



Thesis Proposal:  
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## EXECUTIVE SUMMARY

The following proposal highlights the four analysis areas that will be developed during the Spring 2012 semester that will collectively form a comprehensive thesis report on the Office Building Project. This report will focus on research in Critical Industry Issues, Value Engineering, Constructability Review, and Schedule Reduction tactics. In addition to these construction-related areas of study, architectural engineering breadth topics including structural design and mechanical system loads will be explored to provide further validity to the final results.

The placement of the structural concrete columns at the edge of the floor slabs negatively affects the pace at which interior finish trades can place their work. In order to facilitate productive interior fit out activities, these slab edge columns could be relocated approximately twelve inches from the edge of slab as opposed to the current four inch distance at which they are placed. The productivity of metal studwork, insulation, air barrier taping, and drywall installation are all currently affected by close confines created by the proximity of the structural columns to the exterior façade. Load and blast rating analyses will determine if the columns can be moved in order to eliminate the space constraints created by the existing column design.

Exterior brick masonry production rates currently suffer from the current undulating brick masonry façade design. These losses in productivity are attributed to the multiple recesses in the exterior façade, and the custom brickwork associated with wrapping the brickwork around these recesses. If the building were redesigned with minimal masonry returns, the productivity losses associated with the existing complex façade would be reduced. However, a façade redesign will affect the structural details of the foundation beneath the building and brick masonry façade. An analysis of the existing foundation will determine if additional concrete and reinforcement will be necessary for the support of the building above. Additionally, a realignment of the façade will affect the solar gains through the restructured glazing assemblies. An analysis of these effects will determine if the mechanical system will require resizing to handle these increased loads.

Even though a project-wide 3D model was produced by the design, engineering and mechanical subcontractor teams and were used to detect clashes between the architectural features, structural systems and mechanical equipment. These models were highly underutilized in the field, leaving contractors to facilitate information in a roundabout manner. In-field model review technologies could have prevented this lengthy information facilitation process. Innovative manners in which to implement BIM in the field will be explored in order to determine the most effective manner to utilize the available models in the field.

Changes in tenant requirements led to extensive changes to the initial floor layouts. This redesign, referred to as “Blocking and Stacking”, relocated many of the open office, private office and office support areas in order to provide a better “flow” to the daily operation of the office complex. These changes led to the necessity to remove and replace many of the already installed mechanical, electrical and plumbing systems in Building One. Crews that are required to remove and reinstall their work commonly suffer from the discouraging effects of seeing their quality work demolished. Subsequent work sometimes lacks the initial level of quality that the original work exhibited. Productivity levels also tend to suffer. An analysis of the advantages of introducing a second trade crew in an attempt to minimize these negative effects, as well as allow the initial trade crew to continue their work according to the baseline project schedule will determine if the addition of a second crew is warranted.

Due to the sensitive nature of this project, information regarding the location, owner, tenant and drawing details must remain private. Any inquiries regarding this sensitive information should be directed to Patrick Laninger, the author of this thesis project.

## TABLE OF CONTENTS

Executive Summary .....	2
Project Background.....	4
Analysis 1 – Edge of Slab Column Relocation .....	5
Analysis 2 – Façade Simplification.....	7
Analysis 3 – BIM in the Field.....	9
Analysis 4 – MEP Change Order Crews.....	10
Analysis 5 (Alternative to Analysis 4) – Design-Build Team Dynamic .....	11
Masters Coursework Integration.....	12
Weighting Matrix.....	13
Appendix A – Breadth Analyses.....	14
Appendix B – Spring Schedule .....	16

## PROJECT BACKGROUND

This thesis focuses on Building One of a three building office campus which is tiered into a sloping hillside and are connected to one another by hallways and outdoor walkways. Building One also attaches to Building Two via a steel pedestrian bridge. In total, the office complex is 1.2 million square feet in size, 390,000 of which is contained within Building One. This building consists primarily of open office space, which will eventually contain moveable partitions, but also features multiple conference rooms, kitchenettes and a 45,000 square foot childcare center.

