TECHNICAL REPORT 3

The Metro Museum of American Art

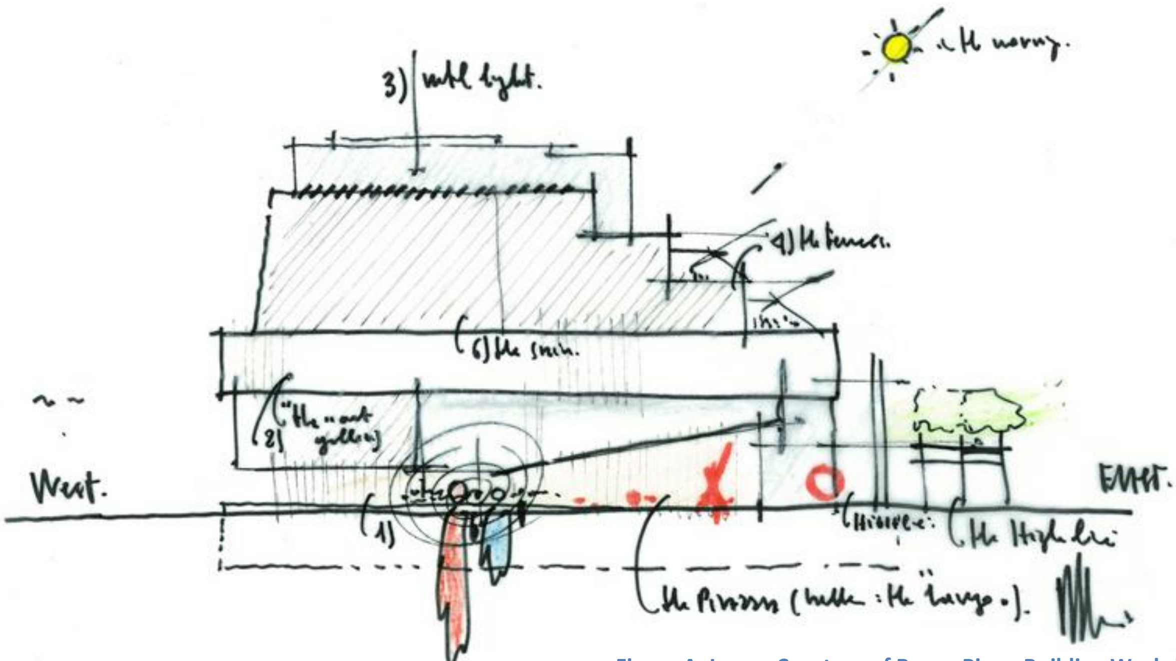

Figure A: Image Courtesy of Renzo Piano Building Workshop.

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This Technical Report will provide an overview of the construction of the Metro Museum of American Art construction project. Included will be a detailed analysis of the LEED requirements, schedule analysis, value engineering topics, critical industry issues, and technical analysis options.

EXECUTIVE SUMMARY

This following technical report details the Metro Museum of American Art (MMAA) building and the construction techniques employed to build it. The project's exact location is to be held confidential; however it can be known that the MMAA will be built in a major US city. This report analyzes the project LEED requirements, schedule, value engineering topics, critical industry issues, and technical analysis options.

The goal for the MMAA is for the project to become LEED certified gold. In order to meet this requirement the project team will have to plan for and earn 60 out of the 110 available points set forth by the 2009 LEED rating system for new construction. Through the use of the Penn State University classification system, it was found that there would be 52 mandatory points, 13 points with a significant effort, 8 points with minimal effort, and 37 points that were not pursued. The strongest divisions for the MMAA were the sustainable sites and innovation in design; while the weakest division by far was energy and atmosphere. The energy and atmosphere section accounted for 21 of the 37 not pursued points. The points in this section were not as feasible due to the nature of the building. Overall, any project that achieves a LEED gold certification is far above the average project and the project team should be praised for their good work in this category.

The main risks to the project completion date are the excavation / foundation phase and the interior fit-out phase. Both of these phases drive the critical path of the schedule and any delays in these areas would delay the substantial completion of the project. Some proposed schedule acceleration techniques would be to implement a SIPS schedule during the gallery fit-out phase or to utilize overtime work throughout the project. However, overtime work should be used with caution due to the loss in productivity and safety on the job.

Value engineering asseses the goals of the owner and identifies areas where the project can be improved by better aligning the project to these goals of the owner. It cannot be simply reducing cost while also reducing quality because this would be "de-value engineering". The MMAA is a unique and high end building. Because of this any value engineering items must be implemented cautiously. One of the systems that is excessive is the curtainwall system which will cost $30.6M or $137 per square foot. This is an area that could be value engineered with the approval of the owner.

