`THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ARCHITECTURAL ENGINEERING
SENIOR THESIS

UPMC Passavant Pavilion

Pittsburgh, Pa

Thesis Final Report

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07 April 2009

UPMC Passavant Pavilion Addition

Pittsburgh, Pa

Project Information

Name: UPMC Passavant Pavilion

Occupant: University of Pittsburgh Medical Center

Size: 209,400 sq. feet

Dates of Construction: November 2007 – May 2010

Cost: $85,900,000

Delivery Method: General Contractor

Structural System

Concrete Spread Footings and Foundation Walls

Structural Steel Framing with Concrete Slabs on Metal Deck

Braced and Moment Frame Lateral Force Resisting Systems

Mechanical

Heating: (2) 45,000MBH Natural Gas Boilers

Cooling: (6) 333.3 Ton Cooling Towers

(2) 1000 Ton, 2388 GPM Chillers

Electrical System

Feed: 23kV from Duquesne Light Co.

Distribution: 480/277V and 208/120V

Emergency Power: UPS and Generators

Lighting System

Primarily 277V System with 120V Fixtures Intermittently Spaced Throughout.

277V Fluorescent Fixtures

120V Incandescents and LEDs

Project Team

Owner

University of Pittsburgh Medical System

Architect

Burt Hill

General Contractor

PJ Dick Inc

Structural Engineer

Atlantic Engineering Services

Mechanical Engineer

Firsching, Marstiller, Rusbarsky, Wolf Engineering

Electrical Engineer

CJL Engineering

Architecture

Exterior Cladding: Brick Veneer with CMU Backup, Brick Veneer with Structural Sheathing Backup, Aluminum and Glass Curtainwall, Metal Panels.

Roofing: TPO Roofing System on Metal Deck and Insulation at the Penthouse Roof.

Green Roofing on the Roof Gardens at the 2nd and 3rd Floors.

Additions: New Oncology and Emergency Department Facilities.

(6) Operating Rooms.

(16) Intensive Care Units.

(72) Patient Rooms.

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The Pennsylvania State University | Department of Architectural Engineering

http://www.engr.psu.edu/ae/thesis/portfolios/2009/jjm5005/

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Acknowledgments

Penn State AE Faculty

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The UPMC Passavant P.J. Dick Inc. Staff

The UPMC Passavant Project Team

Steve Romanchik – UPMC Passavant

My Family and Friends

Fellow AE Students

Michael Hopper

The Members of the Bat Cave

1.0 Executive Summary

This Thesis Final Report is a culmination of analyses conducted over the course of the Spring 2009 semester. The subject of these analyses is the UPMC Passavant Pavilion & Addition project which is located in the suburbs north of Pittsburgh, Pa. UPMC Passavant is the latest addition and renovation to occur at the Passavant Campus as UPMC continues to further their dedication to quality and cutting edge healthcare within Western Pennsylvania.

Within this final report are three analyses that will investigate a critical industry issue that is affecting the overall construction industry and two technical analyses that look to reducing the overall cost and schedule of the Passavant project. The critical industry issue looks at the use of mobile information technology within the construction industry and how to best implement it on the project. Whenever a new technology is introduced in any industry it is met with some resistance and through a thorough review of the system and in speaking with contractors and suppliers I hope to determine how to limit this resistance.

The technical analyses are aimed at decreasing the cost and schedule of the project. The first is an analysis of the viability of utilizing architectural precast concrete wall panels in lieu of the original brick masonry veneer. This study will look to decrease the schedule through shorter construction durations and to decrease cost through less expensive materials and decreased labor hours. The second analysis focuses on the use of matrix schedules. Passavant Pavilion has encountered some delays due to unforeseen conditions and work could possibly need to be accelerated to remain on schedule to meet the contractual completion date. Different sequencing and scheduling methods will be investigated to determine the manner in which to best increase the pace of construction while maintaining the quality that is required.

The main emphasis of the above analyses is construction management, however, structural and architectural studies will be completed as needed to provide the best solution that satisfies all three of these areas of focus.

2.0 Introduction

The UPMC Passavant Pavilion Addition and Renovation serves to further the healthcare goals of the University Of Pittsburgh Medical Center. These goals include improving technology integration, recruiting the best staff, and developing state-of-the-art facilities to support both medical care and staff recruitment. The Pavilion Addition is an integral part of the latter as it will house the emergency and surgical departments, as well as, increase the number of patients that can be served. This addition will also increase the capacity of the UPMC Cancer Center.

The project is approximately 209,400 square feet of addition and 30,000 square feet of renovation area with a total cost of $85.9 million. Construction of the Passavant Pavilion began in November 2007 with minor renovations to the existing hospital to accommodate the new addition. The Pavilion construction will be complete in the Fall of 2009 with renovations to select areas of the existing hospital to commence afterwards and be complete in the Spring of 2010.

Square Footage of Overall Project	
Activity	**Sq. Ft.**
Addition	191,400
Penthouse	18,000
Renovation	30,000

Figure 2.1 Sq. Ft. of Project

Cost & Schedule of Project	
Total Cost:	$85.9 Million
Schedule Dates	
Notice to Proceed:	November 2007
Construction of Pavilion Addition:	Spring 2008 – Fall 2009
Renovation of Existing Hospital:	Fall 2009 – Spring 2010

Figure 2.2 Cost & Schedule of Project

2.1 Area Location

The UPMC Passavant Pavilion and Addition is located in the North Hills of the Pittsburgh Metropolitan area just south of the Town of McCandless. This location is central to major highways, I-79 and I-76, and the city which allows for convenient delivery routes to and from the jobsite in all directions without the congestion of a downtown location.

2.1.1 Location Map

Figure 2.3 Location Map

3.0 Project Overview

3.1 Client Information

The owner of the project is the University Of Pittsburgh Medical Center (UPMC). UPMC is a network of twenty hospitals and other medical care sites throughout Western Pennsylvania. UPMC's mission is 'To provide outstanding patient care to shape tomorrow's health system through clinical innovation, biomedical and health services research, and education.' They were recently ranked 14th among 'America's Best Hospitals' by U.S. News & World Reports.

In order to achieve their mission and continue to be one of the best hospitals in the country UPMC has chosen to expand and renovate Passavant Hospital and many of their other facilities. These renovation and expansion efforts are a result out of their need to better serve the community through larger and more cutting edge facilities. These facilities will increase the capacity that UPMC will be able to provide healthcare to the North Hills area of Pittsburgh. This will be achieved through larger a large emergency department, centralized cancer center, larger surgical department, and additional patient rooms.

3.2 Project Delivery System

The project delivery method for the UPMC Passavant Pavilion is Design-Bid-Build with a general contractor. This method was chosen for the project because it allows for the most complete design before construction begins. Due to the complexity of the systems within a healthcare facility it is key to have a complete, or nearly complete, design before bids are submitted and construction commences. This enables the contractors to submit accurate bids to the owner and architect and there are no bidding assumptions being made as there would be if the project was design-build.

PJ Dick Inc. was chosen by UPMC to serve as the general contractor on the Passvant project. Within this agreement PJ Dick is responsible for the majority of the construction within the project through self performing the work or through subcontractors. Selection of many of the subcontractors was based upon the bidding process, however, the MEP contractors were selected based upon best value. Prior to bidding all MEP subcontractors were involved in the value engineering process. This allowed for contractor input on the systems that should be used and how to best provide systems to meet the hospitals needs and goals without basing contractor selection on lowest price alone.

3.3 Organizational Chart

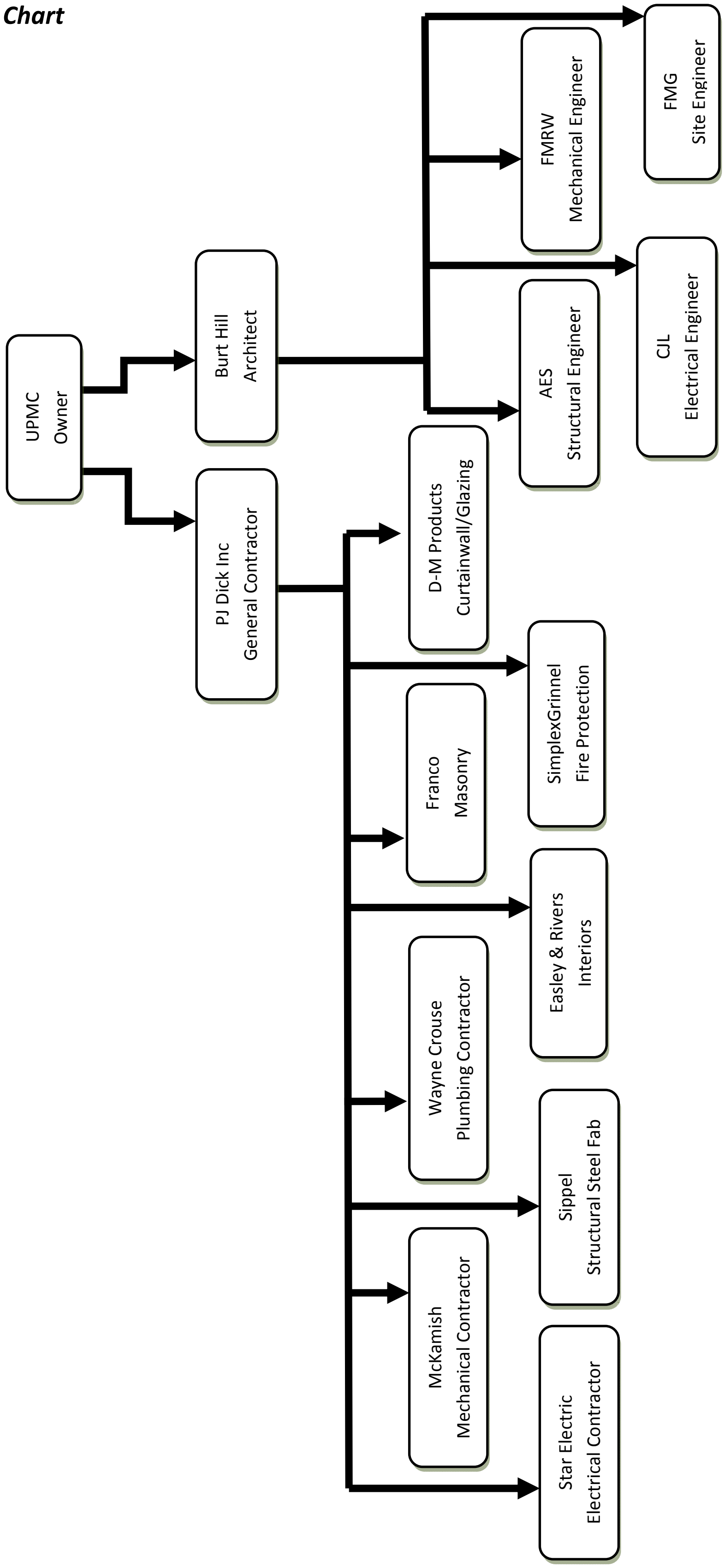


Figure 2.4 Project Organization Chart

3.4 Project Management

P.J. Dick Inc. was chosen by UPMC to serve as the general contractor of the UPMC Passavant Pavilion Addition and Renovation through competitive bidding. After being awarded the lump sum contract PJD began to contract with subcontractors for the various portions of the building for which they were not self performing. During this process subcontracts were awarded based upon bids and pre-qualifications for the majority of subcontracts. For the MEP portion of the project all prospective bidders were brought into the project prior to submitting bids.

The incorporation of prospective MEP bidders into the preconstruction portion of the project allowed them to provide insight into the constructability of the Pavilion. This allowed them to participate in the value engineering process and provide input as to which systems and products the hospital should select to provide them with a more complete and high quality project.

Due to the size of the Passavant Pavilion PJD provided a staff that would be focused on particular areas of the construction process. This staff included a senior project manager, a project manager, two project engineers, a superintendent, and area superintendents. The project manager and project engineers divided the specifications into areas of responsibility with one of the project engineers focused only on the MEP portion of the project and the other splitting responsibility for the remaining work with the project manager. This allowed the staff to have an area of expertise within the project so that all issues pertaining to that knowledge was directed to them allowing for a more complete answer and decision process.

4.0 Design and Construction Overview

4.1 Building Systems

4.1.1 Architecture

The UPMC Passavant Pavilion Addition and Renovation is a key feature in the visionary master plan for the Passavant campus. As the hospital moves to better serve the needs of the community the new Pavilion aims to meet that goal. The design of the new facility aids in bringing a state-of-the-art feel to a leading edge hospital system. This is accomplished through the use of glazed aluminum curtain wall, metal panels and masonry veneer.

The design of the new Pavilion aids UPMC in their goal of better serving the community and this can be seen through the functionality of the building. The addition expands and improves on many of the services already available in the existing hospital. The expanded services include a new oncology department, emergency department, 6 additional operating rooms, 16 new intensive care units, and 72 new patient rooms. The project also increases the mechanical and electrical capabilities of the hospital through the addition of a new central plant with boilers, chiller, and generators.

4.1.2 Structural System

The UPMC Passavant Pavilion is built upon spread footings and the structure bears on foundation walls on the east and west ends. All footings and foundation walls are constructed of 4000 psi normal weight concrete. The foundation along the majority of the south elevation is composed of concrete masonry units.

The framing of the building is constructed of structural steel. The typical column bay size is 28’-0 x 28’-0. The columns that make up the bays are typically W12 or W14 members with varying weights. Typically columns are 3 stories in length and bear on 24” x 24” piers. These piers in turn bear upon footings that range in size from 3’-0 x 3’-0 to 8’-0 x 8’-0 depending upon the loading of the columns. Each floor of the structure is a composite slab on deck that is constructed from 3 ¼” light weight 4000 psi concrete on 2” 20 ga. composite metal decking.

4.1.3 Electrical System

The Pavilion Addition and the new Central Plant are both serviced by two 23kV feeders provided by the Duquesne Light Company. Both 277/480V and 120/208V systems are required within the building and the services are stepped down accordingly. Continuous service within a healthcare facility is very important. To accomplish this, the new addition features two backup emergency systems. The first system is a 225kw 120/208 uninterruptable power supply which is capable of operating at full load for up to 12 minutes. This system allows the hospital to function unimpeded while the second emergency system, three 1.5 MW 4160V diesel generators, powers up. Power is transferred from the emergency power system to the building through the use of automatic transfer switches which are tripped whenever the main electrical system fails.

4.1.4 Mechanical System

The heating system for the Pavilion addition is powered by two 45,000 MBH (1000BtuH) natural gas boilers located on the Ground Floor of the Central Plant. These boilers produce high pressure steam that is then piped to the Pavilion Penthouse where it is transferred through pressure reducing valves to create low and medium pressure steam. This is then used by the air handling units for heating, domestic hot water heaters for hot water supply, and for sterilizers. The steam is transferred to the Penthouse via Shaft E adjacent to the east stair tower and then once the pressure is reduced, the low and medium pressure steam is distributed to the floors via Shaft B located in the western half of the Pavilion.

The cooling system for the Pavilion is supplied utilizing six 333.3 ton cooling towers and two 1000 ton chillers. The cooling towers are located to the northwest of the Central Plant. Once the water is cooled in the cooling towers it is pumped to the Central Plant chillers via condenser water pumps where it is chilled and distributed throughout the building using both primary and secondary chilled water pumps. The chilled water is distributed throughout the building by way of risers located in Shaft E. On the way up the shaft the chilled water supplies an air handler and fan coil unit on the Ground Floor, a fan coil unit on the 1st Floor, and the air handlers in the Penthouse.

4.1.5 Building System Cost Summary

Building System Cost Summary

System	Cost	Cost / SF
Structural	$3,530,000.00	$14.75
Mechanical	$22,926,040.00	$95.76
Electrical	$13,681,330.00	$57.15
Plumbing	$5,125,000.00	$21.41
Fire Protection	$599,500.00	$2.50

Figure 4.1 Building Systems Cost Summary

4.2 Local Conditions

- Regional Construction Method: Structural Steel
- Labor: Union Contractors
- Construction Parking:
    - Project Staff: On-site
    - Construction Staff: Off-site on UPMC Campus
- Recycling & Tipping:
    - Recycling program provided by Empire Roll-Off. All material is sorted off-site.
    - Premium is paid for this service. Cost is about $545/pull.
- Subsurface Conditions:
    - Soil: Primarily clay and shale
    - Bedrock of siltstone and shale
    - Groundwater is expected to be encountered during excavation
- Weather Conditions:
    - Precipitation: 38 inches/year
    - Snow: 41 inches/year
    - Average Temperature:
        - Winter: 32^0 F
        - Spring: 55^0 F
        - Summer: 71^0 F
        - Fall: 53^0 F

4.3 Site Layout Overview

As shown in Figure 4.2 the UPMC Passavant Pavilion site is very tight. This required that all placements of equipment, trailers, and staging areas be thoroughly planned before coming to site to ensure that the areas that were available were utilized to their fullest extent. Due to the size of the steel operations and the amount of area required for laydown and shake out the needs of the steel contractor controlled the use of the space. The steel operations were confined to the footprint of the building and on the western portion of the site. The main staging areas for the concrete and masonry operations were on the eastern portion of the site due to its proximity to the main construction entrance. All other trades were staged within the building or in the newly constructed parking area ¼ mile east of the site.

Because this project is a renovation and addition to an operating hospital special care had to be taken during the planning of the site use. All deliveries were required to be made within the site unless permission was granted to restrict traffic to one lane along the road to the south so that access was always available to the emergency department. This would make an already congested site even more congested. Special care was also taken with regards to the placement of construction machinery and trucks so that the exhaust fumes would not enter the air supply of the building and compromise the operations of the hospital.