In addition to its confidential purpose, name and owner, the office building featured in this thesis has numerous unique aspects, including a 2.5 million gallon storm water retention pond, 102,865 square feet of green roof space, and blast resistant curtain walls. The design also features a mechanical, electrical and plumbing system that is entirely independent of buildings two and three. Although the buildings are not able to be quarantined from one another, the nearby central utility plant provides localized utilities to each of the three tiered structures via underground utility tunnels. This greatly improves the mechanical efficiency of the building and, when coupled with the localized variable air volume boxes, extensive insulation, low conductivity glass and green roof spaces, helps the project achieve its LEED gold rating.

The coordination of the aforementioned unique aspects is made possible through the design-build delivery method implemented on the project. The intense MEP, façade, and landscaping coordination techniques that are being utilized on this project allows the building to effectively combine numerous green aspects in a harmonious manner that capitalizes on the benefits of the systems being used.

Throughout excavation and prior to pouring the cast-in-place foundation and pond walls, Building One required substantial sheeting and shoring systems that held back the hillside for the partially underground Lower Level 9, as well as the western wall of the storm water retaining pond. Structurally, the building sits atop steel piles and concrete pile caps, with a system of concrete grade beams for additional load bearing capabilities. The foundation walls, mat slabs and elevated slabs are all cast in place, due to the regional preference of CIP over precast applications, as well as the ability to utilize tower cranes that are far more suitable for the hillside site as opposed to crawler and truck cranes.

The structure itself is cast-in-place concrete, and features a number of building façade types. Approximately one third of the building is clad in curtain wall assemblies that are attached to the concrete floor slabs by vibration and blast absorbing mounting assemblies. The other two thirds of the building feature CMU knee walls and cast-in-place edge beams that provide the backing for a traditional brick masonry façade that matches the surrounding historical buildings. The space between these knee walls and edge beams is filled with casement strip windows.

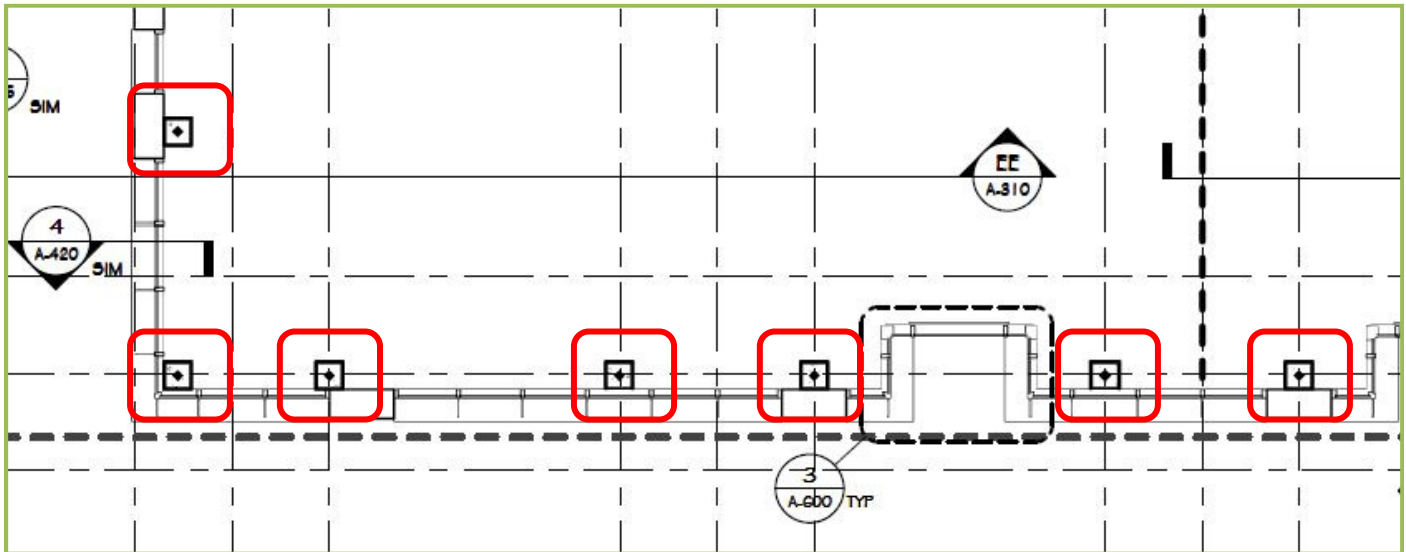
Mechanically, the office campus features a central utility plant (not included in this analysis) that houses three large boilers which feed the buildings with the steam necessary for the localized VAV system that is fed by eight air handling units located throughout the building. Medium and low-voltage switchgear rooms distribute power to the building. The medium voltage switchgear has a redundant emergency switch gear system located in an adjacent room.

