Science and Technology Center

Coppin State University
Baltimore, MD

Thesis Proposal

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Submission Date: 1/11/2013

EXECUTIVE SUMMARY

Before new construction could begin on the Coppin State Science and Technology Center, the Barton Malow project team was put 3 months behind schedule due to property acquisition issues. This immediately brought about problematic areas within the project schedule and put the project in danger of not delivering on time. With many critical items on the construction schedule, there are multiple areas of concern that hinder quick schedule progression. The objective of this Thesis Proposal is to address these issues and accelerate the schedule through the investigation of four analysis areas.

The first analysis will address the feasibility of resequencing the original schedule. In addition, different production methods including the lean principles of Last Planner and flow/pull production will be investigated to provide possible solutions. This will address the critical areas of the schedule and potentially gain back a significant amount of lost time. This depth area correlates to the remaining analyses and breadth areas through schedule reduction techniques.

Analysis 2 will then focus on implementing modularization of the curtain wall system. This method of construction provides many advantages over a stick-built system and has the potential to reduce the onsite installation significantly. With faster production offsite and less expensive labor necessary onsite, this method can provide areas of cost savings – a major owner goal. Analysis 2 will provide an opportunity with a structural breadth in terms of the steel connection system, the erection sequence, and any necessary changes to the waterproofing details.

The third analysis will investigate a value engineering option of changing out fin tube radiators at the window line and replacing with linear diffusers in the ceiling. The labor intensive connections involved with the fin tube radiators can be eliminated by using linear diffusers. Through this analysis, the reduction in heating load on the boilers will be calculated in order to design the additional load on the air handlers. This alternative will then be evaluated for cost effectiveness and reduction in schedule.

The final analysis will focus on an alternative foundation support system in lieu of the current rammed aggregate pier design. Analysis 4 will provide research for a drilled micropile foundation system and compare potential advantages of the system. The foundation system will be designed to accommodate the building loads and soil bearing capacities, as well as consider installation time.

Through these analyses, the expected outcomes are to provide potential solutions to the current issues on the project site. It is the intent to provide a detailed investigation of each analysis to provide the best possible acceleration scenarios.

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PROJECT BACKGROUND

| SUMMARY |

The University of Maryland, Baltimore has contracted Barton Malow Company to construct a new Science and Technology Center on Coppin State University's campus. This four-story,135,000 SF building located in Northwest Baltimore is designed by Cannon Design and will be the new home to the Department of Mathematics and Computer and Natural Sciences. The $76.2 million GMP contract for Barton Malow Company was granted notice to proceed on August 13, 2012 and should reach completion by November 2014.

The project site is located on the southeast corner of the Coppin State campus where an existing 210 row homes stood. The owner was responsible in securing these properties and turning over to Barton Malow in order for construction activities to begin. Currently, this project has contracted out the first bid package including the demolition, earthwork, and site utilities. Barton Malow is in the final stages of securing the rest of the subcontractors for the second bid package.

The building is supported by a rammed aggregate geopier system on the south half of the building due to unsuitable soils in this area. Typical spread footings and foundation walls support the cast-in-place (CIP) concrete floor slabs for all four floors. The penthouse on top of the fourth floor is constructed of braced structural steel frames with metal decking. The top of the building features multiple green roofs and a greenhouse. The exterior skin is wrapped with a brick veneer inset with curtain wall ribbon windows. In addition to this glazing, a large cubic-shape curtain wall is featured on the northwest corner of the building. As seen in Figure 1 and 2, this design includes modern architecture while still holding true to the natural masonry architecture of the existing buildings on campus.

Figure 1 – Rendering NW Corner
Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx

Figure 2 – Rendering SW Corner
Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx

The original project schedule slated the substantial completion in August 2014, however due to delays in the row home property acquisition the project schedule was pushed back almost 3 months. This created an opportunity for schedule acceleration scenarios to be analyzed and implemented on the project. Potentially, further analyses can be performed to realize the full benefits of an alternate schedule scenario. This includes a resequence of the original schedule accounting for the property acquisition delay. In addition, modularization of the curtain wall system will be applied and critiqued in comparison to the currently designed stick-built method. Moving to the interior, a hydronic piping design of the mechanical system will be considered to gain even further days back on the schedule delay. Finally, an alternate foundation system will be considered to find potential benefits over a geopier system.