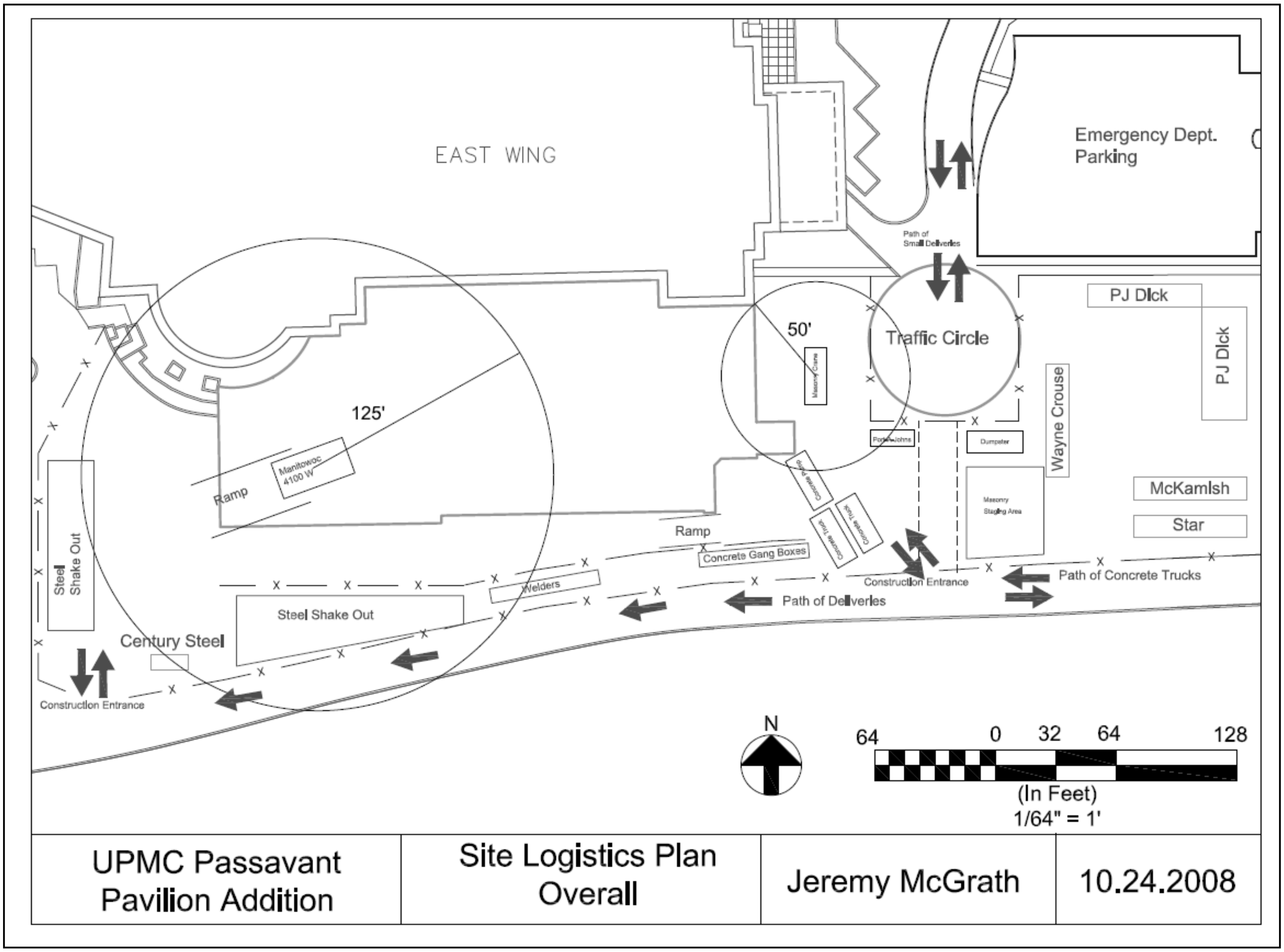
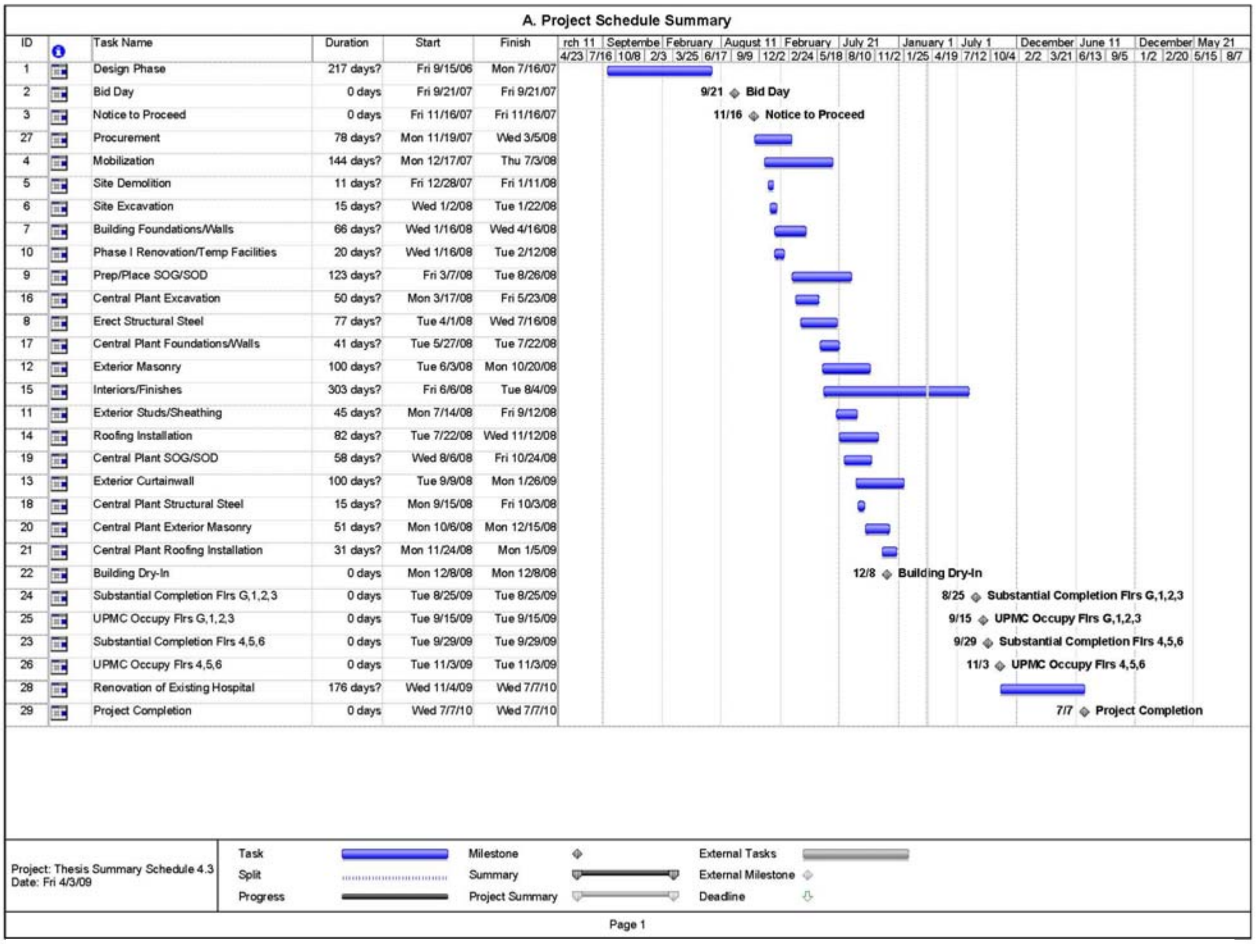


Figure 4.2 Overall Site Logistics Plan

5.0 Project Logistics

5.1 Project Summary Schedule



A. Project Schedule Summary

ID	Task Name	Duration	Start	Finish
1	Design Phase	217 days?	Fri 9/15/06	Mon 7/16/07
2	Bid Day	0 days	Fri 9/21/07	Fri 9/21/07
3	Notice to Proceed	0 days	Fri 11/16/07	Fri 11/16/07
27	Procurement	78 days?	Mon 11/19/07	Wed 3/5/08
4	Mobilization	144 days?	Mon 12/17/07	Thu 7/3/08
5	Site Demolition	11 days?	Fri 12/28/07	Fri 1/11/08
6	Site Excavation	15 days?	Wed 1/2/08	Tue 1/22/08
7	Building Foundations/Walls	66 days?	Wed 1/16/08	Wed 4/16/08
10	Phase I Renovation/Temp Facilities	20 days?	Wed 1/16/08	Tue 2/12/08
9	Prep/Place SOG/SOD	123 days?	Fri 3/7/08	Tue 8/26/08
16	Central Plant Excavation	50 days?	Mon 3/17/08	Fri 5/23/08
8	Erect Structural Steel	77 days?	Tue 4/1/08	Wed 7/16/08
17	Central Plant Foundations/Walls	41 days?	Tue 5/27/08	Tue 7/22/08
12	Exterior Masonry	100 days?	Tue 6/3/08	Mon 10/20/08
15	Interiors/Finishes	303 days?	Fri 6/6/08	Tue 8/4/09
11	Exterior Studs/Sheathing	45 days?	Mon 7/14/08	Fri 9/12/08
14	Roofing Installation	82 days?	Tue 7/22/08	Wed 11/12/08
19	Central Plant SOG/SOD	58 days?	Wed 8/6/08	Fri 10/24/08
13	Exterior Curtainwall	100 days?	Tue 9/9/08	Mon 1/26/09
18	Central Plant Structural Steel	15 days?	Mon 9/15/08	Fri 10/3/08
20	Central Plant Exterior Masonry	51 days?	Mon 10/6/08	Mon 12/15/08
21	Central Plant Roofing Installation	31 days?	Mon 11/24/08	Mon 1/5/09
22	Building Dry-In	0 days	Mon 12/8/08	Mon 12/8/08
24	Substantial Completion Flrs G,1,2,3	0 days	Tue 8/25/09	Tue 8/25/09
25	UPMC Occupy Flrs G,1,2,3	0 days	Tue 9/15/09	Tue 9/15/09
23	Substantial Completion Flrs 4,5,6	0 days	Tue 9/29/09	Tue 9/29/09
26	UPMC Occupy Flrs 4,5,6	0 days	Tue 11/3/09	Tue 11/3/09
28	Renovation of Existing Hospital	176 days?	Wed 11/4/09	Wed 7/7/10
29	Project Completion	0 days	Wed 7/7/10	Wed 7/7/10

Figure 5.1 Project Summary Schedule

5.2 Detailed Schedule

See Appendix A for Detailed Schedule.

5.3 Hospital Cost Summary

Costs By CSI Division				
	Division	TC($)	CC($)	Cost/SF($)
01	General Requirements	$9,243,047		$38.61
02	Site Construction	$5,763,393		$24.07
03	Concrete	$5,094,595	$5,094,595	$21.28
04	Masonry	$1,321,000	$1,321,000	$5.52
05	Metals	$4,814,746	$4,814,746	$20.11
06	Woods and Plastics	$1,857,554	$1,857,554	$7.76
07	Thermal and Moisture Protection	$1,904,375	$1,904,375	$7.95
08	Doors and Windows	$7,025,299	$7,025,299	$29.35
09	Finishes	$6,372,500	$6,372,500	$26.62
10	Specialties	$1,539,707	$1,539,707	$6.43
11	Equipment	$539,744	$539,744	$2.25
12	Furnishings	$300,500	$300,500	$1.26
13	Specialties	$59,500	$59,500	$0.25
14	Conveying Systems	$1,327,650	$1,327,650	$5.55
15	Mechanical	$25,162,100	$25,162,100	$105.10
16	Electrical	$13,044,190	$13,044,190	$54.49
	Total	**$85,369,900**	**$70,363,460**	
	Cost/Sq. Ft.	**$356.60**	**$293.92**	

Figure 5.2 Costs By CSI Division

5.4 General Conditions Estimate Summary

The total cost of the overall general conditions, shown in Figure 5.3, amounts to about 4.1% of the Construction Cost of $70,363,460. This percentage is within the appropriate range of general conditions for a project of this type and size since general conditions typically range from 3% to 10% of the cost of the project.

All cost data for the above general conditions estimate was determined using RS Means Building Construction Cost Data. Lines items for signage and the mobile IT were the only items not calculated using RS Means. Costs for signage were assumed to be $5000 since there was signage used on the jobsite but no definitive take off could be performed. The cost of the mobile IT documents was input as $50 000 based upon the actual cost incurred by the contractor since no RS Means data existed for this line item. The durations used to calculate the costs are from the project schedule and were modified into the appropriate units depending upon which general condition items were being calculated.

Overall General Conditions	
Item	**Total Cost**
Project Staffing	$1,309,325.00
General Conditions	$1,585,639.44
Total	$2,894,964.44

Figure 5.3 General Conditions Costs

See Appendix B for General Conditions Estimate.

6.0 Critical Industry Issue – Mobile Information Technology In Field Operations

6.1 Problem Statement

In recent years the design and construction industry has began to adopt many new forms of technology. These advancements in technology have been primarily aimed towards the design and engineering side of the industry. While some segments of the construction side of the industry have increased their use of technology many segments have not. With the introduction of mobile information technology (IT) documents the construction industry may have an opportunity to increase its use of technology.

Increasing the use of any emerging technology can be difficult but it can be especially challenging when the sector of the industry it is geared towards is historically slow to accept new technology. This is due in part to the computer and technology based skill levels of the workers. In order to make the use of this system more prevalent, a way of introducing and utilizing the technology must be developed that eases the field workers into its use.

6.2 Research Goal

The goal of this analysis is to investigate the means by which to successfully implement mobile information technology into the construction industry with a primary focus on the field operations segment. These implementation methods must be one in which even the most technology adverse foreman or superintendent would be willing and able to utilize the system.

6.3 Background

6.3.1 History

The conveyance of information on construction projects has been at the foundation of the industry from the earliest of times. Information has been transferred to the concerned parties through many forms throughout the years. Beginning with simple sketches and progressing through hand drawn working drawings to the computer aided designs that exist today. Not only is information conveyed through construction documents; contracts, drawings, and specifications but also through varying forms of correspondence.

Over the years the means by which correspondence has been sent between parties has changed substantially with the advent of new technologies. The first correspondence was delivered in person or through hand delivery of letters. If meetings were to occur they would need to be scheduled in advance or take place on the jobsite as needed. This would continue to be the only method of contacting a member of the project team until the telephone became a commercially viable option in the early part of the 20th Century. Further progression of technology throughout the years lead to the widespread use of the fax machine in the 1980’s, cell phones and email in the 1990’s, and now today with mobile computing.

These varying forms of technology were slow to be adopted into the construction industry but could anyone imagine a construction site of today without landline telephones, fax machines, or cell phones? Not only did these advancements revolutionize the means of communications but they also revolutionized the manner and speed by which buildings are constructed. Whereas it would take days for correspondence to reach its intended destination in the past, now this process can occur almost instantaneously. This allows for many of the questions and issues that arise throughout the course of a project to possibly be answered on the same day that they are posed. Even with this availability of expedient communication there are still chances for delayed and errant information transmission due to the lack of a centralized place where information is delivered to each end user.

6.3.2 Current Information Transfer Process

Today the primary means of information transfer in regards to construction documentation is through hard copies of the documents. The majority of these documents are currently delivered through the use of couriers or the U.S. Mail. These systems require at minimum a day between the time that they are sent until the time that they are delivered to their first recipients.

Generally the first stop for these documents is the project management team of either the general contractor or the construction manager. At this point the documents are reviewed and approved prior to being distributed to the subcontractors for pricing. This process continues until finally the documents reach the hands of those that are actually putting the work in place. During the time that this whole process takes to sort itself out construction does not cease and essentially the work that is being put in place could be constructed from outdated documents. The main question in this situation is, 'Is there is a quicker way in which to complete this information transfer?'

6.3.2 Costs of Accurate and Timely Information Transfer

The costs of inaccurate or untimely information can have a significant impact on the budget of any construction project. In a 2000 study *Economist Magazine* found that the inability to provide accurate and timely information results in wasted efforts that can account for up to 30% of a construction project's cost (New Wiring). 60% of that additional cost is related to labor expenses and 10% is attributed to wasted materials caused by the use of outdated or inaccurate information. ("Best Practices").

If throughout the course of construction these costs are borne by the general and subcontractors they will in turn pass them along to the owner through change orders. This often leads to an overall higher construction cost and often affects the financial stability of the project.

6.3.3 Current Technologies in the Construction Industry

In recent years the architectural and engineering (A/E) and portions of the construction segment of the industry have begun to integrate new and emerging technologies into their business practices. Many of these technologies aid in the design and coordination of the overall project. A primary example of these emerging technologies is Building Information Modeling (BIM). BIM is proving to be very successful in aiding in the productivity and profitability of construction projects. BIM has also shown that it can eliminate many steps in the coordination process during the preconstruction and construction phases of a project by allowing for digital clash detection instead of manual detection utilizing several drawing sets and a light table.

While the A/E segments of the industry play a major role in the overall construction process it is the construction segment that physically puts the work in place. All of the information created by the A/E needs to be disseminated to the construction team and this is primarily done so through a general contractor or construction manager. This massive amount of project information can become cumbersome for these parties and has required the creation of digital systems (i.e. Prolog, Constructware, etc.) in which this information can be stored and created. While these programs aid in the creation and storage, as well as, the dissemination of information in a much quicker fashion they are mainly meant for use by the project management team.

6.3.4 Roadblocks to the Integration of New Technologies

While new technology has been made available to field personnel such as superintendents, foremen and project managers it has been met with some resistance from these parties. The primary resistance to the use of this new technology is the age of the current members of the construction industry. In 2005 the average age of construction workers was about 39 years of age. In the same year 54% of all construction managers and 52% of foremen were Baby Boomers (The Center). With such a large percentage of the potential users of this technology within this age group the implementation of this technology will be an uphill battle.

The aging demographic of the construction industry often lacks experience or comfort with the use computers on a daily basis. Often times many construction workers are unfamiliar with computers and lack access to the technology while at home. This unfamiliarity can severely limit their level of acceptance towards any new computer based technology in the workplace. With this in mind in is imperative to develop a means by which to integrate the use of computer based technology into the field operations of the construction industry.

6.4 Uses of Mobile Information Technology Documents

6.4.1 Elimination of Duplication of Efforts

The possible uses of mobile information technology within the construction industry seem to be limited only by the apprehensions of those using the systems. With the main goal of this technology to streamline the information flow within a project, software designers have developed means by which to alleviate the need for duplication of efforts.

Often times construction managers must duplicate information throughout the day to complete the necessary paper work and office functions of their jobs. These functions include the completion of daily reports, inspection reports, and walk through checklists. During these processes the managers are on site and make notes or fill out forms then they must go back to the office and transfer the information into online forms or databases. If this duplication of effort was eliminated the managers would have more time to manage the construction process and not just the paperwork.

The time saved by the above methods would allow the construction manager to spend more time focused on the construction of the building. This would include investigating the drawings and the work-in-place. These investigations often require that several sets of documents be reviewed. These documents include the construction documents, shop drawings, submittals, requests for information, correspondence, etc. With this information being found in many different places the construction manager must attempt to locate and consolidate it so that he can determine what work should be completed and what work needs to be completed as per the contract.

As indicated above the information that is needed on a construction site is often located in many different places and has many different sources. The project managers and superintendents often have their own set of construction drawings that they update and post with comments when their schedules allow. This can lead to discrepancies between the two sets of drawings. These discrepancies are compounded when you consider that subcontractors and suppliers are also maintaining their own sets of documents as well.

6.4.2 Updating of Construction Documents

So what if one of these parties is utilizing their set of drawings which may be out of date and not updated as current as the other? What if an RFI was not posted and work was put in place without the necessary changes required? These situations have a likelihood of arising with the current system of posting and updating drawings. Currently all updates and postings to drawings must be made by hand through the process called 'redlining' and physically attaching RFIs and answers to the construction documents. To error is human and as such occasionally answers may be transcribed wrong or omitted by accident.

Mobile IT documents aim to mitigate the risks of using out dated documents through the use of digital construction documents. These systems utilize a central server on which any and all of the project documents can be placed. The included documents are only limited by what the project team wishes to include. They can be limited to only the construction drawings or can include almost all of the contract and projects documents.

One of the most important documents on the server are the construction drawings. Through the use of the digital drawings the most current revision of the documents is generally always in front of the contractors. The process of updating the drawings on the server may occur up to a few days after the drawings have been approved or they may be updated that day. This is substantially faster than the current process and the speed allows for fewer mistakes due to the use of out dated drawings. With fewer risks associated with out of date drawings the cost of construction could see a decrease as a large portion of the overall construction cost is associated with misinformation.