Next, the 21st annual PACE roundtable meeting was held this year at Penn State University. It provided the opportunity for students and industry members to come together to discuss current industry topics. There were two breakout sessions that focused on the project supply chain and modular construction. Then there was a focus group where students could interact directly with an industry professional in order to generate ideas for senior thesis analysis.

Finally technical analysis options discussed include using a SIPS schedule and prefabrication in order to cut down on the long gallery fit-out schedule. Also, looking at ways to increase the productivity of the aformentioned curtainwall system could be investigated. If that investigation does not produce meaningful savings, alternate systems for the curtainwall could be explored.

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LEED EVALUATION

The United States Green Building Council (USGBC) is one of the leaders in sustainable building design and construction. They offer services that define, certify, and regulate what a sustainable or “green” building is. Their Leadership in Energy and Environmental Design (LEED) program uses a point based system out of 110 to define how green a building is. Through steps such as using local materials, or having a sustainable site a building can earn points with the goal of attaining a LEED rating. The rating structure is defined as follows.

- LEED points available: 110
  - LEED Certified: Must achieve 40/110 points.
  - LEED Silver: Must achieve 50/110 points.
  - LEED Gold: Must achieve 60/110 points.
  - LEED Platinum: Must achieve 80/110 points.

One of the goals for the construction of the Metro Museum of American Art (MMAA) is to have the building become certified LEED gold. This will be based off of the 2009 LEED rating system for new construction. In order for the project to attain this level of LEED certification the project team will have to attain at least 60 of the 110 possible points. In order to effectively do this a LEED plan must be developed, implemented, and maintained by the project team. The first step in this process is to identify the LEED points that are of the most value to the owner and are worth pursuing. A good way to accomplish this is to create a system that rates each LEED point by its importance. Penn State University uses a system such as this that classifies each available point into four classifications. Penn State defines these classification types as follows.

- **Mandatory:** *Credit compliance required. If not already present, achievement must be made prior to completion.*
- **Significant Effort**: *Proof of serious investigation must be completed and proven. If compliance is not achieved, documentation must detail failure through professional demonstration.*
- **Minimal Effort:** *Investigation of compliance must be completed and approved. If beyond program requirements, documentation must detail such, and no additional efforts will be dedicated towards its compliance.*
- **Not Pursued:** *Credits will not be pursued, and no documentation is required.*

The Penn State system will be applied to the MMAA in order to better understand how it will achieve its LEED gold certification and to critically analyze the decisions made by the project team. The 2009 LEED rating system for new construction breaks out the available points into seven distinct categories. They are sustainable sites (26 possible points), water efficiency (10 possible points), energy and atmosphere (35 possible points), materials and resources (14 possible points), indoor environmental quality (15 possible points), innovation and design process (6 possible points), and regional priorities (4 possible points). Table 1 shows the breakdown of the available LEED points in each category and the planned breakdown of those points into the four Penn State classifications.

Table 1: LEED Scorecard Summary

LEED SCORECARD SUMMARY					
Division	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Sustainable Sites	26	21	1	2	2
Water Efficiency	10	3	4	0	3
Energy & Atmosphere	35	9	3	2	21
Materials & Resources	14	3	2	2	7
Indoor Environmental Quality	15	9	3	0	3
Innovation & Design Process	6	6	0	0	0
Regional Priorities	4	1	0	2	1
Totals	**110**	**52**	**13**	**8**	**37**

As you can see from this table there are a total of 52 required points on this project. The project team will have to find a way to get eight more points from either the significant effort or minimal effort categories in order to reach the LEED gold requirement. The 37 points in the not pursued category have been deemed not feasible by the project team most likley due to restrictions caused by the building design, the high cost to implement, and the small gains that would be achieved if implemented.

Also worth noting is that the majority of the mandatory points come from the sustainable sites division while the majority of the not pursued points come from the energy and atmosphere division. This will be discussed in detail in the following sections where each of the seven main divisions will be analyzed individually.

Sustainable Sites

On the next page, Table 2 breaks down each of the available points in the sustainable sites division by requirement category. The sustainable sites category focuses on choosing a project site that allows the construction and use of the building to be as green as possible. This is done through actions such as creating a soil erosion and sedimentation plan, choosing a site that is not on previously undeveloped land, choosing a site that has access to public transportation, and managing stormwater runoff.

