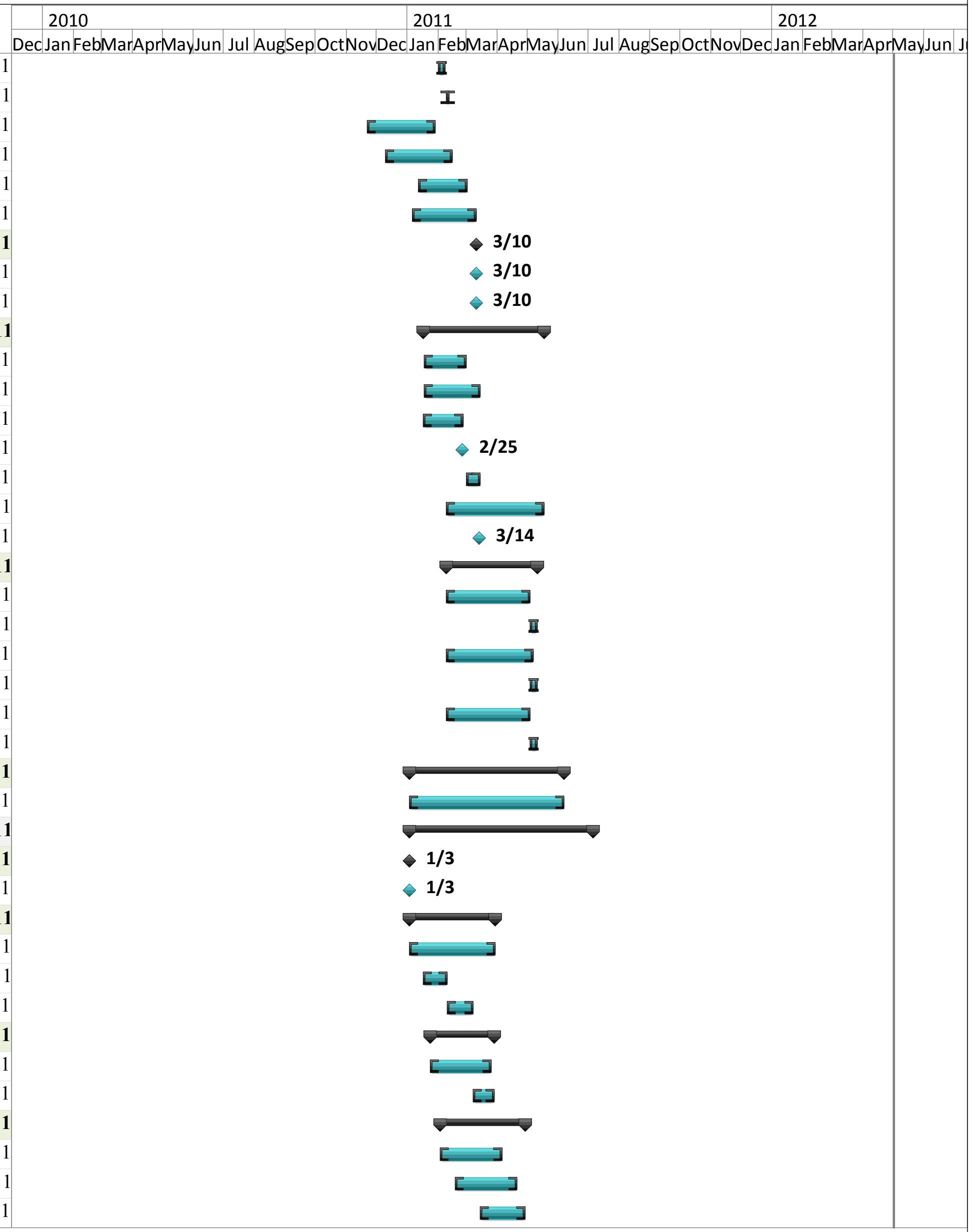
ID	Task Name	Duration	Start	Finish
42	**NW Building**	**156 days**	**Mon 11/1/10**	**Mon 6/6/11**
43	**General**	**0 days**	**Mon 11/1/10**	**Mon 11/1/10**
44	NW Building Addition Vacated	0 days	Mon 11/1/10	Mon 11/1/10
45	Begin NW Bldg Renovation	0 days	Mon 11/1/10	Mon 11/1/10
46	**Demo / Abatement**	**61 days**	**Mon 11/1/10**	**Mon 1/24/11**
47	Begin Demolition - NW	0 days	Mon 11/1/10	Mon 11/1/10
48	Interior Demo at Perm for Progressive Collapse - NW	15 days	Mon 11/1/10	Fri 11/19/10
49	Exterior Demo - NW	25 days	Mon 11/1/10	Fri 12/3/10
50	Demo / Structural Work Roof Equipment - NW	36 days	Mon 12/6/10	Mon 1/24/11
51	**Structure**	**69 days**	**Thu 11/4/10**	**Tue 2/8/11**
52	Core Drill / FRP Ftgs for Prog Collapse - Seq 1 - NW	10 days	Thu 11/4/10	Wed 11/17/10
53	FRP Cols & Beams for Prog Collapse - Seq 1 - NW	5 days	Thu 11/18/10	Wed 11/24/10
54	Erect Steel for Prog Collapse - Seq 1 - NW	6 days	Mon 12/13/10	Mon 12/20/10
55	Detail Steel for Prog Collapse - Seq 1 - NW	6 days	Tue 12/21/10	Tue 12/28/10
56	Core Drill / FRP Ftgs for Prog Collapse - Seq 2 - NW	10 days	Thu 11/11/10	Wed 11/24/10
57	FRP Cols & Beams for Prog Collapse - Seq 2 - NW	5 days	Mon 11/29/10	Fri 12/3/10
58	Erect Steel for Prog Collapse - Seq 2 - NW	6 days	Tue 12/21/10	Tue 12/28/10
59	Detail Steel for Prog Collapse - Seq 2 - NW	7 days	Wed 12/29/10	Thu 1/6/11
60	Core Drill / FRP Ftgs for Prog Collapse - Seq 3 - NW	12 days	Thu 11/18/10	Fri 12/3/10
61	FRP Cols & Beams for Prog Collapse - Seq 3 - NW	5 days	Mon 12/6/10	Fri 12/10/10
62	Erect Steel for Prog Collapse - Seq 3 - NW	7 days	Wed 12/29/10	Thu 1/6/11
63	Detail Steel for Prog Collapse - Seq 3 - NW	5 days	Fri 1/7/11	Thu 1/13/11
64	Core Drill / FRP Ftgs for Prog Collapse - Seq 4 - NW	10 days	Mon 11/29/10	Fri 12/10/10
65	FRP Cols & Beams for Prog Collapse - Seq 4 - NW	5 days	Mon 12/13/10	Fri 12/17/10
66	Erect Steel for Prog Collapse - Seq 4 - NW	5 days	Fri 1/7/11	Thu 1/13/11
67	Detail Steel for Prog Collapse - Seq 4 - NW	6 days	Fri 1/14/11	Fri 1/21/11
68	Core Drill / FRP Ftgs for Prog Collapse - Seq 5 - NW	10 days	Mon 12/6/10	Fri 12/17/10
69	FRP Cols & Beams for Prog Collapse - Seq 5 - NW	6 days	Mon 12/20/10	Mon 12/27/10
70	Erect Steel for Prog Collapse - Seq 5 - NW	6 days	Fri 1/14/11	Fri 1/21/11
71	Detail Steel for Prog Collapse - Seq 5 - NW	6 days	Mon 1/24/11	Mon 1/31/11
72	Core Drill / FRP Ftgs for Prog Collapse - Seq 6 - NW	11 days	Mon 12/13/10	Mon 12/27/10
73	FRP Cols & Beams for Prog Collapse - Seq 6 - NW	6 days	Tue 12/28/10	Tue 1/4/11
74	Erect Steel for Prog Collapse - Seq 6 - NW	6 days	Mon 1/24/11	Mon 1/31/11
75	Detail Steel for Prog Collapse - Seq 6 - NW	6 days	Tue 2/1/11	Tue 2/8/11
76	Seismic Bracing - NW	49 days	Thu 11/11/10	Tue 1/18/11
77	**Façade / Roof**	**79 days**	**Mon 11/22/10**	**Thu 3/10/11**
78	Erect Precast - Seq 1 - NW	5 days	Wed 12/29/10	Tue 1/4/11
79	Erect Precast - Seq 2 - NW	3 days	Fri 1/7/11	Tue 1/11/11
80	Erect Precast - Seq 3 - NW	5 days	Fri 1/14/11	Thu 1/20/11
81	Erect Precast - Seq 4 - NW	4 days	Mon 1/24/11	Thu 1/27/11



7700 Arlington Blvd.
Falls Church, VA

Milestone ◆ | Project Summary | Start-only
Summary | Manual Task | Finish-only

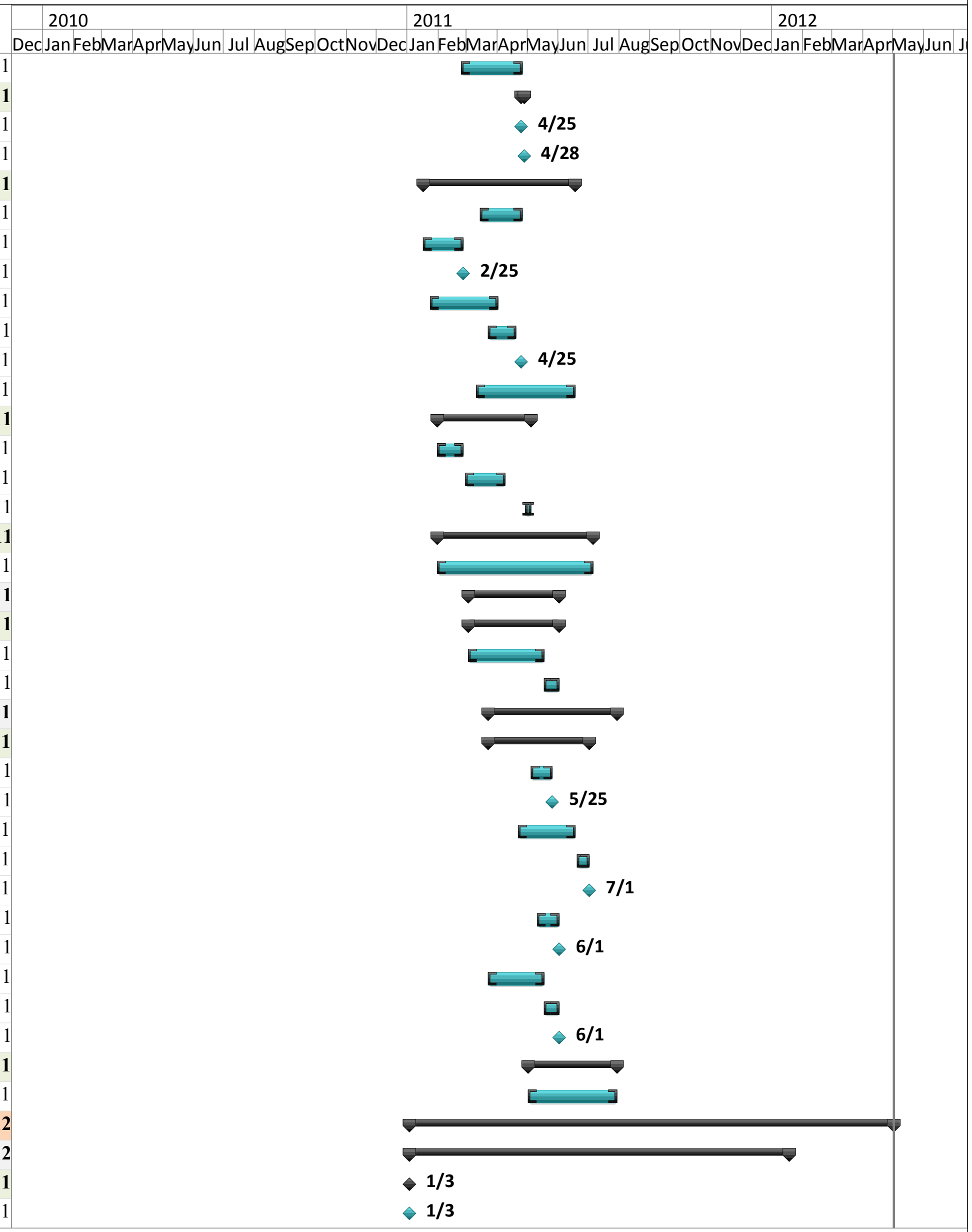
ID	Task Name	Duration	Start	Finish
82	Erect Precast - Seq 5 - NW	5 days	Tue 2/1/11	Mon 2/7/11
83	Erect Precast - Seq 6 - NW	3 days	Wed 2/9/11	Fri 2/11/11
84	Interior Structural Framing for Windows - NW	50 days	Mon 11/22/10	Fri 1/28/11
85	Façade Hardening - NW	47 days	Fri 12/10/10	Mon 2/14/11
86	Replace Windows - NW	35 days	Wed 1/12/11	Tue 3/1/11
87	New Roofing - NW	46 days	Thu 1/6/11	Thu 3/10/11
88	**Enclosure Milestones**	**0 days**	**Thu 3/10/11**	**Thu 3/10/11**
89	Roof Complete - NW	0 days	Thu 3/10/11	Thu 3/10/11
90	Building Dry - NW	0 days	Thu 3/10/11	Thu 3/10/11
91	**Building Cores / Shell Infrastructure**	**87 days**	**Mon 1/17/11**	**Tue 5/17/11**
92	Refurbish MEP & Equipment (Existing) - NW	30 days	Tue 1/18/11	Mon 2/28/11
93	MEP Rough-ins & Equipment - NW	40 days	Tue 1/18/11	Mon 3/14/11
94	Set & Energize Switchboard - NW	30 days	Mon 1/17/11	Fri 2/25/11
95	Permanent Power Available - NW	0 days	Fri 2/25/11	Fri 2/25/11
96	Equipment Checkout / Startup (Existing) - NW	10 days	Tue 3/1/11	Mon 3/14/11
97	Finishes - NW	70 days	Wed 2/9/11	Tue 5/17/11
98	Conditioned Air Available - NW	0 days	Mon 3/14/11	Mon 3/14/11
99	**Elevators**	**65 days**	**Wed 2/9/11**	**Tue 5/10/11**
100	Refurbish Ex Elevators N - NW	60 days	Wed 2/9/11	Tue 5/3/11
101	Install Elevator Cabs N - NW	5 days	Wed 5/4/11	Tue 5/10/11
102	Refurbish Ex Elevators C - NW	63 days	Wed 2/9/11	Fri 5/6/11
103	Install Elevator Cabs C - NW	5 days	Wed 5/4/11	Tue 5/10/11
104	Refurbish Ex Elevators S - NW	60 days	Wed 2/9/11	Tue 5/3/11
105	Install Elevator Cabs S - NW	5 days	Wed 5/4/11	Tue 5/10/11
106	**Tenant Improvements**	**111 days**	**Mon 1/3/11**	**Mon 6/6/11**
107	Tenant Improvements - NW	111 days	Mon 1/3/11	Mon 6/6/11
108	**Main Building**	**132 days**	**Mon 1/3/11**	**Tue 7/5/11**
109	**General**	**0 days**	**Mon 1/3/11**	**Mon 1/3/11**
110	Main Building Vacated	0 days	Mon 1/3/11	Mon 1/3/11
111	**Demo / Abatement**	**62 days**	**Mon 1/3/11**	**Tue 3/29/11**
112	Abatement / Interior Demo - Main	62 days	Mon 1/3/11	Tue 3/29/11
113	Demo Café Structure - Main	18 days	Mon 1/17/11	Wed 2/9/11
114	Demo / Structural Work Roof Equipment - NW	18 days	Thu 2/10/11	Mon 3/7/11
115	**Structure**	**46 days**	**Mon 1/24/11**	**Mon 3/28/11**
116	Seismic Bracing - Main	45 days	Mon 1/24/11	Fri 3/25/11
117	Structure @ MEP Roof Equipment - Main	15 days	Tue 3/8/11	Mon 3/28/11
118	**Façade / Roof**	**61 days**	**Thu 2/3/11**	**Thu 4/28/11**
119	Interior Structural Framing for Windows - Main	44 days	Thu 2/3/11	Tue 4/5/11
120	Façade Hardening - Main	44 days	Fri 2/18/11	Wed 4/20/11
121	Replace Windows - Main	33 days	Tue 3/15/11	Thu 4/28/11



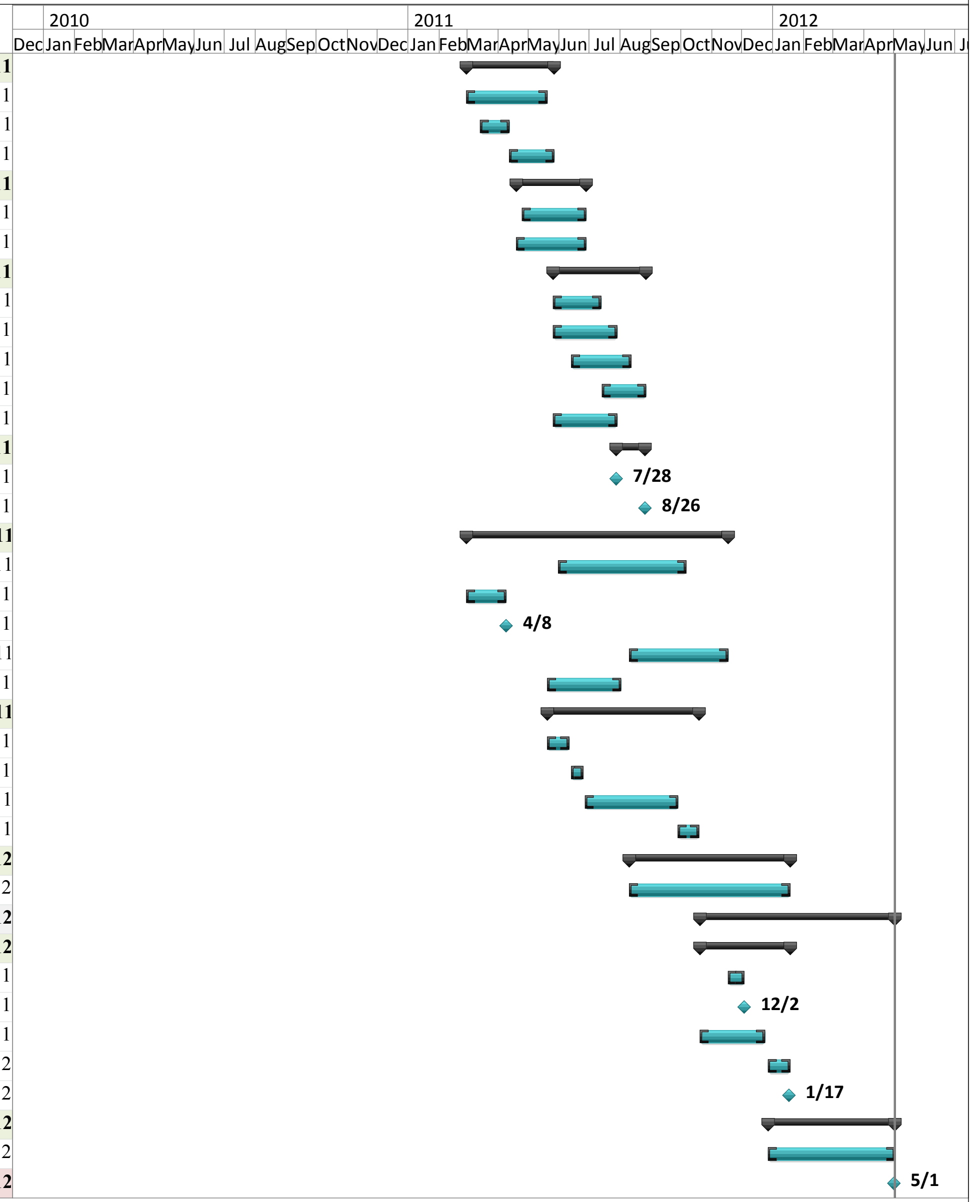
7700 Arlington Blvd.
Falls Church, VA

Milestone | Project Summary | Start-only
Summary | Manual Task | Finish-only

ID	Task Name	Duration	Start	Finish
122	Repair / New Roofing - Main	43 days	Thu 2/24/11	Mon 4/25/11
123	**Enclosure Milestones**	**3 days**	**Mon 4/25/11**	**Thu 4/28/11**
124	Roof Complete - Main	0 days	Mon 4/25/11	Mon 4/25/11
125	Building Dry - Main	0 days	Thu 4/28/11	Thu 4/28/11
126	**Building Cores / Shell Infrastructure**	**110 days**	**Mon 1/17/11**	**Fri 6/17/11**
127	Set MEP Equipment - Main	30 days	Tue 3/15/11	Mon 4/25/11
128	Set & Energize Switchboard - Main	30 days	Mon 1/17/11	Fri 2/25/11
129	Permanent Power Available - Main	0 days	Fri 2/25/11	Fri 2/25/11
130	Rough-In MEP - Main	50 days	Mon 1/24/11	Fri 4/1/11
131	Equipment Checkout / Startup Roof Equipment - Main	20 days	Wed 3/23/11	Tue 4/19/11
132	Conditioned Air Available - Main	0 days	Mon 4/25/11	Mon 4/25/11
133	Finishes - Main	71 days	Fri 3/11/11	Fri 6/17/11
134	**Elevators**	**68 days**	**Mon 1/31/11**	**Wed 5/4/11**
135	Modify Ex Elevator Shaft - Main	20 days	Mon 1/31/11	Fri 2/25/11
136	Install New Holeless Hydraulic Elevator - Main	30 days	Mon 2/28/11	Fri 4/8/11
137	Install Elevator Cab - Main	4 days	Fri 4/29/11	Wed 5/4/11
138	**Tenant Improvements**	**112 days**	**Mon 1/31/11**	**Tue 7/5/11**
139	Tenant Improvements - Main	112 days	Mon 1/31/11	Tue 7/5/11
140	**Sitework**	**65 days**	**Thu 3/3/11**	**Wed 6/1/11**
141	**General**	**65 days**	**Thu 3/3/11**	**Wed 6/1/11**
142	Site Improvements	54 days	Thu 3/3/11	Tue 5/17/11
143	Final Inspections Site Improvements	11 days	Wed 5/18/11	Wed 6/1/11
144	**Complete / Inspections**	**93 days**	**Wed 3/23/11**	**Fri 7/29/11**
145	**Building Cores / Shell Infrastructure**	**73 days**	**Wed 3/23/11**	**Fri 7/1/11**
146	Elevator Final Inspections - Main	15 days	Thu 5/5/11	Wed 5/25/11
147	Elevators Complete - Main	0 days	Wed 5/25/11	Wed 5/25/11
148	Base Bldg Systems Start-up & Commissioning - Main	41 days	Fri 4/22/11	Fri 6/17/11
149	Base Bldg Final Inspections - Main	10 days	Mon 6/20/11	Fri 7/1/11
150	Base Bldg Final Inspections Completed - Main	0 days	Fri 7/1/11	Fri 7/1/11
151	Elevator Final Inspections - NW	16 days	Wed 5/11/11	Wed 6/1/11
152	Elevators Complete - NW	0 days	Wed 6/1/11	Wed 6/1/11
153	Base Bldg Systems Start-up & Commissioning - NW	40 days	Wed 3/23/11	Tue 5/17/11
154	Base Bldg Final Inspections - NW	11 days	Wed 5/18/11	Wed 6/1/11
155	Base Bldg Final Inspections Completed - NW	0 days	Wed 6/1/11	Wed 6/1/11
156	**Tenant Improvements**	**65 days**	**Mon 5/2/11**	**Fri 7/29/11**
157	Tenant Improvements Complete - Main & NW	65 days	Mon 5/2/11	Fri 7/29/11
158	**Phase 2 - 147,000 sf**	**347 days**	**Mon 1/3/11**	**Tue 5/1/12**
159	**SW Building**	**272 days**	**Mon 1/3/11**	**Tue 1/17/12**
160	**General**	**0 days**	**Mon 1/3/11**	**Mon 1/3/11**
161	SW Bldg Building Vacated	0 days	Mon 1/3/11	Mon 1/3/11



