THESIS PROPOSAL

The Metro Museum of American Art

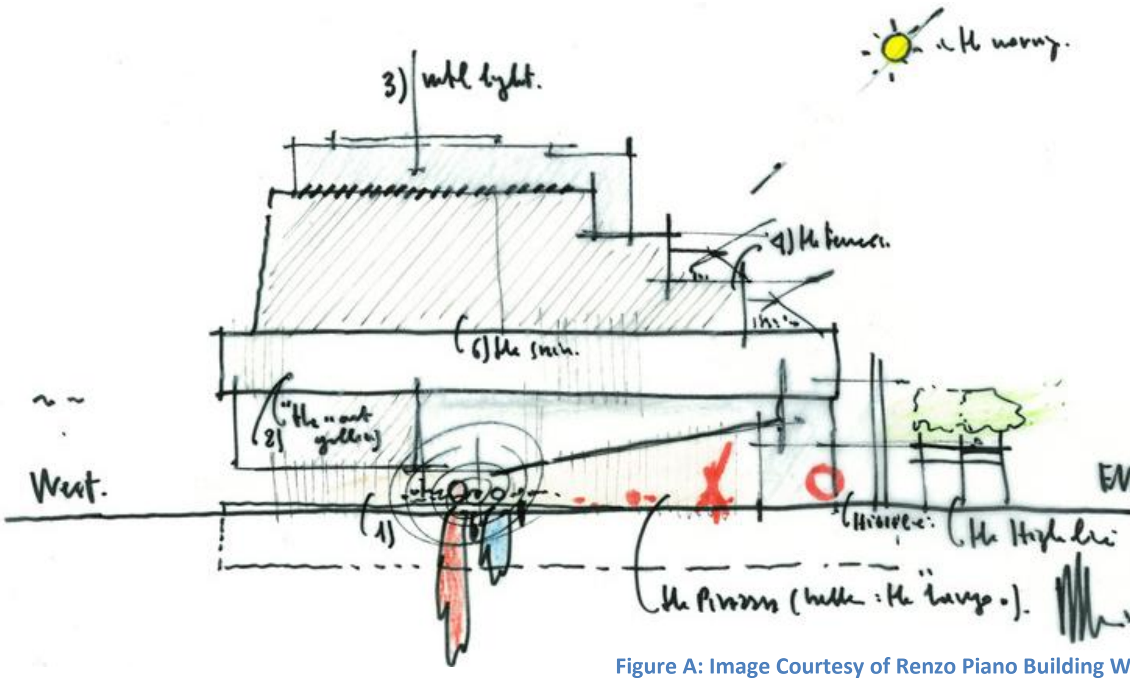

Figure A: Image Courtesy of Renzo Piano Building Workshop.

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This Thesis Proposal will provide an overview of the four analyses that will compose the Spring 2012 thesis work on the Metro Museum of American Art. Also included are descriptions of any breadth studies and a thesis work schedule.

EXECUTIVE SUMMARY

This proposal will describe some of the opportunities available on the Metro Museum of American Art (MMAA) building project that could increase the efficiency of the building process and save the owner money. The analyses that will be conducted in the spring 2013 semester are the prefabrication or redesign of the gallery ceiling system, implementation of a gallery short interval production schedule (SIPS), union division of labor, and the expansion of building information modeling (BIM) on the project.

Analysis 1: Gallery Ceiling Prefabrication / Re-Design

The MMAA has five galleries throughout the building that take on average 416 working days to completely fit-out. 100 of these days are devoted to the installation of the gallery ceiling system. Due to this, the first analysis will focus on the benefits associated with prefabricating or redesigning the gallery ceiling system. Prefabrication has been proven to save time and money in the construction industry. It limits the amount of on-site work that needs to be completed and also makes the construction process more productive and safer.

Analysis 2: Gallery SIPS Implementation

A SIPS has also been proven to cut down on project schedule time, increase worker productivity, and therefore reduce the cost of a construction sequence. They are most effective when they are used on repetitious buildings such as hotels or prisons. One would be useful on the MMAA because all of the gallery spaces are very similar in nature, and due to the overall length of the fit-out phase as detailed in Analysis 1. A SIPS could be used in conjunction with the gallery prefabrication on the MMAA to result in a very efficient gallery space construction sequence.