In the end the MMAA does very well in this category by attaining at least 21 of the possible 26 points. This is mainly due to the selection of the project site. Because it is located in a downtown location and is on previously developed land it will earn almost all of the points allotted to selecting a sustainable site. Also, its close proximity to public transportation and the density of the local community contributed to the success in this category. Overall, the project team did an excellent job in this category.

Table 2: Sustainable Sites Division Summary

SUSTAINABLE SITES DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Site Selection	1	1	0	0	0
Development Density & Community Connectivity	5	5	0	0	0
Brownfield Redevelopment	1	1	0	0	0
Alternative Transportation: Public	6	6	0	0	0
Alternative Transportation: Bicycle	1	1	0	0	0
Alternative Transportation: Fuel Efficient Vehicles	3	3	0	0	0
Alternative Transportation: Parking Capacity	2	2	0	0	0
Site Development: Protect or Restore Habitat	1	0	0	1	0
Site Development: Maximize Open Space	1	0	1	0	0
Stormwater Design, Quantity Control	1	1	0	0	0
Stormwater Design, Quality Control	1	0	0	0	1
Heat Island Effect, Non Roof	1	1	0	0	0
Heat Island Effect, Roof	1	0	0	0	1
Light Pollution Reduction	1	0	0	1	0
Totals	**26**	**21**	**1**	**2**	**2**

Water Efficiency

The intent of the water efficiency category is "To increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems" (USGBC). This is done by treating wastewater, collecting rainfall, using greywater, and reducing the amount of potable water used in the building or by the irrigation systems for the on site plants. Table 3 summarizes the point distribution of the division by category. The MMAA only currently requires 3 out of the possible 10 points in this division. Those three points are for reducing the amount of water used in the building by 35%. A significant effort is required for the water efficient landscaping points which ask for alternate ways of irrigating the on-site plants. This could be accomplished by using collected rainfall or recycled wastewater, using efficient irrigation systems, and using landscaping that does not require permanent irrigation systems. Not being pursued is the innovative wastewater technologies points that call for a reduction in wastewater generation by using water-conserving fixtures or non-potable water.

Overall, the approach for this division is acceptable because 7 out of the 10 possible points will have at least a significant effort applied to them. However, pursuing the two wastewater technologies points would be beneficial to the project team. Using low water use fixtures to cut down on wastewater by 50% would be a relatively simple way to earn two additional points and should be investigated further to determine if it is feasible for this particular project.

Table 3: Water Efficiency Division Summary

WATER EFFICIENCY DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Water Efficient Landscaping	4	0	4	0	0
Innovative Wastewater Technology	2	0	0	0	2
Water Use Reduction	4	3	0	0	1
Totals	**10**	**3**	**4**	**0**	**3**

Energy & Atmosphere

This section focuses mainly on the building's mechanical systems and their environmental impact. Table 4 below summarizes the point distribution by category for this division. As you can see this section is where the MMAA struggled. Only 9 of the possible 35 points are required with 21 of those points not being pursued at all. This is mainly due to the optimize energy performance, and on-site renewable energy points where 21 of the possible 26 points are not being pursued at all.

This category is poor in comparison to the rest of the LEED divisions. Due to the lack of points required in this division additional stress was put on the other divisions in order to still aquire a LEED gold rating. As scheduled in the optimize energy performance section the project team is only aiming for a 14% improvement in the building performance rating, which awards the two points shown in Table 4. Some barriers to improving this rating further are the large open spaces throughout the museum that require a large amount of ventilation and conditioning in order to keep them comfortable for the guests. This is compounded by the fact that the load in these spaces can be variable depending on if the spaces are at full occupancy or not.

Table 4: Energy & Atmosphere Division Summary

ENERGY & ATMOSPHERE DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Optimize Energy Performance	19	2	1	1	15
On-Site Renewable Energy	7	0	0	1	6
Enhanced Commissioning	2	2	0	0	0
Enhanced Refrigerant Management	2	2	0	0	0
Measurement & Verification	3	1	2	0	0
Green Power	2	2	0	0	0
Totals	**35**	**9**	**3**	**2**	**21**

Materials & Resources

The idea behind this division is to limit the amount of waste created during the construction of a building and to use green materials such as recycled and locally manufactured materials. All of these options save energy in their own way and contribute to the overall sustainability of the project. Table 5 below shows the point breakdown by classification for this division.

This division was not one of the strongest for the MMAA. There is only 3 required points out of a total of 14 while there are 7 points that are not pursued at all. It is understandable that the 4 building reuse points are not being pursued due to the unique nature of the museum. One item that could be considered further are the material reuse points. By using 5-10% salvaged or refurbished materials the project could pick up a couple additional points. Due to this the material reuse points should be moved out of the not pursued category and investigated further. Another point that should be pursued further is the certified wood category. Using certified wood will create the same end product, will not detract from any of the goals of the owner, and is available in most markets across the country. Implementing these suggestions will help achieve the LEED gold certification.

