JOHNS HOPKINS HOSPITAL
NEW CLINICAL BUILDING

Baltimore, Maryland

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Architectural Engineering, 5th Year
Construction Management Option

Thesis Proposal
Advisor: Dr. John I. Messner

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Table of Contents

4.1 Executive Summary

This proposal serves as an outline for the intended research and evaluation of the Johns Hopkins Hospital New Clinical Building for the spring semester of Sr. Thesis. The over-arching theme of the proposal is managing the excessive changes on this project. Through each of the topics, research will be conducted to reduce the number of changes, manage the amount of changes, accelerate the schedule to make up for lost time caused by the changes, or reduce the risk of schedule over-run on the project. The four analysis listed below are the areas of interest for improving the JHH New Clinical Building project.

Analysis 1: Alternative Project Delivery Method

Currently, the changes to the project have added $150 million and 7 months to the original contract. The design-bid-build delivery method appears to be inefficient at managing the changes because each team member has their own goals and agenda. I have proposed researching Integrated Project Delivery and Design-Build as possible alternatives. These methods will offer a more integrated team approach that would be brought in early in the design process to add value to the project. This analysis will serve as a critical industry issue and as my MAE requirement.

Analysis 2: Managing the MEP Changes

On average, 1 Construction Change Directive (CCD) is issued each week with significant changes to the MEP design. The CM and subs have had difficulty identifying the changes and their cost and schedule impact. I have proposed using Innovaya Visual Estimating with intelligent 3D models of the drawings to improve the efficiency of tracking, quantifying, and estimating the changes to the MEP systems. The project team is already developing 3D intelligent models for 3D MEP coordination. This analysis will serve as a critical industry issue and as my MAE requirement.

Analysis 3: Alternative Mechanical System

The impact of the 1st package of changes (CCD 1-38) has caused a schedule over-run of 7 months. I have proposed using a different mechanical system in non-invasive spaces that would have required less material and long-lead time equipment as a way to accelerate the MEP trades. A chilled beam system was chosen as the alternative because it uses forced air induction, chilled water for cooling and stand alone units for each room. This system will use less ductwork and will eliminate the need for massive central air handling units. This analysis will serve as a critical industry issue and as a mechanical breadth study.

Analysis 4: Resolve Concrete Over-pour on Decks Due to Steel Deflection

In some areas of the concrete decks there was up to 2" of steel deflection. This was caused by over-pouring the deck and will likely impact the MEP coordination. I have proposed using shores and increasing the steel camber to reduce the steel deflection. This analysis will serve as my structural breadth study.

4.2 Analysis 1: Alternative Project Delivery Method

Problem Statement:
The Design-Bid-Build project delivery method has resulted in 60 Construction Change Directives, 2,700 RFI's, and 700 change orders to date. This has resulted in a cost escalation of $150 million and an extension of 7 months to the original schedule. By most accounts the cause is attributed to poor design document quality, donor enhancements, and the incorporation of the latest and greatest medical equipment and technology in the design, which has delayed the delivery of the design documents to the CM.

Goal:
Demonstrate that an alternative project delivery method can more effectively manage the changes and prevent some of the design issues.

Potential Solution:
An alternative project delivery method such as Integrated Project Delivery or Design-Build may have been better suited for this project. Each alternative would deliver the project in a more integrated team approach. The collaboration of designers, detailers, and construction professionals would potentially add value to the project by aligning the goals of each team player with the interest of the project. More importantly, these alternatives may be able to effectively manage the design changes and mitigate design questions and flaws by capitalizing on the team's expertise by working together early in the design process.

Research Methods:

- Investigate the current delivery method in greater detail by understanding:
  - Contract agreements and incentives/penalties associated with them
  - Goals of the Owner, A/E, CM, and major subcontractors
  - Legal risks
  - Extent of information sharing among team players
  - Cost and schedule associated with original contract and impacts due to changes and enhancements
- Perform literature review of the alternative delivery methods
- Conduct interviews with the Owner, A/E, CM, and major subcontractors to gauge their satisfaction with the current delivery method and their opinion of alternative delivery methods. Example interview questions:
  - Do you feel that the current delivery method has made good use of your professional expertise?
  - Has the environment encouraged you to collaborate with other trades, engineers, and the CM?
  - On a scale of 1-10, 10 being the greatest, what amount of value to the project could you have added if you would have been brought in earlier on the project?
  - How has the quality of the design documents and amount of changes on this project affected you?
  - Has there been a willingness to share information among the team players?