6.4.3 Elimination of Hard Copies

One aim of these systems is to reduce the amount of paper copies of construction documents that are produced during the life of a project. The amount of paper that is used in the creation of construction documents is very significant. These documents are generally several hundred, if not, thousand pages thick. When you consider that on a typical project documents are needed by the owner, general contractor, subcontractors, and vendors it becomes apparent at the massive volume of paper that is used. Table 6.1, below, shows how one software designer quantified the dollar amount of construction documents used on a typical project.

Costs of Document Reproduction				
Contractor	**Sets**	**Purpose**	**Cost/Set**	**Cost**
General	2	Staff	$1150.00	$2,300.00
	20	Subcontractors	$1150.00	$23,000.00
Subcontractor	20	Field Staff	$1150.00	$23,000.00
			Total Cost:	**$48,300.00**

Table 6.1. Costs of Document Reproduction[2]

The above costs are assumed for only one printing at the start of the project. If we consider that on a typical project drawings will need replaced due to wear and tear and when they are updated due to changes the project team will end up needing two to three sets of these drawings. Using the costs from above that equates to about $145,000.00 in reproduction costs.

Often, however, some projects must reproduction these documents to a greater extent due to the nature of the document management system. If construction changes are made frequently and entire drawings are reissued the cost of the reproduction will soon begin to add up quickly.

Through the use of the digital construction documents these reproduction costs could be minimized by allowing for changes to be made to the digital drawings in lieu of printing hard copies.

6.5 Contractor Perspectives

In speaking with contractors about their impressions of mobile information technology documents I asked them to express what they felt were the advantages and disadvantages of such systems. Generally their outlook on the use of these systems was positive and many thought that it was the direction that construction would be taking in the future. This input will render itself important when determining how to best implement these systems into the field since it is the contractors who are on the front lines and will make or break their use.

6.5.1 Advantages

One of the major advantages that was voiced was that the most current information will always be in the hands of the people that need it most, those in the field. In the current practice drawings must be sent to the construction manager, then to the subcontractors' offices, and then finally to the field staff. The new system would allow for changes to be made and made available to contractors in a much quicker fashion which allows for a smooth flow during construction to be maintained.

Another advantage is that the entire set of construction documents can be carried around the site on a single computer thus negating the need to carry around the cumbersome amount of paper that compromises a set of drawings. This allows contractors to focus more on the work that is occurring around them instead of worrying about their drawings. While in the field they can also make notes on the digital copies of the drawings for later review. This allows the note to be made part of the permanent record or it can set as private and easily deleted if it is not part of this record. These notes are then not forgotten about because they were written on a 2x4 or a piece of scrap paper that gets misplaced throughout the course of the day.

Aside from the cost savings due to the decrease in printing and reproduction costs, savings can also be realized because of the lessening of the amount of administrative work that would be required. With less hard copy filing being required the amount of administrative staff may not need to be as great as in the current system. By having drawings, along with other construction documents, being automatically updated less paperwork would pass through the office and more time could be devoted to the actual construction.

6.5.2 Disadvantages

One of the main concerns that was raised was that information may bypass the contractors' main offices. This would relate to changes made during the course of construction that would need to be priced for change orders. If for some reason a document was updated without the input of the project management team the field personnel may unknowingly construct work that was never priced. If this were to occur, even if the impact was minimal, the contractors may become weary of the use of the system thus detracting from its usefulness.

Other concerns were related to the ability to view drawings on the system. If mobile computers were utilized as a stand alone system the screen size may be too small to view the drawings since drawings are generally 24"x36" while the screen size is only a fraction of that. This would require more navigation and searching throughout the drawing as compared to unrolling a set of drawings and going directly to the area in question. This is one of the main aspects that must be addressed when implementing the system in the field.

Like any system, mobile information technology documents are only as good as the effort that goes into maintaining the information and the system. The entire construction and design team must be onboard from the beginning to ensure that the system is utilized to its full capability. If one member of the team strays from the plan then there would be a gap created within the information and the usefulness of the system would greatly decrease in regards to the idea of always having the most up-to-date and complete set of information.

6.5.3 Will Mobile Information Technology Documents Replace the Use of Paper Drawings?

One aim of these types of systems is to reduce the amount of paper that is consumed on the typical project. This stems from need to decrease the cost of construction and from the trend of increasing environmental sustainability. When this is considered the question arises as to if paper drawings will ever be completely replaced. When this question is posed to contractors, the main thought is that there will always be a need for paper drawings.

Many believe that while digital drawings will decrease the need for paper drawings they will never fully replace their use. One of the requirements that would greatly reduce the amount of paper required would be having multiple computer units on the job site and possibly multiple units within each of the contractors' field operations. Often times contractors need to have multiple sets of drawings because they are working in multiple areas of a building at a time and if limited to one unit they would not be able to continue this current method.

Another thought is that as this technology becomes less expensive more contractors will utilize the system and the need for paper drawings will decrease with the increase of the systems use. Also the influx of younger generations into the construction industry will allow for a wider use of mobile computing since many were raised during the rise of personal computer use. The combination of these two factors will greatly increase the usage of the systems and in turn will contribute to lower costs of associated with printing and reproduction and aid in the sustainability of projects.

6.6 Recommendations for Implementation

When determining the best manner in which to implement a new technology into the construction industry it is important to consider the input of all participants within the project team and attempt to address any concerns that they may have. Without the input of the end users the effectiveness of the plan would diminish greatly.

6.6.1 Training

One of the most important aspects of implementing any new form of technology is ensuring that all users are properly trained in its usage. Without proper training those that are inexperienced in the use of computer technology may not be comfortable in using these systems.

This training should include a demonstration of how to use the hardware and the software. Many times the older generations are not as computer savvy as the younger generations who have grown up around computers and can walk themselves through new programs and computer systems. The training should also emphasize that you cannot make mistakes on the system and you won't destroy the information that is located on the server by any possibly thing that you could do within the system.

Once the end users realize that they cannot break the equipment or corrupt the information they will be more apt to consider using it. This training should help to alleviate some of their fears and misconceptions about using computer systems and software. It should also show them the value of these systems not only to the project but also on an individual level and hopefully increase the likelihood of them deciding to utilize this new technology.

6.6.2 Physical Requirements

When implementing mobile information technology documents in a construction project it is important to include supporting technology which allows for ease of use and viewing. This is especially true when utilizing these systems for the viewing of construction documents and drawings.

6.6.2.1 Mobile Computers

The ground level of mobile information technology documents is the mobile computer. Without this piece of technology the system does not lend itself any advantage over the current use of paper drawings since the latter version would still need to be carried throughout the site. They also allow construction managers to limit the amount of repetitive work they are doing since they can complete checklists and inspections directly on the computer and don't have to duplicate this information upon returning to the field office.

Often times the developer of the software will specify the mobile computer that will work best with their system and the choices available may be limited to the models that they are able to supply. Even in this case it is important to ensure that the product that is purchased will be able to withstand the rigors of the job site.

If those using the mobile computer are certain that they cannot and will not be able to damage the computer throughout its general use they will be more inclined to use it throughout the duration of their work day. These computers should be able to be dropped, scratched, exposed to the weather, and viewable outdoors. To meet these requirements they should be shock, dust, and moisture resistant and have a screen that allows for viewing without glare in direct sunlight. Many models are currently marketed towards the military and have these capabilities but the price is at a premium. These high level models aren't always a necessity and often a more economical model may be the better choice.

6.6.2.2 Large Screen Displays

Many times there are situations on a project that may require a group of contractors to gather around a set of plans to discuss issues that have arisen in a certain area. When utilizing 24"x36" drawings this is not an issue but it becomes one when a small computer screen is being utilized.

One of these situations is project coordination meetings. During this meeting digital drawings could be a valuable tool for the construction manager or superintendent to visually display the issues that have arisen and the direction which work will progress for the next week. Drawing on the mobile computer and displaying it to the meeting participants may not be the most effective method of conveying these thoughts however. This is where a large screen display would be useful.

Large screen displays allow for a large viewing area and allow the meeting participants to remain at their seats and still be able to view the screen. The combination of the mobile computer and the large screen allow the superintendent to convey his thoughts visual and orally as opposed to just orally. Utilizing the computer system much like a telestrator is used during football broadcasts the superintendent can visually display the direction the flow of work and make notes directly on the drawing. These notes can then be saved and viewed later making coordination flow smoother.

6.6.2.3 Digital Kiosks

If digital construction drawings were utilized on a project it would be necessary at times for the documents to be viewed on a screen that is larger than that of the mobile computer. Digital kiosks would be able to fill this void. Much like the large screen displays that are mentioned in Section 6.6.2.2 the digital kiosks would contain a large screen that could be utilized for a larger viewing area.

These kiosks could be stand alone units that are connected to the server and allow the contractors to view the drawings directly on that system or they could be a screen that connects to the individual mobile computer units. The latter may be a more acceptable option as the contractor would only need to learn how to use their particular mobile computer instead of having to learn the system within the kiosk as well. This further lends itself to ensuring the system is as user friendly as possible. On large projects such as UPMC Passavant multiple kiosks would need to be used since work is always progressing on multiple floors at any given time.

6.7 Conclusion

In conclusion, I believe that mobile information technology documents will have a great impact on the construction industry. This technology makes the most current information readily available to the construction project team and allows for less risk attributed to the use of outdated drawings and information. It also strives to reduce the amount of time between when changes are approved and they reach the hands of the field staff. Time is very important on a construction project and this technology allows construction managers to decrease the amount of time they spend searching for information and duplicating inspections and reports.

In addition to saving time on construction projects these systems also have the potential to reduce costs because of the reduction in the risk of using out dated drawings. Costs can also be reduced by limiting the number of times that drawings need to be reproduced due to changes. Printing costs can add up quickly on projects and can be a substantial portion of the general conditions.

With these factors along with the other advantages of these systems I believe that mobile documents will help streamline construction management processes and projects and allow for more time to be spent focusing on the actual construction and less on the management of paperwork. This will lead to better delivery of projects with less cost and with less schedule delays and disruptions.

7.0 Technical Analysis 1 – Architectural Precast Concrete Wall Panels vs. Masonry Brick Veneer

7.1 Problem Statement

The exterior façade of the UPMC Passavant Pavilion is composed of aluminum and glass curtain wall, metal panels, and masonry veneer on light gauge framing. When investigating the construction methods for each of these systems it is evident that the masonry portion of the enclosure is the only aspect that is not panelized. Once this fact is realized the question arises as to if there is an alternative to the masonry veneer that offers the same aesthetics and utility while increasing the speed of construction.

7.2 Background

The construction schedule for the UPMC Passavant Pavilion is very fast paced and the construction budget is monitored very closely. This creates a situation in which time and cost savings are always welcome and are explored frequently. When exploring these savings it is often important to implement them as quickly as possible within the construction schedule. The most logical area to first explore would be the erection and detailing of the structural steel. During the course of construction, however, this process was already accelerated and moving at an acceptable speed.

The next most pertinent area to explore would be the exterior façade. The façade is constructed of three main materials; brick veneer, metal panels, and aluminum and glass curtain wall. Within the critical path of the schedule the brick veneer is the controlling factor as it is installed prior to the curtain wall and the metal panels. With this in mind if the masonry could be accelerated it would in turn accelerate the two remaining portions of the façade.

Durations for the installation of the masonry veneer are generally about 15 days for each of the building elevations. There are two options to decreasing this duration; adding manpower or providing an alternate system. Through the addition of manpower the duration would be able to be decreased to a certain extent but would come at the added expense of the additional man hours and could lead to overstaffing and eventually limit the overall production of the crew. This does not appear to be a viable option as the increase in man hours would add cost to the budget and in this situation that would not be acceptable.

Finding an alternative which decreases the overall duration of the masonry installation while maintaining a cost which is equal to or less than the original would be the best option.

7.3 Goal

The goal of this analysis is to determine if there is an alternative construction that could decrease the duration and cost of the masonry veneer while maintaining similar aesthetics and utility. For this analysis I have chosen to explore the use of architectural precast concrete panels in lieu of the original masonry veneer system. When analyzing this change it is important to not only explore the schedule and cost implications for the change of materials but to also explore if there are any structural and architectural implications as a result of the change. These secondary analyses will serve as the structural and architectural breadth analyses of my thesis project. As part of the architectural analysis I will also explore replacing the metal panel system with the same architectural precast concrete panels.

7.4 Analysis Steps

This analysis will be conducted with two separate alternatives being investigated. The first is the substitution of the precast panels in lieu of the masonry veneer and the second is this substitution for both the masonry and the metal panels.

7.4.1 Determination of Panel Size

In consultation with Nitterhouse Concrete Products it was determined that the best manner in which to orient the precast panels would be vertically. This orientation allows the panels to span the floor to floor height but limits them to roughly 12' in width. While this ideal width was maintained for the majority of panels it was at times necessary to increase the width to maintain a consistent layout on the various elevations. Table 7.1 shows the maximum panel size on the project.

Maximum Panel Size Without Metal Panels			
Elevation	Width	x	Height
South	12'-4"	x	18'-0
East	15'-6"	x	14'-0
North	14'-0"	x	20'-0
West	15'-0"	x	26'-6"

Table 7.1 Maximum Precast Panel Size

See Appendix C for all panel sizes.

7.4.2 Structural Implications

Whenever a building material is proposed in lieu of that which was originally proposed it is important to consider the implications that this change may have on the structural design. These implications can be that the size of the structural members can be reduced because the alternative material is of a lesser weight or if the alternative material is of a greater weight the member size may need to be increased.

When considering the alternative of precast concrete panels over the originally designed brick masonry veneer it was determined that the alternative would be of a greater weight and the structural design of the support system would need to be investigated. While the difference between the weight of the materials as shown in Table 7.2 is small the size of the members still needed to be checked as a precautionary measure.

Material Weights			
Material	Density (lb/ft^3)	Thickness (in.)	Weight (lb/ft^2)
Brick Veneer	130	4	43.33
Precast Concrete	150	6	75

Table 7.2 Material Weights

7.4.2.1 Structural Analysis

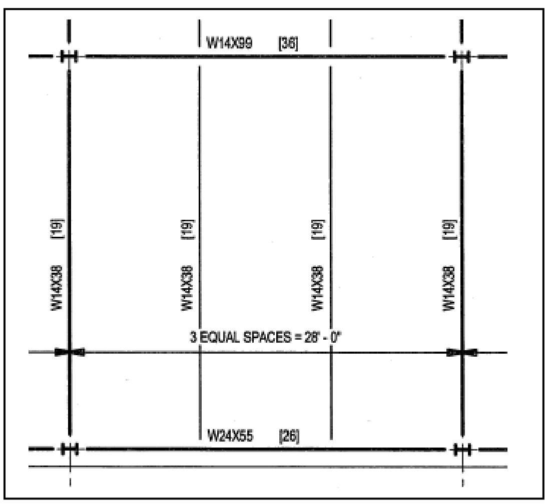


Figure 7.1 Typical Structural Bay

Panel Characteristics	
Density of Concrete:	150 pcf
Thickness of Panel:	0.5 ft
Weight of Panel:	75 psf
Max. Panel Height:	14 ft
Tributary Area:	9.33 ft

Table 7.3 Panel Characteristics

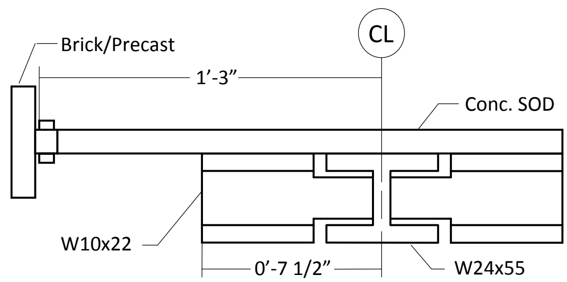


Figure 7.2 Typical Exterior Beam/SOD Detail

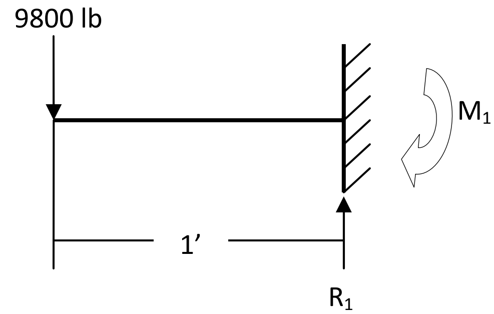


Figure 7.3 Ext. Beam/SOD FBD

R_1 = 9800 lb M_1 = 9800 lb(1 ft) = 9800 ft-lb

V_u = 1.4 (9800 lb) = 13 720 lb = 13.72 k

M_u = 13.72 k (1 ft) = 13.72 ft-k

W10x22:

$\phi_b M_{px}$ = 97.5 ft-k > 13.72 ft-k **OK**

ϕV_n = 73.2 k > 13.72 k **OK**

Check W24x55:

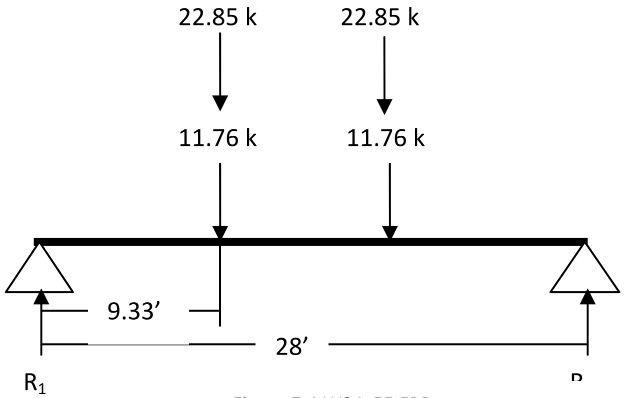
Precast: 1.2(9800 lb) = 11.76 k
Live Load: 60 psf (Hospital)
LL: 60 psf (9.33 ft)((28 ft/2) + 1 ft) = 8397 lb = 8.4 k
Conc. Wt.: 3 ¼" L.W. on 2" – 20 ga. deck. Assume 4 ¼" depth

((4.25 x 12)/144)(115 pcf) = 41 psf (9.33 ft)((28 ft/2) + 1 ft) = 5738 lb

Beam Self Wt:

W24X55: 55 lb/ft x 14 ft = 770 lb
W10x22: 22 lb/ft x 1 ft = 22 lb
= 792 lb

Stud Wall: 10 psf (9.33 ft)(14 ft) = 1306 lb = 1.31 k
DL: 5738 lb + 792 lb + 1306 lb = 7836 lb = 7.84 k
TL: 1.2(7.84 k) + 1.6(8.4 k) = 22.85 k



$R_1 = R_2$

$22.85 + 11.76 = 34.61$ k

$\Sigma F_y = 0$

$-2(34.61) + 2R = 0$

$R = 34.61$ k

Figure 7.4 W24x55 FBD

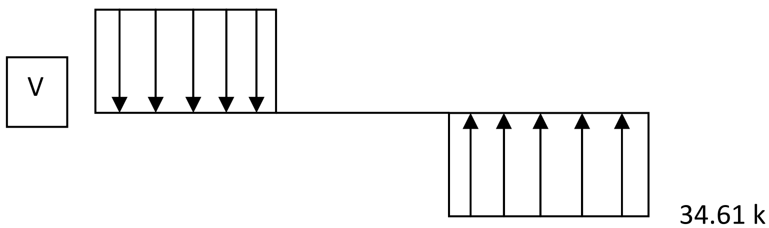
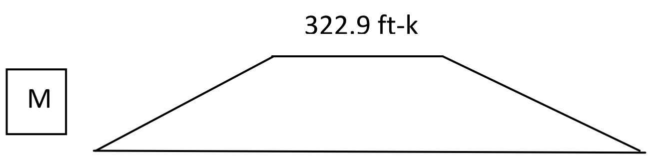


Figure 7.5 Shear Diagram



$M_{max} = 34.61$ k (9.33 ft) = 322.9 ft-k

Figure 7.6 Moment Diagram

Deflection(Total Load):

$\Delta_{max} = (Pa / 24EI)(3l^2 - 4a^2)$

$= ((34.61k)(9.33')(12'')/(24(29000)(1350in^4))(3(28')^2(144in^2/ft^2)-(4(9.33')^2(144in^2)$

$= 1.19$ in

$\Delta = l/240 = 28$ ft (12 in) / (240) = 1.4 in > 1.19 in **OK**

Check W24x55:

$\phi M_n = 503$ ft-k > 323 ft-k **OK**

$\phi V_n = 251$ k > 34.61 k **OK**

The above calculations will also hold true for the situation in which the precast concrete could possibly be utilized in lieu of the metal panels since the beam sizes in these locations are similar to those on which the brick veneer is the applicable material.