ID	Task Name	Duration	Start	Finish
162	**Demo / Abatement**	**64 days**	**Mon 2/28/11**	**Thu 5/26/11**
163	Abatement / Interior Demo - SW	59 days	Mon 2/28/11	Thu 5/19/11
164	Exterior Demo - SW	21 days	Mon 3/14/11	Mon 4/11/11
165	Demo / Structural Work Roof Equipment - SW	33 days	Tue 4/12/11	Thu 5/26/11
166	**Structure**	**50 days**	**Tue 4/19/11**	**Mon 6/27/11**
167	Seismic Bracing - SW	46 days	Mon 4/25/11	Mon 6/27/11
168	Progressive Collapse - SW	50 days	Tue 4/19/11	Mon 6/27/11
169	**Façade / Roof**	**67 days**	**Thu 5/26/11**	**Fri 8/26/11**
170	Precast - SW	34 days	Thu 5/26/11	Tue 7/12/11
171	Interior Structural Framing for Windows - SW	46 days	Thu 5/26/11	Thu 7/28/11
172	Façade Hardening - SW	44 days	Mon 6/13/11	Thu 8/11/11
173	Replace Windows - SW	32 days	Thu 7/14/11	Fri 8/26/11
174	Repair / New Roofing - SW	46 days	Thu 5/26/11	Thu 7/28/11
175	**Enclosure Milestones**	**21 days**	**Thu 7/28/11**	**Fri 8/26/11**
176	Roof Complete - SW	0 days	Thu 7/28/11	Thu 7/28/11
177	Building Dry - SW	0 days	Fri 8/26/11	Fri 8/26/11
178	**Building Cores / Shell Infrastructure**	**188 days**	**Mon 2/28/11**	**Wed 11/16/11**
179	Rough-In MEP & Equipment - SW	92 days	Tue 5/31/11	Wed 10/5/11
180	Set & Energize Switchboard - SW	30 days	Mon 2/28/11	Fri 4/8/11
181	Permanent Power Available - SW	0 days	Fri 4/8/11	Fri 4/8/11
182	Finishes - SW	71 days	Wed 8/10/11	Wed 11/16/11
183	Floor Infill @ Ramp - SW	52 days	Fri 5/20/11	Mon 8/1/11
184	**Elevators**	**108 days**	**Fri 5/20/11**	**Tue 10/18/11**
185	Erect Steel / Structural Demo at New Elevator - SW	16 days	Fri 5/20/11	Fri 6/10/11
186	Construct Shaft & Enclosure at New Elevator - SW	10 days	Mon 6/13/11	Fri 6/24/11
187	Install New Elevators - SW	67 days	Mon 6/27/11	Tue 9/27/11
188	Install New Elevators Cabs - SW	15 days	Wed 9/28/11	Tue 10/18/11
189	**Tenant Improvements**	**115 days**	**Wed 8/10/11**	**Tue 1/17/12**
190	Tenant Improvements - SW	115 days	Wed 8/10/11	Tue 1/17/12
191	**Complete / Inspections**	**139 days**	**Thu 10/20/11**	**Tue 5/1/12**
192	**Building Cores / Shell Infrastructure**	**64 days**	**Thu 10/20/11**	**Tue 1/17/12**
193	Elevator Final Inspections - SW	12 days	Thu 11/17/11	Fri 12/2/11
194	New Elevators Complete - SW	0 days	Fri 12/2/11	Fri 12/2/11
195	Base Bldg Systems Start-up & Commissioning - SW	47 days	Thu 10/20/11	Fri 12/23/11
196	Base Bldg Final Inspections - SW	16 days	Tue 12/27/11	Tue 1/17/12
197	Base Bldg Final Inspections Completed - SW	0 days	Tue 1/17/12	Tue 1/17/12
198	**Tenant Improvements**	**91 days**	**Tue 12/27/11**	**Tue 5/1/12**
199	Tenant Improvements Complete - SW	91 days	Tue 12/27/11	Tue 5/1/12
200	**Building Completion**	**0 days**	**Tue 5/1/12**	**Tue 5/1/12**



7700 Arlington Blvd.
Falls Church, VA

Milestone	◆	Project Summary		Start-only	⊏
Summary		Manual Task		Finish-only	⊐

Appendix C

Site Plans of Site Layout Planning

N

LEGEND

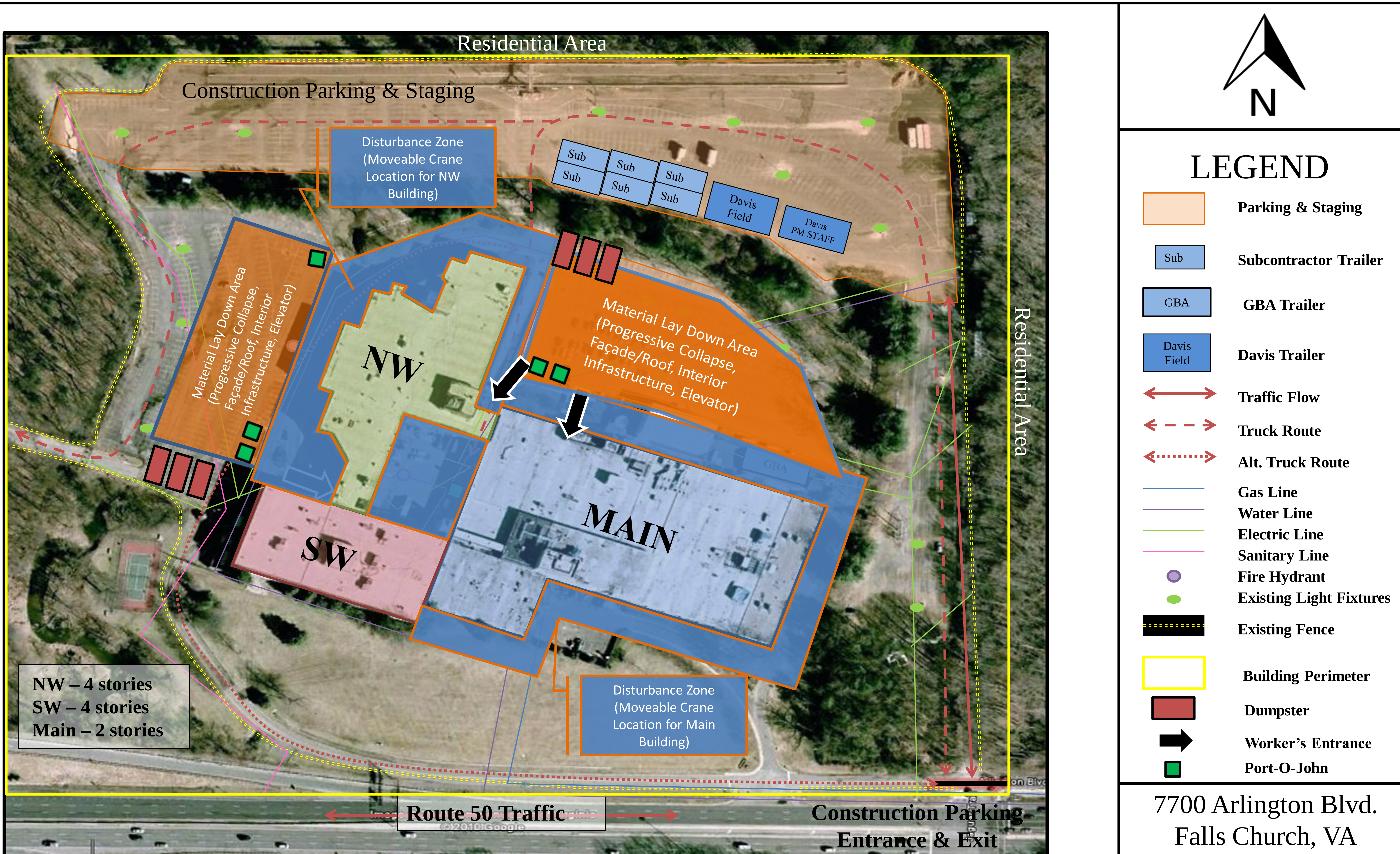
- Parking & Staging
- Sub — Subcontractor Trailer
- GBA — GBA Trailer
- Davis Field — Davis Trailer
- Traffic Flow
- Truck Route
- Alt. Truck Route
- Gas Line
- Water Line
- Electric Line
- Sanitary Line
- Fire Hydrant
- Existing Light Fixtures
- Existing Fence
- Building Perimeter

7700 Arlington Blvd.
Falls Church, VA

Mobilization

Scale: NTS

Christie Smith | 4/4/12



7700 Arlington Blvd.
Falls Church, VA

Phase 1

Christie Smith | 4/4/12

Scale: NTS

N

LEGEND

	Parking & Staging
Sub	Subcontractor Trailer
GBA	GBA Trailer
Davis Field	Davis Trailer
	Traffic Flow
	Truck Route
	Alt. Truck Route
	Gas Line
	Water Line
	Electric Line
	Sanitary Line
	Fire Hydrant
	Existing Light Fixtures
	Existing Fence
	Building Perimeter
	Dumpster
	Worker's Entrance
	Port-O-John

7700 Arlington Blvd.
Falls Church, VA

Phase II

Christie Smith | 4/4/12

Scale: NTS

Appendix D

General Conditions Estimate

Table D-1 | 7700 Arlington Blvd. General Conditions Estimate				
Personnel				
Title	**Unit Rate**	**Unit**	**Quantity**	**Total Cost**
Senior Superintendent	$4,082.00	Week	47.9	$195,527.80
Superintendent – Main Bldg	$3,627.00	Week	37	$134,199.00
Assistant Superintendent – Main Bldg	$1,979.00	Week	34.7	$68,671.30
Senior Superintendent – NW & SW Bldg	$3,521.00	Week	56.3	$198,232.30
Assistant Superintendent – NW Bldg	$2,884.00	Week	30.3	$87,385.20
Superintendent – NW & SW Bldg	$2,662.00	Week	12.1	$32,210.20
Assistant Superintendent – Site	$2,070.00	Week	47.9	$99,153.00
Safety Manager	$2,360.00	Week	56.4	$133,104.00
Layout Engineer	$2,342.00	Week	52.1	$122,018.20
Assistant Layout Engineer	$4,093.00	Week	39.0	$159,627.00
Project Executive	$1,789.00	Week	86.9	$155,464.10
Senior Project Manager	$3,536.00	Week	74.0	$261,664.00
Project Manager	$4,138.00	Week	30.3	$125,381.40
Project Manager – NW & SW Bldg	$2,812.00	Week	60.7	$170,688.40
Project Coordinator	$2,678.00	Week	58.6	$156,930.80
MEP Coordinator	$2,149.00	Week	78.3	$168,266.70
Project Scheduler	$672.00	Week	52.1	$35,011.20
Project Engineer – Main Bldg	$1,759.00	Week	73.9	$129,990.10
Project Engineer – NW & SW Bldg	$1,638.00	Week	69.4	$113,677.20
Project Engineer – NW & SW Bldg	$1,789.00	Week	60.7	$108,592.30
Project Administrator	$547.00	Week	78.3	$42,830.10
Project Accounting	$264.00	Week	87	$22,968.00
Yard Delivery	$198.00	Week	65.1	$12,889.80
Dump Truck Delivery	$281.00	Week	65.1	$18,293.1
			Total	**$2,752,775.20**
Jobsite Operations				
Title	**Unit Rate**	**Unit**	**Quantity**	**Total Cost**
Document Reproduction – Construction	$40,000.00	LS	1	$40,000.00
Document Reproduction – As Builts	$10,000.00	LS	1	$10,000.00
Progress Photos	$500.00	Month	20	$10,000.00
Overnight & Hand Delivery	$750.00	Month	21	$15,750.00
Field Office Expense	$1,500.00	Month	18	$27,000.00
Misc Job Expense – Office	$200.00	Month	18	$3,600.00
Misc Job Expense – Field	$200.00	Month	18	$3,600.00
Copier / Fax / Printer – Monthly	$1,000.00	Month	18	$18,000.00
It / Network – Set up System	$20,000.00	LS	1	$20,000.00
Computer / LAN / Misc. IT	$500.00	Month	21	$10,500.00
Field Telephone – Hook-up	$1,000.00	LS	1	$1,000.00
Field Telephone – Monthly (DSL + Reg)	$750.00	Month	19	$14,250.00
Survey / Layout Equipment	$400.00	Month	9	$3,600.00
Two-way Radio	$75.00	Month	12	$900.00
Equipment Rental	$500.00	Month	15.1	$7,550.00
			Total	**$185,750.00**

Table D-2 | 7700 Arlington Blvd. General Conditions Estimate				
Safety, Clean up, Health				
Title	**Unit Rate**	**Unit**	**Quantity**	**Total Cost**
Trash Carts	$150.00	Month	15.1	$2,265.00
Clean-up Labor 1	$1,306.00	Week	25.8	$33,694.80
Clean-up Labor 2	$1,306.00	Week	25.8	$33,694.80
Clean-up Material	$100.00	Week	65.3	$6,530.00
Dumpers	$450.00	Ld	377	$169,650.00
General Health & Safety	$750.00	Month	15.1	$11,325.00
First Aid Kit & Supplies	$200.00	Month	18	$3,600.00
Fire Extinguishers	$250.00	Month	18	$4,500.00
Temporary Toilets	$2,000.00	Month	15.1	$30,200.00
Portable Water	$200.00	Month	15.1	$3,020.00
Head, Hearing & Eye Protection	$300.00	Month	15.1	$4,530.00
			Total	**$298,479.60**
Permits, Insurance, Bonds				
Title	**Unit Rate**	**Unit**	**Quantity**	**Total Cost**
Permit Expediting	$5,000.00	LS	1	$5,000.00
Certificate of Occupancy	$2,000.00	LS	1	$2,000.00
Preconstruction Survey	$10,000.00	LS	1	$10,000.00
			Total	$17,000.00
Punch List & Close Out				
Title	**Unit Rate**	**Unit**	**Quantity**	**Total Cost**
Warranty / Punchlist – Material	$15,000.00	LS	1	$15,000.00
Warranty / Punchlist – Labor	$2,000.00	Week	12	$24,000.00
			Total	**$39,000.00**

Assumptions:

- Personnel costs include cell phone, car, and other items
- Items do not include tax

Table D-3 | 7700 Arlington Blvd. General Conditions Estimate Summary	
Category	**Total Cost**
Personnel	$2,752,775.20
Jobsite Operations	$185,750.00
Safety, Clean up, Health	$298,479.60
Permits, Insurance, Bonds	$17,000.00
Punch List & Close Out	$39,000.00
General Conditions Total Estimate	**$3,293,004.80**

Appendix E

Detailed Structural System Estimate

Table E-1 | Progressive Collapse Steel Estimate Take-Off Charts (Segments A & B)

Columns

Type	Length (ft)	# of Sections (12'=4, 14'=4, 16'=3)	Quantity	Total Columns w/ Sections
HSS 6x6x5/16	47	4	6	24
HSS 7x7x5/16	47	4	3	12
HSS 8x8x5/16	47	4	4	16
HSS 9x9x1/2	47	4	42	168
HSS 10x10x1/2	47	3	9	27
HSS 12x12x5/8	47	3	1	3
HSS 12x12x1/2	47	3	2	6

Channels

Type	Length	Quantity	Total LF
C6x8.2	2'-3"	43	96.75
C6x8.2	2'-9"	38	104.5
C6x8.2	3'-0"	7	21
C6x8.2	4'-6"	4	18
C6x8.2	5'-0"	1	5
C8x11.5	2'-9"	74	203.5
C8x11.5	3'-0"	4	12
C8x11.5	3'-6"	31	108.5
C8x11.5	5'-0"	3	15
C8x11.5	6'-0"	10	60
C8x11.5	8'-6"	5	42.5

Cap Plates

Type	Unit	Volume (in3)	Density of Steel (lbs/in^3)	Weight (lbs)	Quantity
17x10x1	LB	170	0.284	48.28	6
18x10x1	LB	180	0.284	51.12	1
18x10x1-1/4	LB	225	0.284	63.9	5
18x10x1-1/2	LB	270	0.284	76.68	1
19x10x2	LB	380	0.284	107.92	1
20x10x1-1/2	LB	300	0.284	85.2	2
20x10x1-3/4	LB	350	0.284	99.4	27
20x10x2	LB	400	0.284	113.6	1
20x11x1-3/4	LB	385	0.284	109.34	1
22-1/2x10x1-1/2	LB	337.5	0.284	95.85	1
22-1/2x10x2	LB	450	0.284	127.8	9
33-1/2x10x2	LB	670	0.284	190.28	1
33-1/2x11x1-3/4	LB	644.875	0.284	183.14	5
35-1/2x11x1-3/4	LB	683.375	0.284	194.08	3
36x13x1-3/4	LB	819	0.284	232.6	3

Base Plates

Type	Unit	Volume (in3)	Density of Steel (lbs/in^3)	Weight (lbs)	Quantity
12x12x3/4	LB	108	0.284	30.67	6
13x13x3/4	LB	126.75	0.284	36	3
14x14x3/4	LB	147	0.284	41.75	4
15x15x3/4	LB	168.75	0.284	47.93	3
15x15x1	LB	225	0.284	63.9	5
15x15x1-1/4	LB	281.25	0.284	79.88	13
15x15x1-1/2	LB	337.5	0.284	95.85	2
16x16x1-1/2	LB	384	0.284	109.06	12
16x16x1-1/4	LB	320	0.284	90.88	3
17x17x1-1/2	LB	433.5	0.284	123.11	1
18x18x1-1/2	LB	486	0.284	138.02	7
18x18x1-1/4	LB	405	0.284	115.02	8

Table E-1 | Progressive Collapse Steel Estimate Take-Off Charts (Segments A & B)			
Beams			
Type	**Length (ft)**	**Quantity**	**Total LF**
W24x103	11	2	22
W24x103	22	55	1210
W24x131	22	14	308
W24x146	31.1	4	124.4
W14x61	22	1	22
Angle Framing			
Type	**Length (ft)**	**Quantity**	**Total LF**
Kickers – 3x3x3/8	8	55	440
Anchor Bolts			
Type	**Quantity**	**Unit**	**Total # Sets**
¾" Diameter x 12" long	67	Set	67

Assumptions:

- The HSS columns that were taken off were placed into the closest category listed in RS Means.
- Columns will be connected to existing footings for Segments A & B
- Interpolation was done in order to take off the steel members
- Assuming the biggest size for the kickers based on the type of system
- Assuming any welding that needs to be done is included with the column and steel member pricing
- Used http://hypertextbook.com/facts/2004/KarenSutherland.shtml to get the density of steel

Table E-2 | Progressive Collapse Steel Estimate Pricing (Segments A & B)

Columns

Description	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
HSS 6x6x1/4 (12' Section)	36	Ea.	$305.00	$49.00	$30.00	$384.00	$455.00	$16,380.00
HSS 8x8x3/8 (14' Section)	184	Ea.	$660.00	$53.00	$32.50	$745.50	$855.00	$157,320.00
HSS 10x10x1/2 (16' Section)	36	Ea.	$1,225.00	$55.50	$34.00	$1,314.50	$1,475.00	$53,100.00
							Total	**$226,800.00**

Channels

Description	Total LF	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
C6x8.2	245.25	LF	$5.35	$21.50	$1.98	$28.83	$47.50	$11,649.38
C8x11.5	441.5	LF	$7.75	$33	$3.03	$43.78	$72.50	$32,008.75
							Total	**$43,658.13**