Table 5: Materials & Resources Division Summary

MATERIALS & RESOURCES DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Building Reuse: Walls Floors & Roof	3	0	0	0	3
Building Reuse: Interior Non-Structural Elements	1	0	0	0	1
Construction Waste Management	2	2	0	0	0
Materials Reuse: Building Materials	2	0	0	0	2
Recycled Content (10%,20%)	2	1	1	0	0
Regional Materials (10%,20%)	2	0	1	1	0
Rapidly Renewable Materials (2.5%)	1	0	0	0	1
Certified Wood (50%)	1	0	0	1	0
Totals	**14**	**3**	**2**	**2**	**7**

Indoor Envirnomental Quality

The intent of the indoor environmental quality section is to improve the quality of the indoor space through using proper materials, ventilation, lighting/daylighting, and thermal comfort in order to improve the comfort of the occupants and ultimately make them happier, healthier and more productive. Table 6 shows a breakdown of the points by classification.

As you can see from Table 6 the project team put together a good plan for this division; making 9 out of the 15 points mandatory with 12 out of 15 needing a significant effort required. This is a big step closer to the LEED gold certification. The only points that are not being pursued in this division are the thermal comfort control and daylighting points. This is done because you cannot give individual thermal comfort control to a mixed use facility with this many gallery and high occupancy spaces. Also, due to the architectural features and the very low amount of windows on the north and south elevations of the building daylighting points are simply not feasible for the MMAA even with the clearstories and larger windows on the east and west elevations. Due to this I would not change any of the approaches used for this division.

Table 6: Indoor Environmental Quality Division Summary

INDOOR ENVIRONMENTAL QUALITY DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Outdoor Air Delivery Method	1	1	0	0	0
Increased Ventilation: 30%	1	0	1	0	0
Construction IAQ Plan: Construction	1	1	0	0	0
Construction IAQ Plan: Before Occ.	1	0	1	0	0
Low Emitting Materials: Adhesives & Sealants	1	1	0	0	0
Low Emitting Materials: Paints & Coatings	1	1	0	0	0
Low Emitting Materials: Flooring Systems	1	1	0	0	0
Low Emitting Materials: Composite Wood	1	1	0	0	0
Indoor Chemical & Pollutant Source Control	1	0	1	0	0
Controllability of Systems Lighting	1	1	0	0	0
Controllability of Systems Thermal Comfort	1	0	0	0	1
Thermal Comfort Design	1	1	0	0	0
Thermal Comfort Verification	1	1	0	0	0
Daylight & Views: 75% Daylight	1	0	0	0	1
Daylight & Views: 90% View	1	0	0	0	1
Totals	**15**	**9**	**3**	**0**	**3**

Innovation & Design Process

The intent of the innovation and design process is, "To provide design teams and projects the opportunity to achieve exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System." (USGBC). The breakdown of points by classification for this division can be seen in Table 7. Out of the 6 possible points in this division all 6 are mandatory points. This is obviously exceptional and no changes should be made to this division.

Table7: Innovation & Design Process Division Summary

INNOVATION & DESIGN PROCESS DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Low Mercury Lighting	1	1	0	0	0
Green Housekeeping Plan	1	1	0	0	0
Green Building Education	1	1	0	0	0
Exemplary Performance: Mass Transit	1	1	0	0	0
Emissions Reduction Reporting	1	1	0	0	0
LEED Accredited Professional	1	1	0	0	0
Totals	**6**	**6**	**0**	**0**	**0**

Regional Priorities

This division is focused on awarding points for geographically-specific environmental priorities. The USGBC regional councils determine what environmental factors are important for their region and make 6 regional priority credits available. However, a capped maximum of 4 credits is all that can be earned in this section. On the following page, Table 8 displays the regional credits available to the MMAA and the prospective breakdown of these points by their classification.

As you can see the only mandatory point in this section is for alternative public transportation. This was easily picked up by the MMAA due to its close proximity to a network of public city transportation. The other points in this division are tough for the MMAA to obtain because they are similar to points in the previous sections that were also not very feasible due to site conditions or design. Due to this, and the fact that the project is on track to reach its goal of LEED gold certification, no changes should be made to this section.