## ANALYSIS 1 – EDGE OF SLAB COLUMN RELOCATION

### Background

The current structural design places the exterior concrete columns approximately 4” from the interior faces of the concrete masonry and curtain wall assemblies (see Figure #1). This creates numerous issues pertaining to the work of the interior trades, who have to install their work within these confines. The productivity of metal studwork, insulation, air barrier taping, and drywall installation are all affected by close confines created by the proximity of the structural columns to the exterior façade.

Particularly, the metal studwork and drywall tradesmen are forced to focus the effort of two crew members in a small area in order to maneuver their materials into the tight space. This adversely affects the productivity of these subcontractors, as well as demands the implementation of atypical tools that are capable of operating in close quarters.



*Figure #1 – Slab Edge Columns – Courtesy of Clark Construction*

### Potential Solutions

The problems associated with interior trade work between and around the exterior columns could be minimized if these columns were held back an additional 8” from the interior surface of the façade. This would provide tradesmen a full 12” within which to perform their duties, greatly increasing the quality and productivity with which they install their work.

Due to the blast rating of the exterior walls, the relocation of the structural concrete columns may not be possible. If it appears that preliminary structural analyses prove this, alternative methods of increasing the distance between the interior face of the exterior façade and the exterior surface of the interior columns exist. The thickness of the CMU block knee walls and concrete edge beams could be reduced to facilitate an increase in working area.

### Analysis

A structural analysis using STAAD or Tekla, coupled with blast rating design parameters, will provide an accurate understanding of the extent to which the columns can be relocated away from the edge of the structural slab. In the event that these analyses eliminate the possibility of column relocation, further structural analyses regarding the bearing capacity of smaller concrete masonry units and their ability or inability to support the imposed loads of the

exterior brick façade supports and curtain wall assemblies will dictate the extent to which these blocks can be narrowed to provide enlarged working areas within the building.

Upon proving the ability to increase said working areas, a productivity analysis will be performed. This analysis will require the solicitation of expert input from drywall installation and electrical rough-in professionals in order to accurately predict the schedule and cost savings associated with simplifying the installation processes related to these building systems.

### **Outcome**

At this point in time, through conversations with structural option architectural engineering students, it is apparent that the slab edge rebar can be increased to accommodate additional loads resulting from the cantilever effect imposed on the structure by relocating interior columns further from the edge of slab. However, whether further research into blast resistance requirements will confirm or disprove the ability to relocate the interior columns is yet to be determined. In the event of the inability to relocate these columns, as well as an inability to reduce the thickness of the concrete masonry and cast in place edge beam thicknesses, the proposed techniques for increasing the working area for interior drywall activities will be deemed impossible.

Regardless of the outcome of the structural analyses, it will be advantageous to evaluate the impact of the structural changes on the productivity of interior trade operations. This information will be valuable during the design phase of future projects with similar characteristics and parameters. The development of more robust blast protection isolators and mounting brackets is constantly taking place. If future designs allow for the setback of slab edge columns, data justifying the increased production levels that can be achieved through the set back of slab edge columns will be useful when deciding the location of interior columns. If the savings associated with interior trade work outweigh the costs of high-end blast isolators and increased slab-edge rebar, design professionals will have access to comprehensive evidence supporting this fact, allowing them to make educated design decisions regarding their column placement.

From a constructability standpoint, this analysis embodies the essence of the design review process. The productivity and cost impact analyses will provide conclusive evidence that supports a design related decision regarding the placement of structural columns that will facilitate a more constructible design. Due to the close relationship between these analyses and the constructability of the project, a constructability review emphasis will be placed on this analysis for the duration of the Spring semester.