TECHNICAL ANALYSIS DESCRIPTIONS

| ANALYSIS 1 – SCHEDULE RESEQUENCE |

Opportunity Identification

Property acquisition issues caused a major delay to the initial project start date. This creates multiple opportunities to improve schedule areas and make up a large proportion of the lost time. The outlined project schedule will be evaluated to pinpoint critical tasks that have a major impact to final completion. The 3 month delay of the original schedule must be made up to deliver the project before Fall Semester of 2014.

Background Research

With the project currently under construction, there is a lack of hard data to compare an alternate method of scheduling to the actual outcome. As a result, this analysis will focus on the critical activities of the schedule and possible scenarios to improve efficiency. Lean principles can be applied in the form of Last Planner, SIPS (Short Interval Production Schedule), and pull/flow production. By looking more into these production principles, the schedule can be evaluated to find areas of improvement. Case studies that utilize production methods like Last Planner and SIPS can be studied and the methods applied to this project. This will enable improvements of lessons learned from past situations and institute the best possible methods for schedule sequencing.

Potential Solutions

In analyzing the schedule, a potential solution can include a resequence of how the scopes of work are put in place. The trades on site are contracted to provide double crew production in order to achieve the production necessary in the delayed schedule. The original schedule was not outlined with this construction approach in mind, so there could be potential areas of improvement with resequencing. This includes productivity rates of installing the masonry and exterior skin.. These two items contain the longest durations through the schedule and reducing these can impact the project greatly. In addition, possible scheduling methods could be implemented to achieve a shorter duration. This includes methods such as Last Planner and SIPS. With Last Planner, Barton Malow can establish an absolute end date for each activity and hold the subcontractors to this commitment. The same idea then applies to a SIP schedule; commitments are made to an end date and the work is scheduled within that time period. In regards to SIPS, a production schedule of repetitive activities will benefit the most.

Solution Method

- Gather all original information in regards to the outlined schedule and pertinent durations.

- Evaluate schedule for areas of improvement – masonry and curtain wall installation have longest durations.
    - Evaluate productivity rates of exterior skin materials for improvement; intricate details exist between the connections of different skin materials.
    - Determine possibility of changing out exterior skin material to provide better productivity rates and reduce schedule duration.
- Utilize background research to apply different production principles.
    - Determine the process of installing the labor intensive material and benefits of changing to a new process.
- Analyze each method to quantify the best potential outcomes.
- Determine construction manager and owner capabilities.
    - Evaluate the possibility of new production processes.
- Establish any cost concerns with the owner and areas of flexibility.
- Develop a process for implementation and review with entire project team.
- Critique potential outcome and feasibility of implementation.

Resources

~ Industry Professionals and AE Faculty Members
~ Information from AE 570 course – Production Management in Construction
~ Information from AE 572 course – Project Development and Delivery Planning
~ Relative Project Documents
~ Scheduling Software
~ Process Mapping
~ Barton Malow Project Team Members

Expected Outcome

The initial schedule delay allows for instituting a different production method across the entirety of the project schedule. This delay occurred before any new construction began thus creating numerous opportunities for improvement. Through a sequence analysis and a potential new production method (using more of the same material), the schedule is expected to be reduced by a significant amount. Upon successful completion, a goal is set for 50%-75% reduction of the 3 month delay.

*See Appendix A for MAE Requirements

| ANALYSIS 2 – MODULARIZATION OF CURTAIN WALL |

Problem Identification

In analyzing the schedule for resequencing issues, a major part of construction stood out – the construction of the large curtain wall. Typically these systems are stick-built with the frames installed first and then the glazing attached. This time-intensive process hinders the schedule from being accelerated and the building from being water tight earlier. The PACE Roundtable, as discussed in Technical Report 3, presented the industry issue of modularization and how it can be effectively applied. The Coppin State Science and Technology Center presents an opportunity to change the typical stick-built curtain wall into a modular design. The curtain wall installation time must be reduced in order to reach a shorter duration schedule.