Analysis 3: Critical Industry Issue: Union Division of Labor

One of the challenges associated with prefabricating a system that integrates multiple different trades of work is the division of labor between the unions involved. This is magnified for the MMAA because its project location is known for having difficult unions to work with. The goal of this analysis would be to investigate the issues that are preventing the unions from coming to terms on the division of work. Then to develop a few possible solutions that would attempt to satisfy these unions so that the prefabricated work in question could be completed as planned.

Analysis 4: Extending the Use of BIM on the Project

Finally, BIM is becoming more and more prevalent throughout the industry. The MMAA is already using BIM for 3D coordination and clash detection. However, there are many new applications of BIM that could be implemented on the MMAA successfully such as 4D modeling and phase planning. These and other uses can be used to detect and solve problems before they happen in the field.

All of the above analysis topics have the potential to improve the MMAA construction process. Through research and analysis next semester these topics will be tested to see if they are applicable to the specific conditions at the MMAA project.

TABLE OF CONTENTS

PROJECT BACKGROUND

Metro Museum of American Art (MMAA) building is a new construction building that will house the galleries for the MMAA. It will include 50,000 square feet of traditional indoor gallery space along with 13,000 square feet of outdoor gallery space. Also included in the program is office space for the Metro Museum staff, an education center complete with classrooms and a film room, a restaurant, and a theatre which can hold up to 170 people. The MMAA's exact location is withheld; however, it can be known that it is located downtown in a major US city.

The project delivery method for the MMAA is Design-Bid-Build. Turner Construction Company was awarded the work due to their expertise and reputation and entered into a cost plus contract with an option for a Guaranteed Maximum Price for the owner. The total cost of construction for the project is $266 million, and the gross square footage of the building is 222,952 SF. This results in a cost per square foot of $1,200. This high cost per square foot is attributed to the unique and high end nature of the building.

The MMAA construction schedule is approximately 37 months long. Construction started on the project on October 13, 2011 and its finish date is set for November 28, 2014. One of the main phases that drives the construction schedule is the interior fit out for the gallery spaces. There are large galleries on the first, fifth, sixth, seventh, and eighth floors including the largest column free gallery in the city. On average each of these gallery fit outs takes 416 working days to complete. This is one of the reasons why those gallery spaces will be the focus of this thesis proposal. Below, Figure 1 shows a rendering of the MMAA looking at the northeast corner of the building.

Figure 1: View of the MMAA. Courtesy of Renzo Piano Building Workshop.

GALLERY CEILING PREFABRICATION / RE-DESIGN

Problem Identification

The Metro Museum of American Art (MMAA) has gallery spaces located on the first, fifth, sixth, seventh, and eights floors. The average duration for one of these gallery fit-outs is 416 working days which translates to approximately 19 months. The installation of the gallery ceilings accounts for over 100 of those 416 days. The critical path of the schedule also runs throughout this phase. This is because the vast majority of the activities in this phase cannot start until the previous activity is complete. This creates a chain of activities with no float where if one activity is delayed then all the succeeding activities are also delayed. Also, another risk associated with the gallery fit-out is that the last activity in this phase is a predecessor to the turnover to the owner. This is a potential problem because if there are any delays in the schedule late in this phase there might not be an opportunity to make up time in the schedule.

Background Research Performed

Preliminary research was completed in order to evaluate if prefabricating or redesigning the gallery ceiling was a viable option of study.

Gallery Ceiling Prefabrication Investigation

In order to reduce the schedule time for the gallery fit-out, I plan to investigate the implementation of a prefabricated gallery ceiling. Currently, the ceiling structure will be stick built in the field. This is a time consuming process because it is a unique ceiling system that ties in multiple different trades of work. Also, all of the activities are listed as start to finish which means one activity cannot start until the previous is fully complete. Table 1 details the main construction activities for a typical gallery ceiling installation and the amount of working days needed to complete each activity. As you can see the total duration for a typical ceiling installation is just over 100 working days.