    - What legal risks would you foresee with IPD or Design-Build?
- Visit or conduct phone interviews with project teams on other ongoing projects that are using the alternative delivery methods
    - Clark is building Walter Reed Hospital with a Design-Build delivery method
- Create an analysis to compare the various delivery systems to determine advantages and disadvantages
    - Consult with Russ Manning
- Evaluate results of analysis and recommend best delivery method

Resources:
Raj Vora, Southland Industries – Mechanical Design/Build Subcontractor
Walter Reed Project Team, Clark Construction
Dr. Horman, AE Faculty
Russ Manning, AE PhD student
Lee Evey – Design Build Institute of America
AIA Integrated Project Delivery: A Guide

Expected Outcome:
I plan to demonstrate that an alternative delivery method would have been more successful for this project. Specifically, I believe the IPD is more aligned with the goals and characteristics of this project and will prove to be the best delivery method for this project. Although no quantifiable outcome is expected, a comparison of pros and cons to each delivery system for this project should provide a sound qualitative finding that IPD is a more effective delivery method.

Thesis Requirements Fulfilled:

Critical Industry Issue – the mentioned alternative delivery methods, especially IPD are relatively new to the construction industry. Owners, A/E's and CM's are all faced with these new delivery systems and they must know what the advantages and disadvantages are to each. Legal risks, such as contracting methods and information sharing are some of the critical issues facing the industry with these new delivery systems.

MAE Requirement – AE 572-Project Delivery Methods was a graduate level class that I took with Dr. Horman where we focused on delivery planning strategies and their impact on project performance.

4.3 Analysis 2: Managing MEP Changes

Problem Statement:
Currently, there is 1 Construction Change Directive (CCD) issued on average each week. In most cases they include significant changes to the original MEP construction documents. The cause is poor quality CD's that had significant drawing conflicts and omissions and updates and changes to the MEP systems caused by the selection of medical equipment. Each time a new CCD is issued, the CM and subs must review the new drawings to analyze the cost and schedule impact. Often times this requires significant labor and time to perform manual take-offs and create change order pricing. The compounding effect of all the changes has slowed the MEP coordination because it is difficult to identify what has changed. As a result, the coordination has become a critical path activity, and in some cases has impacted the installation of the MEP systems in the field.

Goal:
Demonstrate that there is an alternative method that more accurately and efficiently tracks, quantifies, and estimates the changes to the MEP design .

Potential Solution:
A more efficient and accurate system for tracking, quantifying, and estimating the changes to the MEP design would be a valuable tool for the CM. Since the coordination of MEP trades is being done with 3D MEP Coordination, the subs are already producing 3D intelligent models of the changes before a change order is negotiated. I propose using Innovaya Visual Estimating software as a way to address this issue. The software is capable of automatic quantity extraction, visual representation of objects that have changed, and producing estimates with the use of MC2 or Timberline databases. This tool could allow the CM to verify the accuracy of subcontractors' change order proposals more efficiently.

Research Methods:

- Examine a typical area where there has been significant changes to the MEP systems
- Determine how long it takes to manually take-off and price the changes using Timberline Extended estimating software
- Acquire BIM models from the CM for the area
  - One model for the baseline
  - One model after the changes were update
- Use Innovaya Visual Estimating to track, quantify, and estimate the changes
  - Verify the accuracy of the software in visually representing what has changed
  - Verify the quantities with the manual take-off
  - Verify the accuracy of the estimate with the manual estimate
- Summarize the results
  - Accuracy
  - Efficiency (time)
  - Ability to track changes
  - Cost of the software and necessary equipment

Resources:
Kevin Yu, Innovaya
Dr. Messner, AE Faculty
Clark Construction

Expected Outcome:
The Innovaya software will be a more efficient way of verifying the subcontractor change order proposals than manual take-offs and estimates. It will also provide a way to track the numerous changes to the MEP systems which is very valuable to the CM. The software may be technically challenging at first, but as the user becomes familiar with the software it will likely save time, and ultimately money by ensuring accuracy.

Thesis Requirements Fulfilled:
Critical Industry Issue – The AEC industry is struggling to keep pace with the Building Information Modeling uses and tools. Innovaya Visual Estimating is just one of the BIM tools on the market that has the potential to not only be used in managing MEP changes, but estimating the entire cost of a building. I intend to demonstrate to the AEC industry that Innovaya is a valuable tool that can be used to track, quantify, and estimate accurately and efficiently.

MAE Requirement - AE 597F-Virtual Facility Prototyping and AE 597G-BIM Implementation were graduate level classes that I took with Dr. Messner where I conducted research on BIM uses and their benefits.