Background Research

Two areas of concern come to mind when looking at a modular design; (1) the structural connections necessary to attach the modular panels to the exterior frame and (2) the production rates and schedule benefits of the installation process. The modular design has to take into account how the panels will be physically connected to the exterior frame and also to each panel. These connections are critical due to the water tight specification that must be reached. Case studies can be researched to identify multiple connection types and the relative benefits. The current design contains a very detailed waterproofing design near the roof parapet, so further research here could identify more effective methods. These connections also govern the size limit of each panel. A larger size panel may need a more complex steel connection and could have more transportation limits however this could also yield a faster installation time onsite.

The second concern involving production rates and schedule benefits can be supported through research conducted in AE 570 (Production Management in Construction) as modularization was a key focus of the curriculum. The information gathered from this project and the case studies referenced will lend itself to a more developed methodology for implementing a modular design.

Potential Solutions

In regards to the structural connections, the first solution can be evaluated from a feasibility perspective of both cost and installation through a constructability review. By researching the typical connection types of a modular curtain wall panel, it can be analyzed in terms of cost and installation method. The owner has a very strict budget on this project, so any savings that can be found are critical. If it can be proved that schedule time will be reduced significantly by using a more expensive connection system, then this method may be more feasible.

In terms of the production rates, the modularization could significantly reduce onsite labor and mobilization of materials. For one, materials will need to be stored onsite during a stick-built installation and take up space where other trade's material could be staged. Also, the onsite skilled labor necessary to stick build a curtain wall greatly increases in comparison to a modular system. The skilled labor will be working in a controlled shop environment where production costs are reduced. By mapping the production process of each module, a cost and production analysis can be performed. This is beneficial in supporting the changeover to a modular system and providing information that it's a feasible alternative. These numbers could then translate to the project site where schedule and cost reductions are realized. From a production standpoint, this will greatly enhance the opportunity of gaining back the schedule delay.

Solution Method

- Develop preliminary panel design alternatives.
- Gather information on potential steel connections with a modular curtain wall system.
- Determine feasible costs and installation benefits of each type of steel connection.
- Evaluate the steel connections with regards to a specific modular panel.
- Determine if any additional bracing is necessary for connecting panels.
- Analyze the module process for production efficiency and cost savings.
- Determine any transportation or installation coordination needs.
- Evaluate possible schedule reduction scenarios.
- Assess modular system with waterproofing specifications.
- Develop a potential installation procedure and any site logistic concerns with equipment or manpower.
- Determine qualifications of installation subcontractor and appropriate procurement strategy.
- Implement modular system to improve schedule duration of install.
- Document the analysis results through a comparison to the original schedule durations.

Resources

- ~ Industry Professionals (recommendations on steel connection system)
- ~ AE Faculty Members (Modularization process improvements)
- ~ AE 570 course – Production Management in Construction
    - Modularization Research Project
- ~ PACE Roundtable Breakout Session
- ~ Process Mapping
- ~ Project Documents
- ~ Barton Malow Project Team Members

Expected Outcome

With respect to any single activity onsite, the curtain wall system stands to be both a major cost and schedule reduction area. By moving the fabrication offsite and installing the modules on a just-in-time basis onsite, the schedule should be improved greatly. The production rates for installation should improve greatly and have significant cost reduction. In addition, this will address the current waterproofing detail at the parapet and curtain wall and provide a better solution. It is believed that a schedule resequencing and a modular curtain wall system will recover a significant part of the 3 month delay.

* See Appendix A for Structural Breadth details and MAE requirements.