Table 8: Regional Priorities Division Summary

REGIONAL PRIORITIES DIVISION SUMMARY					
Point Description	**Available Points**	**Mandatory**	**Significant Effort**	**Minimal Effort**	**Not Pursued**
Alternative Transportation: Public	1	1	0	0	0
Site Development: Protect or Restore Habitat	1	0	0	1	0
Stormwater Design: Quality Control	1	0	0	0	1
Optimize Energy Performance	1	0	0	0	1
Optimize Energy Performance	1	0	0	0	1
On Site Renewable Energy	1	0	0	1	0
Totals	**4**	**1**	**0**	**2**	**1**

Summary

The MMAA project team put together a good strategy in order to achieve a LEED gold certification. Any project that reaches LEED gold certification is already well on its way to being a sustainable building and the project team should be praised for their work in preparing for this. Only the minor modifications in strategy mentioned above should be implemented. These modifications will not allow the building to reach the next level of certification, which is platinum. However, it still will make the building more sustainable overall; which should always be the end goal of any LEED project. If this strategy is implemented correctly the owner will be satisfied and the project will achieve its LEED gold certification.

SCHEDULE ANALYSIS

The Metro Museum of American Art (MMAA) construction schedule start date is set at October 13, 2011, and it is scheduled to finish on November 28, 2014. This translates to a total project duration of approximately thirty seven months or 803 working days. Table 9 is reproduced from Technical Report 2 and it gives an overview of the project schedule. This section will discuss the main construction sequences that define the critical path of the project and the main risks associated with meeting the project completion date. Also, some schedule acceleration proposals will be discussed.

Table 9: MMAA Construction Schedule Overview

MMAA CONSTRUCTION SCHEDULE OVERVIEW			
Phase	**Start Date**	**Finish Date**	**Duration (Working Days)**
Excavation & Foundation	13-Oct-11	24-Aug-12	138
Structural Steel Erection	14-Aug-12	14-Feb-13	129
Superstructure Concrete	22-Oct-12	12-Mar-13	101
Enclosure	05-Feb-13	02-Apr-14	297
Building Watertight	N/A	07-Jan-14	1
Vertical Transportation	01-May-13	03-Apr-14	237
MEP Equipment Install	22-Jan-13	15-Jan-14	248*
Interior Fit Out	25-Oct-12	28-Nov-14	539**
Full Building TCO	N/A	28-Nov-14	1
Full Project	**13-Oct-11**	**28-Nov-14**	**803**

** MEP Equipment Install period does not include the dates between when the MEP equipment was set and when the actual work on the equipment began due to the fact that this large non-working time period skews the data.*
*** Interior Fit Out phase is so length mainly due to the large gallery fit-outs.*

Critical Path

The two phases of the project that drive the construction schedule for the MMAA are the excavation / foundation phase, and the interior fit-out for the gallery spaces. Both of these activites are on the critical path of the schedule and any delays during these phases would ultimately delay the substantial completion date of the project unless schedule time was made up elsewhere.

Excavation / Foundation Phase

As shown in the previous technical reports the excavation / foundation phase is a complex phase of the project. There are multiple different types of excavation techniques used to retain the soil until the foundation can be properly installed. As shown above this phase is scheduled to be 138 working days long. This entire time frame is on the critical path because no other activities can occur on-site until this phase is complete and the building starts to come out of the ground. Because of this any unforseen delays in this early phase will significantly set back the project early on and would put stress on the project team to make up schedule time to get back on track.

Interior Fit-Out Phase

As shown in Table 9, the interior fit out phase is by far the longest phase of the project at 539 working days. This is due mainly to the long durations for the gallery fit-outs. The average duration for a gallery fit-out is 416 working days which translates to approximately 19 months. The critical path also runs throughout the majority of 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 succeding 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.

Schedule Acceleration Scenarios

If there proves to be a delay in the schedule, a plan must be in place to identify any areas that could accelerate the schedule in order to make up time. A few areas where this could be possible is the use of a short interval production schedule in the gallery spaces or working overtime throughout the project where necessary.

Short Interval Production Scheduling

A short interval production schedule (SIPS) is an effective tool to use for scheduling construction activities that are similar or repetitive. Also, they often provide a significant reduction in the total time it takes to complete a given task due to the fact that they maximize the productivity of the tasks involved. This type of scheduling would be useful for the MMAA gallery fit-out spaces. There are five galleries throughout the MMAA and each of which are very similar in nature and overall size. Because of this a SIPS scheulde would be a good way to save time on the project scheulde by maximizing the productivity of the trades involved. Currently each individual trade has an entire gallery space to themselves. However, if a SIPS was used and the workspace was changed from a whole gallery to half of the gallery there could be a significant schedule savings in this phase.