Cap Plates

Description	Weight (lbs)	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
17x10x1	48.28	6	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$599.64
18x10x1	51.12	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$105.82
18x10x1-1/4	63.9	5	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$661.37
18x10x1-1/2	76.68	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$158.73
19x10x2	107.92	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$223.39
20x10x1-1/2	85.2	2	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$352.73
20x10x1-3/4	99.4	27	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$5,555.47
20x10x2	113.6	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$235.15
20x11x1-3/4	109.34	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$226.33
22-1/2x10x1-1/2	95.85	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$198.41
22-1/2x10x2	127.8	9	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$2,380.91
33-1/2x10x2	190.28	1	LB	$1.29	$0.35	$0.22	$1.86	$2.28	$433.84
33-1/2x11x1-3/4	183.14	5	LB	$1.29	$0.35	$0.22	$1.86	$2.28	$2,087.80
35-1/2x11x1-3/4	194.08	3	LB	$1.29	$0.35	$0.22	$1.86	$2.28	$1,327.51
36x13x1-3/4	232.6	3	LB	$1.29	$0.35	$0.22	$1.86	$2.28	$1,590.98
								Total	**$16,138.08**

Base Plates

Description	Weight (lbs)	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
12x12x3/4	30.67	6	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$63.49
13x13x3/4	36	3	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$223.56
14x14x3/4	41.75	4	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$345.69
15x15x3/4	47.93	3	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$297.65
15x15x1	63.9	5	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$661.37
15x15x1-1/4	79.88	13	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$2,149.57
15x15x1-1/2	95.85	2	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$396.82
16x16x1-1/2	109.06	12	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$2,709.05
16x16x1-1/4	90.88	3	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$564.36
17x17x1-1/2	123.11	1	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$254.84
18x18x1-1/2	138.02	7	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$1,999.91
18x18x1-1/4	115.02	8	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$1,904.73
								Total	**$11,571.04**

Table E-2 | Progressive Collapse Steel Estimate Pricing (Segments A & B)									
Beams									
Description	**Total LF**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total Incl O&P**		**Total Cost**
W24x103	22	LF	$127.75	$3.27	$1.47	$132.49	$147.33		$3,241.26
W24x103	1210	LF	$127.75	$3.27	$1.47	$132.49	$147.33		$178,269.30
W24x131	308	LF	$162.24	$3.38	$1.53	$167.14	$186.37		$57,401.96
W24x146	124.4	LF	$181.03	$3.30	$1.49	$185.81	$205.61		$25,577.88
W14x61	22	LF	$75.59	$3.40	$2.08	$81.07	$91.39		$2,010.58
								Total	**$266,500.98**
Angle Framing									
Description	**Total LF**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total Incl O&P**	**Waste Factor**	**Total Cost**
Kickers - 3x3x3/8	440	LF	4.86	20.50	1.91	27.27	45.50	5%	$21,021.00
								Total	**$21,021.00**
Anchor Bolts									
Description	**Quantity**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total Incl O&P**		**Total Cost**
¾" Dia. x 12" long	67	Set	$20.50	$20.50	$0.00	$41.00	$55.50		$3,718.50
								Total	**$3,718.50**
								Total Progressive Collapse Steel Estimate Pricing (Segments A & B)	**$589,407.73**

Table E-3 | Progressive Collapse Estimate Steel Take-Off Charts (Segments C)

Columns

Type	Length (ft)	# of Sections (12'=4, 14'=4, 16'=3)	Quantity	Total Columns w/ Sections
HSS 7x7x3/8	43'-10"	4	4	16
HSS 8x8x3/8	43'-10"	4	4	16
HSS 9x9x3/8	43'-10"	3	32	96
HSS 10x10x3/8	43'-10"	3	4	12

Channels

Type	Length	Quantity	Total LF
C6x8.2	2'-6"	20	50
C6x10.5	2'-9"	69	189.75
C8x11.5	3'-6"	30	105
C8x11.5	3'-8"	6	22
C8x18.7	3'-0"	4	12

Cap Plates

Type	Unit	Volume (in3)	Density of Steel (lbs/in^3)	Weight (lbs)	Quantity
17x10x1/4	LB	42.5	0.284	12.07	4
19x10x1-1/2	LB	285	0.284	80.94	32
20-1/2x10x2	LB	410	0.284	116.44	8

Base Plates

Type	Unit	Volume (in3)	Density of Steel (lbs/in^3)	Weight (lbs)	Quantity
13x13x3/4	LB	126.75	0.284	36	4
14x14x3/4	LB	147	0.284	41.75	4
15x15x1	LB	225	0.284	63.9	32
16x16x1	LB	256	0.284	72.7	4

Beams

Type	Length (ft)	Quantity	Total LF
W24x103	20	42	840

Angle Framing

Type	Length (ft)	Quantity	Total LF
Kickers – 3x3x3/8	8	40	320

CIP Concrete Footings (3000 PSI)

Width (ft)	Length (ft)	Depth (ft)	Concrete (CY)	Quantity	Total Concrete (CY)
2	2	2	0.296	42	12.44

Anchor Bolts

Type	Quantity	Unit	Total # Sets
¾" Dia. x 12" long	42	Set	42

Assumptions:

- The HSS columns that were taken off were placed into the closest category listed in RS Means.
- Columns will be connected to the new spread footings for Segment C
- Interpolation was done in order to take off the steel members
- Assuming the biggest size for the kickers based on the type of system
- Assuming any welding that needs to be done is included with the column and steel member pricing
- Assuming the CIP concrete footing includes the rebar and dowel pricing
- Used http://hypertextbook.com/facts/2004/KarenSutherland.shtml to get the density of steel

Table E-4 | Progressive Collapse Steel Estimate Pricing (Segments C)

Columns

Description	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
HSS 6x6x1/4 (12' Section)	16	Ea.	$305.00	$49.00	$30.00	$384.00	$455.00	$7,280.00
HSS 8x8x3/8 (14' Section)	16	Ea.	$660.00	$53.00	$32.50	$745.50	$855.00	$13,680.00
HSS 10x10x1/2 (16' Section)	108	Ea.	$1,225.00	$55.50	$34.00	$1,314.50	$1,475.00	$159,300.00
							Total	**$180,260.00**

Channels

Description	Total LF	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
C6x8.2	50	LF	$5.35	$21.50	$1.98	$28.83	$47.50	$2,375.00
C6x10.5	189.75	LF	$6.60	$29.50	$2.72	$38.82	$64.50	$12,238.88
C8x11.5	105	LF	$7.75	$33	$3.03	$43.78	$72.50	$7,612.50
C8x11.5	22	LF	$7.75	$33	$3.03	$43.78	$72.50	$1,595.00
C8x18.7	12	LF	$7.75	$33	$3.03	$43.78	$72.50	$870.00
							Total	**$24,691.38**

Cap Plates

Description	Weight (lbs)	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
17x10x1/4	12.07	4	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$99.94
19x10x1-1/2	80.94	32	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$5,361.47
20-1/2x10x2	116.44	8	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$1,928.25
								Total	**$7,389.66**

Base Plates

Description	Weight (lbs)	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
13x13x3/4	36	4	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$298.08
14x14x3/4	41.75	4	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$345.69
15x15x1	63.9	32	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$4,232.74
16x16x1	72.7	4	LB	$1.24	$0.39	$0.00	$1.63	$2.07	$601.96
								Total	**$5,478.47**

Beams

Description	Total LF	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
W24x103	840	LF	$127.75	$3.27	$1.47	$132.49	$147.33	$123,757.20
							Total	**$123,757.20**

Angle Framing

Description	Total LF	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Waste Factor	Total Cost
Kickers - 3x3x3/8	320	LF	4.86	20.50	1.91	27.27	45.50	5%	$14,280.00
								Total	**$14,280.00**

Anchor Bolts

Description	Quantity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Total Cost
¾" Dia. x 12" long	42	Set	$20.50	$20.50	$0.00	$41.00	$55.50	$2,331.00
							Total	**$2,331.00**

CIP Concrete Footings (3000 PSI)

Description	Total Concrete (CY)	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total Incl O&P	Waste Factor	Total Cost
Spread under 1 CY	12.44	CY	158	165	0.84	323.84	445.00	10%	$6,089.38
								Total	**$6,089.38**

Total Progressive Collapse Steel Estimate Pricing (Segments C)	**$364,277.09**

03 30 53 – Miscellaneous Cast-In-Place Concrete

	03 30 53.40 Concrete In Place	Crew	Daily Output	Labor-Hours	Unit	2011 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
3540	Equipment pad (3000 psi), 3′ x 3′ x 6″ thick	C-14H	45	1.067	Ea.	40.50	45.50	.51	86.51	119
3550	4′ x 4′ x 6″ thick		30	1.600		62	68	.77	130.77	180
3560	5′ x 5′ x 8″ thick		18	2.667		111	113	1.28	225.28	305
3570	6′ x 6′ x 8″ thick		14	3.429		150	146	1.65	297.65	405
3580	8′ x 8′ x 10″ thick		8	6		320	255	2.88	577.88	775
3590	10′ x 10′ x 12″ thick		5	9.600		550	410	4.61	964.61	1,275
3800	Footings (3000 psi), spread under 1 C.Y.	C-14C	28	4	C.Y.	158	165	.84	323.84	445
3825	1 C.Y. to 5 C.Y.		43	2.605		185	108	.55	293.55	380
3850	Over 5 C.Y.		75	1.493		171	61.50	.31	232.81	289
3900	Footings, strip (3000 psi), 18″ x 9″, unreinforced	C-14L	40	2.400		119	96.50	.58	216.08	289
3920	18″ x 9″, reinforced	C-14C	35	3.200		141	132	.67	273.67	370
3925	20″ x 10″, unreinforced	C-14L	45	2.133		116	85.50	.51	202.01	268
3930	20″ x 10″, reinforced	C-14C	40	2.800		134	116	.59	250.59	335
3935	24″ x 12″, unreinforced	C-14L	55	1.745		114	70	.42	184.42	240
3940	24″ x 12″, reinforced	C-14C	48	2.333		132	96.50	.49	228.99	305
3945	36″ x 12″, unreinforced	C-14L	70	1.371		111	55	.33	166.33	212
3950	36″ x 12″, reinforced	C-14C	60	1.867		127	77	.39	204.39	266
4000	Foundation mat (3000 psi), under 10 C.Y.		38.67	2.896		192	120	.61	312.61	410
4050	Over 20 C.Y.		56.40	1.986		169	82	.42	251.42	320
4200	Wall, free-standing (3000 psi), 8″ thick, 8′ high	C-14D	45.83	4.364		160	187	16.65	363.65	500
4250	14′ high		27.26	7.337		192	315	28	535	755
4260	12″ thick, 8′ high		64.32	3.109		146	133	11.90	290.90	390
4270	14′ high		40.01	4.999		155	214	19.10	388.10	540
4300	15″ thick, 8′ high		80.02	2.499		140	107	9.55	256.55	340
4350	12′ high		51.26	3.902		140	167	14.90	321.90	445
4500	18′ high		48.85	4.094		156	176	15.65	347.65	475
4520	Handicap access ramp (4000 psi), railing both sides, 3′ wide	C-14H	14.58	3.292	L.F.	278	140	1.58	419.58	535
4525	5′ wide		12.22	3.928		288	167	1.89	456.89	590
4530	With 6″ curb and rails both sides, 3′ wide		8.55	5.614		287	238	2.69	527.69	710
4535	5′ wide		7.31	6.566		292	279	3.15	574.15	780
4650	Slab on grade (3500 psi), not including finish, 4″ thick	C-14E	60.75	1.449	C.Y.	117	61.50	.38	178.88	230
4700	6″ thick	″	92	.957	″	113	41	.25	154.25	191
4701	Thickened slab edge (3500 psi), for slab on grade poured									
4702	monolithically with slab; depth is in addition to slab thickness;									
4703	formed vertical outside edge, earthen bottom and inside slope									
4705	8″ deep x 8″ wide bottom, unreinforced	C-14L	2190	.044	L.F.	3.18	1.76	.01	4.95	6.35
4710	8″ x 8″, reinforced	C-14C	1670	.067		5.30	2.77	.01	8.08	10.40
4715	12″ deep x 12″ wide bottom, unreinforced	C-14L	1800	.053		6.55	2.14	.01	8.70	10.70
4720	12″ x 12″, reinforced	C-14C	1310	.086		10.40	3.53	.02	13.95	17.20
4725	16″ deep x 16″ wide bottom, unreinforced	C-14L	1440	.067		11.10	2.68	.02	13.80	16.60
4730	16″ x 16″, reinforced	C-14C	1120	.100		15.70	4.13	.02	19.85	24
4735	20″ deep x 20″ wide bottom, unreinforced	C-14L	1150	.083		16.85	3.35	.02	20.22	24
4740	20″ x 20″, reinforced	C-14C	920	.122		22.50	5.05	.03	27.58	33
4745	24″ deep x 24″ wide bottom, unreinforced	C-14L	930	.103		24	4.14	.02	28.16	33
4750	24″ x 24″, reinforced	C-14C	740	.151		31.50	6.25	.03	37.78	44.50
4751	Slab on grade (3500 psi), incl. troweled finish, not incl. forms									
4760	or reinforcing, over 10,000 S.F., 4″ thick	C-14F	3425	.021	S.F.	1.29	.82	.01	2.12	2.72
4820	6″ thick		3350	.021		1.89	.84	.01	2.74	3.41
4840	8″ thick		3184	.023		2.59	.88	.01	3.48	4.25
4900	12″ thick		2734	.026		3.88	1.02	.01	4.91	5.90
4950	15″ thick		2505	.029		4.88	1.12	.01	6.01	7.15
5000	Slab on grade (3000 psi), incl. textured finish, not incl. forms									
5001	or reinforcing, 4″ thick	C-14G	2873	.019	S.F.	1.29	.75	.01	2.05	2.61

05 05 23 – Metal Fastenings

05 05 23.05 Anchor Bolts		Crew	Daily Output	Labor-Hours	Unit	Material	2011 Bare Costs Labor	Equipment	Total	Total Incl O&P
0600	30" long	G	2 Carp	29	.552	Set	83.50	24		107.50	131
0610	36" long	G		28	.571		95	24.50		119.50	144
0620	42" long	G		27	.593		106	25.50		131.50	159
0630	48" long	G		26	.615		116	26.50		142.50	172
0640	54" long	G		26	.615		144	26.50		170.50	202
0650	60" long	G		25	.640		155	27.50		182.50	216
0660	2" diameter x 24" long	G		27	.593		96.50	25.50		122	148
0670	30" long	G		27	.593		108	25.50		133.50	161
0680	36" long	G		26	.615		119	26.50		145.50	175
0690	42" long	G		25	.640		132	27.50		159.50	191
0700	48" long	G		24	.667		152	28.50		180.50	214
0710	54" long	G		23	.696		180	30		210	247
0720	60" long	G		23	.696		194	30		224	262
0730	66" long	G		22	.727		207	31.50		238.50	279
0740	72" long	G		21	.762		227	33		260	305
1000	4-bolt pattern, including job-built 4-hole template, per set										
1100	J-type, incl. hex nut & washer, 1/2" diameter x 6" long	G	1 Carp	19	.421	Set	6.90	18.15		25.05	37
1110	12" long	G		19	.421		8.15	18.15		26.30	38.50
1120	18" long	G		18	.444		9.95	19.15		29.10	42.50
1130	3/4" diameter x 8" long	G		17	.471		16.70	20.50		37.20	51.50
1140	12" long	G		17	.471		20.50	20.50		41	55.50
1150	18" long	G		17	.471		26	20.50		46.50	61.50
1160	1" diameter x 12" long	G		16	.500		37.50	21.50		59	76
1170	18" long	G		15	.533		44.50	23		67.50	86.50
1180	24" long	G		15	.533		54	23		77	96.50
1190	36" long	G		15	.533		73	23		96	118
1200	1-1/2" diameter x 18" long	G		13	.615		118	26.50		144.50	174
1210	24" long	G		12	.667		140	28.50		168.50	202
1300	L-type, incl. hex nut & washer, 3/4" diameter x 12" long	G		17	.471		19.25	20.50		39.75	54
1310	18" long	G		17	.471		24	20.50		44.50	59.50
1320	24" long	G		17	.471		29	20.50		49.50	65
1330	30" long	G		16	.500		36	21.50		57.50	75
1340	36" long	G		16	.500		41	21.50		62.50	80
1350	1" diameter x 12" long	G		16	.500		31.50	21.50		53	69.50
1360	18" long	G		15	.533		38.50	23		61.50	80
1370	24" long	G		15	.533		47	23		70	89.50
1380	30" long	G		15	.533		55.50	23		78.50	98.50
1390	36" long	G		15	.533		63	23		86	107
1400	42" long	G		14	.571		76	24.50		100.50	124
1410	48" long	G		14	.571		85	24.50		109.50	134
1420	1-1/4" diameter x 18" long	G		14	.571		58	24.50		82.50	104
1430	24" long	G		14	.571		68.50	24.50		93	115
1440	30" long	G		13	.615		79	26.50		105.50	130
1450	36" long	G		13	.615		89.50	26.50		116	142
1460	42" long	G	2 Carp	25	.640		101	27.50		128.50	156
1470	48" long	G		24	.667		115	28.50		143.50	173
1480	54" long	G		23	.696		135	30		165	197
1490	60" long	G		23	.696		148	30		178	211
1500	1-1/2" diameter x 18" long	G		25	.640		85	27.50		112.50	139
1510	24" long	G		24	.667		99	28.50		127.50	156
1520	30" long	G		23	.696		112	30		142	172
1530	36" long	G		22	.727		128	31.50		159.50	192
1540	42" long	G		22	.727		146	31.50		177.50	211

05 12 23 – Structural Steel for Buildings

05 12 23.17 Columns, Structural		Crew	Daily Output	Labor-Hours	Unit	Material	Labor (2011 Bare Costs)	Equipment (2011 Bare Costs)	Total (2011 Bare Costs)	Total Incl O&P
0010	**COLUMNS, STRUCTURAL** R051223-20									
0015	Made from recycled materials G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections									
0800	Steel, concrete filled, extra strong pipe, 3-1/2" diameter	E-2	660	.085	L.F.	37	4.02	2.46	43.48	51
0830	4" diameter		780	.072		41.50	3.40	2.08	46.98	54
0890	5" diameter		1020	.055		49.50	2.60	1.59	53.69	60.50
0930	6" diameter		1200	.047		65.50	2.21	1.35	69.06	77.50
0940	8" diameter		1100	.051		65.50	2.41	1.47	69.38	78
1100	For galvanizing, add				Lb.	.20			.20	.22
1300	For web ties, angles, etc., add per added lb.	1 Sswk	945	.008		1.13	.41		1.54	2
1500	Steel pipe, extra strong, no concrete, 3" to 5" diameter G	E-2	16000	.004		1.13	.17	.10	1.40	1.64
1600	6" to 12" diameter G		14000	.004		1.13	.19	.12	1.44	1.70
1700	Steel pipe, extra strong, no concrete, 3" diameter x 12'-0" G		60	.933	Ea.	138	44	27	209	260
1750	4" diameter x 12'-0" G		58	.966		202	45.50	28	275.50	335
1800	6" diameter x 12'-0" G		54	1.037		385	49	30	464	545
1850	8" diameter x 14'-0" G		50	1.120		685	53	32.50	770.50	880
1900	10" diameter x 16'-0" G		48	1.167		985	55.50	34	1,074.50	1,200
1950	12" diameter x 18'-0" G		45	1.244		1,325	59	36	1,420	1,600
3300	Structural tubing, square, A500GrB, 4" to 6" square, light section G		11270	.005	Lb.	1.13	.24	.14	1.51	1.82
3600	Heavy section G		32000	.002	"	1.13	.08	.05	1.26	1.45
4000	Concrete filled, add				L.F.	4.03			4.03	4.43
4500	Structural tubing, sq, 4" x 4" x 1/4" x 12'-0" G	E-2	58	.966	Ea.	186	45.50	28	259.50	315
4550	6" x 6" x 1/4" x 12'-0" G		54	1.037		305	49	30	384	455
4600	8" x 8" x 3/8" x 14'-0" G		50	1.120		660	53	32.50	745.50	855
4650	10" x 10" x 1/2" x 16'-0" G		48	1.167		1,225	55.50	34	1,314.50	1,475
5100	Structural tubing, rect, 5" to 6" wide, light section G		8000	.007	Lb.	1.13	.33	.20	1.66	2.05
5200	Heavy section G		12000	.005		1.13	.22	.14	1.49	1.78
5300	7" to 10" wide, light section G		15000	.004		1.13	.18	.11	1.42	1.67
5400	Heavy section G		18000	.003		1.13	.15	.09	1.37	1.60
5500	Structural tubing, rect, 5" x 3" x 1/4" x 12'-0" G		58	.966	Ea.	180	45.50	28	253.50	310
5550	6" x 4" x 5/16" x 12'-0" G		54	1.037		281	49	30	360	430
5600	8" x 4" x 3/8" x 12'-0" G		54	1.037		410	49	30	489	570
5650	10" x 6" x 3/8" x 14'-0" G		50	1.120		660	53	32.50	745.50	855
5700	12" x 8" x 1/2" x 16'-0" G		48	1.167		1,225	55.50	34	1,314.50	1,450
6800	W Shape, A992 steel, 2 tier, W8 x 24 G		1080	.052	L.F.	29.50	2.46	1.50	33.46	38.50
6850	W8 x 31 G		1080	.052		38.50	2.46	1.50	42.46	48
6900	W8 x 48 G		1032	.054		59.50	2.57	1.57	63.64	72
6950	W8 x 67 G		984	.057		83	2.70	1.65	87.35	97.50
7000	W10 x 45 G		1032	.054		55.50	2.57	1.57	59.64	68
7050	W10 x 68 G		984	.057		84	2.70	1.65	88.35	99
7100	W10 x 112 G		960	.058		139	2.76	1.69	143.45	159
7150	W12 x 50 G		1032	.054		62	2.57	1.57	66.14	74.50
7200	W12 x 87 G		984	.057		108	2.70	1.65	112.35	125
7250	W12 x 120 G		960	.058		149	2.76	1.69	153.45	170
7300	W12 x 190 G		912	.061		235	2.91	1.78	239.69	266
7350	W14 x 74 G		984	.057		91.50	2.70	1.65	95.85	108
7400	W14 x 120 G		960	.058		149	2.76	1.69	153.45	170
7450	W14 x 176 G		912	.061		218	2.91	1.78	222.69	247
8090	For projects 75 to 99 tons, add				All	10%				
8092	50 to 74 tons, add					20%				
8094	25 to 49 tons, add					30%	10%			
8096	10 to 24 tons, add					50%	25%			