Critical Industry Issue Analysis

The 21st Annual PACE Roundtable was held this year and provided great insight to current industry issues and potential solutions for these areas. Modularization was a key topic of discussion with the industry members which feature recommendations and challenges. MEP systems proved to be a great area of modularization as rack piping can include many trades into one unit and be placed at one time on a construction site. This saves coordination time onsite for installation and can cut costs greatly. Modular curtain walls were also discussed with the benefits of a safer, faster, and higher quality system. These systems must be designed early on in the process with modular in mind. It is difficult to implement as an “after-thought” of design. Relating to the Science and Technology Center, this information is critical. In order for this analysis to be successful, it must be recognized and implemented early in the design. However, in this case, the modular design will be a product of a schedule delay rather than the original intent of the design. This factor can be accounted for during the thesis investigation and presented accordingly. The goal of this research is to define the feasibility of this modular curtain wall system in terms of production and installation duration.

Industry interviews can be conducted to collect data on the feasibility of changeover to a modular system after design is complete. An outline, as detailed in Appendix C, includes a data tool to gather potential interview information from industry members.

| ANALYSIS 3 – FIN TUBE RADIATOR DESIGN |

Problem Identification

A major goal of the owner is to remain under budget and value engineer as many items feasible to achieve this. To avoid any funding issues, design alternatives are reviewed in order to provide cost reduction. A feature noticed in the mechanical design was the fin tube radiators along the exterior walls of rooms and how many units were involved in the design. These units supply warm air through hydronic piping to maintain the thermal gradient of the space. This system accounts for a larger amount of labor and installation time and an alternative system can be considered to save time and costs.

Background Research

The designed fin tube radiator system involves many units that account for a significant installation time. Installing these units consists of brazing pipe material at each connection and can be very time consuming. Also, the load on the boiler increases significantly with these units. An alternative to research includes linear diffusers at the ceiling and transferring load from the boiler to the air handling unit. The feasibility of this system will be considered in terms of installation time, efficiency, and cost savings.

Potential Solutions

The alternative for this fin tube radiator system will incorporate linear diffusers at the ceiling along the window line of particular spaces. The University of Maryland standard is to deliver air along the windows at the same temperature of the surrounding space. In reviewing the design, certain spaces will be allocated for these linear diffusers. Replacing all fin tube radiators could result in inefficiencies and may not be the most practical alternative. Instead, this analysis will focus on the needs of each space and its load effects on the total system. The load provided from the boilers will then be converted equivalently to the air handlers. In doing so, material costs (pipe length and connections) and installation labor costs could be reduced. This alternative will be compared to the original fin tube radiators for advantages.

Solution Method

- Evaluate current design and amount of fin tube radiators
- Determine the benefits (schedule/cost) of instituting the linear diffusers.
- Determine best areas for replacement based on the current design.
- Calculate the loads necessary for the new diffusers and the savings on the boilers.
- Determine the effects of diffusers on the air handlers and provide upgraded equipment information, if necessary.

- Evaluate the feasibility of implementation in terms of alternative system.
- Propose new system with cost/time savings and impact on project.

Resources

~ Barton Malow Project Team
~ AE Faculty Members
~ AE Classmates
~ Applicable Books, Papers & Websites

Expected Outcome

The major effect of this analysis is expected to have the most savings on installation time and labor costs. Also, there is expected to be savings within the mechanical system. By reducing the load on the boilers through less hydronic piping, this can provide cost savings and may be more efficient.

*See Appendix A for Mechanical Breadth details.

| ANALYSIS 4 – ALTERNATIVE FOUNDATION SYSTEM |

Problem Identification

A rammed aggregate geopier system is the current design for shallow foundation support. This system involves drilling holes at locations in the soil not suitable for bearing capacity. These holes are then filled with aggregate (crushed stone) in 4' lifts. Each lift is compacted successively to specifications (generally reaching a lift height of 3') and creates a bellow shaped pier. This shape yields the proper bearing capacity necessary for the foundations. Alternative systems will be explored to identify any benefits related to lifecycle, total cost, and installation duration.