4.4 Analysis 3: Alternative Mechanical System

Problem Statement:
The 1st package of changes (CCD 1-38) has been evaluated by Clark/Banks and they have determined that the schedule will need to be extended 7 months. The cost of accelerating the schedule from 7 months to 3 months by working 300 mechanical craftsmen overtime is $2 million.

Goal:
Demonstrate that an alternative mechanical system can accelerate the schedule by installing less material and long-lead time equipment with fewer labor requirements.

Potential Solution:
An active chilled beams system would be an excellent alternative system for non-invasive spaces in JHH. They could be used in offices, public spaces, exam rooms, and hospital bed rooms. This accounts for over 70% of the building's space.

The system uses forced air induction which requires significantly less ductwork. There is also no need for long-lead time equipment like air handling units. The system is self contained and could be located in the ceiling plenum where the current VAV boxes are. A 1" chilled water supply would provide the cooling energy. The result is much less ductwork and piping that has to be installed in the ceiling plenum, fewer pieces of long-lead time equipment, and less labor to install. It would also accelerate the coordination process which is currently on the critical path.

Research Methods:

- Identify a typical floor that has a large majority of non-invasive spaces
- Work with the mechanical subcontractor to get an estimate of the current mechanical system for that space
- Ask for the mechanical loads for the space from BR+A, the project's MEP engineers
- Conduct literature review of case studies of healthcare facilities that have used chilled beam systems
    - Very common in the European Union with available research material online
- Interview manufacturer of chilled beam systems such as Frenger Systems
    - Pros and Cons of system
    - Size the units
    - Size the ductwork
    - Size the chilled water lines
    - Energy usage
    - Ask for installer contacts in the D.C. area to get estimates
- Interview installer of chilled beam systems
    - Estimate of system
    - Labor requirements and durations
    - Maintenance requirements
    - Ceiling plenum impact

- Evaluate the impact of chilled beams on:
    - Cost
    - Schedule
    - Energy costs – lifecycle
    - Maintenance requirements
    - Ceiling plenum
        - Coordination
        - Floor-floor height
            - Building enclosure
    - Size of mechanical shafts
    - Reduction in current system size

Resources:
Moses Ling, AE Faculty
BR+A, Project MEP Engineer
Frenger Systems, Manufacture of Chilled Beams in Healthcare Environments
Jim Salvino, Sr. MEP Manager, Clark/Banks

Expected Outcome:
The chilled beam system will prove to be superior to the current system in the non-invasive spaces of JHH. Not only will the system accelerate the MEP installation and coordination, but will reduce energy costs, maintenance costs, and quite possibly the building cost by reducing floor-floor height. This system will be a perfect fit because there is already a large supply of chilled water from the central plant which eliminates the need for adding chillers. Also, there are 9 - 8'x26' mechanical shafts on each floor that would be reduced in size because the large rectangular duct would no longer be required. This would free up a lot of extra floor space.

Thesis Requirements Fulfilled:

Critical Industry Issue – Chilled Beams is an emerging technology in the USA. Commonly used in the EU with great success, the new technology is starting to be used in an effort to address the high energy costs. The benefits of this system are not commonly known by my most contractors in the US. This research topic will aim to identify the advantages and disadvantages of this system.

Mechanical Breadth – This analysis will require my mechanical engineering skills to size the system.

4.5 Analysis 4: Resolve Concrete Over-pour on Decks Due to Steel Deflection

Problem Statement:
The concrete subcontractor poured the concrete decks to finish floor elevation, not to deck thickness which is common practice. The concrete acts as a live load during the pours and on this project caused the steel to deflect up to 2" in some cases because no shoring was required. The result was over-pour of concrete as much as 2" in some areas which increased the floor dead load. Fortunately, on this project the structural engineer had enough factor of safety built into the design to allow for the extra weight.

A potential problem from this could have been overloading the floor which would have required reinforcing the structure. It is not acceptable to pour to thickness to avoid this. If the steel deflects it will cause the floor to wave and not meet the specification for floor flatness. This would require patching to meet the flatness requirement which is very labor intensive. Finally, the deflection has the potential to impact the coordination of the MEP systems in the ceiling plenum. It is not yet known if that will be a problem on this project because the MEP is not installed in the problematic areas of the building.

Goal:
Identify a cost effective method to mitigate the risk of impacting the MEP coordination, not meeting the floor flatness criteria, and over-pouring concrete without impacting the schedule's critical path.

Potential Solution:
The problem may be solved with shoring, cambering the steel or a combination of both.