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.17 Columns, Structural			Crew	Daily Output	Labor-Hours	Unit	2011 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
8098	2 to 9 tons, add					All	75%	50%			
8099	Less than 2 tons, add					↓	100%	100%			
9000	Minimum labor/equipment charge		1 Sswk	1	8	Job		390		390	715

05 12 23.20 Curb Edging			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**CURB EDGING**										
0020	Steel angle w/anchors, shop fabricated, on forms, 1″ x 1″, 0.8#/L.F.	G	E-4	350	.091	L.F.	1.44	4.48	.31	6.23	10.15
0100	2″ x 2″ angles, 3.92#/L.F.	G		330	.097		5.65	4.76	.33	10.74	15.30
0200	3″ x 3″ angles, 6.1#/L.F.	G		300	.107		8.90	5.25	.36	14.51	19.80
0300	4″ x 4″ angles, 8.2#/L.F.	G		275	.116		11.75	5.70	.40	17.85	24
1000	6″ x 4″ angles, 12.3#/L.F.	G		250	.128		17.30	6.30	.44	24.04	31
1050	Steel channels with anchors, on forms, 3″ channel, 5#/L.F.	G		290	.110		7.10	5.40	.38	12.88	18.15
1100	4″ channel, 5.4#/L.F.	G		270	.119		7.65	5.80	.40	13.85	19.50
1200	6″ channel, 8.2#/L.F.	G		255	.125		11.75	6.15	.43	18.33	24.50
1300	8″ channel, 11.5#/L.F.	G		225	.142		16.20	7	.49	23.69	31
1400	10″ channel, 15.3#/L.F.	G		180	.178		21.50	8.70	.61	30.81	40
1500	12″ channel, 20.7#/L.F.	G	↓	140	.229		28.50	11.20	.78	40.48	53
2000	For curved edging, add					↓	35%	10%			
9000	Minimum labor/equipment charge		E-4	4	8	Job		390	27.50	417.50	750

05 12 23.40 Lightweight Framing			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**LIGHTWEIGHT FRAMING**	R051223-35									
0015	Made from recycled materials	G									
0200	For load-bearing steel studs see Section 05 41 13.30										
0400	Angle framing, field fabricated, 4″ and larger R051223-45	G	E-3	440	.055	Lb.	.65	2.69	.25	3.59	5.95
0450	Less than 4″ angles	G		265	.091	″	.68	4.46	.41	5.55	9.40
0460	1/2″ x 1/2″ x 1/8″	G		200	.120	L.F.	.14	5.90	.54	6.58	11.60
0462	3/4″ x 3/4″ x 1/8″	G		160	.150		.38	7.40	.68	8.46	14.70
0464	1″ x 1″ x 1/8″	G		135	.178		.54	8.75	.81	10.10	17.55
0466	1-1/4″ x 1-1/4″ x 3/16″	G		115	.209		1	10.25	.95	12.20	21
0468	1-1/2″ x 1-1/2″ x 3/16″	G		100	.240		1.22	11.80	1.09	14.11	24
0470	2″ x 2″ x 1/4″	G		90	.267		2.15	13.15	1.21	16.51	27.50
0472	2-1/2″ x 2-1/2″ x 1/4″	G		72	.333		2.77	16.40	1.51	20.68	34.50
0474	3″ x 2″ x 3/8″	G		65	.369		3.98	18.15	1.68	23.81	39.50
0476	3″ x 3″ x 3/8″	G		57	.421	↓	4.86	20.50	1.91	27.27	45.50
0600	Channel framing, field fabricated, 8″ and larger	G		500	.048	Lb.	.68	2.36	.22	3.26	5.30
0650	Less than 8″ channels	G		335	.072	″	.68	3.53	.33	4.54	7.55
0660	C2 x 1.78	G		115	.209	L.F.	1.20	10.25	.95	12.40	21
0662	C3 x 4.1	G		80	.300		2.77	14.75	1.36	18.88	31.50
0664	C4 x 5.4	G		66	.364		3.65	17.90	1.65	23.20	39
0666	C5 x 6.7	G		57	.421		4.52	20.50	1.91	26.93	45
0668	C6 x 8.2	G		55	.436		5.35	21.50	1.98	28.83	47.50
0670	C7 x 9.8	G		40	.600		6.60	29.50	2.72	38.82	64.50
0672	C8 x 11.5	G		36	.667		7.75	33	3.03	43.78	72.50
0710	Structural bar tee, field fabricated, 3/4″ x 3/4″ x 1/8″	G		160	.150		.38	7.40	.68	8.46	14.70
0712	1″ x 1″ x 1/8″	G		135	.178		.54	8.75	.81	10.10	17.55
0714	1-1/2″ x 1-1/2″ x 1/4″	G		114	.211		1.58	10.35	.96	12.89	22
0716	2″ x 2″ x 1/4″	G		89	.270		2.15	13.25	1.22	16.62	28
0718	2-1/2″ x 2-1/2″ x 3/8″	G		72	.333		3.98	16.40	1.51	21.89	36
0720	3″ x 3″ x 3/8″	G		57	.421		4.86	20.50	1.91	27.27	45.50
0730	Structural zee, field fabricated, 1-1/4″ x 1-3/4″ x 1-3/4″	G		114	.211		.51	10.35	.96	11.82	20.50
0732	2-11/16″ x 3″ x 2-11/16″	G		114	.211		1.20	10.35	.96	12.51	21.50
0734	3-1/16″ x 4″ x 3-1/16″	G		133	.180		1.82	8.90	.82	11.54	19.20
0736	3-1/4″ x 5″ x 3-1/4″	G	↓	133	.180	↓	2.48	8.90	.82	12.20	19.90

05 12 23 – Structural Steel for Buildings

			Crew	Daily Output	Labor-Hours	Unit	Material	2011 Bare Costs Labor	Equipment	Total	Total Incl O&P
05 12 23.65 Plates											
0100	1/4" thick (10.2 lb./S.F.)	G				S.F.	11.50			11.50	12.6
0300	3/8" thick (15.3 lb./S.F.)	G					17.20			17.20	18.95
0400	1/2" thick (20.4 lb./S.F.)	G					23			23	25.5
0450	3/4" thick (30.6 lb./S.F.)	G					34.50			34.50	38
0500	1" thick (40.8 lb./S.F.)	G					46			46	50.5
2000	Steel plate, warehouse prices, no shop fabrication										
2100	1/4" thick (10.2 lb./S.F.)	G				S.F.	7.15			7.15	7.8
05 12 23.70 Stressed Skin Steel Roof and Ceiling System											
0010	**STRESSED SKIN STEEL ROOF & CEILING SYSTEM**										
0020	Double panel flat roof, spans to 100'	G	E-2	1150	.049	S.F.	9	2.31	1.41	12.72	15.5
0100	Double panel convex roof, spans to 200'	G		960	.058		14.65	2.76	1.69	19.10	23
0200	Double panel arched roof, spans to 300'	G		760	.074		22.50	3.49	2.13	28.12	33.5
05 12 23.75 Structural Steel Members											
0010	**STRUCTURAL STEEL MEMBERS** R051223-10										
0015	Made from recycled materials	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0102	W 6 x 9 R051223-15	G	E-2	600	.093	L.F.	11.15	4.42	2.70	18.27	23
0302	W 8 x 10	G		600	.093		12.40	4.42	2.70	19.52	24.5
0502	x 31	G		550	.102		38.50	4.82	2.95	46.27	53.5
0702	W 10 x 22	G		600	.093		27	4.42	2.70	34.12	41
0902	x 49	G		550	.102		60.50	4.82	2.95	68.27	78
1102	W 12 x 16	G		880	.064		19.80	3.01	1.84	24.65	29.5
1302	x 22	G		880	.064		27	3.01	1.84	31.85	37.5
1502	x 26	G		880	.064		32	3.01	1.84	36.85	43
1702	x 72	G		640	.088		89	4.14	2.53	95.67	108
1902	W 14 x 26	G		990	.057		32	2.68	1.64	36.32	42
2102	x 30	G		900	.062		37	2.95	1.80	41.75	48
2302	x 34	G		810	.069		42	3.27	2	47.27	54.5
2502	x 120	G		720	.078		149	3.68	2.25	154.93	172
2702	W 16 x 26	G		1000	.056		32	2.65	1.62	36.27	42
2902	x 31	G		900	.062		38.50	2.95	1.80	43.25	49
3102	x 40	G		800	.070		49.50	3.32	2.03	54.85	62.5
3302	W 18 x 35	G	E-5	960	.083		43.50	3.99	1.80	49.29	56.5
3502	x 40	G		960	.083		49.50	3.99	1.80	55.29	63.5
3702	x 50	G		912	.088		62	4.20	1.90	68.10	77.5
3902	x 55	G		912	.088		68	4.20	1.90	74.10	84.5
4102	W 21 x 44	G		1064	.075		54.50	3.60	1.63	59.73	68
4302	x 50	G		1064	.075		62	3.60	1.63	67.23	76
4502	x 62	G		1036	.077		76.50	3.70	1.67	81.87	93
4702	x 68	G		1036	.077		84	3.70	1.67	89.37	101
4902	W 24 x 55	G		1110	.072		68	3.45	1.56	73.01	83
5102	x 62	G		1110	.072		76.50	3.45	1.56	81.51	92
5302	x 68	G		1110	.072		84	3.45	1.56	89.01	100
5502	x 76	G		1110	.072		94	3.45	1.56	99.01	111
5702	x 84	G		1080	.074		104	3.55	1.60	109.15	122
5902	W 27 x 94	G		1190	.067		116	3.22	1.45	120.67	135
6102	W 30 x 99	G		1200	.067		123	3.19	1.44	127.63	142
6302	x 108	G		1200	.067		134	3.19	1.44	138.63	154
6502	x 116	G		1160	.069		144	3.31	1.49	148.80	166
6702	W 33 x 118	G		1176	.068		146	3.26	1.47	150.73	168
6902	x 130	G		1134	.071		161	3.38	1.53	165.91	185
7102	x 141	G		1134	.071		174	3.38	1.53	178.91	20[illegible]

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.75 Structural Steel Members			Crew	Daily Output	Labor-Hours	Unit	Material (2011 Bare Costs)	Labor (2011 Bare Costs)	Equipment (2011 Bare Costs)	Total (2011 Bare Costs)	Total Incl O&P
7302	W 36 x 135	G	E-5	1170	.068	L.F.	167	3.28	1.48	171.76	191
7502	x 150	G		1170	.068		186	3.28	1.48	190.76	211
7702	x 194	G		1125	.071		240	3.41	1.54	244.95	272
7902	x 231	G		1125	.071		286	3.41	1.54	290.95	325
8102	x 302	G		1035	.077		375	3.70	1.67	380.37	420
8490	For projects 75 to 99 tons, add						10%				
8492	50 to 74 tons, add						20%				
8494	25 to 49 tons, add						30%	10%			
8496	10 to 24 tons, add						50%	25%			
8498	2 to 9 tons, add						75%	50%			
8499	Less than 2 tons, add						100%	100%			
9000	Minimum labor/equipment charge		E-2	2	28	Job		1,325	810	2,135	3,250

05 12 23.77 Structural Steel Projects

			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**STRUCTURAL STEEL PROJECTS** R050516-30										
0015	Made from recycled materials	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0200	Apartments, nursing homes, etc., 1 to 2 stories R050523-10	G	E-5	10.30	7.767	Ton	2,250	370	168	2,788	3,325
0300	3 to 6 stories	G	″	10.10	7.921		2,300	380	171	2,851	3,400
0400	7 to 15 stories R051223-10	G	E-6	14.20	9.014		2,350	430	133	2,913	3,500
0500	Over 15 stories	G	″	13.90	9.209		2,425	440	136	3,001	3,625
0700	Offices, hospitals, etc., steel bearing, 1 to 2 stories R051223-15	G	E-5	10.30	7.767		2,250	370	168	2,788	3,325
0800	3 to 6 stories	G	E-6	14.40	8.889		2,300	425	131	2,856	3,425
0900	7 to 15 stories R051223-20	G		14.20	9.014		2,350	430	133	2,913	3,500
1000	Over 15 stories	G		13.90	9.209		2,425	440	136	3,001	3,625
1100	For multi-story masonry wall bearing construction, add R051223-25	G						30%			
1300	Industrial bldgs., 1 story, beams & girders, steel bearing	G	E-5	12.90	6.202		2,250	297	134	2,681	3,150
1400	Masonry bearing	G	″	10	8		2,250	385	173	2,808	3,350
1500	Industrial bldgs., 1 story, under 10 tons,										
1510	steel from warehouse, trucked	G	E-2	7.50	7.467	Ton	2,700	355	216	3,271	3,850
1600	1 story with roof trusses, steel bearing	G	E-5	10.60	7.547		2,650	360	163	3,173	3,750
1700	Masonry bearing	G	″	8.30	9.639		2,650	460	209	3,319	3,975
1900	Monumental structures, banks, stores, etc., minimum	G	E-6	13	9.846		2,250	470	146	2,866	3,475
2000	Maximum	G	″	9	14.222		3,725	680	210	4,615	5,550
2200	Churches, minimum	G	E-5	11.60	6.897		2,100	330	149	2,579	3,050
2300	Maximum	G	″	5.20	15.385		2,800	735	335	3,870	4,775
2800	Power stations, fossil fuels, minimum	G	E-6	11	11.636		2,250	560	172	2,982	3,675
2900	Maximum	G		5.70	22.456		3,375	1,075	330	4,780	6,025
2950	Nuclear fuels, non-safety steel, minimum	G		7	18.286		2,250	875	270	3,395	4,350
3000	Maximum	G		5.50	23.273		3,375	1,125	345	4,845	6,100
3040	Safety steel, minimum	G		2.50	51.200		3,275	2,450	755	6,480	8,850
3070	Maximum	G		1.50	85.333		4,325	4,100	1,250	9,675	13,500
3100	Roof trusses, minimum	G	E-5	13	6.154		3,150	295	133	3,578	4,150
3200	Maximum	G		8.30	9.639		3,825	460	209	4,494	5,250
3210	Schools, minimum	G		14.50	5.517		2,250	264	119	2,633	3,075
3220	Maximum	G		8.30	9.639		3,275	460	209	3,944	4,675
3400	Welded construction, simple commercial bldgs., 1 to 2 stories	G	E-7	7.60	10.526		2,300	505	242	3,047	3,700
3500	7 to 15 stories	G	E-9	8.30	15.422		2,650	740	261	3,651	4,525
3700	Welded rigid frame, 1 story, minimum	G	E-7	15.80	5.063		2,350	243	116	2,709	3,150
3800	Maximum	G	″	5.50	14.545		3,050	695	335	4,080	4,975
3810	Fabrication shop costs (included in project material cost, above)										
3820	Mini mill base price, A992	G				Ton	770			770	845
3830	Mill extra for delivery to shop						240			240	264

Christie Smith | 10/19/11 | TECH II

Structural steel members Interpolation

- In order to find a price that reflects the members on the project, I interpolated what was given in RS Means to what I needed.

$$y_2 = \frac{(x_2 - x_1)(y_3 - y_1)}{(x_3 - x_1)} + y_1$$

W24X103

	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total (Incl O&P)
W24X84	104	3.55	1.60	109.15	122
W30X108	134	3.19	1.44	138.63	154

using interpolation

W24X103	127.75	3.27	1.47	132.49	147.33

W24X131

	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total (Incl O&P)
W24X84	104	3.55	1.60	109.15	122
W33X130	161	3.38	1.53	165.91	185

using interpolation

W24X131	162.24	3.38	1.53	167.14	186.37

W24X146

	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total (Incl O&P)
W24X84	104	3.55	1.60	109.15	122
W36X150	186	3.28	1.48	190.76	211

using interpolation

W24X146	181.03	3.30	1.49	185.81	205.61

W14 X 61

W14X34	42	3.27	2	47.27	54.5
W14X120	149	3.68	2.25	154.93	172

using interpolation

W14X61	75.59	3.40	2.08	81.07	91.39

05 12 Structural Steel Framing

05 12 23 – Structural Steel for Buildings

05 12 23.77 Structural Steel Projects

				Daily Output	Labor-Hours	Unit	2011 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
3840	Shop extra for shop drawings and detailing					Ton	270			270	297
3850	Shop fabricating and handling						730			730	805
3860	Shop sandblasting and primer coat of paint						135			135	149
3870	Shop delivery to the job site						105			105	116
3880	Total material cost, shop fabricated, primed, delivered					↓	2,250			2,250	2,475
3900	High strength steel mill spec extras:										
3950	A529, A572 (50 ksi) and A36: same as A992 steel (no extra)										
4000	Add to A992 price for A572 (60, 65 ksi)	G				Ton	100			100	110
4100	A242 and A588 Weathering	G				"	85			85	93.50
4200	Mill size extras for W-Shapes: 0 to 30 plf: no extra charge										
4210	Member sizes 31 to 65 plf, deduct	G				Ton	.01			.01	.01
4220	Member sizes 66 to 100 plf, deduct	G					8.40			8.40	9.25
4230	Member sizes 101 to 387 plf, add	G				↓	58			58	64
4300	Column base plates, light, up to 150 lb	G	2 Sswk	2000	.008	Lb.	1.24	.39		1.63	2.07
4400	Heavy, over 150 lb	G	E-2	7500	.007	"	1.29	.35	.22	1.86	2.2[illegible]
4600	Castellated beams, light sections, to 50#/L.F., minimum	G		10.70	5.234	Ton	2,375	248	152	2,775	3,200
4700	Maximum	G		7	8		2,600	380	232	3,212	3,775
4900	Heavy sections, over 50# per L.F., minimum	G		11.70	4.786		2,475	227	139	2,841	3,275
5000	Maximum	G	↓	7.80	7.179		2,700	340	208	3,248	3,800
5390	For projects 75 to 99 tons, add						10%				
5392	50 to 74 tons, add						20%				
5394	25 to 49 tons, add						30%	10%			
5396	10 to 24 tons, add						50%	25%			
5398	2 to 9 tons, add						75%	50%			
5399	Less than 2 tons, add					↓	100%	100%			

05 12 23.80 Subpurlins

			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**SUBPURLINS** R051223-50										
0015	Made from recycled materials	G									
0020	Bulb tees, shop fabricated, painted, 32-5/8" O.C., 40 psf L.L.										
0100	Type 178, max 8'-9" span, 2.15 plf, 2" high x 1-5/8" wide	G	E-1	4200	.006	S.F.	1.56	.27	.03	1.86	2.2[illegible]
0200	Type 218, max 10'-2" span, 3.19 plf, 2-1/8" high x 2-1/8" wide	G	"	3100	.008		1.81	.37	.04	2.22	2.6[illegible]
1420	For 24-5/8" spacing, add						33%	33%			
1430	For 48-5/8" spacing, deduct					↓	50%	50%			

05 14 Structural Aluminum Framing

05 14 23 – Non-Exposed Structural Aluminum Framing

05 14 23.05 Aluminum Shapes

			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**ALUMINUM SHAPES**										
0015	Made from recycled materials	G									
0020	Structural shapes, 1" to 10" members, under 1 ton	G	E-2	1050	.053	Lb.	2.98	2.53	1.54	7.05	9.4[illegible]
0050	1 to 5 tons	G		1330	.042		2.73	1.99	1.22	5.94	7.8[illegible]
0100	Over 5 tons	G		1330	.042		2.61	1.99	1.22	5.82	7.7[illegible]
0300	Extrusions, over 5 tons, stock shapes	G		1330	.042		3.10	1.99	1.22	6.31	8.2[illegible]
0400	Custom shapes	G	↓	1330	.042	↓	3.10	1.99	1.22	6.31	8.2[illegible]

Appendix F

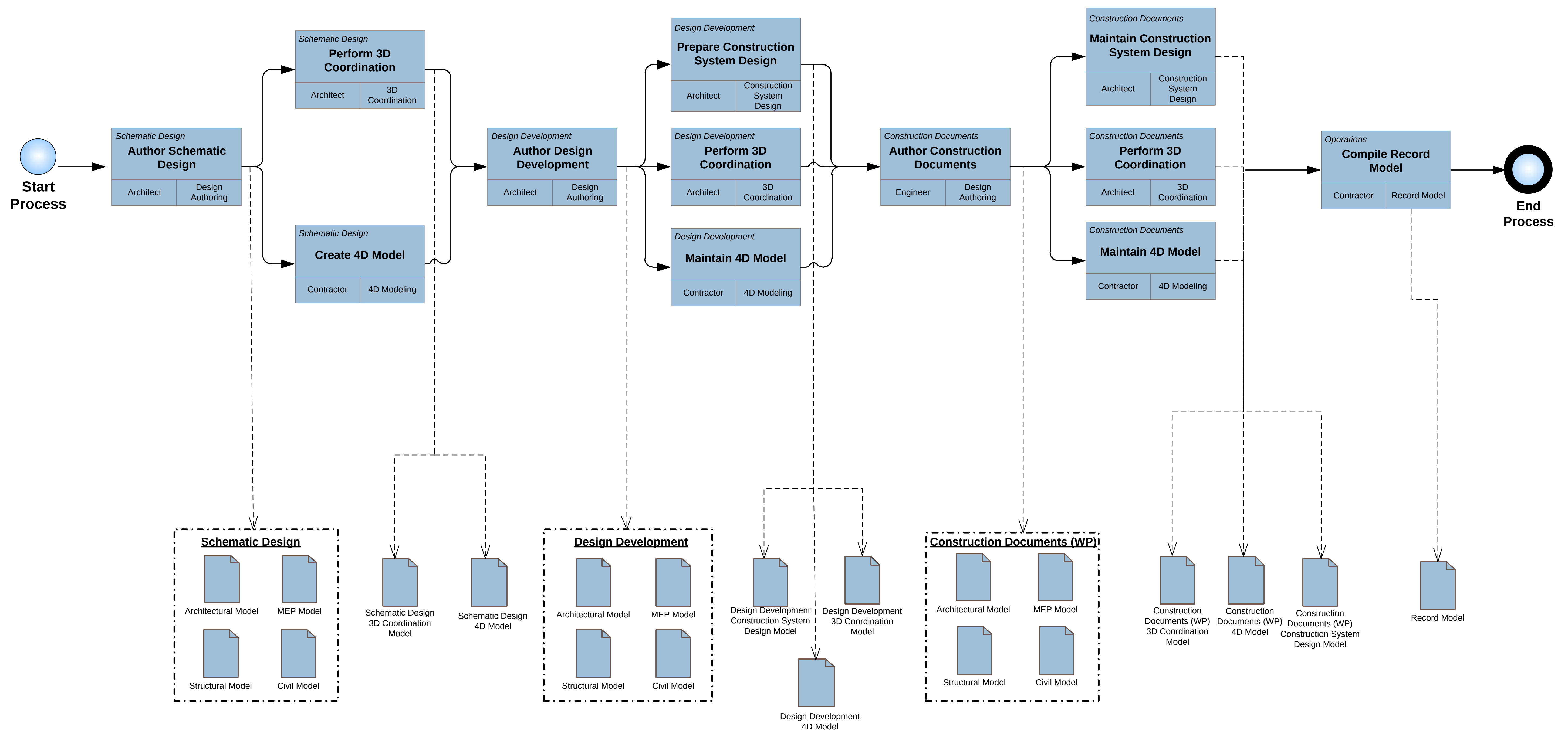
BIM Use Evaluation

Table F-1 | BIM Goals Worksheet		
Priority (1-3)	**Goal Description**	**Potential BIM Uses**
1 – Most Important	**Value added objectives**	
1	Reduce the project schedule duration	4D Modeling, Construction System Design
1	Reduce the project cost	4D Modeling, Existing Conditions Modeling
1	Increase the overall quality of the project	Design Reviews, 3D Coordination, Record Modeling, Engineering Analysis
2	Efficient design documentation	Design Authoring, Design Reviews, 3D Coordination
3	Automated takeoffs	Cost Estimation
2	Eliminate field conflicts	3D Coordination
2	Increase project productivity levels	Design Reviews, 3D Coordination, Programming
2	Track progress during construction	4D Modeling
1	Identify concerns with the 2-phase construction sequence	4D Modeling
3	Easily analyze different costs from design changes	Cost Estimation