Background Research

In order to find a feasible alternative to the geopier system research must be conducted for other foundation support types. Drilled micropiles are a potential alternative to support the foundations in this building. Research can be conducted to find the popular foundation systems near the location of this project. With this known, basic costs can be compared to see if an alternate system is more feasible than the original rammed aggregate geopier.

Potential Solutions

An alternative to the geopier system includes drilled micropiles. The installation methods can be compared relative to labor, material, and equipment costs. The two systems will also be compared in regards to bearing capacity and lifecycle. A major effort will be put forth on a cost analysis, as cost savings are a major goal of the project. Finally, the two foundation systems will be compared with respect to total installation time to cut down on site construction time. This comparison will then be repeated and performed with other alternative systems to show other additional advantages or disadvantages.

Solution Method

- Gather design and construction information for alternative foundation systems.
- Determine the costs and installation time of each alternative.
- Compare all aspects to the rammed aggregate pier system – consider site logistics and procurement issues.
- Evaluate the benefits and possible implementation on the project.
- Propose the most appropriate alternative system with supporting data.

Resources

~ Industry Professionals (those experienced with both foundation systems)
~ AE Faculty Members

- ~ AE Classmates (Structural)
- ~ Barton Malow Project Team
- ~ Applicable books, manuals & websites

Expected Outcome

The expected results are to find an alternate system that may be less cost than the original geopier system. Also, this alternate system should reduce installation time in order to help make up for the original schedule delay.

*See Appendix A for Structural Breadth details.

THESIS INVESTIGATION OBJECTIVES

| ANALYSIS WEIGHT MATRIX |

As shown in Table 1 below, a weight matrix has been created to visually portray the time allocated to each analysis. This involves the four core thesis investigation areas of (1) critical industry research, (2) value engineering analysis, (3) constructability review, and (4) schedule reduction/acceleration scenarios. The most time will be distributed towards the schedule resequencing in finding a solution to the initial schedule delay on the project. This directly correlates to the highest core investigation area of schedule reduction/acceleration. These two items represent the focus of this Thesis Proposal due to the importance to the project. The remaining items in the matrix are distributed fairly even and represent the duration of time spent for analysis in the Spring Semester.

Table 1 – Weight Matrix

Description	Critical Industry Research	Value Engineering Analysis	Constructability Review	Schedule Reduction/ Acceleration	**Total**
Schedule Resequence	5%		10%	15%	30%
Curtain Wall Modularization	5%	5%	5%	10%	25%
Hydronic Piping Design	5%	10%	5%		20%
Alternative Foundation System	5%	10%	5%	5%	25%
Total	20%	25%	25%	30%	**100%**

| SPRING SEMESTER PROJECTED TIMETABLE |

While referencing the Table 1 weights, a preliminary timetable has been created for the outline of the Spring Semester as detailed in Appendix B. This includes a week by week summary of the analysis tasks and target dates for completion. A milestone activity summary is also included to show the completion dates of relative tasks.

| CONCLUSIONS |

The goal of these four analysis topics is to gain further information in regards to the core thesis research areas to evaluate potential solutions for schedule acceleration. Feasible implementation solutions are expected to resolve the original schedule delay on this project. It is believed that a realistic outcome will be reached through detailed research of industry issues, value engineering, constructability challenges, and schedule acceleration scenarios. In concluding these analyses, the Science and Technology Center delivery could be improved and these methods could be utilized on future projects to eliminate large schedule delays.

APPENDIX A – BREADTH TOPICS AND MAE REQUIREMENTS

| BREADTH TOPICS |

Structural Breadth [Incorporated into Analyses 2 and 4]

The modular curtain wall system, as detailed in Analysis 2, provides an opportunity to apply research and analysis outside of construction management areas. This system will incorporate steel connections to the CIP concrete slabs in order to support the modular curtain wall panels. A further investigation into steel connection types, capacities, and tolerances will yield a better design choice for this new modular system. The constructability of these steel connections will heavily rely on the design choice and the integration with the panels. This could also include the possibility of adding additional bracing to support panels between structural bays as the panel size may be limited by transportation methods. In addition, the waterproofing of the panels is critical to the success of the curtain wall system. These issues will need to be further reviewed to pinpoint erection and installation sequences.