After this detailed analysis of the current structural system it was determined that it is adequate for the installation of the alternative exterior façade material as proposed and no changes to the superstructure will need to be implemented thus there will be no schedule or budget impacts because of the structural system.

7.5 Architectural Implications

When examining the exterior façade one sees that UPMC Passavant is composed of three primary cladding materials; brick, aluminum and glass curtain wall, and metal panels. This combination of materials helps to draw inspiration from the brick exterior of the original hospital and the brick and curtain wall of the addition that was built in the 1990's. In using these materials the Pavilion Addition aesthetically merges the previous two building segments into a more complete unit with itself.

The contemporary look of the Pavilion Addition is a symbol of the advancements that UPMC is making through the construction of this project and through their study and practice of medicine. The previous building addition brought the look of the overall building into the 1990's and the Pavilion brings the Passavant Campus into the 21st century just as UPMC is leading healthcare into the 21st century.

Figure 7.7 Sequence of Building Additions

From an architectural perspective this is a complete design and tells the story UPMC Passavant's progression through the years. However, when looking at the façade from a construction perspective questions arise about the constructability of the three different systems. Among these are how will the interfaces between the materials be constructed, what are the cost and schedule implications of using these three materials, what is the order of construction, and is there a learning curve that will decrease or increase the speed at which the building is enclosed. When exploring these questions it is easy to see that these three materials may have an impact on the cost, schedule, and labor of the project.

Having changed the brick veneer to precast concrete to accelerate the schedule of exterior enclosure I believe that one of the other two materials would be able to be changed in a similar fashion. Since the curtain wall is a necessary part of the window system I do not believe that this portion of the façade could be changed. This leaves only the metal panel system.

The metal panels that are part of the building enclosure have interfaces with both of the other materials. The elimination of this one material would allow the number of varying interface conditions to be limited thus decreasing the risk of errors when terminating the brick or curtain wall at the metal panel system.

Exterior Renderings

Figure 7.8 Comparison of Exterior Facades. Top: Original with Metal Panels. Bottom: Proposed without Metal Panels.

Figure 7.9 Comparison of Exterior Facades. Top: Original with Metal Panels. Bottom: Proposed without Metal Panels.

The exterior renderings shown in Figure 7.8 and 7.9 show the original exterior cladding of the Passavant Pavilion and the proposed exterior after the material changes have been made. From these renderings it can be seen that the changes do not have any adverse effects on the aesthetics of the Pavilion. The precast panels still provide the contemporary look that was achieved through the use of the metal panels.

After reviewing these renderings I believe that the elimination of the metal panel system will not be detrimental to the aesthetics of the Passavant Pavilion. A façade that is composed of only precast panels and aluminum and glass curtain wall is as effective as that with metal panels.

When reviewing the above changes to the exterior façade it also becomes apparent that some changes may need to be made to the exterior wall construction. The most obvious is that the rigid insulation that is placed behind the masonry brick veneer could not remain in place due to the nature of precast construction. This would require eliminating this insulation and substituting a batt insulation within the wall cavity that could be placed after the wall panels were erected. This change is reflected in Figure 7.10 below. Alterations may need to be made to this wall section to provide adequate access to the precast wall panel connections.

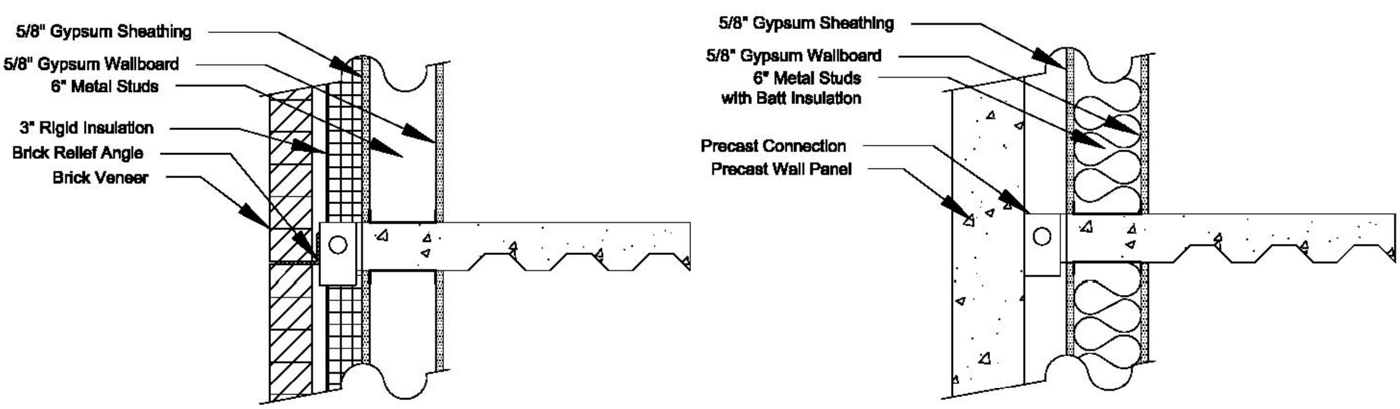


Figure 7.10 Exterior Wall Section

7.6 Construction Durations & Schedule Savings

7.6.1 Construction Durations

The construction durations for the panel erection process can be determined from the sizing of the panels for each of the elevations. Typically a panel erector can place between 15 and 20 panels per day. Table 7.4 shows the durations based upon this production rate. Because these durations are significantly less than that of the original systems I have chosen to increase the durations by an additional day to allow for any inefficiencies or delays that may occur.

Panel Quantity & Duration						
	With Metal Panels			Without Metal Panels		
Elevation	Quantity	Duration	Assumption	Quantity	Duration	Assumption
South	15	1 Day	2 Day	36	3 Day	3 Day
East	26	2 Day	2 Day	42	3 Day	3 Day
North	16	1 Day	2 Day	17	1 Day	2 Day
West	14	1 Day	2 Day	17	1 Day	2 Day

Table 7.4 Panel Quantity & Duration

As stated above the durations for the precast panels are significantly lower than those for the masonry veneer and the metal panel installation. This can be seen in Table 7.5.

Comparison of Durations					
	Masonry vs. Precast		Masonry & Metal Panel vs. Precast		
Elevation	Masonry	Precast	Masonry	Mtl. Panel	Precast
South	15 Days	2 Days	15 Days	15 Days	3 Days
East	20 Days	2 Days	20 Days	15 Days	3 Days
North	10 Days	2 Days	10 Days	--	2 Days
West	15 Days	2 Days	15 Days	15 Days	2 Days

Table 7.5 Comparison of Durations

7.6.2 Schedule Savings

After a thorough review of the construction schedule it was determined that the masonry veneer located at the east, south, and west elevations are all on the critical path. This means that any savings generated by these three line items, with all other things equal, would generate a time savings for the entire project. As shown in Tables 7.4 and 7.5 the use of precast concrete panels in lieu of brick veneer alone and in conjunction with the metal panels will allow for substantial reductions in the project schedule.

Table 7.6, below, shows the impact that the use of the precast concrete panels will have on the critical path of the schedule through a comparison of the completion dates with and without the use of these panels. The primary implication of this savings is that the exterior of the building can be completed much sooner than previously expected. Not only does this allow for the installation of the interior finishes to begin soon but it also allows for reduced preparation and energy costs during the winter heating season.

Comparison of Critical Path Dates				
	Start		Completion	
Activity	Original	Proposed	Original	Proposed
Masonry Veneer @East Studs/Sheathing	8/4/2008	8/4/2008	8/29/2008	8/5/2008
Masonry Veneer/Cast Stone Sill @ South	9/1/2008	8/11/2008	9/19/2008	8/12/2008
Masonry Veneer/Cast Stone Bands @ West	9/22/2008	8/13/2008	10/10/2008	8/14/2008
Substantial Completion G-3			8/25/2009	7/30/2009
Substantial Completion 4-6			9/29/2009	9/3/2009

Table 7.6 Comparison of Critical Path Dates

While these critical path dates may be accelerated they may need to be reined back to ensure that all of the required concrete slabs on deck are installed prior to the installation of the exterior studs and sheathing and the precast. The completion of these slabs could also be accelerated through the scheduling of multiple concrete pours per week or through alternate schedule sequencing.

See Appendix E for CPM Schedules for both masonry brick veneer and architectural precast wall panels.

7.7 Cost Savings

At the UPMC Passavant Pavilion, as with any construction project, the cost of implementing an alternative material or construction on the project is a major factor in the decision to utilize this alternative. Below Tables 7.7 and 7.8 provide a summary of the material costs and savings associated with the use of the alternative precast concrete panel system in lieu of the masonry brick veneer and in lieu of the metal wall panel system.

Summary of Material Costs & Savings (With Metal Panels)					
Elevation	Item	SF	Cost/SF	Cost	Total/Elevation
South	Precast	2849	$35.00	$99,713.78	
	Masonry	2802	$74.00	-$207,382.41	
	Louver	47	$480.00	-$22,560.00	
					-$130,228.63
East	Precast	4907	$35.00	$171,750.25	
	Masonry	1952	$82.00	-$160,057.44	
	Masonry	2955	$17.00	-$50,238.91	
					-$38,546.10
North	Precast	2434	$35.00	$85,189.86	
	Masonry	2434	$23.00	$55,981.91	
					$29,207.95
West	Precast	2902	$35.00	$101,566.50	
	Masonry	3148	$68.00	-$214,057.20	
	Curtain wall	103	$120.00	$12,360.00	
					-$100,130.70
				Proposed Savings	**-$239,697.48**

*Precast costs provided by Nitterhouse Concrete Products. ** Other costs associated with actual project costs.

Table 7.7 Summary of Material Costs & Savings

Summary of Material Costs & Savings (Without Metal Panels)					
Elevation	Item	SF	Cost/SF	Cost	Total/Elevation
South	Precast	5933	$35.00	$207,661.48	
	Masonry	-2802	$74.00	-$207,382.41	
	Metal Panel	-3274	$53.46	-$175,001.31	
	Louver	-47	$480.00	-$22,320.00	
					-$197,042.24
East	Precast	5384	$35.00	$188,433.00	
	Masonry	-1952	$82.00	-$160,057.44	
	Masonry	-2955	$17.00	-$50,238.91	
	Metal Panel	-475	$53.46	-$25,393.50	
	Louver	-144	$480.00	-$22,320.00	
					-$116,376.85
North	Precast	2643	$35.00	$92,504.86	
	Masonry	-2434	$23.00	-$55,981.91	
	Metal Panel	-209	$53.46	-$11,173.14	
					$25,349.81
West	Precast	4742	$35.00	$165,984.00	
	Masonry	-3148	$68.00	-$214,057.20	
	Curtain wall	103	$120.00	$12,360.00	
	Metal Panel	-1841	53.46	-$98,393.13	
					-$134,106.33
				Proposed Savings	**-$422,175.61**

*Precast costs provided by Nitterhouse Concrete Products. ** Other costs associated with actual project costs.

Table 7.8 Summary of Material Costs & Savings

7.8 Conclusion and Recommendation

Based upon the information presented in Sections 7.6 and 7.7 of this analysis it can be easily seen that the use of the precast concrete panel system in lieu of the masonry brick veneer on the exterior façade is a logical alternative. Not only does this alternative save the schedule up to 18 days but it can also decrease the total cost by about $240,000. These two factors are especially important when both the construction schedule and the budget are tight as they are in the case of the UPMC Passavant Pavilion. Even if the precast cannot accelerate the schedule a substantial amount the cost alone should provide a very intriguing option for saving costs.

Also in the above mentioned sections and Section 7.5 Architectural Implications it would also benefit the project if the metal panels were replaced by the alternate system as well since it would allow for up to approximately $422,000 in savings. This change saves a substantial amount of money versus the original systems that were designed while not affecting the overall aesthetics of the building. It also eliminates a material from the façade which could result in a decrease in complications caused by the multiple materials interfacing at the same locations.

The ultimate decision would be left up to UPMC as to which avenue to pursue. In this case, however, I would suggest that at least one of the options be considered since they both save substantial costs and time. At a minimum the precast panels should be considered since they allow for the same aesthetics as the brick veneer at a lower cost and take less time to complete.

8.0 Analysis 2 – Matrix Scheduling

8.1 Problem Statement

When completing a construction project delays, ranging from insignificant to major, can arise and must be handled in an expedient manner so that costs are not incurred because of untimely completion. If a delay does in fact occur it is important for the project team to be resourceful and thorough in their examination and mitigation of the problem. Many methods should be investigated to determine how to best manage the situation.

One method which aids in the recovery of time from delays is to increase the production of the construction crews. This can be achieved through the creation matrix schedules. Matrix schedules lay out a plan of action and create a parade of trades for the areas involved in the schedule. This method sets a strict time frame in which each trade is required to complete their work so that the subsequent trades can stay on schedule. While matrix schedules are generally not used in healthcare facilities due to their complex nature and non-repetitive floor plans, the UPMC Passavant Pavilion does offer the opportunity to utilize this scheduling method due to the similar amounts of each activity on every floor.

8.2 Research Goal

The goal of this analysis is to investigate the project schedule and determine if a matrix schedule is a viable means in which to attempt to make up any lost time caused by delays from earlier in the project. Matrix schedules can, and in many cases do, increase the productivity of the building trades that are included in the schedule. This regimented process requires the timely completion of each activity within the schedule. These matrix schedules should prove to be a successful schedule reduction method and allow for the recovery of delays within the allotted schedule with the aim to minimize a project duration longer than what was planned during preconstruction.

8.3 Background

As with most construction projects, UPMC Passavant was not immune to site and construction delays during its course of construction. During the site excavation phase of the project it was found that within the footprint of the Pavilion there were unsuitable fill conditions as well as expansive soils. This required the site to be over excavated in these areas and filled with inert fill. It also required that the Pavilion footings be formed instead of cast within the footing excavations. Both of these activities require time to complete and delayed the project by approximately two weeks. This delay does not necessarily mean the completion date was moved two weeks back but that the project would now have two less weeks to complete the remaining work. This delay would then need to be remediated to avoid the accrual of liquidated damages.

8.4 Method

When creating a matrix schedule it is important to determine the proper durations for which to set up your schedule. In order to implement this method on the Passavant project I reviewed the current construction schedule and sequencing to determine the durations of each of the activities. The majority of the durations for activities on each floor were within the 10 to 20 day range with many being less than that and some being more. With the majority within the 10 to 20 range I determined that durations of 15 days per floor, 5 days per zone, would be adequate as the baseline duration for this scheduling method.

While a portion of the activities within the schedule were originally scheduled to take longer to complete than the above 15 day duration baseline I determined that the streamlining of the schedule and generally allowing only one trade within a space at any one time would allow the trades to complete their work in a much more expedient manner. In utilizing this method of scheduling the trades also have to be willing to work within the allotted time slots and if need be they must staff the project accordingly to achieve successful completion of their portion of work.

The activities that were considered for inclusion within this schedule were those which make up the interiors portion of the building. This schedule also only includes the activities which occur on the 1st through 6th floors of the Pavilion. The Ground Floor and the Penthouse were omitted from the schedule for two reasons. The first is that the Ground Floor activities are caused to be out of sequence because of the expansive soils that were found. In order to stay on schedule the steel was erected prior to some of the underground work being complete below the slab on grade. With that in mind the matrix schedule could not be developed using the Ground Floor activities unless the start date was pushed back or the work was conducted out of sequence which would interfere with the flow of the construction activities. The Penthouse level was left out of the matrix schedule because of the complex nature of the work that is required within that space. Also many of the activities that exist on the lower floors do not exist within the Penthouse. This space houses the majority of the mechanical equipment for the Pavilion and as such there are few finishes that are required.

8.4.1 Understanding the Schedule

When creating a matrix schedule it is important to ensure that those reading the schedule will be able to understand what it is saying. With this in mind I would like to explain the layout of the schedule. Each activity or set of activities will be given a letter or a number that denotes its position within the schedule. The letters correspond to the structural steel activities that must be complete prior to any work commencing within the building. The numbers correspond to an activity or activities that are required to be performed during the time frame specified. Ideally these activities are specific to one trade contractor, however, at times it is necessary to combine the activities of different contractors within the same time period. In addition to numbering the activities they are also color coded to correspond to the contractor which owns that activity.

The original schedule for the project was based upon the three zones in which the steel was erected and the three concrete pours that were required for each floor level. For ease in transitioning between the original schedule and the proposed matrix schedule I have chosen to maintain the three zone or three pour sequencing. Each floor is noted on the schedule and is broken into the three pours. These are denoted through an F#/P# designation where F# is the floor and P# is the pour number. For example, F1/P1 would be the designation for Floor 1, Pour 1.

8.4.2 Current Sequencing

To aid in the avoidance of fluctuating the size of the construction crews for each trade from week to week it was important to review the sequencing of the building construction. Currently the flow and sequence of construction follows that of the structural steel. Due to site size and constraints the steel structure was erected from east to west in three separate zones. These zones extended the full height of the building and when one zone was completely erected they then would move onto the next zone. The concrete installation and the finish trades tended to follow this sequencing throughout the building until multiple zones were complete and the focus could be shifted to working on entire floors at a time.

When sequencing the concrete, however, the zone in which the concrete would be placed, as well as, the same floor in the adjacent zone would need to be decked and detailed prior to concrete placement to ensure the structure was properly plumbed and aligned. This creates a lag between the steel and concrete. The question that arises from this is rather or not this lag could be extended such that the concrete could be placed completely on all floors before moving up to allow trades to follow in the same manner.

Using the current sequencing method the trade contractors would often be working on multiple floors of the building at one time and would move up through the building instead of across the floors and then up. This is an inefficient use of time as material and tools must be moved multiple times to complete all of the work on the individual floors. As stated above there is a question as to if this sequencing can be changed.