Table F-2 | BIM Use Analysis Worksheet

BIM Use	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
	High / Med / Low		High / Med / Low	Scale 1-3 (1=low)					Yes / No / Maybe
				Resources	Competency	Experience			
Record Modeling	Med	Contractor	Med	3	3	3			Yes
		Facility Manager	High	1	1	1	Requires training & software		
		Architect	Med	3	3	3			
Construction System Design	High	Architect	Med	3	2	2	Requires training & software		Yes
		Contractor	High	3	3	3			
3D Coordination	High	Architect	High	3	2	2	Coordination software required as well as some training		Yes
		MEP Engineer	Med	3	2	2			
		Structural Engineer	High	3	2	2			
		Contractor	High	3	3	3		Contractors to facilitate coordination	
Design Authoring	Med	Architect	High	3	3	3			Yes
		MEP Engineer	Med	3	3	3			
		Structural Engineer	High	3	3	3			
		Civil Engineer	Low	2	1	1	Large learning curve	Not required	
Engineering Analysis	Med	MEP Engineer	Med	2	2	2			Maybe
		Architect	High	2	2	2			
Programming	Med	Architect	Low	1	2	1			No
Design Reviews	High	Architect	Low	2	2	2	Requires training & software		Maybe
4D Modeling	High	Contractor	High	3	3	3		Huge benefit to Owner	Yes
Cost Estimation	High	Contractor	High	2	1	1			Maybe
Existing Conditions Modeling	Low	Architect	Med	1	1	1	Large learning curve		No
		Civil Engineer	Med	1	1	1			
		Contractor	Med	2	1	1			

Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team.
http://www.engr/psu.edu/ae/cic/bimex



Appendix G

LEED Scorecard

LEED 2009 for Commercial Interiors

Project Checklist

7700 Arlington Blvd.

4/4/2012

Y	?	N					Points
10	2	9		**Sustainable Sites**		Possible Points:	**21**
0	2	3	d	Credit 1		Site Selection	1 to 5
					0	Option 1: Select a LEED Certified Building	5
						OR	
					0	Path 1: Brownfield Redevelopment	1
					0	Path 2: Stormwater Design—Quantity Control	1
					0	Path 3: Stormwater Design—Quality Control	1
					0	Path 4: Heat Island Effect—Nonroof	1
					0	Path 5: Heat-Island Effect—Roof	1
					0	Path 6: Light Pollution Reduction	1
					0	Path 7: Water Efficient Landscaping—Reduce by 50%	2
					2	Path 8: Water Efficient Landscaping—No Potable Water Use or Irrigation	2
					0	Path 9: Innovative Wastewater Technologies	2
					0	Path 10: Water Use Reduction—30% Reduction	1
					0	Path 11: On-site Renewable Energy	2
					0	Path 12: Other Quantifiable Environmental Performance	1
0	0	6	d	Credit 2		Development Density and Community Connectivity	6
6	0	0	d	Credit 3.1		Alternative Transportation—Public Transportation Access	6
2	0	0	d	Credit 3.2		Alternative Transportation—Bicycle Storage and Changing Rooms	2
2	0	0	d	Credit 3.3		Alternative Transportation—Parking Availability	2

Y	?	N				Points
6	0	5		**Water Efficiency**	Possible Points:	**11**
Y			d	Prereq 1	Water Use Reduction—20% Reduction	
6	0	5	d	Credit 1	Water Use Reduction	6 to 11

Y	?	N				Energy and Atmosphere	Possible Points: 37
16	0	21					
Y			C	Prereq 1		Fundamental Commissioning of Building Energy Systems	
Y			d	Prereq 2		Minimum Energy Performance	
Y			d	Prereq 3		Fundamental Refrigerant Management	
2	0	3	d	Credit 1.1		Optimize Energy Performance—Lighting Power	1 to 5
					0	15% Reduction	1
					2	20% Reduction	2
					0	25% Reduction	3
					0	30% Reduction	4
					0	35% Reduction	5
2	0	1	d	Credit 1.2		Optimize Energy Performance—Lighting Controls	1 to 3
					1	Daylight Controls for Daylit Areas	1
					0	Daylight Controls for 50% of the Lighting Load	1
					1	Occupancy Sensors for 75% of the Connected Lighting Load	1
5	0	5	d	Credit 1.3		Optimize Energy Performance—HVAC	5 to 10
					0	Equipment Efficiency	5
					5	Zoning Controls	5
						OR	
					0	Reduce Design Energy Cost and 15% Improvement	5
					0	Reduce Design Energy Cost and 30% Improvement	10
2	0	2	d	Credit 1.4		Optimize Energy Performance—Equipment and Appliances	1 to 4
					0	70% ENERGY STAR	1
					2	77% ENERGY STAR	2
					0	84% ENERGY STAR	3
					0	90% ENERGY STAR	4
5	0	0	C	Credit 2		Enhanced Commissioning	5
0	0	5	d	Credit 3		Measurement and Verification	2 to 5
					0	Install Sub-Metering Equipment	2
					0	Tenant Pays for Energy	3
						OR	
					0	Metering, Measurement and Payment Accountability	5
0	0	5	d	Credit 4		Green Power	5

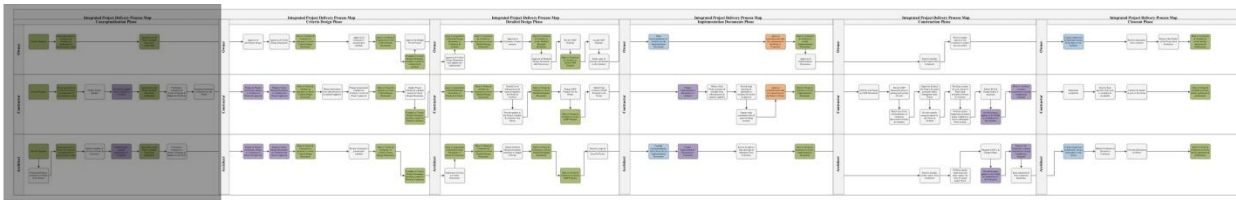
Y	?	N				Possible Points
5	0	9			**Materials and Resources**	Possible Points: **14**
Y			d	Prereq 1	Storage and Collection of Recyclables	
1	0	0	d	Credit 1.1	Tenant Space—Long-Term Commitment	1
0	0	2	d	Credit 1.2	Building Reuse	1 to 2
				0	40% Reuse	1
				0	60% Reuse	2
1	0	1	C	Credit 2	Construction Waste Management	1 to 2
				1	Divert 50% from Disposal	1
				0	Divert 75% from Disposal	2
1	0	1	C	Credit 3.1	Materials Reuse	1 to 2
				1	5% Reuse	1
				0	10% Reuse	2
0	0	1	C	Credit 3.2	Materials Reuse—Furniture and Furnishings	1
0	0	2	C	Credit 4	Recycled Content	1 to 2
				0	10% of Content	1
				0	20% of Content	2
1	0	1	C	Credit 5	Regional Materials	1 to 2
				1	20% of Materials Manufactured	1
				0	20% of Materials Manufactured and 10% Extracted	2
0	0	1	C	Credit 6	Rapidly Renewable Materials	1
1	0	0	C	Credit 7	Certified Wood	1

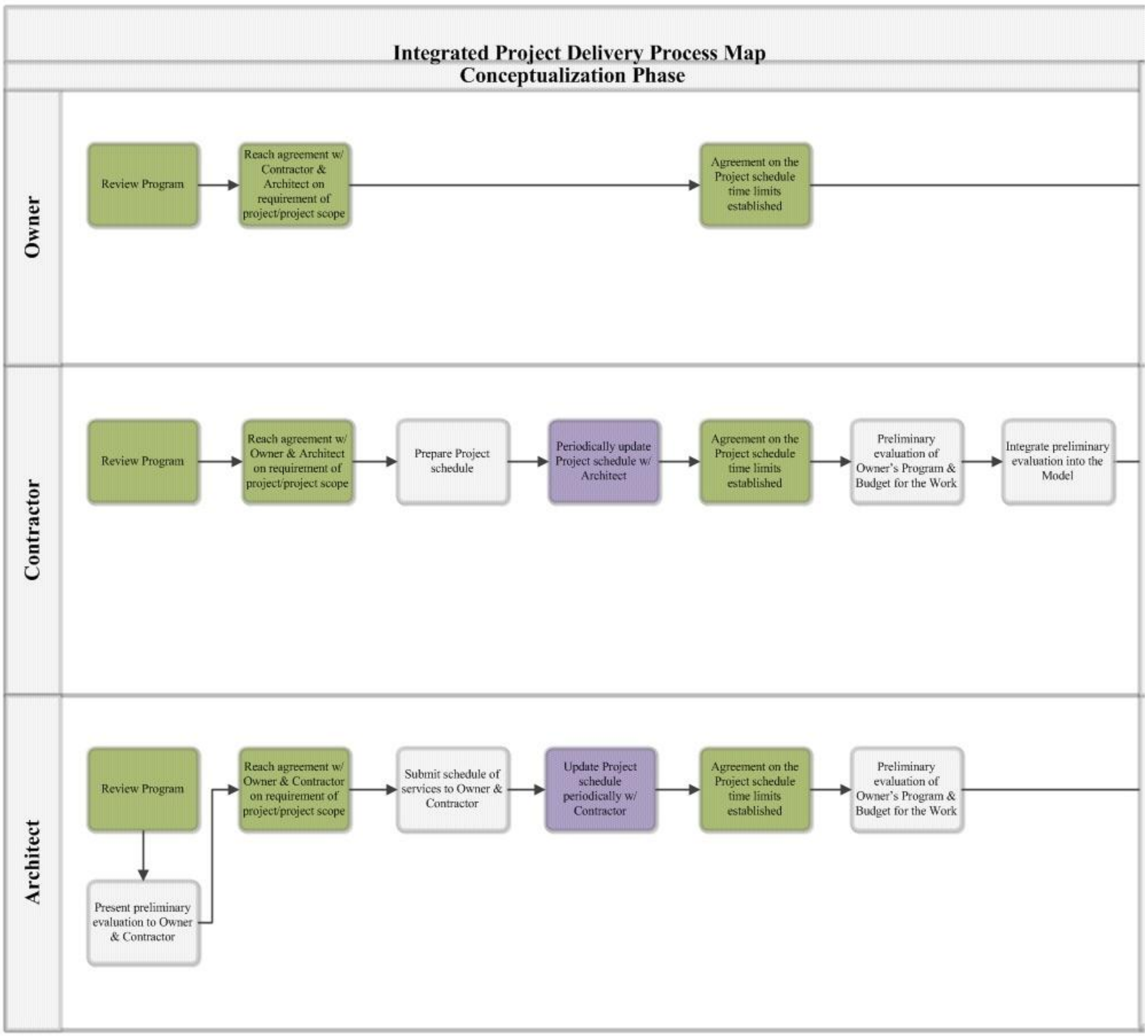
Y	?	N				Points
16	0	1			**Indoor Environmental Quality**	Possible Points: **17**
Y	?	N				
Y			d	Prereq 1	Minimum IAQ Performance	
Y			d	Prereq 2	Environmental Tobacco Smoke (ETS) Control	
1	0	0	d	Credit 1	Outdoor Air Delivery Monitoring	1
1	0	0	d	Credit 2	Increased Ventilation	1
1	0	0	C	Credit 3.1	Construction IAQ Management Plan—During Construction	1
1	0	0	C	Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
1	0	0	C	Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
1	0	0	C	Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1	0	0	C	Credit 4.3	Low-Emitting Materials—Flooring Systems	1
1	0	0	C	Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
1	0	0	C	Credit 4.5	Low-Emitting Materials—Systems Furniture and Seating	1
1	0	0	d	Credit 5	Indoor Chemical & Pollutant Source Control	1
1	0	0	d	Credit 6.1	Controllability of Systems—Lighting	1
1	0	0	d	Credit 6.2	Controllability of Systems—Thermal Comfort	1
1	0	0	d	Credit 7.1	Thermal Comfort—Design	1
1	0	0	d	Credit 7.2	Thermal Comfort—Verification	1
1	0	1	d	Credit 8.1	Daylight and Views—Daylight	1 to 2
					1 — 75% of Spaces	1
					0 — 90% of Spaces	2
1	0	0	d	Credit 8.2	Daylight and Views—Views for Seated Spaces	1
1	0	5			**Innovation and Design Process**	Possible Points: **6**
Y	?	N				
0	0	1	d/C	Credit 1.1	Innovation in Design: Specific Title	1
0	0	1	d/C	Credit 1.2	Innovation in Design: Specific Title	1
0	0	1	d/C	Credit 1.3	Innovation in Design: Specific Title	1
0	0	1	d/C	Credit 1.4	Innovation in Design: Specific Title	1
0	0	1	d/C	Credit 1.5	Innovation in Design: Specific Title	1
1	0	0	d	Credit 2	LEED Accredited Professional	1
0	0	4			**Regional Priority Credits**	Possible Points: **4**
Y	?	N				
0	0	1	d/C	Credit 1.1	Regional Priority: Specific Credit	1
0	0	1	d/C	Credit 1.2	Regional Priority: Specific Credit	1
0	0	1	d/C	Credit 1.3	Regional Priority: Specific Credit	1
0	0	1	d/C	Credit 1.4	Regional Priority: Specific Credit	1
54	2	54			**Total**	Possible Points: **110**

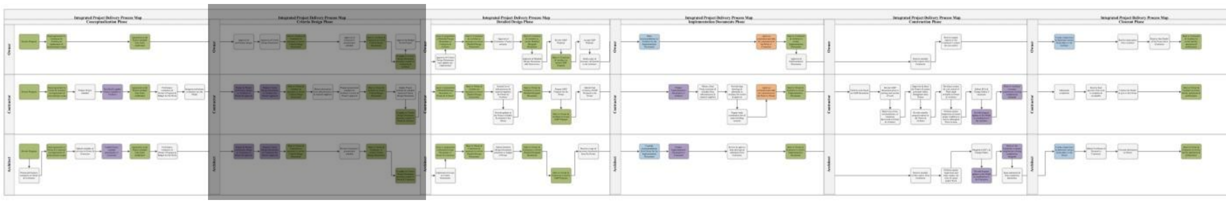
Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