Table 1: Typical Gallery Construction Schedule

TYPICAL GALLERY CEILING CONSTRUCTION SCHEDULE	
Activity	**Duration (Working Days)**
Ceiling Layout/ Hanging Drop Rods	25
Install W5 Sections & Infill Pieces	35
Rough-In Lighting System	10
Install Sprinkler System	15
Install Ceiling Panels	12
Ceiling Trim	5
Total	**102**

Prefabricating the ceiling off-site and transporting it to the MMAA to be lifted into place has the potential to save a significant amount of schedule time. Some of the benefits of prefabrication include the following:

- Decreased On-site Installation Time
    - *Materials will be delivered to the jobsite already assembled. The only on-site installation work is moving the prefabricated modules into their specified positions and making the final connections.*
- Increase in Worker Productivity
    - *Workers will be more productive because they will be working in a climate controlled factory at a comfortable working height. This is opposed to typical construction where the workers can be subjected to the elements and working overhead a large portion of the time.*
- Safer Work Environment
    - *This is another byproduct of working in a controlled environment at a comfortable working height.*
- Reduction in Material Waste

All of these benefits add value to the project in some way or another. A cross section of the ceiling system can be seen in Figure 2 below. As you can see the ceiling is hung from the structural steel above using slotted connections. According to the project team this design feature was the main reason that the system was not prefabricated. These will have to be changed to a different type of connection such as a hanger in order to accommodate the needed tolerance from prefabrication.

One of the difficult aspects of prefabrication is transporting the material to the jobsite. Through investigating the ceiling system it was found that the spacing of the W5 members is 10'. This is a good width for a prefabricated module because it will fit easily on the back of a truck and make the transportation process easier and reduce the possibility of damage to the material.

Gallery Ceiling Redesign

Another option is to completely redesign the gallery ceiling system in order to make it easier to construct. This option would completely change the design of the ceiling structure. The goal here would be to modify the interior architecture of the building in order to facilitate simpler and faster construction methods while still providing a high quality finished product to the owner that adds value to the project. It would also be beneficial to design the ceiling structure so that it can be prefabricated in order to benefit from some of the reasons described above. Some initial possibilities include using an open grid ceiling that will expose the metal deck, structural members, and mechanical systems above. This

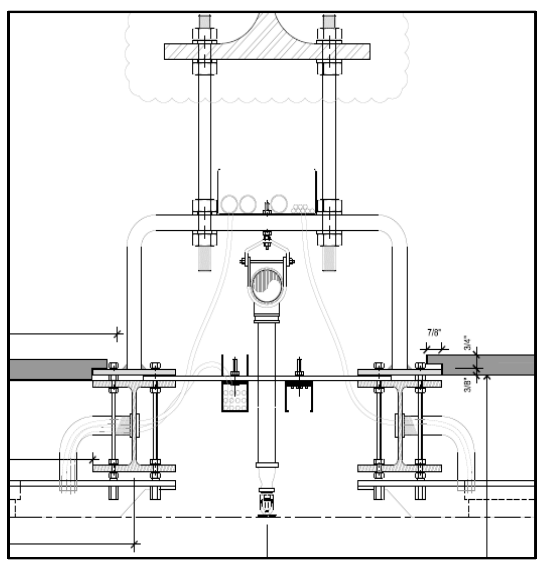


Figure 2: Section of the ceiling system.

would also add the possibility of creating some interesting lighting schemes in the gallery spaces.

Potential Solutions

After this analysis is run and completed the possible solutions that could be reached are as follows:

- The prefabrication of the existing structure is not feasible and should not be implemented.
- The prefabrication of the existing structure changes the aesthetics of the finished product in a way that is undesirable to the owner and should not be implemented.
- The prefabrication of the existing structure saves time and money and should be implemented.
- The redesign of the ceiling system is easier to construct, is accepted as equal to the original design, and should be implemented.
- The redesign of the ceiling system saves money but is not as aesthetically pleasing to the owner and therefore should not be implemented.