Overtime

Another, less attractive option, is implementing overtime work to accelerate the schedule if necessary. Overtime can be used to increase the man hours on the job for a given week so that more work will be put in place. However, there are a lot of downsides to using overtime and it should be used with caution. First off overtime comes at a premium price and often at a lower productivity rate. According to Del-Mar Enterprises overtime losses in productivity can be describes as following; “In the first few weeks of schedule overtime, total productivity per man is normally greater than in a 40-hour week but not as much more as the number of additional work hours. After seven to nine consecutive 50 or 60 hour weeks, the total weekly productivity is likely to be no more than that attainable by the same work force in a 40 hour week. Productivity will continue to diminish as the overtime schedule continues.” This diminishing return in productivity must be taken into account before it is implemented and paid for with a premium price. Another important factor to consider when implementing overtime is the decrease in on-site safety associated with prolonged overtime work. As more overtime weeks go by the workforce will become more and more fatigued. This can cause physical and mental errors that will increase the prevalence of injuries on the job. All of these factors must be considered before implementing overtime work.

VALUE ENGINEERING TOPICS

Value engineering is often a very useful tool for a project team. It asseses the goals of the owner and identifies areas where the project can be improved by better aligning the project to these goals of the owner. Often value engineering is believed to be any way a project can save money. This can create massive cuts in the project scope and quality that in the end will end up subtracting value from the project instead of adding to it. This is called de-value engineering which reduces cost by providing a lower quality product. The goal for the MMAA is to find ways to save cost or schedule that will not infringe on the intent of the design.

This proved to be a difficult task due to the unique nature of the building. As you can see in Figure 1, the MMAA is a very unique building with an interesting architectural design. This coupled with all of the high end finishes in the building make the overall project cost much higher than other typical commercial buildings. This seems to be acceptable to the owner because they want the highest quality product that is available. Because of this any value engineering items should be considered carefully so they do not de-value the project as discussed previously. The goal of the project team should be to deliver a high quality building to the owner that fits what they want but is not too excessive.

Figure 1: View of the MMAA from the north. Image courtesy of Renzo Piano Building Workshop.

The project team could not comment on what value engineering items were implemented or considered for the project before the submission of this technical report was due. However, here are areas where value engineering could be implemented successfully. First, as discussed in the previous technical reports the curtainwall system is mainly composed of a metal panel rain cladding system with a insulated stud wall back-up system. The cost for the curtainwall enclosure system as a whole is $30,600,000. This extrapolates to $137 per square foot of the building. This seems excessive because $137 per square foot can be the total cost for commercial office buildings in the US. There are many products out on the market that would be comparable to this metal cladding system. Value engineering research could easily be applied here to save the owner a significant amount of money while still providing a high quality finish to the building. The owner should be consulted on all value engineering topics so that none of the decisions made will detract from their goals. This is especially important for the MMAA because it is such a high end building and the owner may want the building to be excessive in some areas. This type of value engineering could be applied throughout the building and especially in the gallery spaces. However, as stated before care must be taken to not de-value the building.

CRITICAL INDUSTRY ISSUES

This section of the report will focus on The Partnership for Achieving Construction Excellence (PACE) Roundtable event held on Penn State University's campus on November 5th and 6th, 2012.

About the PACE Roundtable Event

The PACE roundtable event is an annual event held at Penn State University where Penn State Architectural Engineering students and construction industry professionals come together to meet and talk about current industry topics. It is a valuable experience for the students because they can interact with the industry professionals and develop possible ideas for their senior thesis project. This year was the 21st annual PACE roundtable meeting and was held November 5th and 6th, 2012. The topic of this years meeting was "Improving Efficiency through Innovation". It has never been more important to be innovative in the construction industry due to the tough economy and the struggle to obtain quality work that comes along with that. This made for an interesting day of discussion that is very prevalent to the current state of the industry. The Roundtable consisted of two break-out sessions where industry topics such as supply chain, delivery of services, modularization, and operation and maintenance of building would be discussed. I chose to attend the supply chain and modularization sessions. After the break-out sessions were complete a focus group was conducted so that students could interact individually with the industry professionals.

Breakout Session 1: Supply Chain

The first session attended was, "Supply Chain: Integrating Strategies and Technologies". This meeting focused on the planning and delivery of materials to the jobsite. First, some of the typical problems associated with the supply chain were discussed. The group found that information and communication barriers were one of the leading causes to a poor supply chain. A prime example of this barrier is shown through the transfer of information as in the submittal process. Contractors typically have their own system or software to handle the submittal log and other project management items. Problems can arise when this information is sent to the architect because they may be getting information for multiple different jobs from multiple contractors who all use a different delivery method. Because of this, it is important to pick up the phone and call if submittals or any other items become outstanding. The same idea can apply to suppliers. Sometimes the contractor has to be the "squeaky wheel" and keep calling the suppliers so that a relationship can be developed and the material procured on time.