A structural breadth is also incorporated into the alternate foundation system, as detailed in Analysis 4. This alternative system (potentially drilled micropiles) includes a change of design for foundation support. Proper bearing capacity and building loads will need to be considered with the new system. From a constructability perspective, this system can analyzed in terms of construction sequence and provide evidence of schedule savings. This will contribute to the overall goal of reducing the schedule and delivering the project within the original timeline.

Mechanical Breadth [Incorporated into Analysis 3]

The current mechanical system involves multiple fin tube radiators along the window lines in the spaces. There is significant installation time due the labor intensive connections with each unit. To contribute to schedule savings, an alternative for this system is to include linear diffusers at the ceiling height in lieu of the fin tube radiators. A University of Maryland standard is to deliver air at the same temperature at both the window line and inside the space to provide more thermal controllability.

Analysis 3 will focus on providing these linear diffusers at beneficial locations throughout the building, as opposed to replacing all of the radiator units. This will be dependent upon the total load on the system and how it can be provided. By reducing the number of fin tube radiators, the total heating load on the boilers will be reduced. This heating load will then be used to design the air handling unit size. As part of the analysis, it will be determined which areas (small or large) will benefit the most from this change (cost per unit of energy supplied in each system).

In constructability terms, this alternative will then be evaluated for cost effectiveness and reduction in schedule as a result of labor time/cost changes.