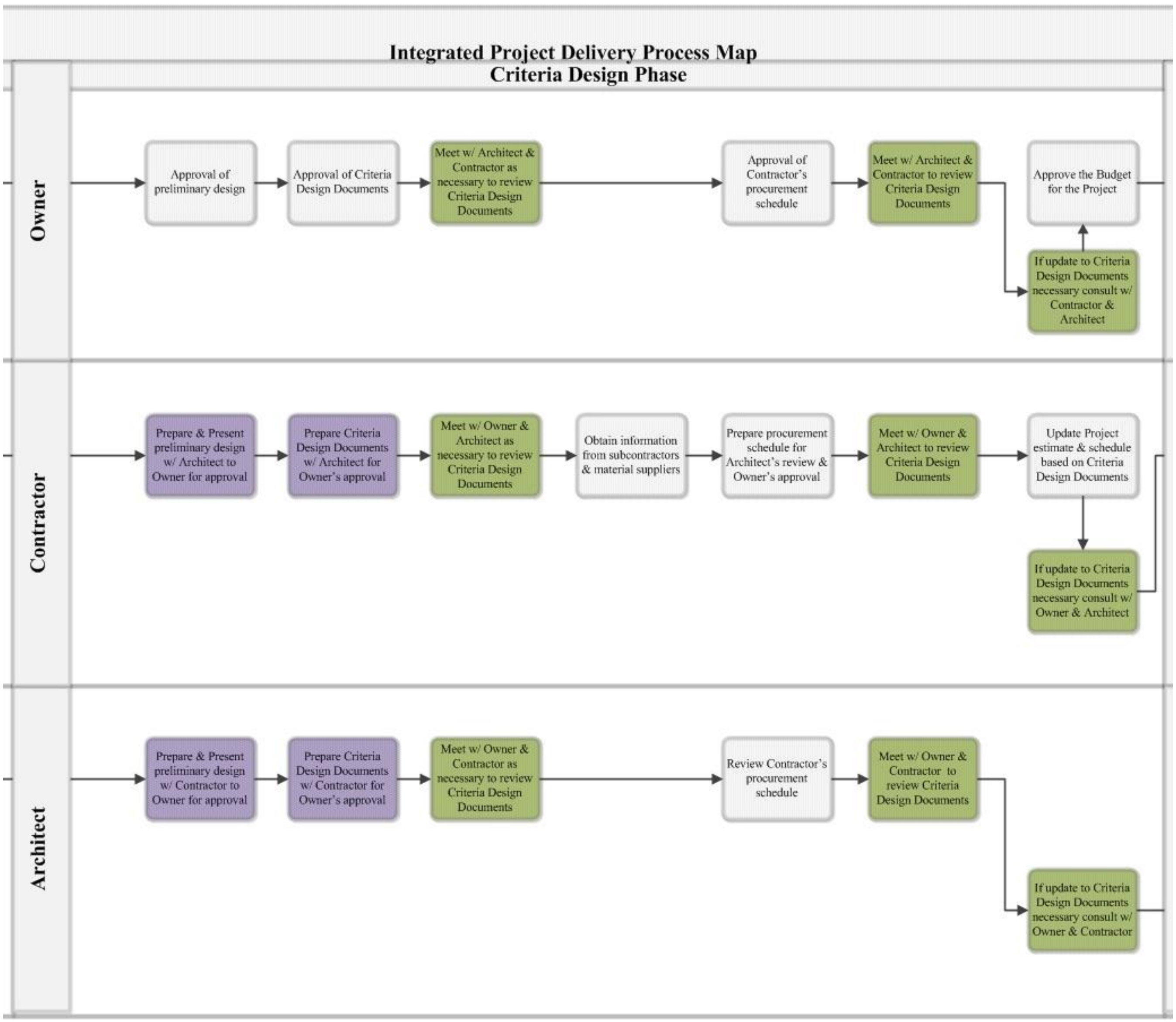
Appendix H

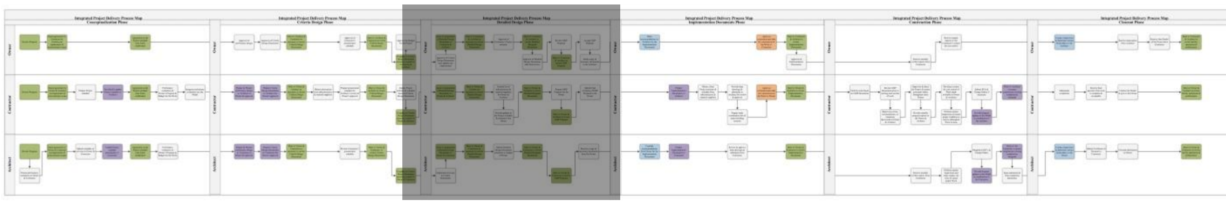
IPD Process Map

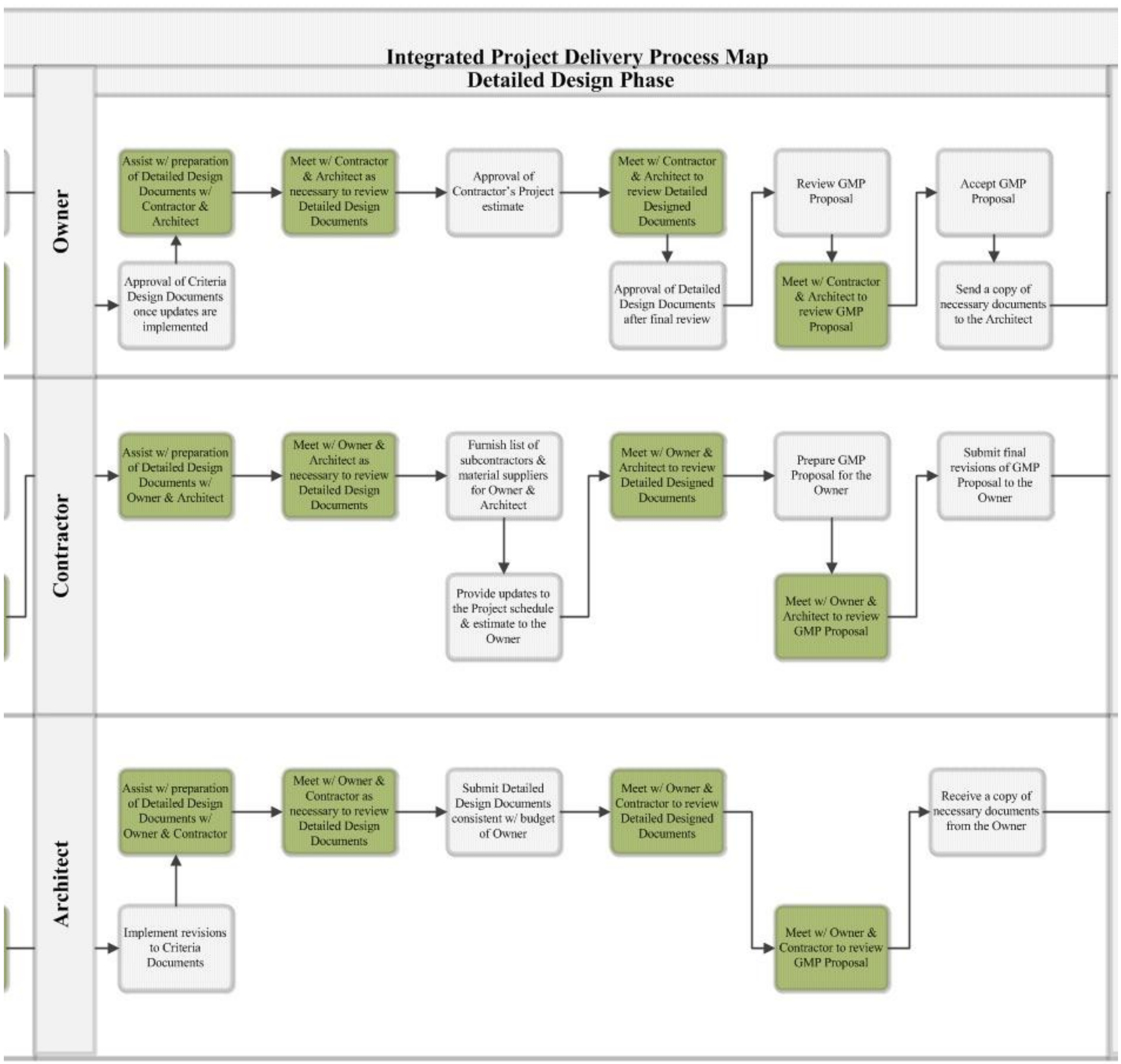


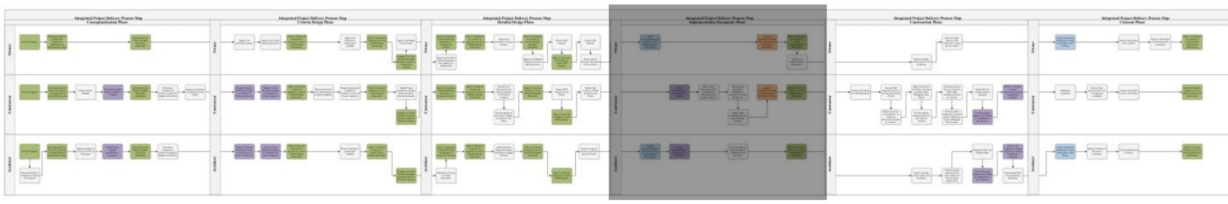

Integrated Project Delivery Process Map
Conceptualization Phase
Owner
Review Program
Reach agreement w/ Contractor & Architect on requirement of project/project scope
Agreement on the Project schedule time limits established
Contractor
Review Program
Reach agreement w/ Owner & Architect on requirement of project/project scope
Prepare Project schedule
Periodically update Project schedule w/ Architect
Agreement on the Project schedule time limits established
Preliminary evaluation of Owner's Program & Budget for the Work
Integrate preliminary evaluation into the Model
Architect
Review Program
Present preliminary evaluation to Owner & Contractor
Reach agreement w/ Owner & Contractor on requirement of project/project scope
Submit schedule of services to Owner & Contractor
Update Project schedule periodically w/ Contractor
Agreement on the Project schedule time limits established
Preliminary evaluation of Owner's Program & Budget for the Work

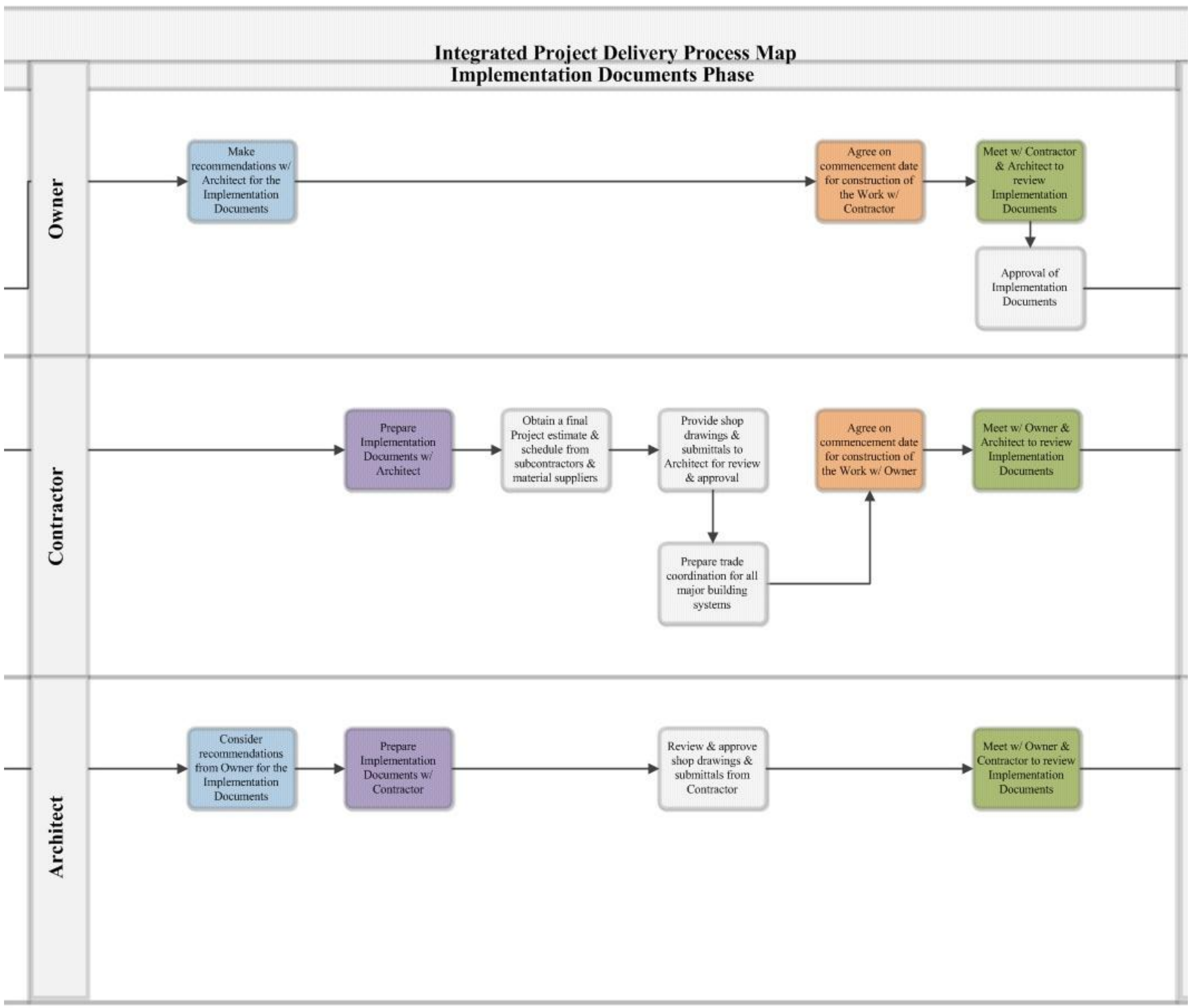



Integrated Project Delivery Process Map
Criteria Design Phase
Owner
Approval of preliminary design
Approval of Criteria Design Documents
Meet w/ Architect & Contractor as necessary to review Criteria Design Documents
Approval of Contractor's procurement schedule
Meet w/ Architect & Contractor to review Criteria Design Documents
Approve the Budget for the Project
If update to Criteria Design Documents necessary consult w/ Contractor & Architect
Contractor
Prepare & Present preliminary design w/ Architect to Owner for approval
Prepare Criteria Design Documents w/ Architect for Owner's approval
Meet w/ Owner & Architect as necessary to review Criteria Design Documents
Obtain information from subcontractors & material suppliers
Prepare procurement schedule for Architect's review & Owner's approval
Meet w/ Owner & Architect to review Criteria Design Documents
Update Project estimate & schedule based on Criteria Design Documents
If update to Criteria Design Documents necessary consult w/ Owner & Architect
Architect
Prepare & Present preliminary design w/ Contractor to Owner for approval
Prepare Criteria Design Documents w/ Contractor for Owner's approval
Meet w/ Owner & Contractor as necessary to review Criteria Design Documents
Review Contractor's procurement schedule
Meet w/ Owner & Contractor to review Criteria Design Documents
If update to Criteria Design Documents necessary consult w/ Owner & Contractor

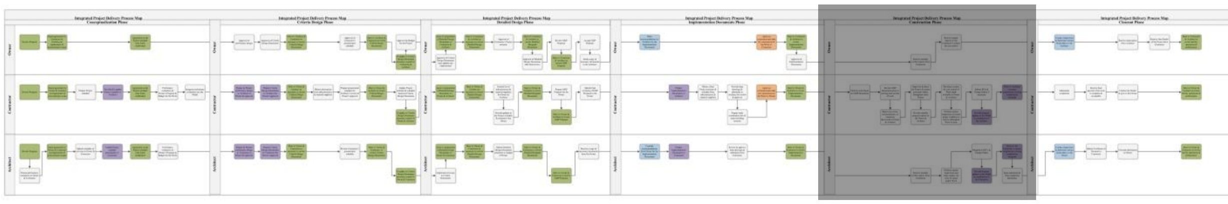


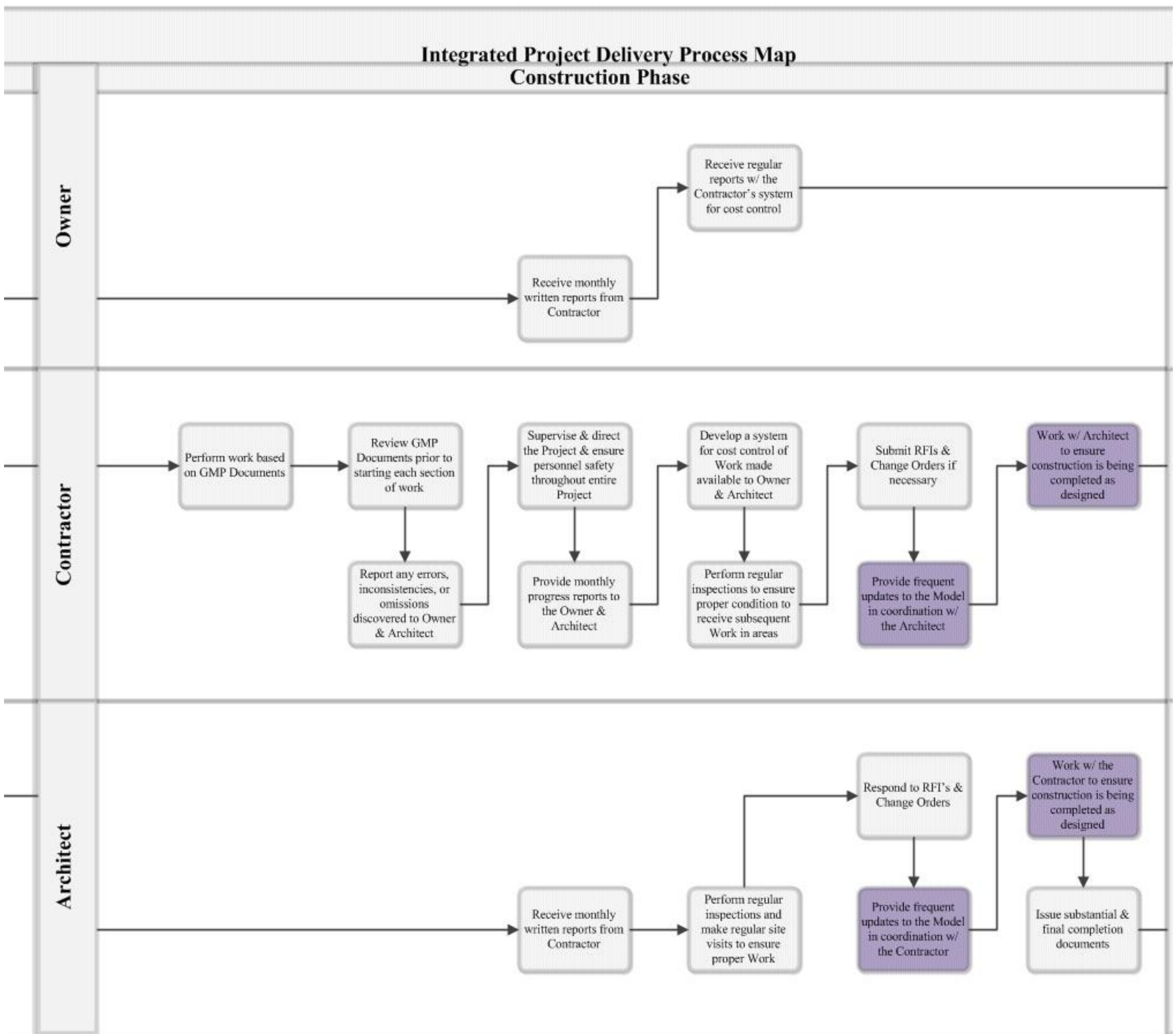

Integrated Project Delivery Process Map
Detailed Design Phase
Owner
Assist w/ preparation of Detailed Design Documents w/ Contractor & Architect
Meet w/ Contractor & Architect as necessary to review Detailed Design Documents
Approval of Contractor's Project estimate
Meet w/ Contractor & Architect to review Detailed Designed Documents
Review GMP Proposal
Accept GMP Proposal
Approval of Criteria Design Documents once updates are implemented
Approval of Detailed Design Documents after final review
Meet w/ Contractor & Architect to review GMP Proposal
Send a copy of necessary documents to the Architect
Contractor
Assist w/ preparation of Detailed Design Documents w/ Owner & Architect
Meet w/ Owner & Architect as necessary to review Detailed Design Documents
Furnish list of subcontractors & material suppliers for Owner & Architect
Meet w/ Owner & Architect to review Detailed Designed Documents
Prepare GMP Proposal for the Owner
Submit final revisions of GMP Proposal to the Owner
Provide updates to the Project schedule & estimate to the Owner
Meet w/ Owner & Architect to review GMP Proposal
Architect
Assist w/ preparation of Detailed Design Documents w/ Owner & Contractor
Meet w/ Owner & Contractor as necessary to review Detailed Design Documents
Submit Detailed Design Documents consistent w/ budget of Owner
Meet w/ Owner & Contractor to review Detailed Designed Documents
Receive a copy of necessary documents from the Owner
Implement revisions to Criteria Documents
Meet w/ Owner & Contractor to review GMP Proposal

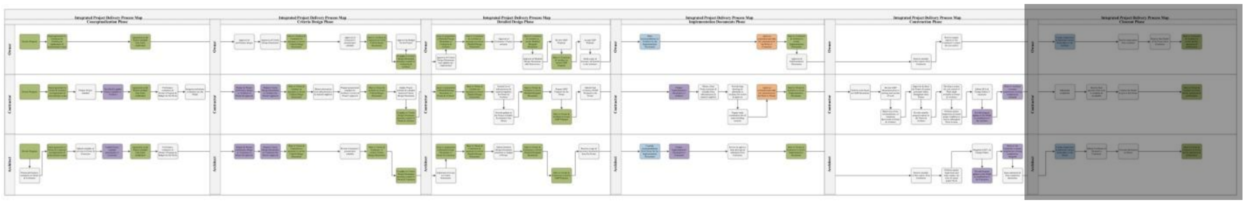


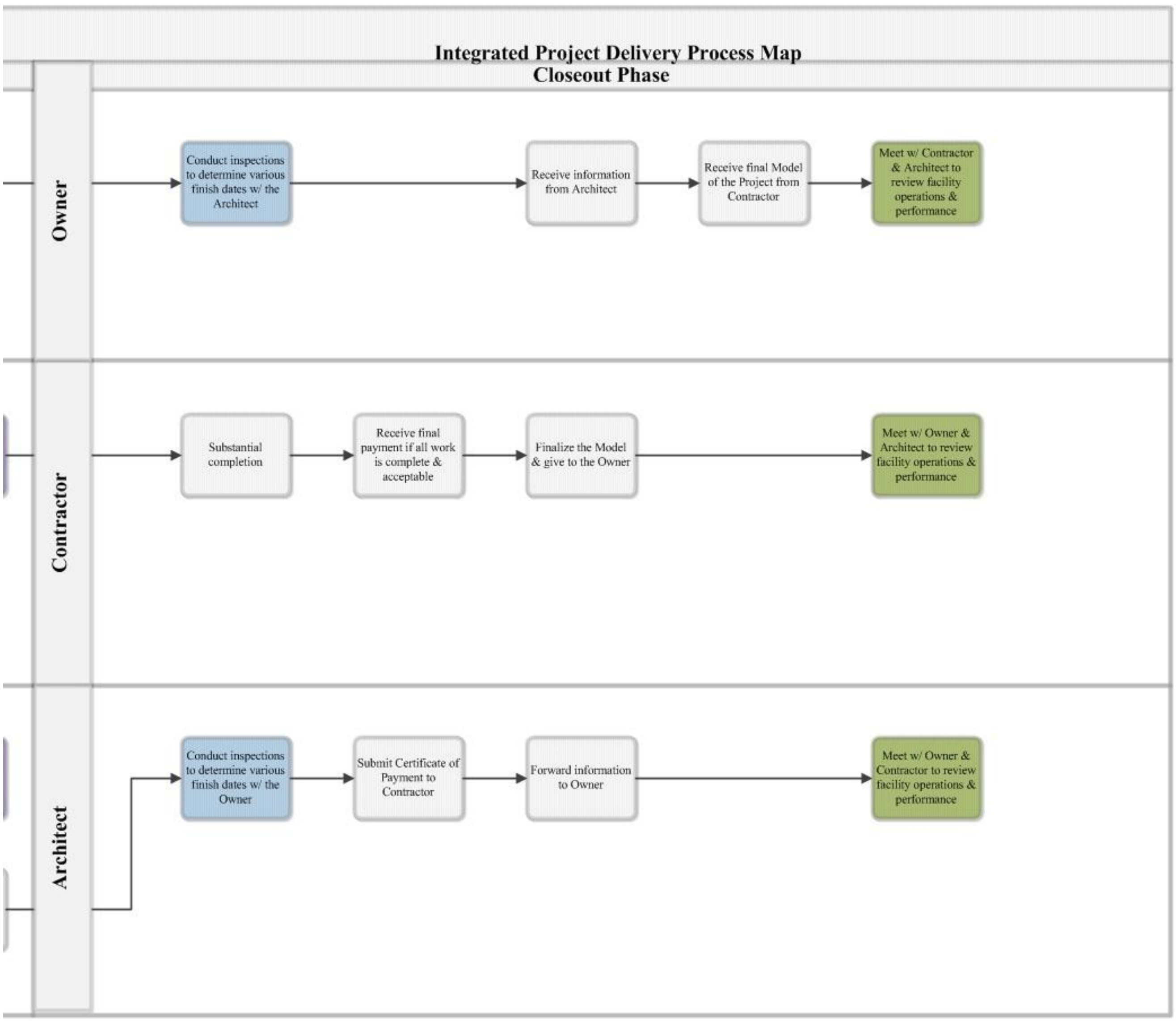


Integrated Project Delivery Process Map
Implementation Documents Phase
Owner
Make recommendations w/ Architect for the Implementation Documents
Agree on commencement date for construction of the Work w/ Contractor
Meet w/ Contractor & Architect to review Implementation Documents
Approval of Implementation Documents
Contractor
Prepare Implementation Documents w/ Architect
Obtain a final Project estimate & schedule from subcontractors & material suppliers
Provide shop drawings & submittals to Architect for review & approval
Agree on commencement date for construction of the Work w/ Owner
Meet w/ Owner & Architect to review Implementation Documents
Prepare trade coordination for all major building systems
Architect
Consider recommendations from Owner for the Implementation Documents
Prepare Implementation Documents w/ Contractor
Review & approve shop drawings & submittals from Contractor
Meet w/ Owner & Contractor to review Implementation Documents




Integrated Project Delivery Process Map
Construction Phase
Owner
Contractor
Architect
Receive regular reports w/ the Contractor's system for cost control
Receive monthly written reports from Contractor
Perform work based on GMP Documents
Review GMP Documents prior to starting each section of work
Supervise & direct the Project & ensure personnel safety throughout entire Project
Develop a system for cost control of Work made available to Owner & Architect
Submit RFIs & Change Orders if necessary
Work w/ Architect to ensure construction is being completed as designed
Report any errors, inconsistencies, or omissions discovered to Owner & Architect
Provide monthly progress reports to the Owner & Architect
Perform regular inspections to ensure proper condition to receive subsequent Work in areas
Provide frequent updates to the Model in coordination w/ the Architect
Respond to RFI's & Change Orders
Work w/ the Contractor to ensure construction is being completed as designed
Receive monthly written reports from Contractor
Perform regular inspections and make regular site visits to ensure proper Work
Provide frequent updates to the Model in coordination w/ the Contractor
Issue substantial & final completion documents




