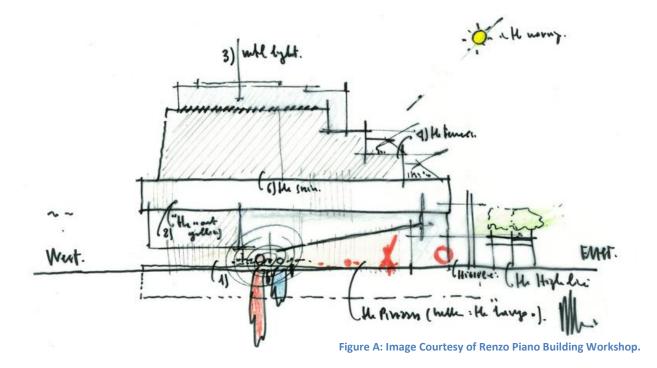
FINAL REPORT

The Metro Museum of American Art



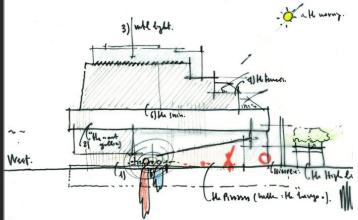
Vincent A. Rossi

The Pennsylvania State University Department of Architectural Engineering Construction Management Option

> AE 481W – Spring 2013 Faculty Advisor: Ray Sowers

This Thesis Final Report will provide an in depth analysis of the Metro Museum of American Art (MMAA). Analysis topics include the feasibility of prefabricating the MMAA gallery ceiling, redesigning the MMAA gallery ceiling, implementing a SIPS schedule for the gallery fit outs, exploring the union division of labor issues associated with implementing a prefabrication process, and exploring expanding the BIM use on the project.

THE METRO MUSEUM OF AMERICAN ART



MAJOR CITY, USA

Project Overview

Function	Museum
Project Cost	\$266 Million
Total Stories	9
Size (GSF)	222,952
Construction Dates	10.13.11 - 11.28.14
Project Delivery Method	Design-Bid-Build

PI	roject Team		Α
	Owner	Metro Museum	
	Design Architect	Renzo Piano Building Workshop	
	Architect of Record	Cooper Robertson & Partners	
	Construction Manager	Turner Construction Company	
	MEP Engineer	Jaros, Baum, & Bolles	
	Structural Engineer	Robert Silman Associates	

Mechanical System

- The gallery and office spaces will be served by an all-air, variable air volume conditioning system. This system will consist of a total of four air conditioning units.
- The chilled water originates from three electrically driven centrifugal refrigeration machines that are sized at 300 tons-refrigeration each.
- Five condensing three million BTU hot water boilers provide the heat for the building.

Architecture

- 50,000 square feet of interior gallery space and 13,000 square feet of outdoor gallery space.
- Large cantilevered entrance invites the public into the space and gives them a space to gather.
- The abandoned highline runs along the east side of the building and has been turned into a park / pedestrian walkway.
- The east side of the building is stepped away from the street & highline providing terraces and excellent views of the city.

Structural System

- The structural system for the MMAA consists of a concrete slab on composite metal deck that bears on structural steel framing.
- The structural system uses multiple concentrically braced frames to resist the horizontal forces on the building.



All images are courtesy of Renzo Piano Building Workshop.

VINCENT A. ROSSI – CONSTRUCTION MANAGEMENT OPTION http://www.engr.psu.edu/ae/thesis/portfolios/2013/var5039/index.html

EXECUTIVE SUMMARY

The Senior Thesis Final Report displays the research and findings of four analyses that were performed on the Metro Museum of American Art (MMAA) project. The MMAA is a new construction building that is being built in order to house the expanding galleries of the MMAA. It is a \$266M job that has a construction schedule of approximately 37 months. The building is 222,952 GSF large which gives a cost per square foot of approximately \$1,200. The goals of these analyses are to expedite the interior fit out schedule so that the risk associated with this phase can be mitigated.