Next, procurement strategies were discussed. The overall theme to this discussion was that the project team needs to know what they will need to procure early on in the project. This early procurement can mitigate some of the risks involved with these long lead items. Also, sometimes it can be economical to store materials off site until needed. An example that was brought up in the discussion was a project that was built in three phases. It consisted of three buildings, all of which were almost identical. A custom curtain wall was required for these buildings. So in order to benefit from the economy of scale all of these curtainwalls were manufactured when the first building's curtainwall was needed. The last building's curtainwall would not be installed for multiple years down the road. However, procuring, manufacturing, and storing the material early made the most sense on this project. Every project and every situation is different and each individual situation must be analyzed acordingly.

The last topic that was discussed in the first session was the use of technology in the supply chain. One of the most useful tools making its way into the construction industry today is the use of barcodes / RFID tags to track material to the jobsite and its final destination on the project. Doing this allows the project team to know exactly where and when the material has been at each step of the procurement process from fabrication to inspection. This is a great tool for the project team by making information about the supply chain of materials easily accessible to anybody on the project team and increasing the level of quality control on a project.

Breakout Session 2: Modularization

The next breakout session attended was titled, " Supply Chain: Modularization". This focused on the insustry trend of modularization and prefabrication of different building components or systems. There are many benefits to modularizing building components. These include a decrease in the overall project schedule, and increase in quality, and an increase in safety on the job. These benefits can be attributed to the fact that when modularizing building components they are built off the job site and shipped to the project when needed. This increases worker productivity because they are moved from the harsh conditions of the jobsite into a controlled factory environment. Instead of working in the elements with a lot of overhead and ladder work, the workers can work comfortably indoors at a more productive working height. This creates a much safer and productive work environment that allows the workers to deliver a higher quality product. Once the prefabricated sections are complete they can be shipped to the job and lifted into place. This cuts down on the on-site material storage and on-site safety problems as well.

One of the keys to prefabrication is to design the modules to be repetitive. This will increase the worker productivity to its maximum level. Also, it is important to get the contractors involved early on in the project if these strategies are to be used. This is especially important when multi-trade prefabrication is used, such as MEP runs down corridors. This early involvement will allow all parties to be on board and plan ahead so that the best product can be designed and developed. Often if the contractors are not brought in early enough the systems would have to be redesigned in order to take advantage of the repetitive nature of prefabrication. Also worth noting is the fact that the size of these modules are very important. They cannot be so large that they are diffucult to handle because that will detract from the productivity gained during the off site prefabrication. However, as the modules get smaller and smaller there will be a diminishing return on productivity gains because of the high number of on-site connections that must then be made. Overall, modularizaton and prefabrication are powerful tools that are available to the innovative contractor that can save them time, money, and make them a safer builder.

Focus Group: Student Research Topics

After the breakout sessions were complete a group of three students and an industry professional were put together in order to discuss the student's thesis project and develop possible ideas of study for the spring semester. Through discussion with this industry member and the roundtable event as a whole, I developed a few possible areas of study. These include investigating the prefabrication of the back-up system for my metal exterior wall system. That way it could simply be delivered to the jobsite and hoisted into place. Another idea would be to investigate the LEED points that are not being pursued from the energy and atmosphere section to determine if these can be pursued further. Finally, as the MMAA has the largest column free gallery in the city, it would be a good study to look at the structural system that supports this to see if there are any alternate systems that could be used. There are many questons that have to be answered about the topics such as how exactly is the back-up wall system currently being constructed or what was the design criterial for the structural system? The main contacts that I will have to use are the members of the project team who are working on the MMAA.

PROBLEM IDENTIFICATION & TECHNICAL ANALYSIS OPTIONS

This section will discuss some of the problematic features of the MMAA that have been discovered so far through preliminary research. These problematic features could be possible areas for a detailed analysis during the coming spring semester. The problematic features that I have discovered so far are the long gallery fit-out schedule and the high cost of the curtainwall system.

Gallery Fit-Out Schedule

As mentioned previously, the interior fit-out phase is by far the longest phase of the project at 539 working days. This is due mainly to the long durations for the gallery fit-outs. The average duration for a gallery fit-out is 416 working days which translates to approximately 19 months. Because this phase is on the critical path any schedule reductions would also reduce the overall project schedule. This would be extremely beneficial to the project because it could save a significant sum of money in general conditions costs or get the schedule back on track if necessary.