## ANALYSIS 2 – FAÇADE SIMPLIFICATION

### Background

During the initial phases of masonry façade construction, it was thought that the brick masonry contractor was not effectively maintaining the project schedule demands for façade brickwork. It was later determined that the losses in productivity could be attributed to the multiple recesses in the exterior façade, and the custom brickwork associated with wrapping the brickwork around these recesses (see Figure #2).

If the building were designed with a linear façade, the pitfalls associated with tedious brickwork could have been avoided. At this point in time, the project team is still struggling with finding opportunities to accelerate the Building One brickwork schedule in order to maintain the milestone goals for the rest of the campus.

The recessions in the current façade design demand extensive custom cutting of bricks for placement at the complex corners. This process elongates the time necessary for brick placement by reducing the ability to keep a constant brick placement pace across the entire façade.



*Figure #2 – Recessed Façade Features – Courtesy Clark Construction*

### Potential Solutions

The simplification of the façade on areas of the building that feature complex returns and setbacks will increase the productivity of the brick laying tradesmen. The custom cutting of small brick fragments in order to maintain the interlocking stretcher pattern requires the dedication of a bricklayer solely to brick cutting operations. A simplified design would eliminate this requirement, allowing the brick crew to focus on their production rate rather than the meticulous craftsmanship associated with an undulating façade layout.



## Analysis

The realignment of the façade would require a foundation redesign in order to support the redistributed weight of the bricks above. While most of the foundation would maintain a relatively similar size to that of the original design, some areas may require an increase in the foundation thickness or reinforcement. In order to determine whether a foundation redesign is required, shallow footing design techniques will be utilized to test the sufficiency of the existing foundation size. If a simple realignment of the foundations is deemed insufficient, the sizing and reinforcement details will have to be adjusted to accommodate the realigned masonry loads.

In addition to a structural analysis, the realignment of the building's glazing will greatly impact the amount of solar gain experienced by the building's interior spaces. Trane Trace modeling will be used to explore the impact of this solar gain increase on the building's cooling loads. Mechanical equipment may require resizing to accommodate these increases. Low pressure ductwork may also require realignment to address the increased loads near the building's perimeter which are predominantly office areas, where an increased solar gain would not go unnoticed by the building's occupants.

Aside from engineering analyses, the sole reason for a façade redesign is the increase in façade construction productivity rates. Research into the rate at which production could be increased, as well as the impact on other trade work that depends on the rapid completion of the brick work will provide schedule duration reduction and financial justifications for the alteration of the building's façade. In order to obtain this information, research into the details of the masonry trade will be required. Interviews of experienced brick masons could further justify the changes to the building façade by providing tangible productivity increases based on their expert input.

## Outcome

Through the simplification of the building's façade, it is a relatively safe assumption that the construction costs and time commitments will be reduced by minimizing complicated brick laying operations. The cost of realigning and potentially resizing the foundations will be fairly minimal. The only uncertain costs at this point in time are those associated with the potential increase in the mechanical cooling load, which could demand an increase in the air handling and cooling system size. Conversely, the construction-related benefits of a continuous façade will not only affect the productivity rates and installation costs associated with the brick activities, but also create a "trickle-down effect" that will positively impact the schedule constraints and construction costs associated with trade packages affected by façade construction operations.



## ANALYSIS 3 – BIM IN THE FIELD

### **Background**

Due to owner requirements, the entire project was modeled by the design, engineering and mechanical subcontractor teams. These models were used to detect clashes between the architectural features, structural systems and mechanical equipment. Unfortunately, these models were highly underutilized in the field, leaving contractors to obtain information in a roundabout manner. If an in-field conflict that was overlooked during the coordination process was detected, contractor foremen were forced to first notify the project team, who would then review congested 2D coordination drawings in an attempt to discover the cause of the conflict. Occasionally, the necessary information could not be drawn from these overcrowded drawings, requiring the project team to solicit further information from the 3D coordination team. The process of obtaining an image from the 3D model usually took upwards of 2 or 3 days, leaving the field personnel to abandoned their current task and move on to another area until the required information was made available.