Methodology

In order to complete this technical analysis the following items must be completed:

Prefabricated System

- Research case studies for similar systems and productivity rates for the components of the ceiling structure.
- Obtain the estimated productivity rates and costs for the original system.
- Examine the system and determine how the structure will be separated into modules to best facilitate simple final connections on the job-site.
- Evaluate how the ceiling system will be built and how this affects the productivity rates of the workers.
- Calculate costs incurred from operating a prefabrication factory and any difference in trucking costs.
- Engineer a way for the modules to be hoisted to their final locations and determine the rate at which the modules can be installed.
- Determine if there was a savings in the overall schedule. If yes, calculate savings attributed to that.
- Compare the total costs of the original system to the total costs of the prefabricated system.

System Redesign

- Design the architectural ceiling for the galleries.
- Consult with Professor Holland for feedback and any possible ideas.
- Redesign the lighting and fire protection systems for this design.
- Test the acoustical properties of the new system. If needed adjust the design to conform with acceptable gallery noise standards.
- Model the redesign using the base Revit model supplied by Turner Construction.
- Finalize the Design.

Expected Outcome

Prefabricating the existing ceiling structure will provide a significant savings of the overall cost of the system. Most of the savings will come from the shortened on-site project schedule which has the potential to save a large sum on money through general conditions savings. Along with that there should be a large increase in productivity that will decrease the overall labor cost for the system. The system redesign will probably save the most amount of money due to the plan of a simplistic architectural finish. The final decision between the prefabricated original system and the redesigned system would be a cost benefit analysis that falls to the owner.

GALLERY SIPS IMPLEMENTATION

Problem Identification

The problem for this analysis deals with the same problems as the first proposed analysis. As stated before the interior fit out for the gallery spaces is one of the longest phases of the project and it lays on the critical path due to its sequential nature and tie in with the project turnover. The average schedule length for each gallery is 416 days and any delays during this timeframe would push back the turnover date to the owner. Any way to reduce this phase's schedule length would be beneficial to the project.

Background Research Performed

In order to facilitate a faster interior fit-out phase for the gallery spaces, I plan to implement a short interval production schedule (SIPS). A SIPS breaks down a project sequence into more detail than a typical project schedule would. It defines a duration for each activity, crew size needed to complete that activity in a certain timeframe, and the area that the work will be performed in. Doing this allows all members of the project team to know what they will be doing at all points of the day, sometimes down to the hour or minute.

Usually, a SIPS will be used on a project that is highly repetitive in nature such as a dormitory or prison. Also, the project is split up into defined construction zones. These zones should be similar in size and nature so that it takes a trade or team the same amount of time to complete each zone. A SIPS will also be applicable on the Metro Museum of American Art (MMAA) for multiple reasons. The MMAA may not be as repetitive as a dormitory but the gallery spaces are all constructed in a similar fashion. Currently the gallery fit-out schedules have the entire gallery space devoted to a single activity. There is the potential to explore dividing up these large gallery spaces into multiple zones to allow more activities to begin before the previous activity is fully completed in the gallery space. Also, most of the activities in the fit-out schedule are approximately 15 days long. This similar activity length will set up nicely for a SIPS because the work flow is most productive when all the crews move at the same pace. This is effective because it eliminates any work stoppages of the crews. There are a few activities that are scheduled for significantly longer than 15 days long. One of these is the layout and installation of the W5 members for the ceiling structure. If proved feasible in analysis one the entire ceiling structure may be able to be prefabricated and lifted into place eliminating the differential in schedule time required. This would allow the SIPS to provide the most benefit to the project. Also, worth noting is the fact that using a SIPS will typically increase the worker productivity. Because they are doing the same task every day, just in a different zone, they become more and more productive as they work through the zones. Their productivity will start relatively low and then increase as the project progresses.

Potential Solutions

- Using a SIPS is beneficial to the project by increasing productivity and reducing schedule time and should be implemented.

- Using a SIPS is beneficial to the project by increasing productivity but it does not reduce the schedule at all. It should still be implemented due to the productivity increase if there are no outside costs incurred by implementing SIPS.
- Using a SIPS is not feasible for this project due to the design of the galleries and will provide no benefit to the project. Therefore it should not be implemented.