Integrated Project Delivery Process Map
Closeout Phase
Owner
Conduct inspections to determine various finish dates w/ the Architect
Receive information from Architect
Receive final Model of the Project from Contractor
Meet w/ Contractor & Architect to review facility operations & performance
Contractor
Substantial completion
Receive final payment if all work is complete & acceptable
Finalize the Model & give to the Owner
Meet w/ Owner & Architect to review facility operations & performance
Architect
Conduct inspections to determine various finish dates w/ the Owner
Submit Certificate of Payment to Contractor
Forward information to Owner
Meet w/ Owner & Contractor to review facility operations & performance

Appendix I

TRACE 700 Data Sheets

System Checksums

By ACADEMIC

System - 001 | **Water Source Heat Pump**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 17; Outside Air: OADB/WB/HR: 89 / 76 / 114

Clg Space Peak — Mo/Hr: Sum of; OADB: Peaks

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	629,813	629,813	11	0	0
Glass Solar	720,549	0	720,549	12	697,541	18
Glass/Door Cond	41,207	0	41,207	1	63,209	2
Wall Cond	15,713	5,180	20,894	0	19,346	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	516,311		516,311	9	170,431	4
Sub Total ==>	1,293,780	634,993	1,928,773	33	950,527	25
Internal Loads						
Lights	456,129	456,129	912,257	16	456,129	12
People	841,119	0	841,119	14	467,288	12
Misc	1,696,799	0	1,696,799	29	1,696,799	44
Sub Total ==>	2,994,047	456,129	3,450,175	59	2,620,216	68
Ceiling Load	186,941	-186,941	0	0	305,567	8
Ventilation Load	0	0	392,556	7	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-88,764	-88,764	-2		
Sup. Fan Heat			197,160	3		
Ret. Fan Heat		1	1	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	4,474,768	815,418	5,879,901	100.00	3,876,309	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 17

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-517,958	18.52
Glass Solar	0	0	0.00
Glass/Door Cond	-221,748	-221,748	7.93
Wall Cond	-56,299	-77,498	2.77
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-607,830	-607,830	21.74
Sub Total ==>	-885,877	-1,425,035	50.96
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-150,874	0	0.00
Ventilation Load	0	-1,443,065	51.60
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		71,638	-2.56
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1,036,752	-2,796,462	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.2	73.0
Ra Plenum	77.2	66.2
Return	77.2	66.2
Ret/OA	77.6	59.5
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	184,836	184,836
Terminal	184,836	184,836
Main Fan	184,836	184,836
Sec Fan	0	0
Nom Vent	25,383	25,383
AHU Vent	25,383	25,383
Infil	10,692	10,692
MinStop/Rh	0	0
Return	195,528	195,528
Exhaust	36,075	36,075
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	13.7	13.7
cfm/ft²	0.69	0.69
cfm/ton	377.22	
ft²/ton	545.50	
Btu/hr·ft²	22.00	-10.46
No. People	1,869	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	490.0	5,879.9	4,851.0	184,836	78.5	64.2	67.0	56.2	53.6	57.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	490.0	5,879.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	267,289		
Part	0		
Int Door	0		
ExFlr	0		
Roof	66,822	0	0
Wall	53,400	15,348	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-2,796.5	184,836	59.5	73.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2,796.5			

ENERGY CONSUMPTION SUMMARY

By ACADEMIC

	Elect Cons. (kWh)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1				
Primary heating				
Primary heating	4,719	0.3 %	16,106	48,323
Other Htg Accessories	1	0.0 %	3	8
Heating Subtotal	**4,720**	**0.3** %	**16,109**	**48,331**
Primary cooling				
Cooling Compressor	418,222	26.1 %	1,427,391	4,282,601
Tower/Cond Fans		0.0 %	0	0
Condenser Pump		0.0 %	0	0
Other Clg Accessories	72	0.0 %	246	739
Cooling Subtotal....	**418,294**	**26.1** %	**1,427,638**	**4,283,341**
Auxiliary				
Supply Fans	424,859	26.5 %	1,450,044	4,350,568
Pumps	64,464	4.0 %	220,016	660,115
Stand-alone Base Utilities		0.0 %	0	0
Aux Subtotal....	489,323	30.5 %	1,670,061	5,010,683
Lighting				
Lighting	689,766	43.0 %	2,354,171	7,063,220
Receptacle				
Receptacles	1,214	0.1 %	4,145	12,435
Cogeneration				
Cogeneration		0.0 %	0	0
Totals				
Totals**	**1,603,318**	**100.0** %	**5,472,123**	**16,418,010**

Note: Add primary heating, primary cooling, and auxiliary loads to calculate approximate total source energy for the building.

Total Source Energy for the building = 9,342,355 k Btu/yr

* Note: Resource Utilization factors are included in the Total Source Energy value .
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

System Checksums

By ACADEMIC

System - 001 — **Variable Volume Reheat (30% Min Flow Default)**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 17; Outside Air: OADB/WB/HR: 89 / 76 / 114

Clg Space Peak — Mo/Hr: 7 / 17; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	631,503	631,503	9	0	0
Glass Solar	748,371	0	748,371	11	748,371	19
Glass/Door Cond	63,209	0	63,209	1	63,209	2
Wall Cond	24,177	7,831	32,008	0	24,177	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	538,893		538,893	8	170,431	4
Sub Total ==>	1,374,650	639,334	2,013,984	29	1,006,188	26
Internal Loads						
Lights	456,129	456,129	912,257	13	456,129	12
People	841,119	0	841,119	12	467,288	12
Misc	1,696,799	0	1,696,799	24	1,696,799	43
Sub Total ==>	2,994,047	456,129	3,450,175	49	2,620,216	67
Ceiling Load	291,966	-291,966	0	0	291,966	7
Ventilation Load	0	0	1,279,401	18	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-155,734	-155,734	-2		
Sup. Fan Heat			352,702	5		
Ret. Fan Heat		99,123	99,123	1		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	4,660,663	746,886	7,039,651	100.00	3,918,370	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 17

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-481,895	19.86
Glass Solar	0	0	0.00
Glass/Door Cond	-221,748	-221,748	9.14
Wall Cond	-60,754	-82,038	3.38
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-607,830	-607,830	25.05
Sub Total ==>	-890,332	-1,393,511	57.44
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-441,104	0	0.00
Ventilation Load	0	-11	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		62,075	-2.56
OA Preheat Diff.		-1,094,672	45.12
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1,331,436	-2,426,119	100.00

TEMPERATURES

	Cooling	Heating
SADB	57.3	1,418.5
Ra Plenum	78.5	62.8
Return	78.9	62.8
Ret/OA	80.2	17.0
Fn MtrTD	0.2	0.0
Fn BldTD	0.4	0.0
Fn Frict	1.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	198,394	0
Terminal	198,394	0
Main Fan	198,394	0
Sec Fan	0	0
Nom Vent	25,383	0
AHU Vent	25,383	0
Infil	10,692	10,692
MinStop/Rh	0	0
Return	209,086	10,692
Exhaust	36,075	10,692
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	12.8	98.0
cfm/ft²	0.74	0.00
cfm/ton	338.19	
ft²/ton	455.63	
Btu/hr·ft²	26.34	-8.98
No. People	1,869	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	586.6	7,039.7	5,422.6	198,394	80.2	65.6	71.2	55.7	54.0	59.7
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	586.6	7,039.7								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	267,289		
Part	0		
Int Door	0		
ExFlr	0		
Roof	66,822	0	0
Wall	53,400	15,348	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-1,305.1	0	55.7	1,418.5
Aux Htg	0.0	0	0.0	0.0
Preheat	-1,094.7	25,383	17.0	55.7
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2,399.8			

ENERGY CONSUMPTION SUMMARY

By ACADEMIC

	Elect Cons. (kWh)	Gas Cons. (kBtu)	Water Cons. (1000 gals)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 2						
Primary heating						
Primary heating		84,203		0.7 %	84,203	88,635
Other Htg Accessories	635			0.0 %	2,167	6,503
Heating Subtotal	**635**	**84,203**		**0.7** %	**86,370**	**95,138**
Primary cooling						
Cooling Compressor	384,959			11.3 %	1,313,865	3,941,988
Tower/Cond Fans	96,430		2,757	2.8 %	329,115	987,443
Condenser Pump				0.0 %	0	0
Other Clg Accessories	2,851			0.1 %	9,730	29,194
Cooling Subtotal....	**484,240**		**2,757**	**14.2** %	**1,652,710**	**4,958,626**
Auxiliary						
Supply Fans	454,538			13.4 %	1,551,339	4,654,482
Pumps				0.0 %	0	0
Stand-alone Base Utilities				0.0 %	0	0
Aux Subtotal....	454,538			13.4 %	1,551,339	4,654,482
Lighting						
Lighting	689,766			20.3 %	2,354,171	7,063,220
Receptacle						
Receptacles	1,748,924			51.4 %	5,969,078	17,909,026
Cogeneration						
Cogeneration				0.0 %	0	0
Totals						
Totals**	**3,378,103**	**84,203**	**2,757**	**100.0** %	**11,613,669**	**34,680,492**

Note: Add primary heating, primary cooling, and auxiliary loads to calculate approximate total source energy for the building.

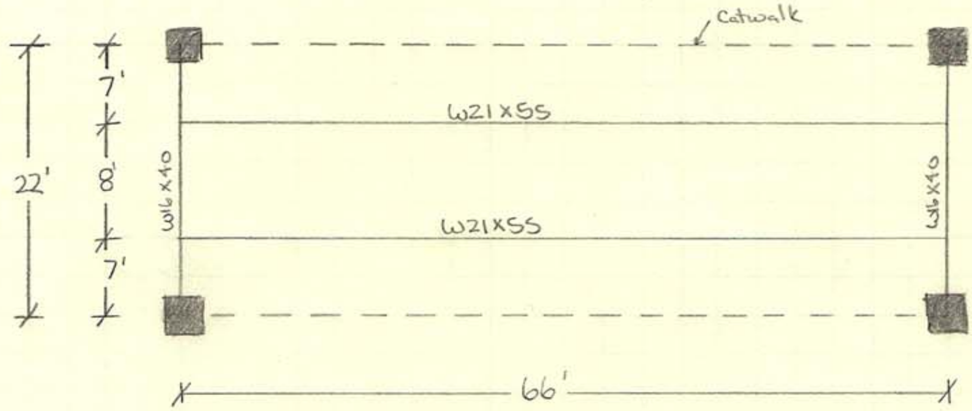
Total Source Energy for the building = 9,708,246 k Btu/yr

* Note: Resource Utilization factors are included in the Total Source Energy value .
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Appendix J

Raised Platform Design #1 & #2

Raised Platform Design #1



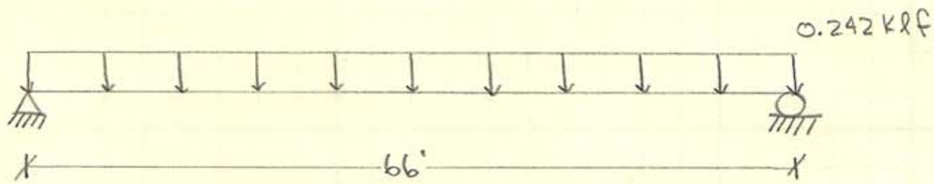
RTU weighs 32000 lbs

$$\frac{32000\text{ lbs}}{2\text{ beams}} = 16000\text{ lbs each}$$

$$\frac{16000\text{ lbs}}{66'\text{ long}} = 242.42\text{ plf} = 0.242\text{ klf}$$

Assumptions

RTU ≈ 52'x22' → assuming load is distributed throughout entire platform (66'x22')



Deflection

$\Delta_T \leq L/240$

$$L/240 = \frac{5wl^4}{384EI}$$

$$\frac{66'\times 12}{240} = \frac{5(0.242\text{ klf})(66'^4)(1728)}{384(29000)\,I}$$

$I = 1081.471\text{ in}^4 < I = 1140\text{ in}^4$ (W21X55) okay ✓

Try W21X55 from pg. 3-21 in Steel Manual
3-19

$I = 1140\text{ in}^4$

$\phi M_n = 473\text{ k}\cdot\text{ft}$

$\phi V_n = 234\text{ k}$

Flexure

$w_u = 1.4(0.242\ klf) = 0.3388\ klf$

$M_u = \frac{wl^2}{8}$

$M_u = \frac{(0.3388\ klf)(66'^2)}{8}$

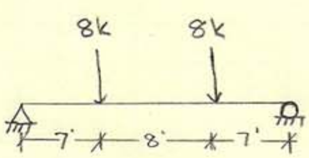
$M_u = 184.477\ k\cdot ft < \phi M_n = 473\ k.ft$ okay ✓

Shear

$V_u = \frac{(0.3388\ klf)(66')}{2}$

$V_u = 11.18\ k < \phi V_n = 234\ k$ okay ✓

Therefore, based on deflection, flexure, + shear (2) W21X55 transversely will support RTU load. These beams will be laterally braced through proper connections to (2) horizontal beams (designed below)



$0.242\ klf \times 33' \approx 8K$

Deflection

$\Delta_T \leq L/240$

$L/240 = \frac{Pl^3}{28EI}$

$\frac{7' \times 12}{240} = \frac{(8k)(22'^3)(1728)}{28(29000)\ I}$

$I = 517.94\ in^4 < I = 518\ in^4$ (W16x40) okay ✓

Try W16X40 from pg. 3-21 / 3-17 in Steel Manual

$I = 518\ in^4$

$\phi M_n = 274\ k\cdot ft$

$\phi V_n = 146\ K$

Flexure

$P_u = 1.4(8K) = 11.2\ K$

$M_u = P\ell$

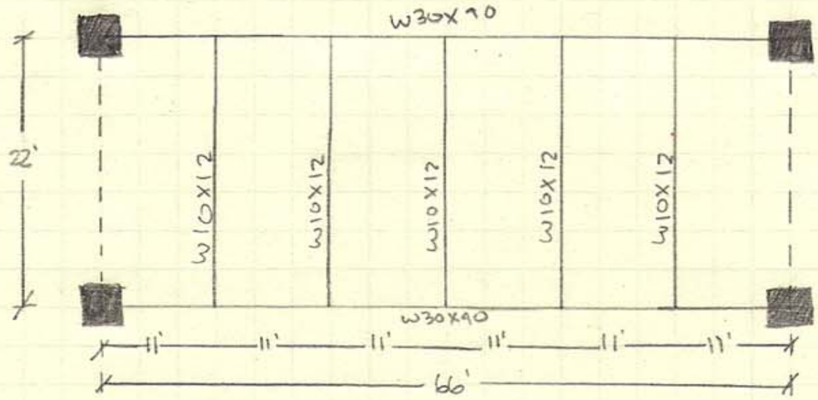
$M_u = (11.2k)(7') = 78.4\ k \cdot ft < \Phi M_n = 274\ k \cdot ft$ okay ✓

Shear

$V_u = \frac{11.2\ k}{2} = 5.6K < \Phi V_n = 146K$ okay ✓

Design #1 consists of (2) W16X40 laterally braced to (2) W21X55 w/ a catwalk incorporated into the structure.

Raised Platform Design # 2



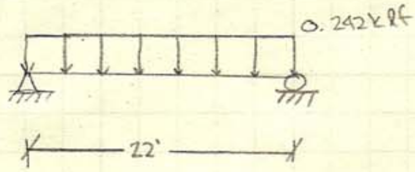
RTU weighs 32000lbs

Assumptions

RTU ≈ 32'x22' → assuming load is distributed throughout entire platform (66'x22')

$$\frac{32000\text{lbs}}{6\text{ beams}} = 5333.33\text{lbs each}$$

$$\frac{5333.33\text{lbs}}{22'\text{ long}} = 242.42\text{ plf} = 0.242\text{ klf}$$



Deflection

$$\Delta_T \leq L/240$$

$$L/240 = \frac{5wl^4}{384EI}$$

$$\frac{22' \times 12}{240} = \frac{5(0.242\text{klf})(22'^4)(1728)}{384(29000)I}$$

$I = 39.985\text{in}^4 < I = 53.8\text{in}^4$ (W10X12) okay ✓

Try W10X12 from pg. 3-21 / 3-19 in Steel Manual

$$I = 53.8\text{in}^4$$

$$\phi M_n = 46.9\text{ k}\cdot\text{ft}$$

$$\phi V_n = 56.3\text{ k}$$

Flexure

$w_u = 1.4\,(0.242\text{ klf}) = 0.3388\text{ klf}$

$M_u = \dfrac{wl^2}{8}$

$M_u = \dfrac{(0.3388\text{ klf})(22'^2)}{8}$

$M_u = 20.497\text{ k·ft} < \Phi M_n = 46.9\text{ k·ft}$ okay ✓

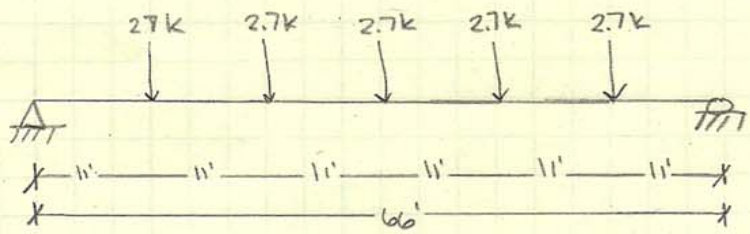
Shear

$V_u = \dfrac{(0.3388\text{ klf})(22')}{2}$

$V_u = 3.727\text{ k} < \Phi V_n = 56.3\text{ K}$ okay ✓

Therefore, based on deflection, flexure + shear (6) W10X12 horizontally will support RTU load. These beams will be laterally braced through proper connections to (2) transverse beams (designed below)

$0.242\text{ klf} \times 11' = 2.7\text{k}$



Deflection

$\Delta_T \le L/240$

$L/240 = \dfrac{Pl^3}{28EI}$

$\dfrac{11' \times 12}{240} = \dfrac{(2.7\text{k})(66'^3)(1728)}{28(29000)\,I}$

$I = 3003.5\text{ in}^4 < I = 3610\text{ in}^4$ (W30X90)

Try W30X90 from pg. 3-21 / 3-15 in Steel Manual

$I = 3610\text{ in}^4$

$\Phi M_n = 1060\text{ k·ft}$

$\Phi V_n = 375\text{ k}$

Flexure

$P_u = 1.4(2.7k) = 3.78k$

$M_u = Pl$

$M_u = (3.78k)(11')$

$M_u = 41.58\ k \cdot ft < \phi M_n = 1060 k \cdot ft$ okay ✓

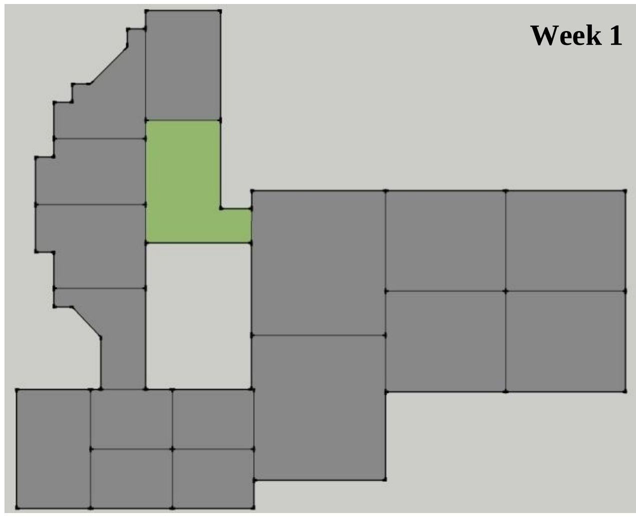
Shear

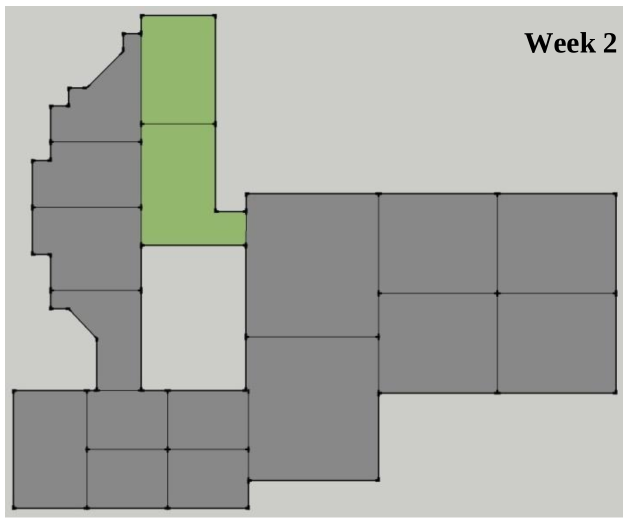
$V_u = \frac{3.78k}{2} = 1.89k < \phi V_n = 375\ k$ okay ✓

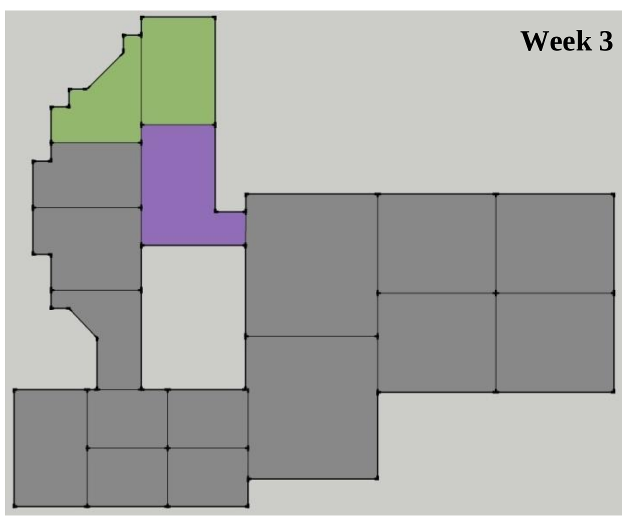
Design #2 consists of (6) W10X12 laterally braced to (2) W30X90 w/ a catwalk incorporated into the structure.