### **Potential Solutions**

With 3D modeling files readily available in the form of NavisWorks and Revit files, the absence of an ability to open and review those files underutilizes available project resources. At the very least, select personnel on the project team should have had the ability to rapidly access and review those files on site in order to quickly address problems in the field. Instead, the aforementioned 3 day process was initiated upon failing to obtain the required information from the 2D coordination drawings. An aggressive approach to this issue would have been to provide in field BIM kiosks and provide basic training to subcontractor foremen, allowing them to review the coordinated models themselves. While this may not have solved every conflict that arose, more often than not the 3D model screenshots provided by the coordination team offered solid evidence as to who had improperly installed their work, and the steps that needed to be taken in order to remedy the situation.

### **Analysis**

Research into the available in-field BIM systems will present an accurate understanding of the types and nature of the systems that would provide the best value for the project in relation to the specific details of the construction process unique to this project. A comparison of two systems, Latista and Vela, will determine which system would be more appropriate for the project. The implementation of a true in-field BIM approach will be compared to an approach limited to the general contractor's personnel in order to determine if the increased costs associated with implementing BIM in the field are justifiable, or if it would be adequate to implement in the on-site office trailer alone. A cost analysis will determine the magnitude of the financial aspects that the project stands to gain from the implementation of an in-field BIM system.

### **Required Research**

In depth research into the details surrounding the Latista and Vela systems, as well as the available in-field BIM technologies will determine which approach would be most beneficial. Information regarding the training processes and learning curves associated with the implementation of said systems will provide additional support or opposition to the use of either system.

### **Outcome**

The execution of some form of in-field BIM procedure would undoubtedly provide value to the project. This analysis will determine exactly which approach will provide the best balance of cost and value on site. Whether it be in the form of office dedicated model review capabilities, or full blown, in-field model access technologies, the implementation of BIM in the field on this project will help reduce the time and monetary commitments associated with the model review techniques currently in place.

## ANALYSIS 4 – MEP CHANGE ORDER CREWS

### **Background**

Due to insufficient communication between the owner and the future building tenant, extensive changes were made to the initial floor layouts. This “Blocking and Stacking” redesign relocated many of the open office, private office and office support areas in order to provide a better “flow” to the daily operation of the office complex. These changes demanded a complete redesign of the high, medium and low pressure ductwork, as well as re-coordination of floor penetrations and support embeds. Unfortunately, most of this work was already completed on the lower three levels of Building One. Changes to existing ductwork layouts led to the demolition and reinstallation of these assemblies. Naturally, the effects of the Blocking and Stacking redesign had extremely negative effect on the project budget and schedule. However, the emotional effects on the tradesmen responsible for removing and replacing previously completed work are often overlooked. It is widely known in the industry that quality and productivity diminishes when crews are directed to remove and replace work in place. Tradesmen take pride in their work and it is extremely demeaning to force them to tear out completed work due to changes in design.

### **Potential Solutions**

Additional crews from each contractor could be utilized for the demolition and reinstallation of altered system components. This dedicated “change order” crew would be responsible for all work involving the demolition and reinstallation of system components affected by the blocking and stacking changes. This will allow the original trade crew to continue installing their work according to the baseline project schedule while the additional crew focuses on meeting the project change order requirements. This will not only allow the primary trade crews to progress through the building as planned, but also minimize the negative productivity and quality connotations associated with rework. By not being required to remove and reinstall work that they previously placed, the primary trade crews will be able to maintain the level of productivity and quality of installation with which they began the project.

### **Analysis**

Some owners do not recognize the true effects of their decisions beyond how much they cost and their immediate effect on the project schedule. An analysis of the psychological effects on trade workers that are required to perform rework on previously completed assemblies will provide a clear picture of the full extent of the effects that design changes have on a project. The Office Building schedule will be analyzed to verify the amount of time that can be saved through the implementation of additional trade crews. Trade specialists will be interviewed to gain insight to the level at which quality and productivity is sacrificed when crews are required to remove previously installed work. The cost of implementing additional crews will be compared to the potential quality related rework costs, as well as losses in productivity and schedule elongation.

### **Outcome**

A comparison between the financial requirements of additional crews and the additional costs associated with schedule delays, quality related rework, and productivity losses will determine whether the use of additional trade crews is warranted. Due to the fast tracked nature of this project, it is likely that the cost of additional crews is negligible in comparison to the consequences of the project running over schedule or suffering from quality and productivity related issues.