Methodology

- Research SIPS and any relevant case studies that were performed on similar interior building systems.
- Obtain information regarding the current crew sizes and productivity rates that are being estimated for the work in the galleries.
- Review the gallery spaces to see if they can be divided into even areas of work.
- Examine each of the activities that are currently scheduled to see if their crew size and productivity can be adjusted to complete each zone in a prescribed amount of time.
- If necessary adjust the zone size or work sequence to make a SIPS possible. Also, some minor adjustments to the design of the gallery spaces may be necessary in order to make a SIPS feasible.
- If possible schedule the activities using a SIPS and perform an analysis to determine if its implementation would be beneficial to the project or not.

Expected Outcome

Using a SIPS will accelerate the interior gallery fit-out construction length by a significant amount of time. The SIPS will increase the coordination between the different trades. Also, the fact that the workers will know exactly where they will be at every step in the process will eliminate any unproductive work stoppages and will make them responsible for getting their work done. The worker productivity should increase as they work through the multiple zones of construction and become familiar with the tasks that they need to complete. Using the SIPS in conjunction with the prefabricated ceiling structure should bring benefit to the project and ultimately save money. All of these factors should lead to a more productive workforce that completes their scope of work in less time than originally scheduled.

CRITICAL INDUSTRY ISSUE: UNION DIVISION OF LABOR

Problem Identification

One of the challenges associated with prefabricating a system that integrates multiple different trades of work is the division of labor between the unions involved. This is magnified for the Metro Museum of American Art (MMAA) because its project location is known for having difficult unions to work with. The goal of this research would be to investigate the issues that are preventing the unions from coming to terms on the division of work. Then to develop a few possible solutions that would attempt to satisfy these unions so that the prefabricated work in question could be completed as planned. Hopefully a solution will be found that benefits all parties involved including the unions, contractors, and the MMAA.

Background Research Performed

One of the main challenges associated with prefabricating multiple trades of work is getting the unions to accept the division of work. There are multiple steps in the prefabrication process that cause discrepancies in what union gets the opportunity to perform the work. Listed below are some of the main topics associated with this:

- The first topic that is usually brought up is what trade will be responsible for lifting the final prefabricated modules into place. This work is a significant because it makes up the majority of the on-site labor. The final modules will have multiple trades of work built together. In the case of the gallery ceilings for the MMAA there are miscellaneous steel members, fire protection, and electrical work together on the final modules.
- Another issue could be getting the unions to work together to coordinate their work in advance. This is critical because in order for a prefabrication process to run smoothly there must be early coordination of the trades. Along with the coordination of the actual systems that will end up in the building, there needs to be early coordination regarding the logistics of the working process. This includes in what order are the individual modules constructed, where will each trade be constructing their scope of the work, and how will these modules be transported.
- Next, there could be issues with who is liable for the modules while they are in the possession of the different parties involved, and who is liable when the modules are in transit from one location to another.

These are some of the issues that need to be researched and understood before a prefabrication process is undertaken. If an agreement can be reached by all the parties involved in the process, then prefabrication could be very beneficial to the project.

Potential Solutions

- The issues listed above can be overcome and an agreement can be made by all the unions to make the prefabrication process run smoothly. The prefabrication process should be implemented because of this.
- The issues listed above cannot be overcome and an agreement will not be able to be made by all the unions. This will make the prefabrication process very difficult to implement.

Methodology

- Research the union division of labor issues.
    - Resources will be the Penn State library system that holds journals and magazines of many reputable sources.
- Discuss with the project team any union issues that they would have expected or foreseen if a prefabrication process was implemented.
- Research any applicable case studies that deal specifically with the union division of labor for prefabrication processes.
- If necessary contact some of the union representatives to see what their main concerns are regarding prefabrication work.
- After the research is complete, develop a proposal that can be used to satisfy all the parties involved.