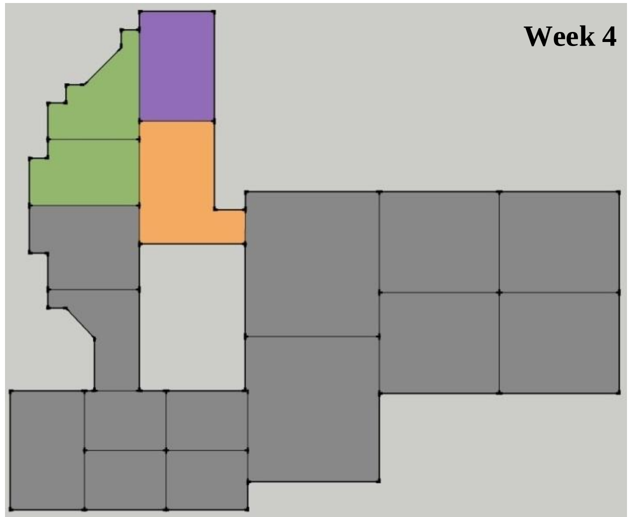
Appendix K

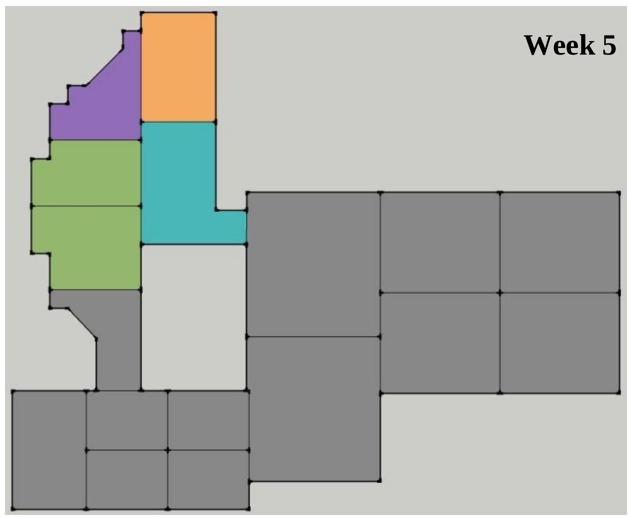
SIPS Big Picture Flow Diagram

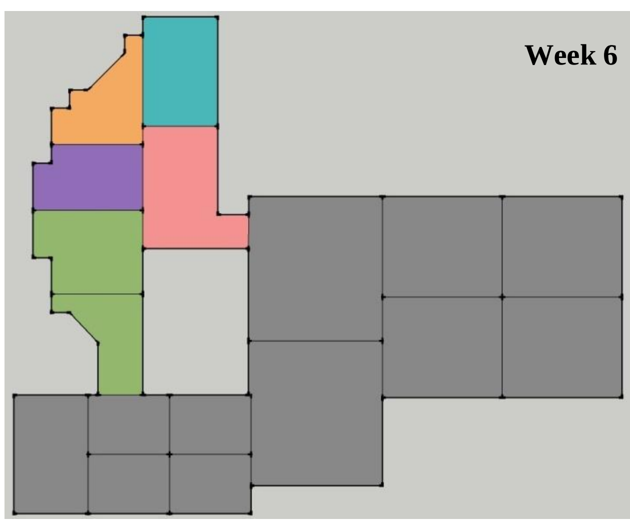

Week 1

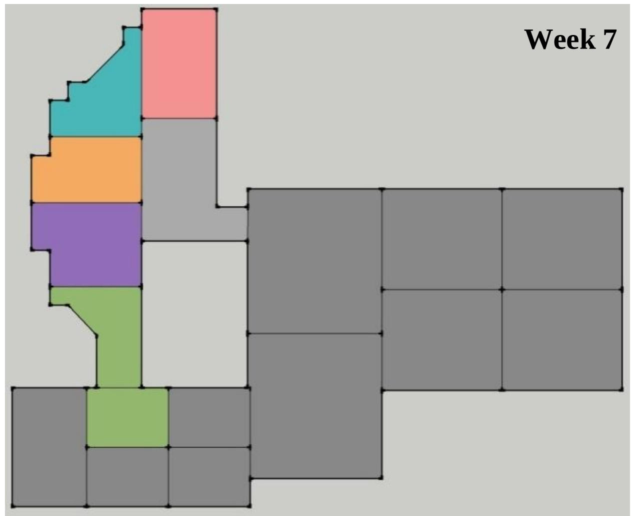

Week 2

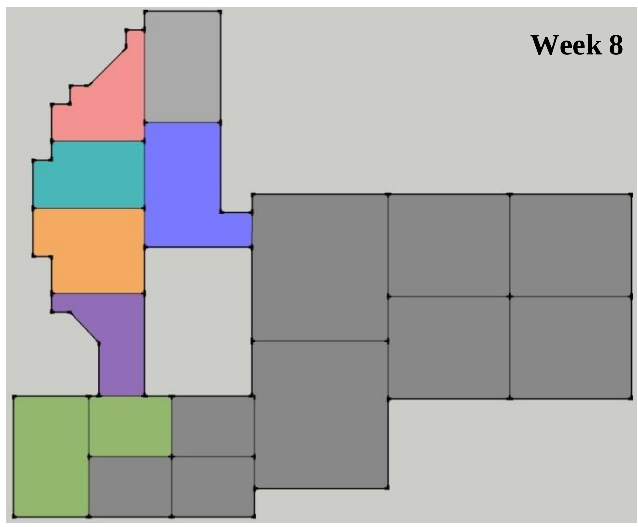

Week 3

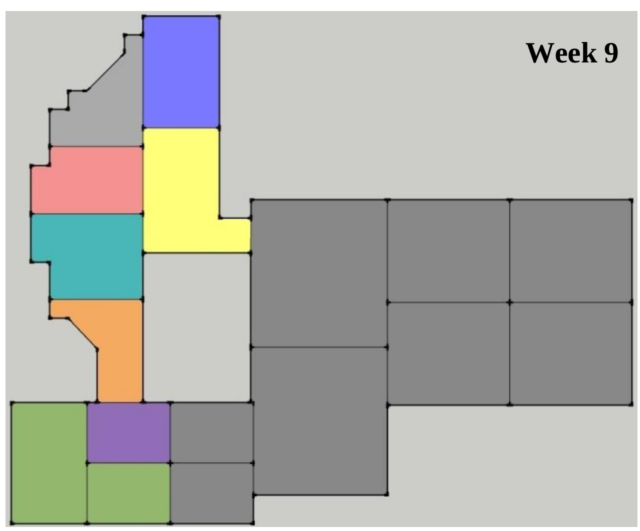

Week 4

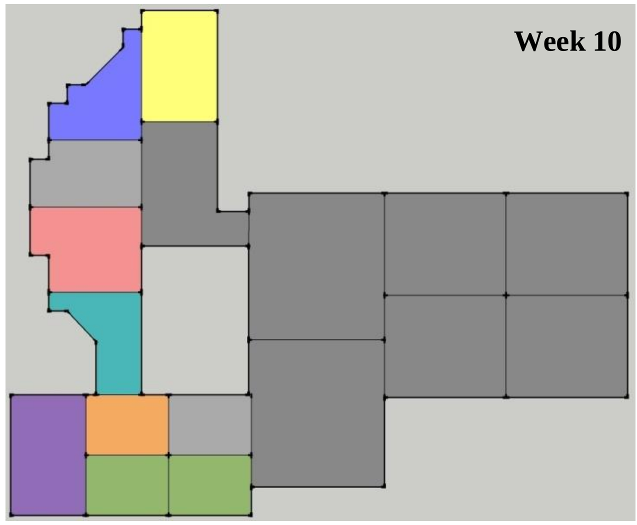

Week 5

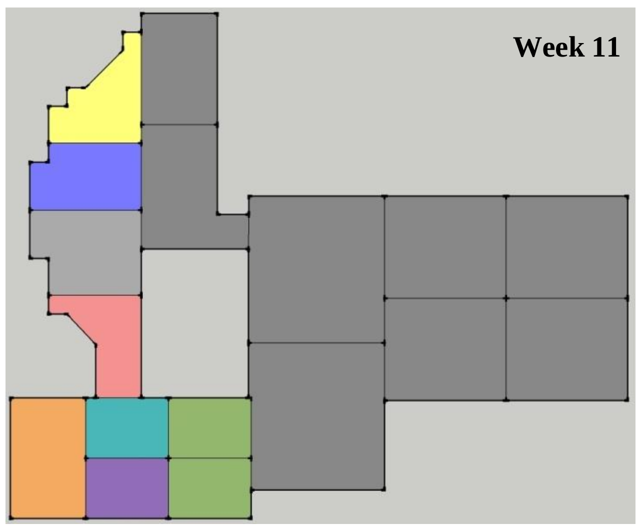

Week 6

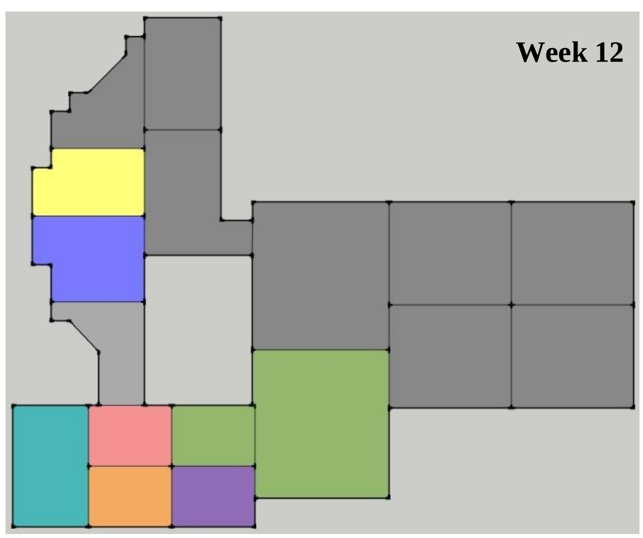

Week 7

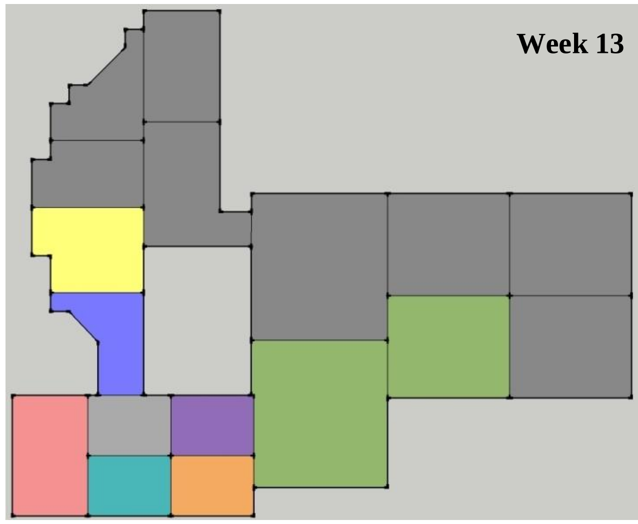

Week 8

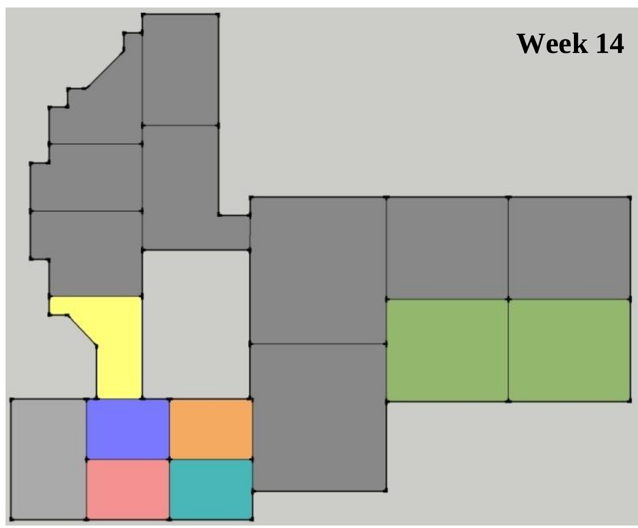

Week 9

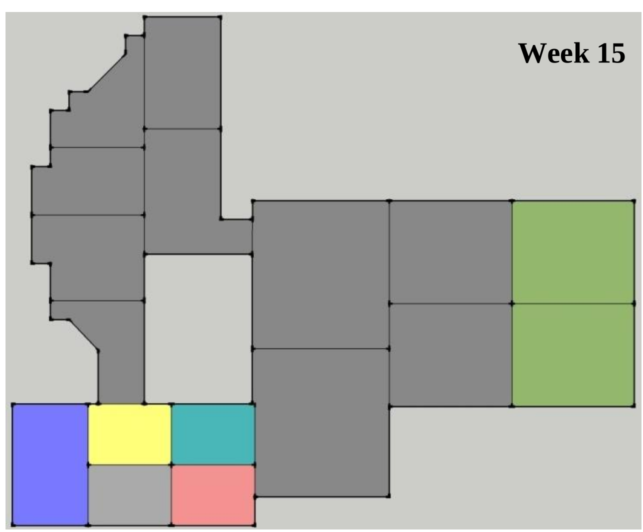

Week 10

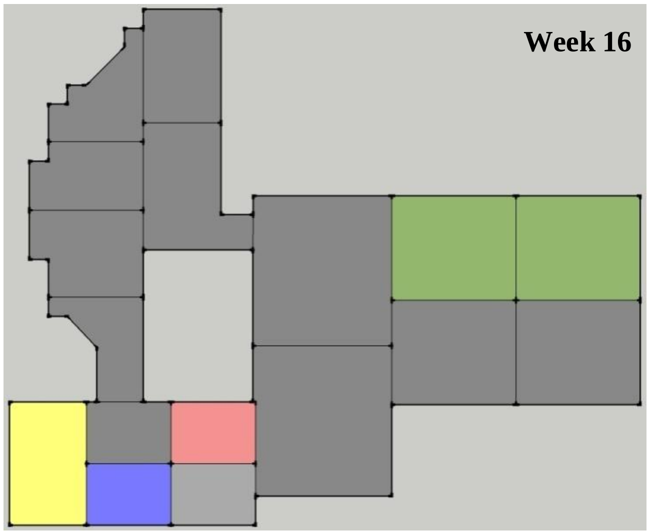

Week 11

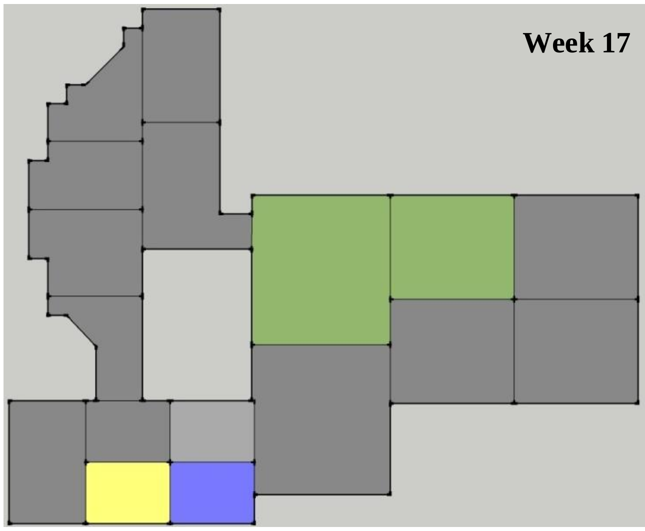

Week 12

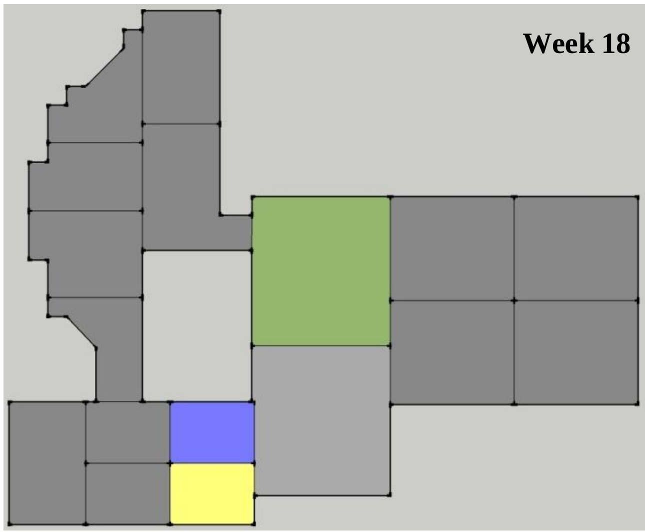

Week 13

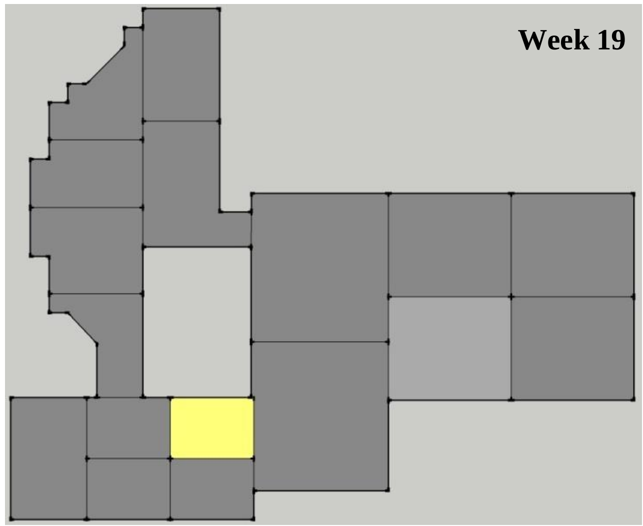

Week 14

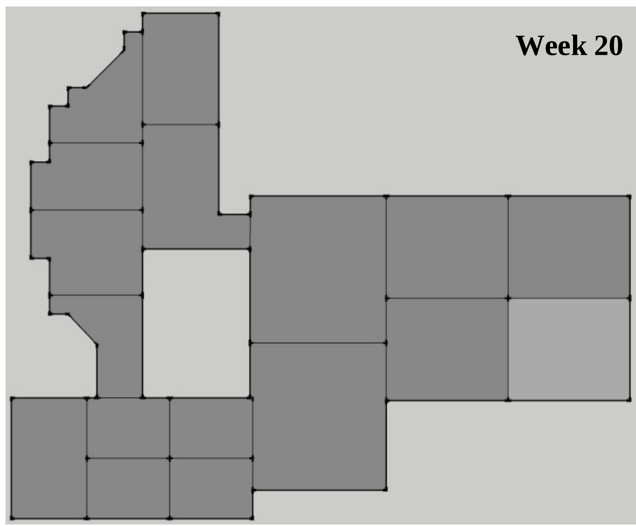

Week 15

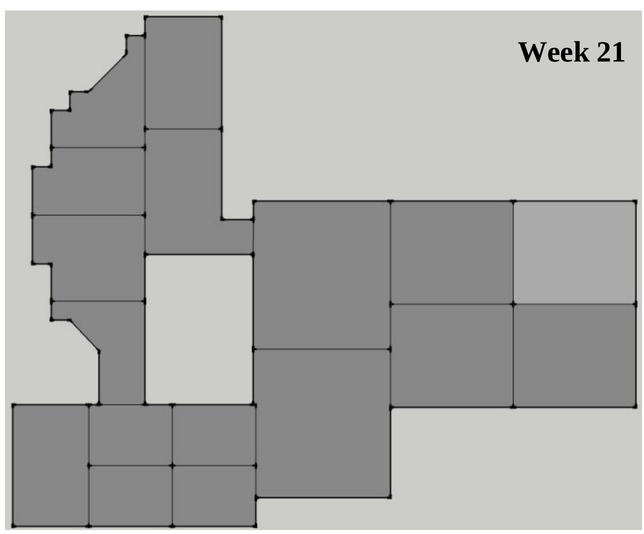

Week 16

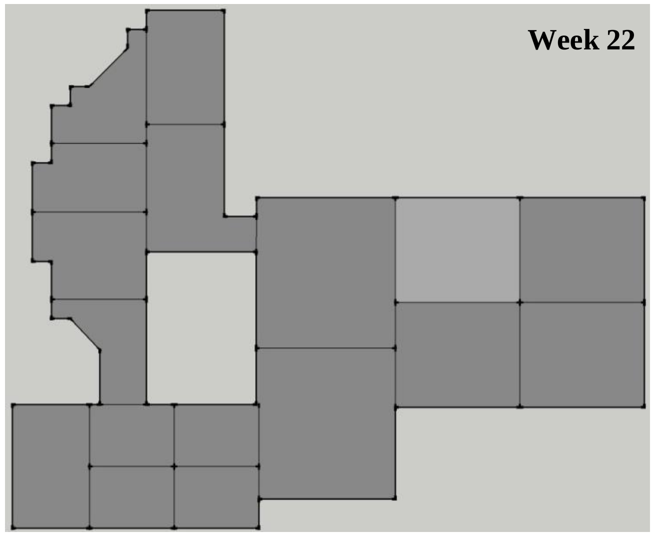

Week 17

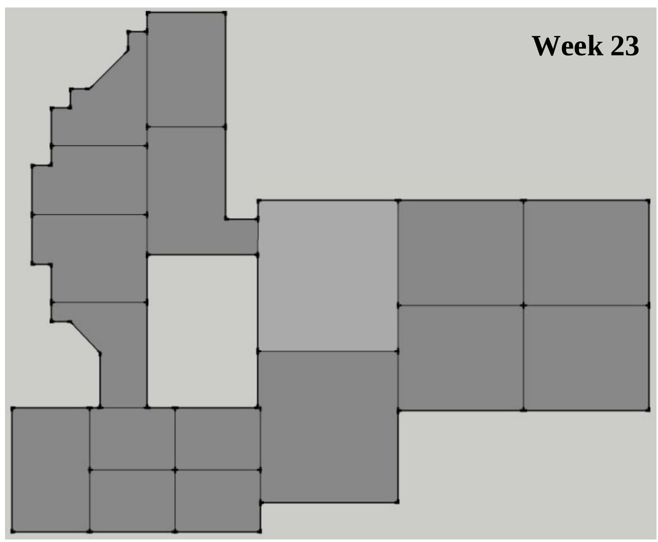

Week 18


Week 19


Week 20


Week 21


Week 22


Week 23


Demolition
Core Drill
FRP Footings for PC
FRP Cols & Beams for PC
Strengthening
Seismic Bracing
Erect Steel for PC
Detail Steel for PC