8.4.3 Proposed Sequences

There are two possible options when reviewing the sequencing of the construction activities within the scope of the interior of the Pavilion. The first is to allow the trade contractors to continue to follow the structural steel vertically through the zones and then horizontally across the floors once the zones are complete. The second is to increase the lag between the steel and the concrete and allow the trade contractors to work horizontally across the floors and then move vertically once the floors are complete. Both of these sequences each have their advantages and implications on the schedule that affects the interior of the building, as well as, the exterior.

Sequence by Zones

Sequencing the construction activities by zones allows the trades to get a faster start on their work than if the activities were sequenced by floor. In this sequence the activities are controlled by the same floor in the adjacent zone. Due to the structural design and the manner in which the project was erected the concrete cannot be placed until the adjacent zone has been decked and detailed. For example Floor 1/Pour 1 cannot be made until Floor 1/Pour 2 has been decked and completely detailed. This ensures that the zone is properly plumbed and aligned prior to the concrete being placed.

Utilizing this sequence allows the trade contractors to mirror the steel erection by working vertically through the zone while the steel is being erected in the adjacent zone. As a contractor's is complete on a particular floor they would then move to the next floor and so on until they would then return to the lower floors of the adjacent zone to repeat the process.

The advantage of using this sequencing is that the construction activities can begin within three weeks of the completion of the decking and detailing of the structural steel within that zone. The disadvantage is that the contractors cannot work on simultaneous floors or within the adjacent sections until there working is complete in the previous zone. This sequencing also extends the completion of the concrete pours on the individual floors which in turn would negatively impact the schedule of the exterior finishes that rely on the concrete slabs on deck.

Figure 8.1 on the next page shows the matrix schedule utilizing this sequencing method.

	Year	2008																																						
	Month	April					May				June					July				August				September					October				November				December			
	Date	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22
Area	R/P3										A	B	B	B																										
	F7/P3										A	B	B	B																										
	F6/P3									A	B	B	B	A	B	B	B									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	F5/P3									A	B	B	B	A	B	B	B								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	F4/P3								A	B	B	B	A	B	B	B								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	F3/P3								A	B	B	B	A	B	B	B							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	F2/P3							A	B	B	B	A	B	B	B							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	F1/P3							A	B	B	B	A	B	B	B						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	G/P3																																							
	R/P2							A	B	B	B																													
	F7/P2							A	B	B	B																													
	F6/P2						A	B	B	B										1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	F5/P2						A	B	B	B									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	F4/P2						A	B	B	B								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	F3/P2						A	B	B	B							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	F2/P2					A	B	B	B							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	F1/P2					A	B	B	B						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	G/P2																																							
	R/P1				A	B	B	B																																
	F7/P1				A	B	B	B																																
	F6/P1			A	B	B	B							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	F5/P1			A	B	B	B						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	F4/P1		A	B	B	B						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	F3/P1		A	B	B	B					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	F2/P1	A	B	B	B					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	F1/P1	A	B	B	B				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	G/P1																																							
		31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22
		April					May				June					July				August				September					October				November				December			
		2008																																						

	Year	2009																														
	Month	January					February				March					April				May				June				July				
	Date	29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
Area	R/P3																															
	F7/P3																															
	F6/P3	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42				
	F5/P3	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42					
	F4/P3	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42						
	F3/P3	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42							
	F2/P3	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42								
	F1/P3	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42									
	G/P3																															
	R/P2																															
	F7/P2																															
	F6/P2	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42										
	F5/P2	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42											
	F4/P2	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42												
	F3/P2	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42													
	F2/P2	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42														
	F1/P2	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42															
	G/P2																															
	R/P1																															
	F7/P1																															
	F6/P1	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																
	F5/P1	29	30	31	32	33	34	35	36	37	38	39	40	41	42																	
	F4/P1	30	31	32	33	34	35	36	37	38	39	40	41	42																		
	F3/P1	31	32	33	34	35	36	37	38	39	40	41	42																			
	F2/P1	32	33	34	35	36	37	38	39	40	41	42																				
	F1/P1	33	34	35	36	37	38	39	40	41	42																					
	G/P1																															
		29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27
		January					February				March					April				May				June				July				
		2009																														

1	Install SOD Penetrations/Embeds
2	Duct Hangers
3	Prep/Place SOD
4	Layout Mtl Stud Track/Plumb Hangers/Mech. Htg Piping
5	Spray Fireproofing
6	Interior Metal Studs
7	Elec. Conduit
8	Plumbing RI
9	In-wall Blocking
	Install HM Frames
10	Plumbing Rough In
11	Mechanical Rough In
12	ATC Installation
13	Fireprotection RI Mains/Branches
14	Pneumatic Tube RI
15	Mechanical Insulation
	HTG Piping Equipment Set
16	Plumbing Insulation
17	Hang Drywall Walls
18	Tape Finish Drywall
19	Frame Drywall Ceilings
20	Pull Systems Wiring
	Pull wire to Lighting Fixtures
	Pull Wire to Electrical Devices

21	Hang Drywall Ceilings
	Tape/Finish Drywall Ceilings
22	Telecom Services
	Panels & Feeders
23	Prime/1st Coat Paint
	Interior Glass
24	Install ACT Grid
	Install Fire Extinguisher Cabinets
25	SM Finishes
26	Install Light Fixtures
	Terminate Light Fixtures
27	Fire Protection Finishes
28	Ceramic Floor & Wall Tile @ Toilet Rooms
	Install Cubicle/IV Track
29	Plumbing Fixtures @ T.R.
	Install Toilet Compartments
	Install toilet Accessories
30	Install Wood Tile Ceiling
	Install ACT
	Install Caswork
31	Install Vinyl Flooring
	Plumbing Fixtures @ Casework
	Install Lockers
32	Finish Paint Walls

33	Terminations/Trimout Systems
34	Install OF-CI Items
35	Install Vinyl/Acrylic Wall Protection
	Finish Paint HM Frames
36	Install Electrical Devices/Trim
37	Install Carpet Tile/Sheet Carpet
	Finish Paint Ceilings
38	Base @ Vinyl Flooring
	Install Base @ Carpeted Flooring
39	Set/Install OF-OI Items
	Install Med Gas Headwall
	Install Medical Equipment
40	Install Wood Doors
	Install Door Hardware
	Install Mirrors @ T.R.
	Install Television Ceiling Mounts
	Install Roller Window Shades
	Install Visual Display boards
41	Final Clearning
	ATC Programming
42	Punchlist Work

	Electrical
	Mechanical
	Electrical/Mechanical
	Plumbing
	Drywall
	Concrete
	GC
	Fire Protection
	Pneumatic Tube
	Finishes

Figure 8.1 Matrix Schedule with Sequencing by Zones

Sequence by Floor

The other manner by which to sequence the construction activities is by floor. This entails placing all of the concrete pours on a particular floor prior to advancing to the next floor. Due to the situation where the adjacent zone must be decked and detailed as described above, the concrete pours must lag the steel far more than when sequencing the activities by zone. This lag is then further increased so that the flow of work can remain consistent and not require any breaks within the sequence of activities.

Work using this sequencing begins at F1/P1 and then moves to F2/P2 and so on and so forth until the concrete is complete at F6/P3. The controlling factor at the beginning of construction is the completion of the steel within the adjacent zone. The F1/P1 the controlling factor, however, switches to the preceding floor since the overall start date is adjusted for F1/P1.

The advantage of this sequencing is that the work progresses horizontally across each floor before moving vertically to the next floor. This allows the contractors to move their materials and tools less than the current scheduling sequence because they are not returning to lower floors to complete the same activity once they leave that area. The disadvantage is that the construction activities are delayed to maintain a consistent flow. This means that the construction activities begin 5 weeks after those utilizing the sequencing by zone. This sequencing also further delays the completion of the concrete placement and the exterior finishes.

Figure 8.2 on the next page shows the matrix schedule utilizing this sequencing method

	Year	2008																																							2009																																	
	Month	April					May				June				July					August				September				October					November				December				January					February				March				April					May				June				July					August			
	Date	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
Area	F7/P3										A	B	B	B																																																													
	F7/P2																																																																										
	F7/P1																																																																										
	F6/P3													A	B	B	B														1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42			
	F6/P2						A	B	B	B																				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42				
	F6/P1			A	B	B	B																						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42					
	F5/P3													A	B	B	B											1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42						
	F5/P2						A	B	B	B																	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42							
	F5/P1			A	B	B	B																			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42								
	F4/P3													A	B	B	B								1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42									
	F4/P2						A	B	B	B														1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42										
	F4/P1		A	B	B	B																	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42											
	F3/P3													A	B	B	B					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42												
	F3/P2						A	B	B	B											1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42													
	F3/P1		A	B	B	B														1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42														
	F2/P3											A	B	B	B				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42															
	F2/P2					A	B	B	B									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																
	F2/P1	A	B	B	B												1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																	
	F1/P3											A	B	B	B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																		
	F1/P2					A	B	B	B						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																			
	F1/P1	A	B	B	B									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42																				
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		31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
		April					May				June				July					August				September				October					November				December				January					February				March				April					May				June				July					August			
		2008																																							2009																																	

1	Install SOD Penetrations/Embeds
2	Duct Hangers
3	Prep/Place SOD
4	Layout Mtl Stud Track/Plumb Hangers/Mech. Htg Piping
5	Spray Fireproofing
6	Interior Metal Studs
7	Elec. Conduit
8	Plumbing RI
9	In-wall Blocking
	Install HM Frames
10	Plumbing Rough In
11	Mechanical Rough In
12	ATC Installation
13	Fireprotection RI Mains/Branches
14	Pneumatic Tube RI
15	Mechanical Insulation
	HTG Piping Equipment Set
16	Plumbing Insulation
17	Hang Drywall Walls
18	Tape Finish Drywall
19	Frame Drywall Ceilings
20	Pull Systems Wiring
	Pull wire to Lighting Fixtures
	Pull Wire to Electrical Devices

21	Hang Drywall Ceilings
	Tape/Finish Drywall Ceilings
22	Telecom Services
	Panels & Feeders
23	Prime/1st Coat Paint
	Interior Glass
24	Install ACT Grid
	Install Fire Extinguisher Cabinets
25	SM Finishes
26	Install Light Fixtures
	Terminate Light Fixtures
27	Fire Protection Finishes
28	Ceramic Floor & Wall Tile @ Toilet Rooms
	Install Cubicle/IV Track
29	Plumbing Fixtures @ T.R.
	Install Toilet Compartments
	Install toilet Accessories
30	Install Wood Tile Ceiling
	Install ACT
	Install Caswork
31	Install Vinyl Flooring
	Plumbing Fixtures @ Casework
	Install Lockers
32	Finish Paint Walls

33	Terminations/Trimout Systems
34	Install OF-CI Items
35	Install Vinyl/Acrylic Wall Protection
	Finish Paint HM Frames
36	Install Electrical Devices/Trim
37	Install Carpet Tile/Sheet Carpet
	Finish Paint Ceilings
38	Base @ Vinyl Flooring
	Install Base @ Carpeted Flooring
39	Set/Install OF-OI Items
	Install Med Gas Headwall
	Install Medical Equipment
40	Install Wood Doors
	Install Door Hardware
	Install Mirrors @ T.R.
	Install Television Ceiling Mounts
	Install Roller Window Shades
	Install Visual Display boards
41	Final Clearning
	ATC Programming
42	Punchlist Work

	Electrical
	Mechanical
	Electrical/Mechanical
	Plumbing
	Drywall
	Concrete
	GC
	Fire Protection
	Pneumatic Tube
	Finishes

Figure 8.2 Matrix Schedule with Sequencing by Floors

8.5 Schedule Impact

When compared to the original project schedule the proposed methods of sequencing and scheduling the construction activities have a positive impact on the overall completion date. The current schedule shows a Substantial Completion Date of September 29, 2009 and a Punch List Completion Date of November 3, 2009. Utilizing the matrix scheduling method, however, allows for completion by July 6 when sequencing by zone and August 10 when sequencing by floor. These dates are a full 13 and 8 weeks sooner, respectively, than the current schedule. Table 8.1 shows the completion dates by floor for the original schedule and each of the alternative sequencing methods.

Comparison of Schedule Dates						
Floor	**Original**		**Sequencing By Zone**		**Sequencing By Floor**	
	Start	Complete	Start	Complete	Start	Complete
1	4/29/2008	7/7/2009	5/19/2008	5/29/2009	6/23/2008	4/24/2009
2	5/2/2008	7/14/2009	5/26/2008	6/5/2009	7/14/2008	5/11/2009
3	5/6/2008	7/21/2009	6/2/2008	6/12/2009	8/4/2008	6/5/2009
4	5/12/2008	8/7/2009	6/9/2008	6/19/2009	8/25/2008	6/26/2009
5	5/13/2008	8/7/2009	6/16/2008	6/26/2009	9/15/2008	7/17/2009
6	5/16/2008	8/25/2009	6/23/2008	7/3/2009	10/6/2008	8/7/2009

Table 8.1 Comparison of Schedule Dates

8.5.1 Impact on Exterior Finishes Schedule

When proposing alternatives to the sequencing and duration of the interior finishes within a building the impact on the schedule of the exterior finishes must also be considered. One of the most important questions to ask is if accelerating the schedule for the interiors will show that drywall installation is to begin prior to building dry in. This is especially critical for the Passavant Pavilion since it is a healthcare building and any issues with mold would be detrimental to the project. It is also important to investigate the relationship of the exterior finishes with the concrete slabs within the building to determine if all slabs are needed prior to construction of the exterior.

Proposing to change the sequence of the construction activities from that of the original schedule it is also important to investigate how this change will affect the sequencing of the exterior finishes. If the sequence of the interior finishes is by zone and the exterior is by floor this may also create a clash between the schedules. Table 8.2, below, shows the critical dates of the exterior finish schedule.

Critical Dates			
Area	**Activity**	**Start**	**Finish**
East Elevation	Exterior Studs/Sheathing	7/14/2008	8/1/2008
	Curtain Wall Framing	9/9/2008	9/29/2008
South Elevation	Exterior Studs/Sheathing	7/15/2008	8/5/2008
	Curtain Wall Framing	9/9/2008	10/31/2008
North Elevation	Exterior Studs/Sheathing	8/8/2008	9/12/2008
	Curtain Wall Framing	9/30/2008	11/3/2008
West Elevation	Exterior Studs/Sheathing	8/22/2008	9/12/2008
	Curtain Wall Framing	11/3/2008	11/21/2008
Roof	Penthouse Roofing - Dry In	8/19/2008	9/2/2008
	East Low Roofing - Dry In	9/9/2008	9/15/2008
	3rd Flr Roof Garden - Dry In	9/16/2008	9/25/2008
	West Low Roofing - Dry In	10/14/2008	10/20/2008
Building	Building Dry In Date		12/8/2008

Table 8.2 Critical Exterior Finish Dates

All of the critical dates for the roofing are able to meet the needs of both of the matrix scheduling sequences with some modification. In the case of the schedule which is sequenced by zone the four roofing activities would need to happen concurrently during the scheduled time for the Penthouse roofing or all roofing activities would need to be accelerated. In the case of the schedule which is sequenced by floor only the West Low Roofing would need to be accelerated. These modifications are needed to ensure that the roof is dried in prior to installation of gypsum wall board. If these dates cannot be accelerated then the use of mold resistant gypsum wall board could be considered although this comes at a premium of about $.25/sf of wall area. As an example a 10’x10’ room with 8’ ceilings would produce an upcharge of about $80. Using this method, however, does not allow the finishing to take place as scheduled because of its lack of water resistance.

The other critical dates that must be considered are the installation dates of the exterior studs and sheathing, masonry, and curtain wall. These three activities are heavily dependent on the interiors finishes and vice versa. The installation of the studs and sheathing cannot begin until the concrete slabs on deck are installed and the structural steel has been fire proofed. Only after the studs and sheathing are installed can the masonry veneer be completed which is then followed by the curtain wall.

The installation of the curtain wall framing is an important date because it signals when the building is essentially at the dry in state. While it is not completely dried in until the glaze is installed this can be temporarily achieved through the use of plywood or visqueen on the framing. At this point the installation of the gypsum wall board can begin without worry of being damaged by water and mold which is extremely important when working within a hospital environment.

Tables 8.3 and 8.4 show the proposed alternative exterior finishes dates based upon matrix schedule sequencing that will be used.

Proposed Alternative Exterior Dates (Sequence By Zone)			
Area	**Activity**	**Start**	**Finish**
Zone 1	Exterior Studs/Sheathing	7/7/2008	8/8/2008
	Masonry Veneer	7/28/2008	8/15/2008
	Curtain Wall Framing	8/4/2008	9/12/2008
Zone 2	Exterior Studs/Sheathing	8/18/2008	9/19/2008
	Masonry Veneer	9/8/2008	9/26/2008
	Curtain Wall Framing	9/15/2008	10/24/2008
Zone 3	Exterior Studs/Sheathing	9/29/2008	10/31/2008
	Masonry Veneer	10/20/2008	11/7/2008
	Curtain Wall Framing	10/27/2008	12/5/2008

Table 8.3 Proposed Alternative Exterior Dates (Sequence By Zone)

The above start and finish dates for the exterior finishes activities will allow them to be installed prior to the beginning of gypsum wall board installation within each zone. It would be preferable if all of the curtain wall was installed prior to the installation of the wall board to ensure that there is no water infiltration from above. This, however, is not an absolute necessity. If it should be desired the curtain wall installation would need to be accelerated by about 5 days so that the installation is complete before the wall board installation begins. These dates also create large gaps between when each trade is working on a zone which leads to down time and inefficiency.

Proposed Alternative Exterior Dates (Sequence By Floor)			
Floor	**Activity**	**Start**	**Finish**
1	Exterior Studs/Sheathing	8/18/2008	8/29/2008
	Masonry Veneer	9/1/2008	9/12/2008
	Curtain Wall Framing	9/8/2008	9/26/2008
2	Exterior Studs/Sheathing	9/8/2008	9/19/2008
	Masonry Veneer	9/22/2008	10/3/2008
	Curtain Wall Framing	9/29/2008	10/17/2008
3	Exterior Studs/Sheathing	9/29/2008	10/10/2008
	Masonry Veneer	10/13/2008	10/24/2008
	Curtain Wall Framing	10/20/2008	11/7/2008
4	Exterior Studs/Sheathing	10/20/2008	10/31/2008
	Masonry Veneer	11/3/2008	11/14/2008
	Curtain Wall Framing	11/10/2008	11/28/2008
5	Exterior Studs/Sheathing	11/10/2008	11/21/2008
	Masonry Veneer	11/24/2008	12/5/2008
	Curtain Wall Framing	12/1/2008	12/19/2008
6	Exterior Studs/Sheathing	11/24/2008	12/5/2008
	Masonry Veneer	12/15/2008	12/16/2008
	Curtain Wall Framing	12/22/2008	1/9/2009

Table 8.3 Proposed Alternative Exterior Dates (Sequence By Floor)

Again the above start and finish dates for the exterior finishes will allow them to be installed prior to the beginning of the gypsum wall board for that particular floor and the zone of the building which it is in. This allows the construction sequences to remain the same and none of the exterior finishes durations need to be accelerated. The possible downfall of this sequencing is that there is a risk of infiltration from the floors above near the edges of the building. This risk could possibly be mitigated through the use of a layer of visqueen over the edges of the slab and curtain wall. This sequencing also creates a lull in the flow of work for the stud and sheathing contractor of about a week between floors. While this is not an ideal situation it does allow the curtain wall to have a continuous flow from the first floor through the sixth floor.