Expected Outcome

This analysis will be difficult to complete. The unions in the area of the MMAA are known to be difficult to work with. The industry has already recognized the benefits of the prefabrication process and you would think most players in the industry would be eager to accept and implement it as much as possible. Due to this, I anticipate that there will be a major roadblock that is standing in the way of an agreement on the division of labor. This means that my goal will be to research and propose possible ways to get rid of this roadblock. There may not be a clear and concise solution, but hopefully I can gain a better understanding of the issues involved in the prefabrication process and help find a possible solution.

EXTENDING THE USE OF BIM ON THE PROJECT

Problem Identification

This analysis does not necessarily focus on a problem that exists on the Metro Museum of American Art (MMAA) project; instead it focuses on ways to add value to the project. The project team currently uses building information modeling (BIM) mainly for clash detection purposes. This includes modeling the building systems such as the mechanical ductwork, electrical conduit, and plumbing lines virtually in 3D; and then using analysis programs to detect where there are space defined conflicts in the building. This upfront investment in the project allows the installation of the systems in the field to be efficient and conflict free which reduces the number of RFIs and saves a significant amount of time and money.

Background Research Performed

However, this does not have to be the stopping point for BIM on the project. There are many other applications for BIM in the construction industry that have proved to provide value to their projects. This analysis will investigate some of the innovative BIM uses that could be worth implementing on the MMAA. Some of the possible BIM uses that will be investigated further are as follows:

- Phase Planning (4D Modeling): This BIM use integrates a virtual model of the building and combines it with the schedule. Attaching the schedule to the model essentially defines the fourth dimension as time. Using this tool, the sequencing of activities on a jobsite can be understood much easier. It will show the building being constructed virtually from the ground up as it would in the field. This virtual construction allows all of the subcontractors to know and understand when they will be responsible for exact portions of their scope. Also, it potentially can resolve problems before they even happen due to all of the subcontractors giving their input on possible problems that would not have been foreseen without 4D modeling.
- Site Utilization Planning: This use does not apply directly to the focus of this thesis, which is the gallery space of the MMAA. However, it could still be very useful on the project. As outlined in the technical reports the MMAA has a very restricted downtown site location. Because of this using BIM to model the logistics of the site as the phases change and progress could be beneficial to the project.
- Expanding 3D Coordination: Another interesting BIM topic to look into is expanding the use of 3D coordination. This means instead of just using 3D coordination to determine where clashes are, use it to provide innovative ways to become a more efficient builder. Examples of this include using 3D coordination to know where all the MEP equipment will be installed down to the location of the hangers. Then when prepping the above slab on metal deck for a concrete pour, those hangers could be dropped through the metal deck ready to be embedded once the concrete is poured. This would make the space ready for the MEP rough in and eliminate the overhead work of installing the hangers. Exploring this and other efficiencies that were made possible by BIM would be a very interesting analysis.

Potential Solutions

- All of the BIM uses researched would bring value to the project and should be implemented if possible and considered for future projects.
- Some of the BIM uses researched would bring value to the project and should be implemented if possible and considered for future projects. Other uses would not bring value to the project and should not be implemented, but they should be considered for future projects.
- None of the BIM uses researched would bring value to the project and should not be implemented on the project. However, these uses should be considered for future projects.

Methodology

- Research case studies of the different BIM uses to see if they have been used successfully elsewhere.
- Investigate the MMAA to see if any of these uses would be a viable option for the site specific conditions. If any uses are deemed viable they should be developed using the base model provided by Turner Construction.
- Quantify if these BIM uses would bring value to the MMAA project or not.
- Make recommendations on what uses should be implemented or considered further.

Expected Outcome

The MMAA would benefit from an expanded use of BIM technology and several of the investigated uses will most likely be implemented. The MMAA is a complex project and BIM's ability to simplify a project will help the project team find and correct many problems before they happen. In the end expanding the BIM use will shorten the project construction duration and the owner money.

ANALYSIS WEIGHT MATRIX

This section will focus on how much time and effort will be devoted to each analysis during the Spring 2013 semester. Table 2 below summarizes the total effort devoted to each analysis along with the breakdown of effort within the core thesis investigation areas. These core thesis investigation areas are as follows.