Analysis 1A: Gallery Ceiling Prefabrication

The first analysis focused on the gallery ceilings due to the long schedule lengths associated with them. The MMAA has five galleries throughout the building that take on average 416 working days to completely fit-out; with 100 of these days devoted to the installation of the gallery ceiling system. In order to cut down on this installation time the fifth through seventh floor galleries were prefabricated off site and transported to the site ready to be installed. This analysis resulted in a five week reduction of the project schedule and an estimated \$346K in savings.

Analysis 1B: Gallery Ceiling Redesign

This analysis also focused on the gallery ceiling due to their long schedule length. Instead of prefabricating the ceiling, this analysis looked to completely redesign the ceiling system in order to facilitate simpler construction methods. The redesign saw the complex network of steel component that originally defined the ceiling system get replaced with suspended ceilings that include acoustical panels, open cell grid, and exposed structure. This analysis would ultimately save five weeks of schedule time and an estimated \$1.18M. Note that this analysis includes architectural and acoustic breadths.

Analysis 2: Gallery SIPS Implementation

The second analysis looked to implement a SIPS schedule on the project. This analysis was used in order to speed up the lengthy gallery fit out schedule. Activities were originally scheduled start to finish with each trade occupying an entire gallery. By dividing up the galleries into zones and adjusting the workforce productivity the SIPS turned out to be very successful; it shortened the project scheule by 5 weeks and saved the project an estimated \$497K.

Analysis 3: Critical Industry Issue: Union Division of Labor

The third analysis focused on the critical industry issue of the union division of labor when utilizing a prefabrication process. The main issue associated with the union division of labor is determining who gets to lift the completed modules into place because there are multiple trades of work complete on the modules. In the MMAA case the iron workers would be the ones to lift the modules into place because their work defines the structure of the ceiling system and their work connects the modules to the structural steel above. The other trades would be allowed one representative to be present during the installation to ensure that their work is not damaged during the hoisting process.

Analysis 4: Extending the Use of BIM on the Project

The fourth analysis focused on expanding the BIM use on the project. 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 that would provide value to the project. This analysis used the *BIM Project Execution Planning Guide Version 2.1* that was researched and developed by the Computer Integrated Construction Research Program at the Pennsylvania State University in order to identify 4D modeling and site utilization planning as potential BIM uses that would be beneficial to the MMAA. A project execution plan was also developed for the MMAA.

ACKNOWLEDGMENTS

Industry Acknowledgments



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Bob Holland – Architecture Advisor

Penn State AE Faculty



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Whitney Museum of American Art

Family and Friends

Images courtesy of Turner Construction and Renzo Piano Building Workshop Respectively

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PROJECT BACKGROUND

Metro Museum of American Art (MMAA) building is a new construction building that will house the art 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 the museum 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. One of the main goals of this thesis will be to evaluate any opportunities for the long gallery fit out schedule to be reduced. 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.

SITE PLAN & EXISTING CONDITIONS

The existing conditions site plan can be seen in Appendix A. In order to get a better understanding of the project site's constraints refer to this plan when reading the text below.



Figure 2: View of the site from above. Courtesy of google.com.

The construction site for the Metro Museum of American art is located in the downtown area of a major US city. Access to the site can be difficult especially during rush hour traffic times. The MMAA site is one block wide east to west and approximately half a block wide north to south. As shown in Figure 2, on the west side of the building is a main vehicular highway and just beyond is the city's river. Directly adjacent to the west side of the building is street "C", which is a small back road that eventually has access to the highway. Along the south side of the MMAA site is а 90' tall existing structure. Separating the MMAA and this structure is street "B" which is on average 30'



Figure 3: View of the highline walkway taken from across street from the southeast corner of the site. Photo taken by Vincent Rossi.

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wide from sidewalk to sidewalk. On the east side of the building runs the highline structure. Seen in Figures 3 & 4, the highline is an abandoned metro line that has been transformed into a pedestrian walkway / park. It is approximately 20' off the ground and runs along the entire east side of the MMAA. Past the highline is street "A" and across the street are various shops and restaurants. At the north east corner of the site is a separate and ongoing construction project. This project is the construction of the highline maintenance building. Its finish height will be at the sixth floor of the MMAA, and this project will be completed before the MMAA. The north side of the building is lined with some of the old manufacturing district buildings and warehouses. These buildings are not very tall; with the closest building adjacent to the MMAA being only 30' high. Note that there is no parking listed on the site plan due to the fact that space is limited around the site and no worker parking is available directly at the site.