The first step in cutting down on the project schedule would be to implement the SIPS schedule mentioned previously. This should cut down on the total phase duration and improve the daily output of the workforce. All of which will save the owner money. An analysis will have to be run that defines what is the best way to divide the galleries into sequential work sections so that the work will be as productive as possible. The systems in the gallery would have to be researched in depth in order to better understand how the galleries will come together and what flow of trades would accomodate this properly. This however, would only be the first step in shortening the gallery fit-out phase.

Next, some of the longer activities in this phase will be investigated to see if they can be prefabricated off-site. For exampe, the typical duration for the activities in this phase are approximately 15 days. These types of activities include installing hangers, sprinklers, and ceiling panels. However, there are a few activities that are significantly longer than the rest which tie up the galleries and in effect delay the succeeding work from being performed. These activities include MEP rough in at 40 days, layout and installation of the W5 ceiling sections at 60 days, and installing the sleepers and plywood subfloor at 45 days. If any of these activities could be prefabricated off site and erected into place a significant schedule savings could be achieved. This would also tie into the SIPS schedule much better because a SIPS schedule works much better if each actvity duration is similar or the same. Each of the aformentioned systems would have to be investigated to determine if prefabrication is feasible or not. Also, case studies of similar prefabrication should be researched in order to better understand the challenges associated with that particular type of prefabrication. Finally, productivity rates for this type of work must be investigated in order to compare field productivity to off-site productivity. If feasible the combination of a SIPS schedule and prefabrication of select systems could provide a significant schedule savings on the project.

Curtainwall System

As mentioned previously the curtainwall system is one of the most expensive systems on the MMAA. It consists mainly of a metal clad rainscreen system that is backed up by a insulated metal stud wall. At $30.6M and $137 per square foot this system is excessively expensive. This is another area of potential study for the spring semester.

First, the system could be looked at in detail to see if there are any ways to make the construction of the system more economical by increasing productivity. This could possibly be done by looking to prefabricate the back up system. First, the project team would have to be contacted to see exactly how thay are planning to construct the system. Then after looking into the system an analysis would need to be done to see if it is feasible to prefabricate this system or not.

If prefabrication does not produce a significant savings and no other productivity savings could be found then an analysis of system alternates could be used. As mentioned in the value engineering section, it would be important to ensure that any changes to the system would not detract from the goals of the owner. The alternate system cannot be simply a cheaper system that is not of the same quality as the currently specified system. An important criteria would be that it is if equal value to the owner or better to proceed. There are many types of metal curtainwall systems on the market and significant research would need to be conducted in order to find a acceptable substitute. Also, detailed pricing information and labor rates would be required from the project team in order to effectively compare the two systems. One of these two soultions should be able to bring value to the owner without reducing the quality of the end product.

APPENDIX A

PACE ROUNTABLE NOTES

Student Name Vincent Rossi

Session #1

Topic: Supply Chain – Integrating Strategies & Technologie

Research Ideas:

- Information & Communication Barriers.
- Procurement Strategies
  * Early Procurement to mitigate risks.
  * Store off site until needed.
  * Need to know what you need early.
- Technology.
  * RFID tags. – from fab to inspection
    - helps greatly w/ QC.
    - issue with allocation of resources
      → office/field.
- Develope relationships & be the "squeaky wheel".

Session #2

Topic: Modularization.

Research Ideas:

- Schedule + Quality → Safety
- Design to be repetitive
  ↳ key is early involvement.
- Multi-trade takes a lot of early involvement.
  → Makes delivery method key.
- Prefab Labor – break even still reduces risk significantly.
- Diminishing returns for small modules.

Industry Panel: Differentiation in a Down Economy

Research Ideas:

(1)

Not Applicable to This Pace Roundtable.

(2)

Industry Member Discussion

Key Feedback:

Which research topic is most relevant to industry? What is the scope of the topic?

* PREFABRICATION.
  - Possibly metal stud backup wall for curtainwall.
  - Possibly gallery space prefabrication.

* LEED points not going after?

* Steel System for large column free gallery.
  - Possible alternates?

Suggested Resources:

What industry contacts are needed? Is the information available?

* Mostly need input from the project team.

* Case studies or contractors who have prefabricated similar items.

APPENDIX B

WORKS CITED

WORKS CITED

Del-Mar Enterprises. "Overtime Productivity Losses." *Del-Mar.com*. N.p., n.d. Web. 5 Nov. 2012. <http://www.del-mar.com/Templates/Overtime%20and%20Productivity.pdf>.

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