## ANALYSIS 5 (ALTERNATIVE TO ANALYSIS 4) – DESIGN-BUILD TEAM DYNAMIC

### **Background**

The Office Building project implemented a design-build approach, and while most subcontractors fully embraced the collaborative atmosphere, others did not adapt to the relatively new project delivery approach as quickly and successfully. While some subcontractors swiftly adjusted to the expectations of interdisciplinary interaction, others were slow to adopt the means and methods that make rapid coordination and installation possible.

### **Potential Solutions**

In order to promote a team-based project approach and facilitate the formation of a group-oriented project team, one would first need to determine the social and environmental factors that caused one subcontractor to adjust to a project atmosphere that promotes interdisciplinary communication and coordination more rapidly than another. After determining these factors, educational programs and methods that would help accelerate the adjustment process can be developed to address the slower developing project team members. Additional solidarity could be established amongst the team members through the inclusion of a shared savings or reward clause into the project contracts.

### **Analysis**

Through researching company backgrounds and interviewing employees, it will be possible to determine the factors that helped certain subcontractors adjust to a collaborative environment better than others. After pinpointing these characteristics, research into the types of educational programs that teach project management principles will be performed in order to determine the most effective educational method for developing a collaborative project team. A balanced education program, featuring team building activities and educational seminars will be developed to ensure that future design-build project teams do not suffer from issues related to varying degrees of project commitment amongst the subcontractors. The legal aspects and financial feasibility of a shared rewards or savings clause will also be explored, determining the applicability of such a program on future projects.

### **Outcome**

The information obtained and explored through this analysis will be used to develop an educational program that can be used on design-build projects to facilitate the rapid acceptance of collaborative building techniques. The implementation of this educational program will assist during the initial phases of a design-build project, when subcontractors and construction managers are tasked with developing the collaborative environment through which the project will be delivered. The intent of this program will be to ensure that the project begins as smoothly as possible, allowing the team to benefit from trade partnerships as early as possible, which may lead to increased productivity levels and installation accuracy in the initial project stages. Contract modifications in the form of a shared savings or rewards clause may be applicable in order to strengthen team member commitments to a collaborative atmosphere on site.

## MASTERS COURSEWORK INTEGRATION

### **AE 572 – Project Development and Delivery Planning**

The exploration of the factors affecting the varying degrees of subcontractor commitment in a design-build project approach is directly related to the topics covered in the project development and delivery planning course. The benefits of a design-build approach with a fully vested team will be compared to the setbacks of a team with stratified levels of commitment. The factors that determine the degree of subcontractor buy-in will be analyzed in order to determine effective approaches to developing an evenly committed project team that embraces the design-build mentality early in the project and is able to benefit from a collaborative work atmosphere during initial construction phases.

### **AE 570 – Production Management in Construction**

Through the implementation of in-field BIM technology, an information pull system can be established that minimizes the time spent awaiting answers from the engineering and design professionals. The pull method was discussed in AE 570, but was limited primarily to the concept of material and labor pull. However, the method is not limited to these resources, and could be applied to the information solicitation process as well.

### **AE 598D – Legal Aspects of Engineering and Construction**

The feasibility of a shared savings or rewards clause within a design-build project will be analyzed using knowledge obtained from AE 598D.

## WEIGHTING MATRIX

### Weight Matrix

Description	Research	Value Eng.	Constr. Rev.	Sched. Red.	Total
Column Relocation	10%	5%	10%	5%	<b>30%</b>
Façade Simplification	5%	10%	10%	10%	<b>35%</b>
BIM in the Field	10%			5%	<b>15%</b>
MEP Change Order Crews	5%		5%	10%	<b>20%</b>
<b>Total</b>	<b>30%</b>	<b>15%</b>	<b>25%</b>	<b>30%</b>	<b>100%</b>

**APPENDIX A – BREADTH ANALYSES**

## STRUCTURAL

The Edge of Slab Column Relocation analysis will require a structural design review that will determine the feasibility of relocating the columns that create interior trade productivity issues. Not only live and dead load analyses will be explored, but also the effect of column relocation on the blast rating of the structure. Alternative blast protection techniques may provide the additional protection required to permit the relocation of said columns.