1. Critical Issue Research
2. Value Engineering Analysis
3. Constructability Review
4. Schedule Acceleration

Table 2: Analysis Weight Matrix

ANALYSIS WEIGHT MATRIX					
Analysis Description	**Critical Issue Research**	**Value Engineering**	**Constructability Review**	**Schedule Acceleration**	**Total**
Gallery Prefabrication/ Redesign	0%	5%	15%	15%	**35%**
Gallery SIPS	0%	0%	10%	15%	**25%**
Union Division of Labor	20%	0%	0%	0%	**20%**
BIM Expansion	5%	10%	5%	0%	**20%**
Total	**25%**	**15%**	**30%**	**30%**	**100%**

As you can see from Table 2, the analysis that will be focused on the most is the gallery prefabrication and redesign. The other analyses will each receive slightly less attention. Also, the constructability review and schedule acceleration core thesis investigation areas will equally be focued on the most. This is mainly due to their ties with the gallery prefabrication and SIPS scheduling analyses.

CONCLUSIONS

This proposal defined some of the opportunities available on the Metro Museum of American Art (MMAA) building project that could increase the efficiency of the building process and save the owner money. The analyses that will be conducted in the spring 2013 semester are the prefabrication or redesign of the gallery ceiling system, implementation of a gallery short interval production schedule (SIPS), union division of labor, and the expansion of building information modeling (BIM) on the project.

Prefabrication has been proven to save time and money in the construction industry. It limits the amount of on-site work that needs to be completed and also makes the construction process more productive and safer. A SIPS has also been proven to cut down on schedule, increase worker productivity, and therefore reduce the cost of a construction sequence. This SIPS could be used in conjunction with the gallery prefabrication to result in a very efficient gallery space construction sequence. One issue that could possibly inhibit the prefabrication process is the union division of labor. The location that the MMAA is being built in is known for having tough unions to deal with. Hopefully through research in the spring a few possible solutions can be found. Finally, BIM is exploding throughout the industry. There are many new applications of BIM that could be implemented on the MMAA successfully such as 4D modeling and phase planning. All of the above analysis topics have the potential to save the owner time and money. Through research and analysis next semester these topics will be tested to see if they are applicable to the specific conditions at the MMAA project.

APPENDIX A

BREADTH TOPICS

CONCLUSIONS

In order to complete the thesis requirements, breadth in two areas other than construction must be demonstrated. Both of the thesis breadths will focus on the redesign of the gallery spaces. First, there will be an architectural breadth due to the aesthetic changes that will be made to the gallery spaces. Secondly, there will be an acoustical breadth that evaluates the gallery acoustics to ensure that they are acceptable after the redesign.