8.6 Conclusion and Recommendation

Both of the proposed matrix schedules and sequences have their advantages and disadvantages. The matrix that is sequenced by zone is able to be completed up to five weeks ahead of that of the one that is sequenced by floor. While this schedule allows for an earlier completion date than when sequencing by floors it requires the trade contractors to work vertically before moving horizontally across the building. This means that they will be required to move materials and supplies more than if it were sequenced by floor.

As stated above the schedule that is sequenced by floor has a completion date that is about 5 weeks greater than that of the schedule sequenced by zones. This sequencing, however, allows the contractors to work horizontally across the floors prior to moving vertically. This amounts to fewer movements of materials and supplies which in turn provides the contractors with more time to focus on the work that is being put in place.

Both of these sequences also requires the exterior finishes to be accelerated or the elevations to be erected at the same time, i.e. north and south elevation studs must be erected simultaneously. Since this occurs in both of the schedules this does not have a bearing on which is a more viable option than the other.

When evaluating both of these schedules and sequences to determine which should be utilized on the project the sequence of the original schedule must be considered. If a matrix schedule was to be utilized as a makeup schedule it would have to use the sequencing that was utilized in the beginning. In the case of the Passavant Pavilion this would mean that the schedule which is sequenced by zones would be used.

However, if a matrix schedule was to be utilized from the beginning it would be up to the project team to determine which schedule to choose. Based purely on a time savings approach the schedule which is sequenced by zones would be the logical choice. This is due to the fact that is completed up to 13 weeks ahead of the originally scheduled completion date while the schedule that is sequenced by floors is only completed 8 weeks prior to that.

If the schedules were to be chosen by the consistency of the work flow the schedule that is sequenced by floor would be the logical choice. This is dues to the fact that the contractors are able to complete their particular tasks on each floor prior to moving onto the next floor. This aids in efficiency and allows for more time to be spent on the construction rather than relocating materials and supplies.

In conclusion, I cannot determine a definitive answer as to which schedule and sequence should be utilized without first determining the situation in which it is to be applied. As stated above the schedule that is sequenced by zones is ideally for a makeup schedule while if a matrix schedule was to be used from the start that which is sequenced by floor may be the best option to maximize work flow.

It can be concluded, however, that matrix schedules do provide an alternative to the traditionally Gant Chart method of scheduling. They are able to visually display the areas in which the contractors are to be conducting their work and when they are to be there much quicker than a Gant Chart. This scheduling method also allows the construction manager to specify the amount of time that each contractor will have within a particular area to complete a specific task. This then places the risk of delays on the subcontractors. They are given a time frame to complete their work and must determine the best manner in which to accomplish this task. It also allows the subcontractors to be in control of how they will complete their work without competing with other contractors for space because they have exclusive rights to that area at that time. This then allows for faster construction durations for each activity.

9.0 Conclusion and Recommendations

Through the course of the three analyses of this report multiple ways in which to reduce the cost and schedule were investigated and substantiated. If theses means were implemented into the UPMC Passavant Pavilion Addition the budget and schedule could be adjusted in a positive manner and aid in the quality and timely completion of the project.

The first of these analyses investigated the use and implementation of mobile information technology documents in construction. This is a computer based software that utilizes mobile computers to allow all construction documents to be provided to the project team in digital format. Being that these documents are in this format and can be opened on mobile computers means that the construction manager can always have their documents with them when on site. A primary feature of this system is that when the information is updated on the central server it is automatically distributed to the entire project team.

The automatic updating of construction documents allows the most current set of documents to allows be in front of the people that need them the most, the field staff. Too many times portions of projects are constructed using out of date drawings and changes must be made after the work is put in place. The aim of this technology is to eliminate this risk and ensure that only the most current set of documents is available.

The benefits of this technology can be easily seen but they can only be achieved through proper implementation. This implementation must ensure that the end users of the system are well trained and not afraid to use the technology during the course of their day on the jobsite. With the proper training and hardware this technology could be a success on any jobsite.

After researching this topic and speaking with contractors and software suppliers I would recommend that this technology be further adapted to the UPMC Passavant Pavilion. The benefits of the use of such a system outweigh the disadvantages and have been shown to have the potential to eliminate a variety of costs. The major cost that is eliminated is mistakes caused by the use of out of date drawings and documents. Another cost that is reduced is the reproduction costs associated with the printing of construction documents. The costs associated with reproduction can add up very quickly especially on a project like this where full size drawings are issued for every change. If digital construction documents were readily available these updates would only need to be printed on an as needed basis.

The second analysis that was considered was the use of architectural precast panels in lieu of masonry brick veneer. This analysis was aimed at determining if the alternate material would be able to reduce the schedule and cost of the exterior façade. While this change may not substantially reduce the schedule without the rescheduling of the concrete pours it does substantially reduce the overall cost of the façade.

By replacing the hand laid brick veneer with precast concrete wall panels the project can save about $240,000. The cost of this change is even greater when considering to utilize this alternative in lieu of the metal panel wall system as well. In that case the alternative could produce a cost savings of about

$422,000. These changes not only save costs but they also do not adversely affect the structure or architectural aesthetics of the building which makes it a viable candidate for its use.

As I stated previously in this report the decision to utilize precast concrete panels in lieu of the masonry brick veneer is ultimately in the hands of the owner as they may wish to maintain the existing design or pursue these avenues which have be shown to produce substantial cost savings. In my opinion it would be wise to implement at least the use of precast in lieu of the brick veneer. This allows for a cost savings with no increase in schedule duration and can possibly save a few days over the original system. These cost savings could then be used in other portions of the building where value engineering may have taken place during preconstruction.

The final analysis focused on the use of matrix schedules to possibly act as a makeup schedule if the project becomes delayed or delayed more so than it has already become. Utilizing this scheduling method did prove to offer schedule savings of between 8 and 13 weeks depending upon the manner in which the schedule is sequenced. These sequences are either by floor or by zone.

The schedule sequence by floor allows the contractors to work horizontally before moving vertically while the sequence by zone is the converse and is what is currently in use at Passavant. When choosing which sequence is the most viable for the project it is important to consider the situation that is requiring the use of this scheduling method.

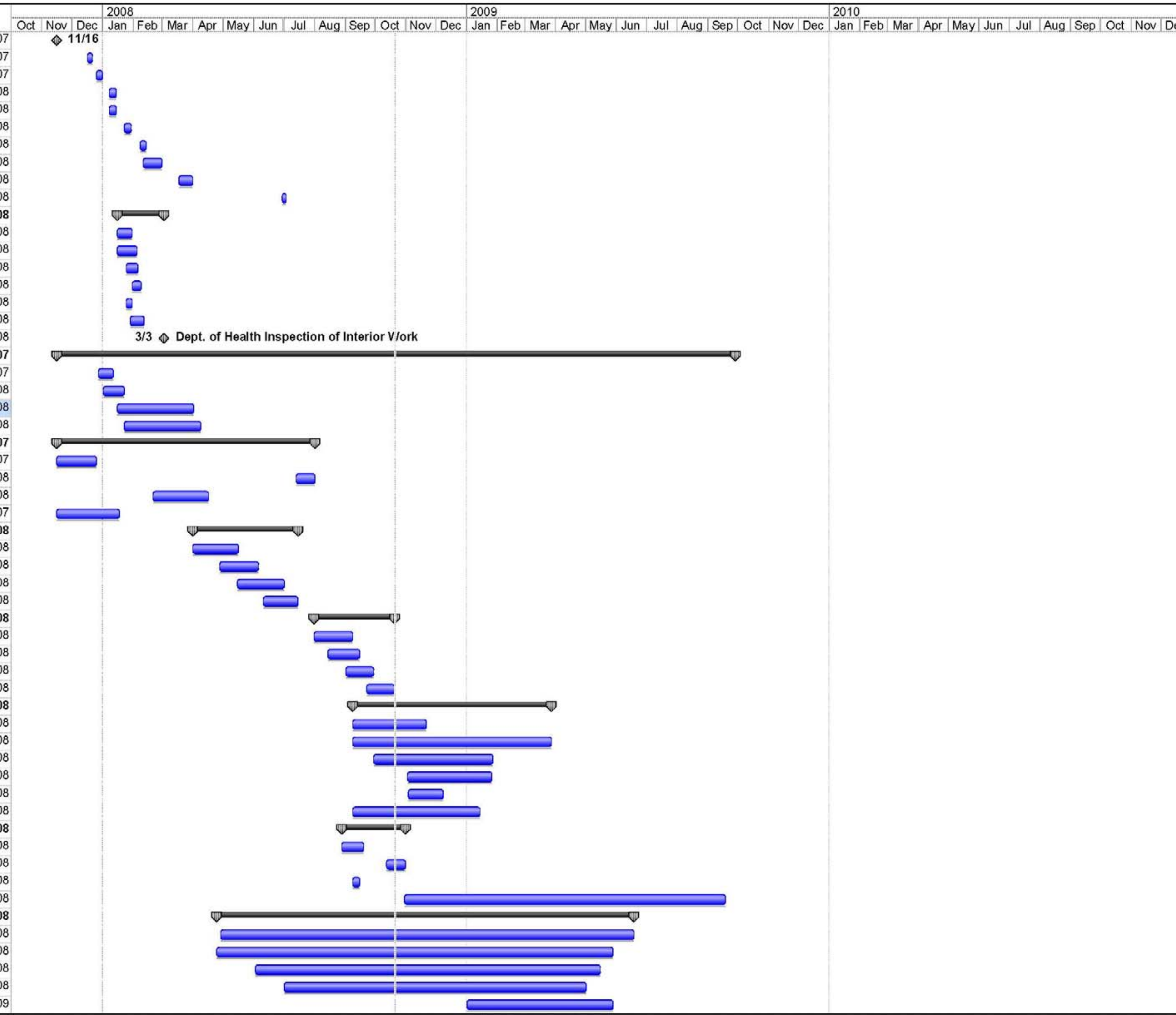
If the project has fallen behind through the course of construction and a matrix schedule is being utilized for recovery it would be prudent to use a sequence that is similar to that which is currently in use. In that case the best sequence to use would be the one which is by zones. If, however, the matrix schedule was proposed prior to the start of construction either of these options could be utilized. As stated previously this decision is ultimately in the hands of the project management team. In the case where the schedule is created during preconstruction I would recommend using that which is sequenced by floor to allow for a smoother flow of construction activities and decrease the amount of times the contractors must move their materials and supplies.

Overall I believe that the findings of these three analyses could prove beneficial to the construction of UPM C Passavant Pavilion. The use of mobile IT documents and precast panels have the potential to generate cost savings while all three analyses have the potential to generate schedule savings. When used in conjunction with one another the benefits could be compounded and increased.

Appendix A

Detailed Construction Schedule

ID	Task Name	Duration	Start
1	Notice To Proceed	0 days	Fri 11/16/07
2	General Contractor Mobilization	5 days	Mon 12/17/07
3	Excavator Field Mobilization	4 days	Wed 12/26/07
4	Electrical Field Mobilization	5 days	Tue 1/8/08
5	Plumbing Field Mobilization	5 days	Tue 1/8/08
6	Site Utility Field Mobilization	5 days	Wed 1/23/08
7	Mason Field Mobilization	4 days	Fri 2/8/08
8	Mechanical Field Mobilization	15 days	Mon 2/11/08
9	Structural Steel Erector Field Mobilization	10 days	Tue 3/18/08
10	Fire Protection Field Mobilization	4 days	Mon 6/30/08
11	**Phase 1 - Renovation/Prep**	**33 days**	**Wed 1/16/08**
12	Mechanical Demo	11 days	Wed 1/16/08
13	Electrical Demo	14 days	Wed 1/16/08
14	Electrical Rough In - Power, Lighting, Systems	8 days	Fri 1/25/08
15	Electrical Trim Out/Fixtures	7 days	Thu 1/31/08
16	General Contractor Architectural Demo	4 days	Fri 1/25/08
17	General Contractor Finishes	10 days	Tue 1/29/08
18	Dept. of Health Inspection of Interior Work	0 days	Mon 3/3/08
19	**Phase 2 - Pavilion**	**487 days?**	**Fri 11/16/07**
20	Site Demo	11 days?	Fri 12/28/07
21	Bulk Excavation	15 days	Wed 1/2/08
22	Building Foundations/Walls	55 days	Wed 1/16/08
23	Plumbing Under Slab Utilities	55 days	Wed 1/23/08
24	**Concrete**	**186 days?**	**Fri 11/16/07**
25	Prep/Place SOG	28 days?	Fri 11/16/07
26	Complete SOG	15 days	Mon 7/14/08
27	Masonry Foundation Walls	40 days	Thu 2/21/08
28	Backfill Foundation Walls	45 days	Fri 11/16/07
29	**Structural Steel**	**76 days?**	**Tue 4/1/08**
30	Structural Steel Erection/Detailing/Decking Zone 1	34 days	Tue 4/1/08
31	Structural Steel Erection/Detailing/Decking Zone 2	29 days?	Mon 4/28/08
32	Structural Steel Erection/Detailing/Decking Zone 3	33 days?	Fri 5/16/08
33	Structural Steel Erection/Detailing/Decking Zone 4	25 days?	Wed 6/11/08
34	**Masonry**	**57 days?**	**Fri 8/1/08**
35	East Elevation	27 days?	Fri 8/1/08
36	North Elevation	22 days?	Fri 8/15/08
37	South Elevation	20 days?	Tue 9/2/08
38	West Elevation	20 days?	Tue 9/23/08
39	**Curtain Wall**	**144 days?**	**Tue 9/9/08**
40	East Elevation	54 days?	Tue 9/9/08
41	South Elevation	144 days?	Tue 9/9/08
42	North Elevation	86 days?	Tue 9/30/08
43	West Elevation	61 days?	Mon 11/3/08
44	Bridge	25 days?	Tue 11/4/08
45	Translucent Panels	92 days?	Tue 9/9/08
46	**Metal Wall Panels**	**46 days?**	**Fri 8/29/08**
47	East Elevation	16 days?	Fri 8/29/08
48	West Elevation	15 days?	Mon 10/13/08
49	Louvers	5 days?	Tue 9/9/08
50	Elevators	231 days?	Fri 10/31/08
51	**Ground Floor**	**300 days?**	**Fri 4/25/08**
52	Mechanical	298 days?	Tue 4/29/08
53	Electrical	285 days?	Fri 4/25/08
54	Plumbing	249 days?	Tue 6/3/08
55	Partitions/Drywall/Ceilings	218 days?	Wed 7/2/08
56	Finishes	105 days?	Fri 1/2/09

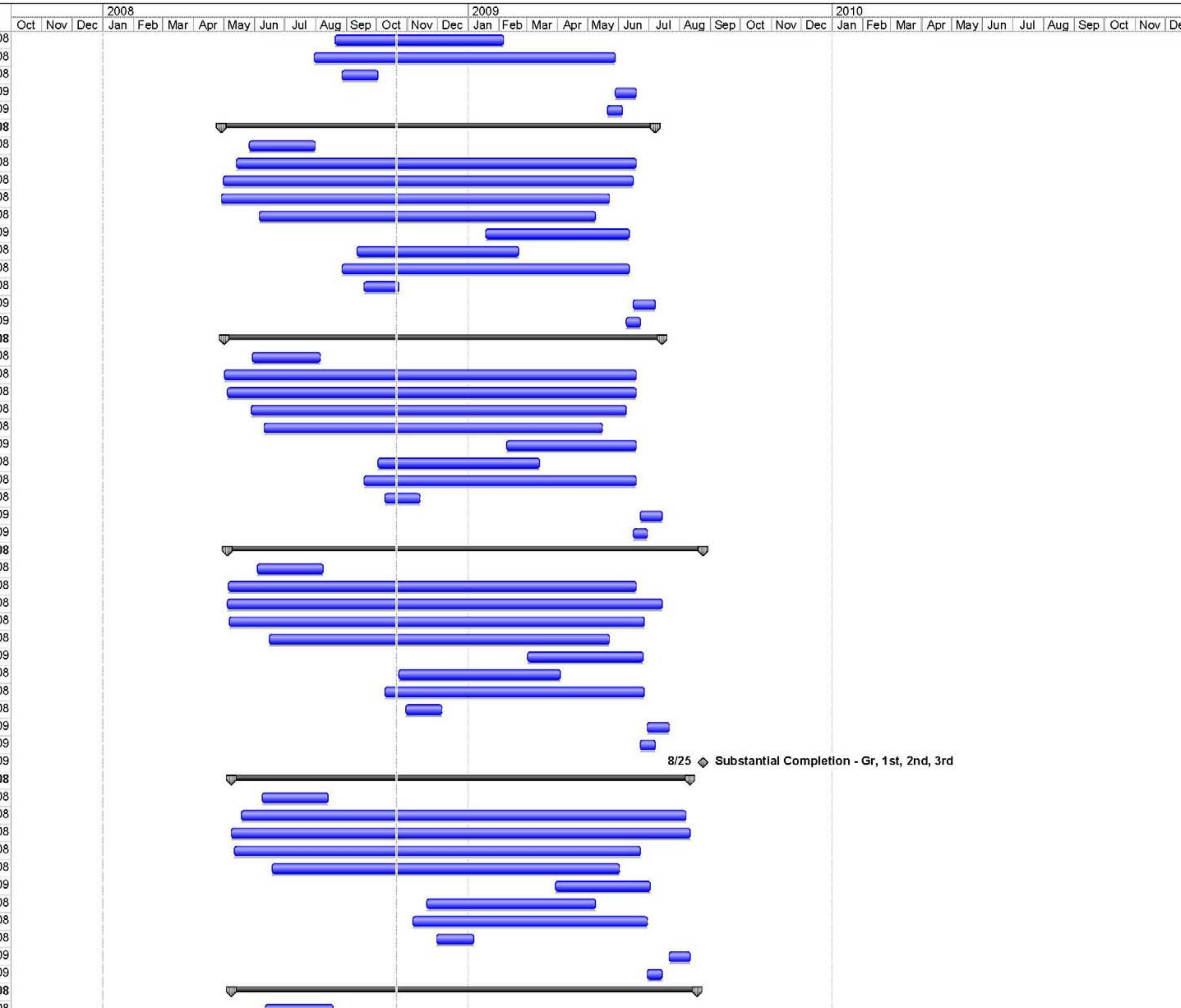


Project: Thesis Tech II Project Schedu
Date: Tue 10/21/08

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Page 1

ID	Task Name	Duration	Start
57	Fire Protection	121 days?	Thu 8/21/08
58	FF&E	216 days?	Thu 7/31/08
59	Pneumatic Tubing	26 days?	Thu 8/28/08
60	Punch List	15 days?	Fri 5/29/09
61	Final Cleaning	11 days?	Thu 5/21/09
62	**1st Floor**	**311 days?**	**Tue 4/29/08**
63	Concrete SOD	48 days?	Tue 5/27/08
64	Mechanical	287 days?	Wed 5/14/08
65	Electrical	293 days?	Thu 5/1/08
66	Plumbing	279 days?	Tue 4/29/08
67	Partitions/Drywall/Ceilings	241 days?	Fri 6/6/08
68	Finishes	104 days?	Mon 1/19/09
69	Fire Protection	116 days?	Fri 9/12/08
70	FF&E	206 days?	Thu 8/28/08
71	Pneumatic Tubing	25 days?	Fri 9/19/08
72	Punch List	16 days?	Tue 6/16/09
73	Final Cleaning	10 days?	Tue 6/9/09
74	**2nd Floor**	**313 days?**	**Fri 5/2/08**
75	Concrete SOD	48 days?	Fri 5/30/08
76	Mechanical	295 days?	Fri 5/2/08
77	Electrical	294 days?	Mon 5/5/08
78	Plumbing	268 days?	Thu 5/29/08
79	Partitions/Drywall/Ceilings	243 days?	Wed 6/11/08
80	Finishes	94 days?	Mon 2/9/09
81	Fire Protection	116 days?	Fri 10/3/08
82	FF&E	195 days?	Fri 9/19/08
83	Pneumatic Tubing	25 days?	Fri 10/10/08
84	Punch List	16 days?	Tue 6/23/09
85	Final Cleaning	10 days?	Tue 6/16/09
86	**3rd Floor**	**341 days?**	**Mon 5/5/08**
87	Concrete SOD	48 days?	Wed 6/4/08
88	Mechanical	293 days?	Tue 5/6/08
89	Electrical	312 days?	Mon 5/5/08
90	Plumbing	298 days?	Wed 5/7/08
91	Partitions/Drywall/Ceilings	245 days?	Mon 6/16/08
92	Finishes	84 days?	Mon 3/2/09
93	Fire Protection	116 days?	Fri 10/24/08
94	FF&E	186 days?	Fri 10/10/08
95	Pneumatic Tubing	26 days?	Fri 10/31/08
96	Punch List	16 days?	Tue 6/30/09
97	Final Cleaning	11 days?	Tue 6/23/09
98	Substantial Completion - Gr, 1st, 2nd, 3rd	0 days	Tue 8/25/09
99	**4th Floor**	**328 days?**	**Fri 5/9/08**
100	Concrete SOD	48 days	Mon 6/9/08
101	Mechanical	320 days?	Mon 5/19/08
102	Electrical	328 days?	Fri 5/9/08
103	Plumbing	291 days?	Mon 5/12/08
104	Partitions/Drywall/Ceilings	248 days?	Thu 6/19/08
105	Finishes	69 days?	Mon 3/30/09
106	Fire Protection	121 days?	Fri 11/21/08
107	FF&E	167 days?	Fri 11/7/08
108	Pneumatic Tubing	27 days?	Mon 12/1/08
109	Punch List	15 days?	Wed 7/22/09
110	Final Cleaning	11 days?	Tue 6/30/09
111	**5th Floor**	**333 days?**	**Fri 5/9/08**
112	Concrete SOD	48 days?	Thu 6/12/08