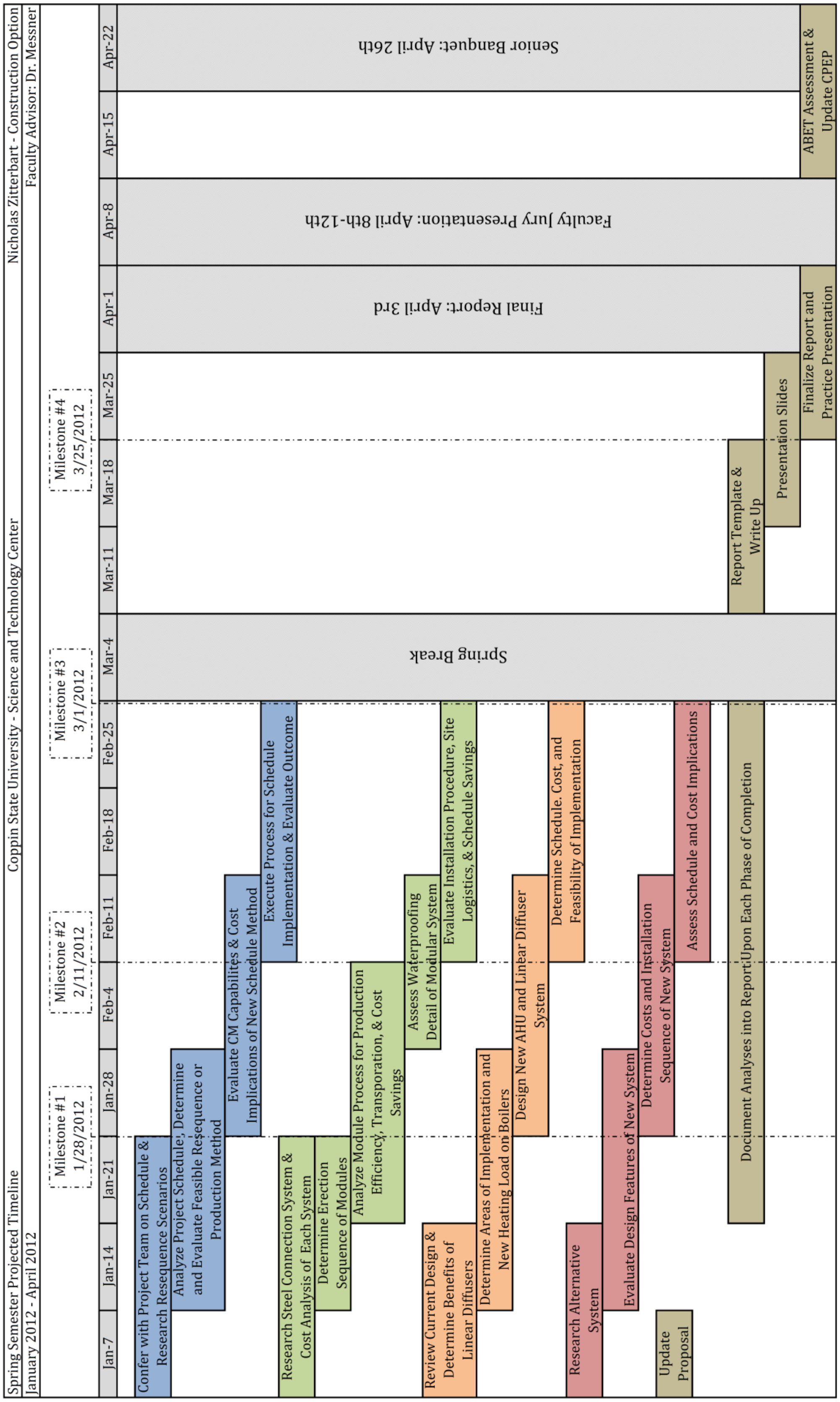
| MAE REQUIREMENTS |

These analyses will be aided by the knowledge gained in graduate level courses from the MAE curriculum. The courses that will be referenced include AE 570 [Production Management in Construction] and AE 572 [Project Development and Delivery Planning].

Information from AE 570 will be give support to Analyses 1 and 2 with a focus on production tracking and methods. In terms of the schedule resequencing, production principles in lean construction such as Last Planner, pull/flow production, and SIPS can lend to more effective planning methods. If it is deemed that a resequence is inefficient, then these production methods could be applied to this project. Case studies and research will support the implementation of these principles and provide advantages of each method. In addition to these production methods, the modularization of the curtain wall system will also apply to the AE 570 course. A research project was conducted involving the many aspects of modular construction and the potential benefits to a project schedule. The information from this class will help support the implementation of the analysis areas.

AE 572 provided information that will support Analysis 1 of this proposal. This course focused on scheduling and planning methods that result in a more efficient design and construction process. The schedule resequence analysis will focus on information gained from this class in respect to scheduling methods. The current CM-at-Risk delivery method will not be modified, more so the information gathered from the course will contribute to the overall theme of schedule reduction scenarios.

APPENDIX B – SPRING SEMESTER PROJECTED TIMETABLE



Milestone Activity Summary

#1	Research Complete
#2	Schedule Method, Modular Production Process, Mechanical and Foundation Design Complete
#3	Finalize Depth, Modularization, Mechanical and Foundation System
#4	Complete Report Draft and Begin Presentation Slides

Analysis Descriptions

Analysis 1	Schedule Resequence
Analysis 2	Modularization of Curtain Wall
Analysis 3	Fin Tube Radiator Design - Mech. Breadth
Analysis 4	Alternative Foundation System - Struct. Breadth

APPENDIX C – INTERVIEW QUESTIONS

(1) Have you had first-hand experience on a project implementing modularization? If so, can you name the project type, why it was implemented, and the results of this approach?

(2) What measurable benefits do you see with a modular system?

(3) How would you plan the install coordination of a modular curtain wall system? What hinders do you foresee?

(4) Are waterproofing details, quality issues, and installation procedures improved or decline as a result of modularization?

(5) In your opinion, would you recommend a modular curtain wall system?

(6) Are there particular project types and sizes or client circumstances that this would be most advantageous?

(7) What type of steel connection system would you recommend?

APPENDIX D – REFERENCES

Rendering on Cover Page Courtesy of www.coppin.edu/CapitalPlanning/STC.aspx