Research Methods:

- Work with the project's structural engineer to understand the current design
  - Typical deflections
  - Allowable deflection by code
  - Construction loading
  - Steel camber
- Work with Dr. Hanagan to calculate deflections and necessary shoring and/or cambering required to reduce deflection
- Interview the concrete subcontractor
  - Gain a better understanding of standard concrete placing methods
  - How they typically account for over-pour
  - Cost of shoring
  - Schedule impact of shoring
  - Typical cost and schedule impact for correcting floor flatness
- Interview the steel subcontractor to evaluate the cost of cambering the steel
- Interview Clark/Banks' MEP coordinator to determine the effects of the steel deflection on MEP coordination
- Evaluate the cost, schedule, and MEP coordination impact of solution

Resources:
Zachary Yates, Project Structural Engineer, Thornton-Tomasetti
Dr. Hanagan, AE Faculty
Clark Concrete, Concrete Subcontractor
SteelFab, Steel Subcontractor
Jim Salvino, Sr. MEP Manager, Clark/Banks

Expected Outcome:
Minimum shoring at mid-span of each beam with a 1 ½" of steel camber would reduce the deflection within the 1" allowable limit. The shoring would only be necessary for approximately a week while the concrete bonds to the reinforcement which would then act in tension to resist deflection. The cost of shoring would be saved by reducing the cost of over-poured concrete. Shoring would also have minimum impact on the schedule. Each floor was broken into 3 pour sequences per tower. A pour was made every two days, with 3 days to prepare each pour. With enough shores on site to meet the schedule, an additional laborer would be able to move the shores for each pour.

Thesis Requirements Fulfilled:

Structural Breadth – The analysis will require structural load, deflection, and shoring calculations.

4.6 Proposal Summary

The intent of the proposed areas of investigation was to address the largest constructability challenge for this project, the amount of changes to the design. All four topics incorporate construction management topics related to changes at some level either reducing the number of changes, optimizing the management process of changes, accelerating the schedule to make up for lost time, or reducing the risk of schedule over-run. Three of my topics are critical industry issues that aim to familiarize and educate the AEC about new project delivery methods, BIM tools, and mechanical systems. Most importantly, my proposed areas of research are of interest to me. I firmly believe that if I conduct a thorough and accurate analysis of each topic, I will be a better AE in the end.

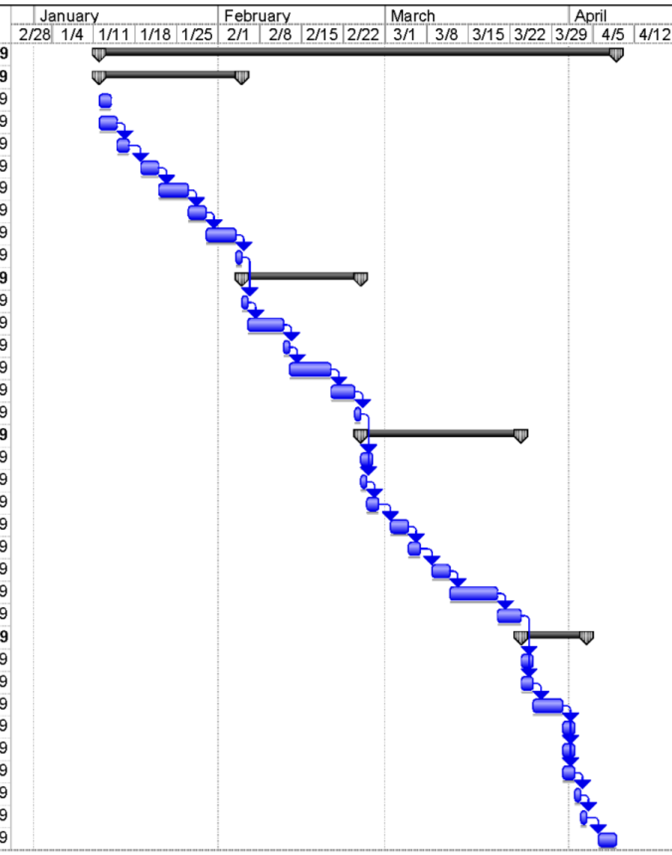
4.7 Weight Matrix

The following weight matrix is a breakdown of the emphasis on critical industry issue research, value engineering, constructability review, and schedule reduction/acceleration for each proposed thesis investigation area.