The redesign of the exterior façade in order to facilitate a simplified brick masonry layout will also require a structural analysis to determine the effect of a linear façade on the brick support systems as well as the foundation layout required to support the concentrated masonry loads.

## MECHANICAL

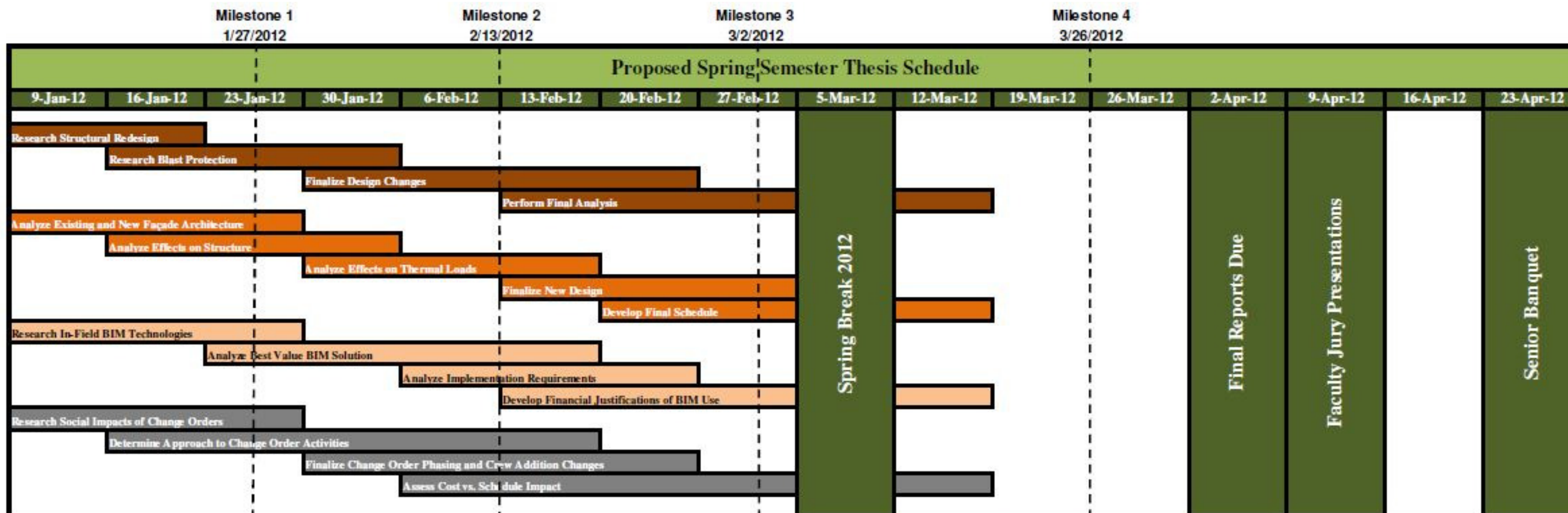
Redesigning the exterior façade in an attempt to expedite brick masonry installation will have an effect on the arrangement of exterior glazing. This reduction in shaded “coves” along the façade will affect the amount of solar gain that the building experiences, increasing the size of the cooling load that must be handled by the heating, ventilation and air conditioning (HVAC) system. An analysis of the extent of the effects on the cooling load exhibited by the alteration of the glazing alignment will be required to determine if the HVAC system requires enlarging. Additionally, the arrangement of the low pressure duct lines may require modifications to address the localized impact of solar gain on many of the office areas within the building in order to minimize extreme temperature gradients within the space.

## ARCHITECTURAL

Architectural justifications of the alteration of the façade alignments must be made in order to support the productivity and financial gains of the simplification of the masonry installations. Each arrangement must be modeled in order to effectively understand the aesthetic impact of the façade changes.



**APPENDIX B – SPRING SCHEDULE**



Milestones	
1	Research and Industry Interviews In Progress
2	All Appropriate Research and Interviews Complete
3	All Analyses in Evaluation Stages
4	All Analyses Complete & Ready for Formatting

Analysis 1	Column Relocation
Analysis 2	Façade Simplification
Analysis 3	BIM in the Field
Analysis 4	Change Order Crews