Project: Thesis Tech II Project Schedu
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Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

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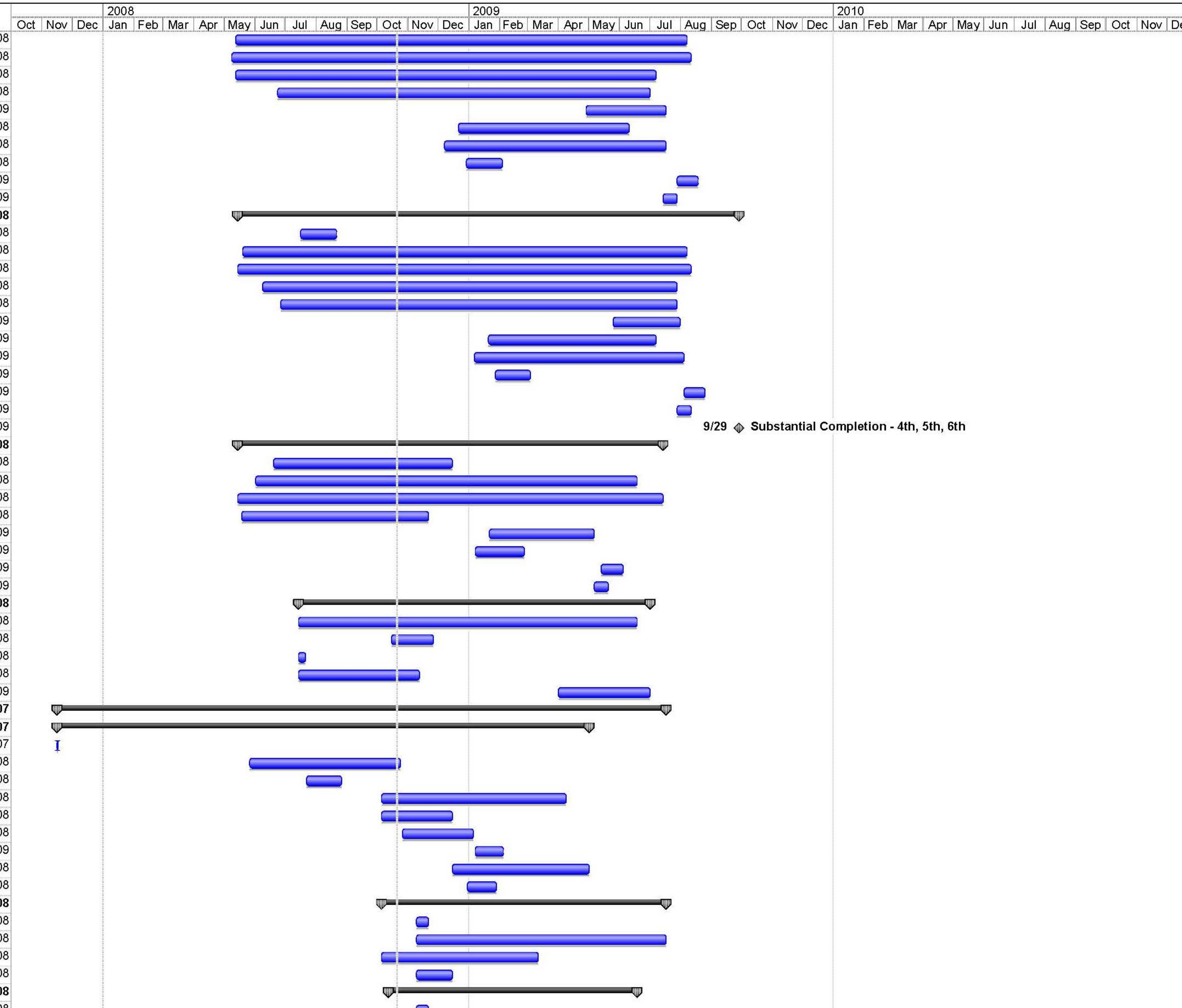
ID	Task Name	Duration	Start
113	Mechanical	324 days?	Tue 5/13/08
114	Electrical	328 days?	Fri 5/9/08
115	Plumbing	301 days?	Tue 5/13/08
116	Partitions/Drywall/Ceilings	267 days?	Tue 6/24/08
117	Finishes	58 days?	Wed 4/29/09
118	Fire Protection	123 days?	Mon 12/22/08
119	FF&E	160 days?	Mon 12/8/08
120	Pneumatic Tubing	26 days?	Tue 12/30/08
121	Punch List	15 days?	Wed 7/29/09
122	Final Cleaning	10 days?	Wed 7/15/09
123	**6th Floor**	**358 days?**	**Thu 5/15/08**
124	Concrete SOD	26 days?	Thu 7/17/08
125	Mechanical	319 days?	Tue 5/20/08
126	Electrical	324 days?	Thu 5/15/08
127	Plumbing	297 days?	Mon 6/9/08
128	Partitions/Drywall/Ceilings	283 days?	Fri 6/27/08
129	Finishes	49 days?	Tue 5/26/09
130	Fire Protection	120 days?	Wed 1/21/09
131	FF&E	150 days?	Wed 1/7/09
132	Pneumatic Tubing	25 days?	Wed 1/28/09
133	Punch List	15 days?	Wed 8/5/09
134	Final Cleaning	10 days?	Wed 7/29/09
135	Substantial Completion - 4th, 5th, 6th	0 days	Tue 9/29/09
136	**7th Floor**	**304 days?**	**Thu 5/15/08**
137	Concrete SOD	127 days?	Fri 6/20/08
138	Mechanical	274 days?	Mon 6/2/08
139	Electrical	304 days?	Thu 5/15/08
140	Plumbing	135 days?	Mon 5/19/08
141	Finishes	75 days?	Thu 1/22/09
142	Fire Protection	35 days?	Thu 1/8/09
143	Punch List	16 days?	Thu 5/14/09
144	Final Cleaning	10 days?	Thu 5/7/09
145	**Roof**	**252 days?**	**Tue 7/15/08**
146	Mechanical	243 days?	Tue 7/15/08
147	Electrical	30 days?	Thu 10/16/08
148	Plumbing	5 days?	Tue 7/15/08
149	Roofing	87 days?	Tue 7/15/08
150	Roof Garden	66 days?	Wed 4/1/09
151	**Phase 2 - Central Plant**	**436 days?**	**Fri 11/16/07**
152	**Structure**	**381 days?**	**Fri 11/16/07**
153	Structural Steel Erection/Detailing/Decking - Zone 5	1 day?	Fri 11/16/07
154	Concrete	109 days?	Tue 5/27/08
155	Plumbing - subgrade	25 days?	Wed 7/23/08
156	Electrical - subgrade	133 days?	Mon 10/6/08
157	Masonry	51 days?	Mon 10/6/08
158	Roofing	51 days?	Mon 10/27/08
159	Fire Protection - Stand pipe	20 days?	Thu 1/8/09
160	Mechanical	99 days?	Tue 12/16/08
161	Louvers	21 days?	Wed 12/31/08
162	**Ground Floor**	**205 days?**	**Mon 10/6/08**
163	Concrete - Pads	10 days?	Mon 11/10/08
164	Mechanical	180 days?	Mon 11/10/08
165	Electrical	113 days?	Mon 10/6/08
166	Plumbing	26 days?	Mon 11/10/08
167	**1st Floor**	**179 days?**	**Mon 10/13/08**
168	Concrete - Pads	10 days?	Mon 11/10/08



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Task | Progress | Summary | External Tasks | Deadline
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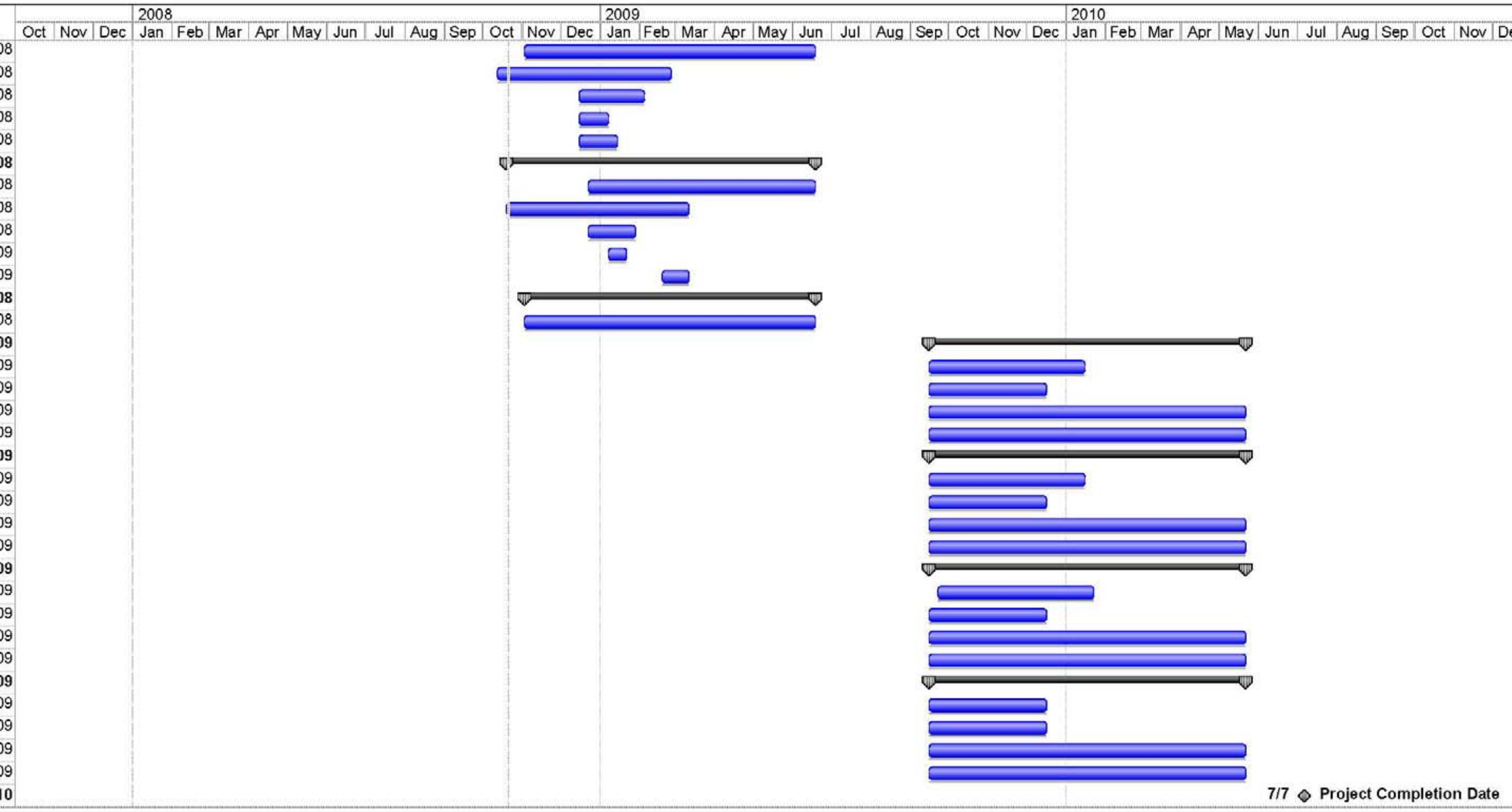
ID	Task Name	Duration	Start
169	Mechanical	164 days?	Mon 11/3/08
170	Electrical	98 days?	Mon 10/13/08
171	Plumbing	37 days?	Tue 12/16/08
172	Masonry	17 days?	Tue 12/16/08
173	Fire Protection	22 days?	Tue 12/16/08
174	**2nd Floor**	**174 days?**	**Mon 10/20/08**
175	Mechanical	128 days?	Tue 12/23/08
176	Electrical	103 days?	Mon 10/20/08
177	Plumbing	27 days?	Tue 12/23/08
178	Masonry	10 days?	Thu 1/8/09
179	Fire Protection	15 days?	Thu 2/19/09
180	**Roof**	**164 days?**	**Mon 11/3/08**
181	Mechanical	164 days?	Mon 11/3/08
182	**Phase 3 - Renovation**	**178 days?**	**Wed 9/16/09**
183	Mechanical	88 days?	Wed 9/16/09
184	Demo - Gr., 1st, 2nd Floors	66 days?	Wed 9/16/09
185	Renovation - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
186	Electrical - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
187	**Phase 4 - Renovation**	**178 days?**	**Wed 9/16/09**
188	Mechanical	88 days?	Wed 9/16/09
189	Demo - Gr., 1st, 2nd Floors	66 days?	Wed 9/16/09
190	Renovation - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
191	Electrical - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
192	**Phase 5 - Renovation**	**178 days?**	**Wed 9/16/09**
193	Mechanical	88 days?	Wed 9/23/09
194	Demo - Gr., 1st, 2nd Floors	66 days?	Wed 9/16/09
195	Renovation - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
196	Electrical - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
197	**Phase 6 - Renovation**	**178 days?**	**Wed 9/16/09**
198	Mechanical	66 days?	Wed 9/16/09
199	Demo - Gr., 1st, 2nd Floors	66 days?	Wed 9/16/09
200	Renovation - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
201	Electrical - Gr., 1st, 2nd Floors	178 days?	Wed 9/16/09
202	**Project Completion Date**	**0 days**	**Wed 7/7/10**



Project: Thesis Tech II Project Schedu
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Appendix B

General Conditions Estimate

General Conditions Costs

General Conditions	**Duration (Months)**	**# of Trailers**	**Cost/Trailer/Month**	**Total Cost**	**Cost/Week**
Site Trailers	31	$3.00	$375.00	$34,875.00	$262.22
	Duration (Months)	# of Toilets	Cost/Toilet/Month	Total Cost	Cost/Week
Port-A-Johns	31	$6.00	$171.00	$31,806.00	$239.14
	Duration (Years)	L.F.	$/L.F./Year	Total Cost	Cost/Week
Site Fencing	2.6	$1,700.00	$3.58	$15,823.60	$118.97
	Duration (Weeks)	Pulls/Week	$/Pull	Total Cost	Cost/Week
Waste Management	133	1	$600.00	$79,800.00	$600.00
Field Office Expenses	Duration (Months)	Cost/Month		Total Cost	Cost/Week
Office Equipment	31	$150.00		$4,650.00	$34.96
Office Supplies	31	$95.00		$2,945.00	$22.14
Telephone	31	$210.00		$6,510.00	$48.95
Lights & HVAC	31	$110.00		$3,410.00	$25.64
Temporary Utlilities	Duration (Weeks)	CSF of Building	$/Week/CSF	Total Cost	Cost/Week
Temporary Heating	20	2,094	$3.07	$128,571.60	$966.70
Temporary Electric	64	2,094	$2.39	$320,298.24	$2,408.26
Insurance and Bonds	% of Project Cost	Project Cost		Insurance Cost	Cost/Week
All-Risk Insurance	0.35%	$85,900,000.00		$300,650.00	$2,260.53
Performance Bond	0.70%	$85,900,000.00		$601,300.00	$4,521.05
Misc.				Total Cost	
Signage				$5,000.00	
Mobile IT Documents				$50,000.00	
			Total	$1,585,639.44	

Staffing Costs

General Conditions			
Staffing	**Duration(Weeks)**	**Cost/Week**	**Total Cost**
Project Executive	93.1	$2,500.00	$232,750.00
Project Manager	134	$1,850.00	$247,900.00
General Superintendent	108	$1,700.00	$183,600.00
Asst. Superintendent	43	$1,200.00	$51,600.00
Area Superintendent	104	$1,000.00	$104,000.00
Project Engineer	100	$1,125.00	$112,500.00
Project Engineer	117	$1,125.00	$131,625.00
Safety Engineer	32.7	$1,000.00	$32,700.00
Secretary	130	$1,005.00	$130,650.00
Interiors Superintendent	26	$1,000.00	$26,000.00
Engineering Intern	70	$800.00	$56,000.00
TOTAL		$14,305.00	$1,309,325.00

Appendix C

Precast Panel Sizes

(With Metal Panels)