WEIGHT MATRIX					
Description	**Research**	**Value Engr.**	**Constr. Rev.**	**Sched. Red.**	**Total**
Alter. Delivery Method	15%				15%
Managing MEP Changes	10%	10%		5%	25%
Alter. Mech. System	5%	10%	10%	15%	40%
Conc. Over-pour on Decks			15%	5%	20%
Total	**30%**	**20%**	**25%**	**25%**	**100%**

4.8 Research Schedule

ID		Task Name	Duration	Start	Finish
1		**Thesis Research**	**63 days?**	**Jan 12 '09**	**Apr 8 '09**
2		**Alternative Project Delivery**	**18 days**	**Jan 12 '09**	**Feb 4 '09**
3		Set-up Interviews/Visits	2 days	Jan 12 '09	Jan 13 '09
4		Understand Current Method	3 days	Jan 12 '09	Jan 14 '09
5		Literature Review	2 days	Jan 15 '09	Jan 16 '09
6		Conduct Interviews	3 days	Jan 19 '09	Jan 21 '09
7		Visit/Interview Similar Projects	3 days	Jan 22 '09	Jan 26 '09
8		Perform Analysis	3 days	Jan 27 '09	Jan 29 '09
9		Evaluate Results	3 days	Jan 30 '09	Feb 3 '09
10		Final Write-up	1 day	Feb 4 '09	Feb 4 '09
11		**Managing MEP Changes**	**14 days?**	**Feb 5 '09**	**Feb 24 '09**
12		Examine Typical Area	1 day	Feb 5 '09	Feb 5 '09
13		Manual Take-off & Pricing	4 days	Feb 6 '09	Feb 11 '09
14		Acquire BIM Models	1 day	Feb 12 '09	Feb 12 '09
15		Perform Analysis w/Innovaya	5 days	Feb 13 '09	Feb 19 '09
16		Summarize Results	2 days	Feb 20 '09	Feb 23 '09
17		Final Write-up	1 day?	Feb 24 '09	Feb 24 '09
18		**Alternative Mech. System**	**19 days**	**Feb 25 '09**	**Mar 23 '09**
19		Set-up Interviews	2 days	Feb 25 '09	Feb 26 '09
20		Examine Typical Area	1 day	Feb 25 '09	Feb 25 '09
21		Mech. Loads From BR+A	2 days	Feb 26 '09	Feb 27 '09
22		Literature Review	3 days	Mar 2 '09	Mar 4 '09
23		Interview Manufacturer	2 days	Mar 5 '09	Mar 6 '09
24		Interview Installer	3 days	Mar 9 '09	Mar 11 '09
25		Evaluate Impact	6 days	Mar 12 '09	Mar 19 '09
26		Final Write-up	2 days	Mar 20 '09	Mar 23 '09
27		**Conc. Over-pour on Decks**	**9 days?**	**Mar 24 '09**	**Apr 3 '09**
28		Set-up Interviews	2 days	Mar 24 '09	Mar 25 '09
29		Understand Current Design	2 days	Mar 24 '09	Mar 25 '09
30		Calcs. - Deflect./Shoring/Camber	3 days	Mar 26 '09	Mar 30 '09
31		Interview Conc. Sub.	2 days	Mar 31 '09	Apr 1 '09
32		Interview Steel Sub.	2 days	Mar 31 '09	Apr 1 '09
33		Interview MEP Coord.	2 days	Mar 31 '09	Apr 1 '09
34		Evaluate Solution	1 day?	Apr 2 '09	Apr 2 '09
35		Final Write-up	1 day?	Apr 3 '09	Apr 3 '09
36		Final Report Preparation	3 days	Apr 6 '09	Apr 8 '09



Project: Thesis Schedule
Date: Dec 12 '08

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

Page 1

4.9 Appendix A – Breadth Areas

Breadth One: Mechanical

Alternative Mechanical System Analysis

I have proposed to do a schedule reduction analysis with the use of an alternative mechanical system. I have chosen chilled beams as my alternative system. I will need to calculate the loads for a typical floor where I will then be able to size the chilled beams, ductwork and chilled water loop with the aid of a manufacturer's engineer. An energy analysis of the chilled beams will be calculated with the assistance of the project's mechanical engineer. With this information, I will be able to estimate the cost, schedule, and coordination impact of the new system.

Breadth Two: Structural

Resolve Concrete Over-pour on Decks Due to Steel Deflection

My project experienced 2" of concrete over-pour in some areas due to the deflection of the steel. The project did not require the use of shoring. As a potential solution to this problem, I propose to shore and camber the steel. I will work with the project's structural engineer to analyze the allowable deflection by code. I will also calculate the necessary shoring and steel camber required to limit the deflection within the code requirements. I have spoken to Dr. Hanagan and she has agreed to assist me with the calculations for this analysis.