Architectural Breadth

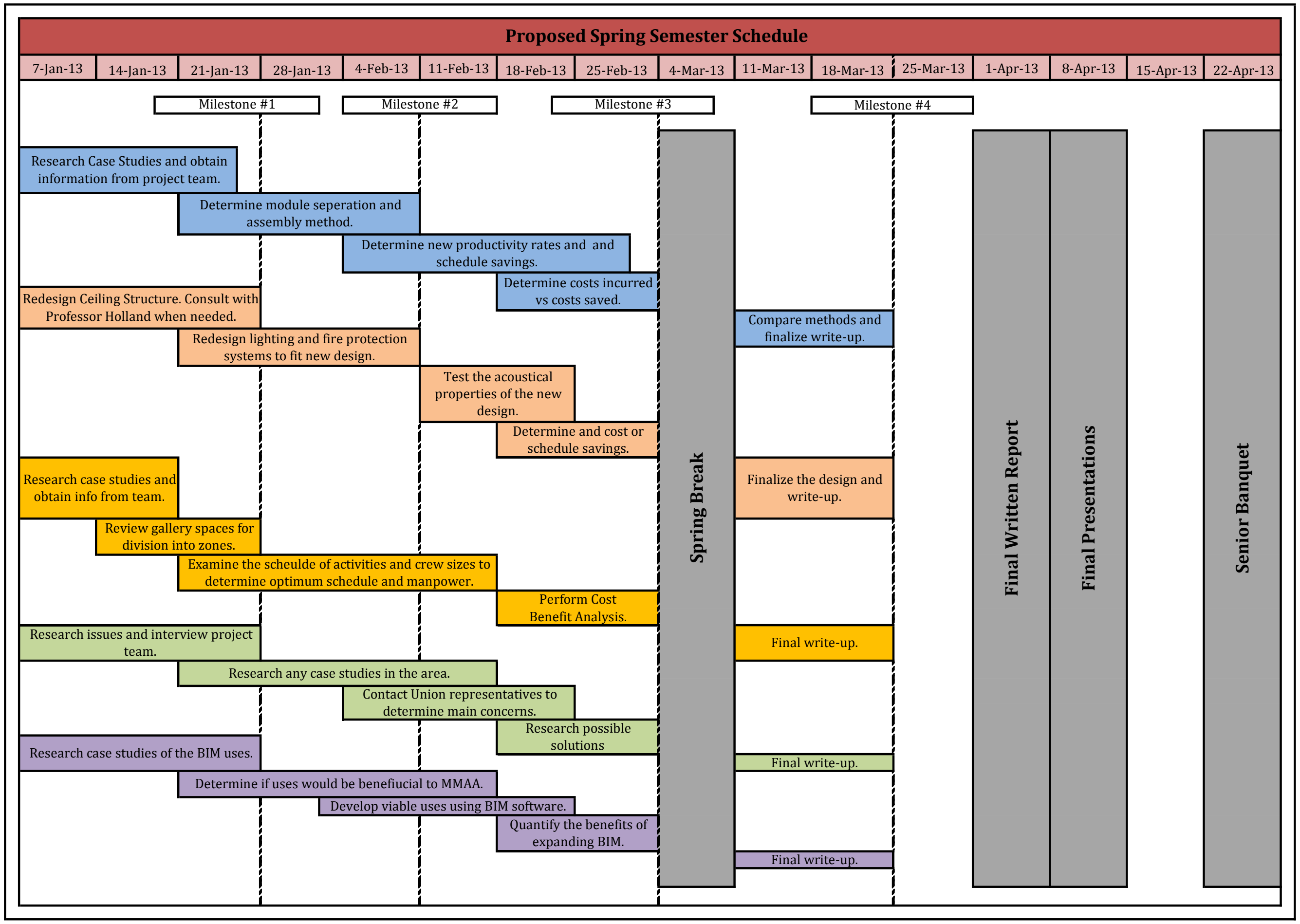
The first breadth that will be undertaken is architectural. The gallery spaces and specifically their ceiling structure will be redesigned in a way that makes them simpler to construct. The gallery ceilings are scheduled to be one of the longest activities during the gallery fit-out schedule. Therefore, they will be the focus of the gallery redesign. This redesign will be a major change to the building's architecture because the gallery spaces will be one of the highlights of the museum. The goal will be to completely change the ceiling structure and possibly other elements of the gallery spaces so that it still fits in with the overarching architectural principles of the building but become easier and more cost effective to construct.

Acoustical Breadth

The second breadth that will be investigated is an acoustical evaluation of the redesigned gallery spaces. These gallery spaces are very large spaces that will have a large occupancy when finished. Due to this, the noise volumes in the space could be magnified very easily. A space that is not evaluated for its acoustical properties could end up being very uncomfortable to its occupants. Often post construction fixes will have to be implemented that are time consuming and costly. One of the possible architectural redesigns would be to expose more of the structure structural steel and mechanical systems. This would expose a lot of materials that reverberate sound waves easily. Due to this an acoustical analysis would be considered good design practice.

APPENDIX B

SENIOR THESIS WORK SCHEDULE



Analysis Key	
(blue)	1a: Gallery Prefabrication
(light orange)	1b: Gallery Redesign
(yellow)	2: Gallery SIPS
(green)	3: Union Division of Labor
(purple)	4: Expanding the BIM Use

Milestones	
#1	Redesign Ceiling Structure and Divide Gallery Spaces into zones. Most research complete.
#2	Prefabrication process complete.
#3	Finalize all major investigation and prepare for write-up.
#4	Completed Write-Up and Practice Presentation