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
South	Precast	Add	11	12.33	18	2441	$35.00	$85,446.90
	Precast	Add	1	6	27.5	165	$35.00	$5,775.00
	Precast	Add	1	1.67	37.5	63	$35.00	$2,191.88
	Precast	Add	1	5	20	100	$35.00	$3,500.00
	Precast	Add	1	4	20	80	$35.00	$2,800.00
	Masonry	Delete	-11	12.33	18	-2441	$74.00	-$180,659.16
	Masonry	Delete	-1	6	27.5	-165	$74.00	-$12,210.00
	Masonry	Delete	-1	1.67	37.5	-63	$74.00	-$4,634.25
	Masonry	Delete	-1	5	20	-100	$74.00	-$7,400.00
	Masonry	Delete	-1	4	20	-80	$74.00	-$5,920.00
	Louver	Delete	-1	15.5	3	-47	$480.00	-$22,320.00
	Masonry	Add	1	15.5	3	47	$74.00	$3,441.00
							Total	**-$129,988.64**

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
East	Precast	Add	2	12	13.33	320	$35.00	$11,197.20
	Precast	Add	8	12	12	1152	$35.00	$40,320.00
	Precast	Add	2	12	20	480	$35.00	$16,800.00
	Masonry	Delete	-2	12	13.33	-320	$82.00	-$26,233.44
	Masonry	Delete	-8	12	12	-1152	$82.00	-$94,464.00
	Masonry	Delete	-2	12	20	-480	$82.00	-$39,360.00
	Precast	Add	2	15.5	14	434	$35.00	$15,190.00
	Precast	Add	2	15.5	13.33	413	$35.00	$14,463.05
	Precast	Add	8	15.5	12	1488	$35.00	$52,080.00
	Precast	Add	2	15.5	20	620	$35.00	$21,700.00
	Masonry	Delete	-2	15.5	14	-434	$17.00	-$7,378.00
	Masonry	Delete	-2	15.5	13.33	-413	$17.00	-$7,024.91
	Masonry	Delete	-8	15.5	12	-1488	$17.00	-$25,296.00
	Masonry	Delete	-2	15.5	20	-620	$17.00	-$10,540.00
							Total	**-$38,546.10**

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
North	Precast	Add	1	4.5	12	54	$35.00	$1,890.00
	Precast	Add	1	1.833	12	22	$35.00	$769.86
	Precast	Add	8	11	12	1056	$35.00	$36,960.00
	Precast	Add	1	11	20	220	$35.00	$7,700.00
	Precast	Add	1	14	20	280	$35.00	$9,800.00
	Masonry	Delete	-1	4.5	12	-54	$23.00	-$1,242.00
	Masonry	Delete	-1	1.833	12	-22	$23.00	-$505.91
	Masonry	Delete	-8	11	12	-1056	$23.00	-$24,288.00
	Masonry	Delete	-1	11	20	-220	$23.00	-$5,060.00
	Masonry	Delete	-1	14	20	-280	$23.00	-$6,440.00
	Precast	Add	1	18	26.5	477	$35.00	$16,695.00
	Precast	Add	1	3	22	66	$35.00	$2,310.00
	Precast	Add	1	7	7	49	$35.00	$1,715.00
	Precast	Add	1	7	30	210	$35.00	$7,350.00
	Masonry	Delete	-1	3	22	-66	$23.00	-$1,518.00
	Masonry	Delete	-1	7	7	-49	$23.00	-$1,127.00
	Masonry	Delete	-1	7	30	-210	$23.00	-$4,830.00
							Total	**$29,207.95**

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
West	Precast	Add	1	30	13.33	400	$35.00	$13,996.50
	Precast	Add	4	24.5	12	1176	$35.00	$41,160.00
	Precast	Add	1	30	26.5	795	$35.00	$27,825.00
	Masonry	Delete	-1	30	13.33	-400	$68.00	-$27,193.20
	Masonry	Delete	-4	24.5	12	-1176	$68.00	-$79,968.00
	Masonry	Delete	-1	30	26.5	-795	$68.00	-$54,060.00
	Masonry	Delete	-4	2	12	-96	$68.00	-$6,528.00
	Cast Stone	Delete	-5	1	30	-150	$68.00	-$10,200.00
	Curtain Wall	Add	3	1	5	15	$120.00	$1,800.00
	Curtain Wall	Add	4	2	11	88	$120.00	$10,560.00
	Stone Panels	Delete	-1	3	22	-66	$68.00	-$4,488.00
	Precast	Add	1	31	15	465	$35.00	$16,275.00
	Masonry	Delete	-1	31	15	-465	$68.00	-$31,620.00
							Total	**-$100,130.70**
							Total South	-$129,988.64
							Total East	-$38,546.10
							Total North	$29,207.95
							Total West	-$100,130.70
							Total	**-$239,457.48**

Appendix D

Precast Panel Sizes

(Without Metal Panels)

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
South	Precast	Add	11	12.33	18	2441	$35.00	$85,446.90
	Precast	Add	1	6	27.5	165	$35.00	$5,775.00
	Precast	Add	1	1.67	37.5	63	$35.00	$2,191.88
	Precast	Add	1	5	20	100	$35.00	$3,500.00
	Precast	Add	1	4	20	80	$35.00	$2,800.00
	Masonry	Delete	-11	12.33	18	-2441	$74.00	-$180,659.16
	Masonry	Delete	-1	6	27.5	-165	$74.00	-$12,210.00
	Masonry	Delete	-1	1.67	37.5	-63	$74.00	-$4,634.25
	Masonry	Delete	-1	5	20	-100	$74.00	-$7,400.00
	Masonry	Delete	-1	4	20	-80	$74.00	-$5,920.00
	Louver	Delete	-1	15.5	3	-47		$0.00
	Masonry	Add	1	15.5	3	47	$74.00	$3,441.00
	Metal Panel	Delete	-1	14	95	-1330	$53.46	-$71,101.80
	Precast	Add	1	14	14	196	$35.00	$6,860.00
	Precast	Add	1	14	13.33	187	$35.00	$6,531.70
	Precast	Add	4	14	12	672	$35.00	$23,520.00
	Precast	Add	1	14	20	280	$35.00	$9,800.00
	Precast	Add	2	4	20	160	$35.00	$5,600.00
	Precast	Add	1	10	15.5	155	$35.00	$5,425.00
	Metal Panel	Delete	-1	22.5	20	-450	$53.46	$1,069.20
	Metal Panel	Delete	-1	20.5	61	-1251	$53.46	$3,261.06
	Metal Panel	Delete	-1	2	4	-8	$53.46	$213.84
	Precast	Add	1	2	4	8	$35.00	$280.00
	Precast	Add	2	10	13.33	267	$35.00	$9,331.00
	Precast	Add	6	10	12	720	$35.00	$25,200.00
	Precast	Add	1	10	20	200	$35.00	$7,000.00
	Precast	Add	1	12	20	240	$35.00	$8,400.00
							Total	**-$78,841.74**

				Dimensions				
East	Precast	Add	2	12	13.33	320	$35.00	$11,197.20
	Precast	Add	8	12	12	1152	$35.00	$40,320.00
	Precast	Add	2	12	20	480	$35.00	$16,800.00
	Masonry	Delete	-2	12	13.33	-320	$82.00	-$26,233.44
	Masonry	Delete	-8	12	12	-1152	$82.00	-$94,464.00
	Masonry	Delete	-2	12	20	-480	$82.00	-$39,360.00
	Precast	Add	2	15.5	14	434	$35.00	$15,190.00
	Precast	Add	2	15.5	13.33	413	$35.00	$14,463.05
	Precast	Add	8	15.5	12	1488	$35.00	$52,080.00
	Precast	Add	2	15.5	20	620	$35.00	$21,700.00
	Masonry	Delete	-2	15.5	14	-434	$17.00	-$7,378.00
	Masonry	Delete	-2	15.5	13.33	-413	$17.00	-$7,024.91
	Masonry	Delete	-8	15.5	12	-1488	$17.00	-$25,296.00
	Masonry	Delete	-2	15.5	20	-620	$17.00	-$10,540.00
	Metal Panel	Delete	-1	3	95	-285	$53.46	-$15,236.10
	Precast	Add	1	3	14	42	$35.00	$1,470.00
	Precast	Add	1	3	13.33	40	$35.00	$1,399.65
	Precast	Add	4	3	12	144	$35.00	$5,040.00
	Precast	Add	1	3	20	60	$35.00	$2,100.00
	Metal Panel	Delete	-1	2	95	-190	$53.46	-$10,157.40
	Precast	Add	1	2	14	28	$35.00	$980.00
	Precast	Add	1	2	13.33	27	$35.00	$933.10
	Precast	Add	4	2	12	96	$35.00	$3,360.00
	Precast	Add	1	2	20	40	$35.00	$1,400.00
							Total	**-$47,256.85**

				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
North	Precast	Add	1	4.5	12	54	$35.00	$1,890.00
	Precast	Add	1	1.833	12	22	$35.00	$769.86
	Precast	Add	8	11	12	1056	$35.00	$36,960.00
	Precast	Add	1	11	20	220	$35.00	$7,700.00
	Precast	Add	1	14	20	280	$35.00	$9,800.00
	Masonry	Delete	-1	4.5	12	-54	$23.00	-$1,242.00
	Masonry	Delete	-1	1.833	12	-22	$23.00	-$505.91
	Masonry	Delete	-8	11	12	-1056	$23.00	-$24,288.00
	Masonry	Delete	-1	11	20	-220	$23.00	-$5,060.00
	Masonry	Delete	-1	14	20	-280	$23.00	-$6,440.00
	Precast	Add	1	18	26.5	477	$35.00	$16,695.00
	Precast	Add	1	3	22	66	$35.00	$2,310.00
	Precast	Add	1	7	7	49	$35.00	$1,715.00
	Precast	Add	1	7	30	210	$35.00	$7,350.00
	Masonry	Delete	-1	3	22	-66	$23.00	-$1,518.00
	Masonry	Delete	-1	7	7	-49	$23.00	-$1,127.00
	Masonry	Delete	-1	7	30	-210	$23.00	-$4,830.00
	Metal Panel	Delete	-1	11	19	-209	$53.46	-$11,173.14
	Precast	Add	1	11	19	209	$35.00	$7,315.00
							Total	**$25,349.81**

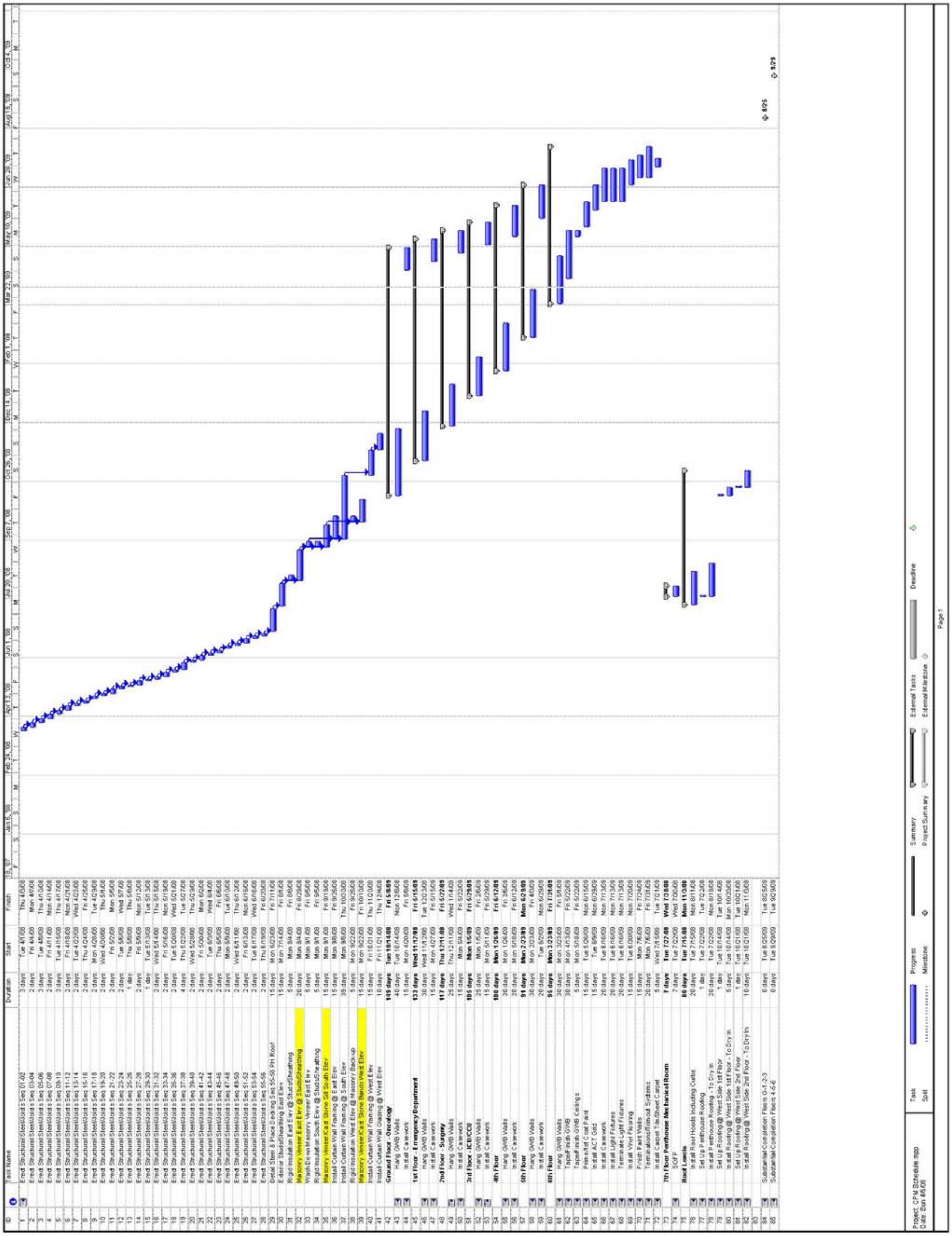
				Dimensions				
Elevation	**Item**	**Action**	**Quantity**	**Width**	**Height**	**SF**	**Cost/SF**	**Cost**
Elevation	Item	Action	Quantity	Width	Height	SF	Cost/SF	Cost
West	Precast	Add	1	30	13.33	400	$35.00	$13,996.50
	Precast	Add	4	24.5	12	1176	$35.00	$41,160.00
	Precast	Add	1	30	26.5	795	$35.00	$27,825.00
	Masonry	Delete	-1	30	13.33	-400	$68.00	-$27,193.20
	Masonry	Delete	-4	24.5	12	-1176	$68.00	-$79,968.00
	Masonry	Delete	-1	30	26.5	-795	$68.00	-$54,060.00
	Masonry	Delete	-4	2	12	-96	$68.00	-$6,528.00
	Cast Stone	Delete	-5	1	30	-150	$68.00	-$10,200.00
	Curtain Wall	Add	3	1	5	15	$120.00	$1,800.00
	Curtain Wall	Add	4	2	11	88	$120.00	$10,560.00
	Precast	Add	1	3	22	66	$35.00	$2,310.00
	Metal Panel	Delete	-1	17	76.5	-1301	$53.46	-$69,524.73
	Metal Panel	Delete	-1	27	20	-540	$53.46	-$28,868.40
	Precast	Add	1	17	76.5	1301	$35.00	$45,517.50
	Precast	Add	1	27	20	540	$35.00	$18,900.00
	Precast	Add	1	31	15	465	$35.00	$16,275.00
	Masonry	Delete	-1	31	15	-465	$68.00	-$31,620.00
							Total	**-$134,106.33**
							Total South	-$78,841.74
							Total East	-$47,256.85
							Total North	$25,349.81
							Total West	-$134,106.33
							Total	**-$234,855.10**

Appendix E

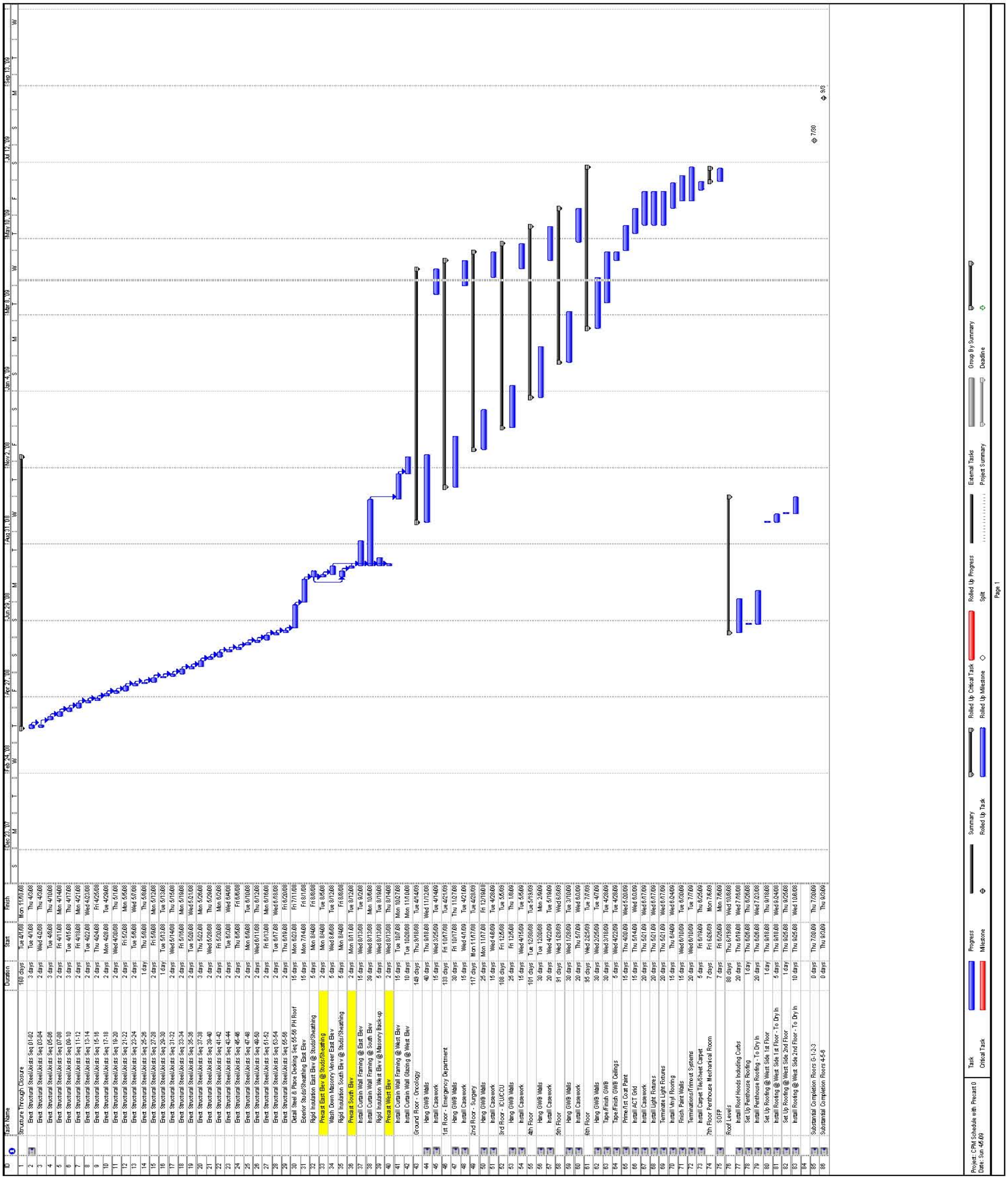
Schedules for Architectural Precast

vs.

Masonry Veneer



CPM Schedule with Masonry



CPM Schedule with Precast

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