Figure 4: View of the southeast corner of the site and the termination of the highline walkway. Photo taken by Vincent Rossi.

Also, note that the original phasing plans for the excavation, foundation, and superstructure phases can be seen in Appendix B. These phase plans really highlight how constricted the MMAA will be when all of the construction equipment and temporary facilities that are required to construct museum arrive on site.

LOCAL CONDITIONS & CLIENT INFORMATION

This section will describe the local conditions associated with the project including typical construction methods in the region, parking availability, and subsurface soil and water conditions. Next the owner of the project and their expectations will be described.

Local Conditions

The MMAA is located in a major US city that has a vast history of building skyscrapers. Although the MMAA is not a skyscraper (topping out at approximately 170 feet) it still utilizes some of the same type of construction methods that skyscrapers do. It uses caissons/piles to bear directly on the bedrock below the surface. The superstructure consists of concrete slab on composite metal decking that bears on structural steel. This type of construction is very common in the area and is one of the preferred methods of construction.

One problem that naturally comes with being in a city is the lack of available parking. This is especially true at the MMAA where there is no on-site parking available for the workers. Even going to visit the site, it is difficult to find a parking spot within walking distance of the site. There will be no parking provided for the workers who will be responsible for getting themselves to the site daily.

URS supplied the owners and project team with a full geotechnical report that detailed the subsurface soil and water conditions. An interesting finding of the report is that the shoreline of the city's river used to be just east of the site, so the entire site was underwater at this point in time. The groundwater was measured at the site to be approximately 6.5 to 12 feet below the surface. Also, the report found that the site has anywhere from nine to 30 feet of fill material below the surface. Underneath this fill is a layer of organic silt and clay that is thicker on the west side of the site and thins out moving east. The general thickness of this layer ranges from 36 feet to five feet. Below this is a four to ten foot layer of clayey sand followed by a layer of sand and glacial till. Finally, bedrock was encountered and varied in depth from 75 to 91 feet

below the surface except for a section on the far east side of the site where the depth of bedrock dropped off to a range between 110 and 119 feet below the surface.

Due to the poor soil conditions under the site it was recommended that the foundation consist of caissons/piles that are socked into bedrock. Also, due to the high water table the foundation slab would have to be designed to resist the hydrostatic uplift forces. This is why the foundation slab is designed as a pressure slab that has the capacity to resist the tensile forces that this will create. A section of this foundation wall/slab can be seen to the right in Figure 5.

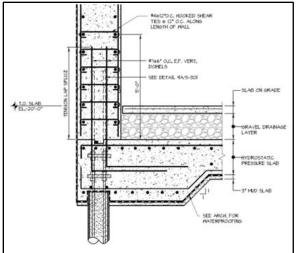


Figure 5: Sectional view of the foundation slab to wall connection. Courtesy of Renzo Piano Building Workshop.

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Client Information

The Metro Museum of American Art is an art museum that displays works of art from the twentieth and twenty-first centuries. Ever since its founding in the early 1900s, it has been expanding and growing its art collection as well as its following. Because of this they have decided to build a new facility in a downtown location. The MMAA will expand to this location which will provide ample gallery space for its collection, an education center, and many other amenities. This expansion will provide the MMAA the opportunity to grow and become part of the community even more than it is already. One way that the museum will give back to the community is by having the 1st floor gallery open and free to the public at all times.

The owner expects this building to be of a very high quality. Its overall cost per square foot is approximately \$1,200. Because of this, implementing a good quality control plan will be key element in providing owner satisfaction. Another important item is keeping the project on schedule so that the temporary certificates of occupancy can be issued on time. Approximately half of the building is to receive its temporary certificate of occupancy on September 8th of 2014, while the full building temporary certificate of occupancy is scheduled for November the 28th 2014. These items need to be completed successfully in order to have a satisfied owner.

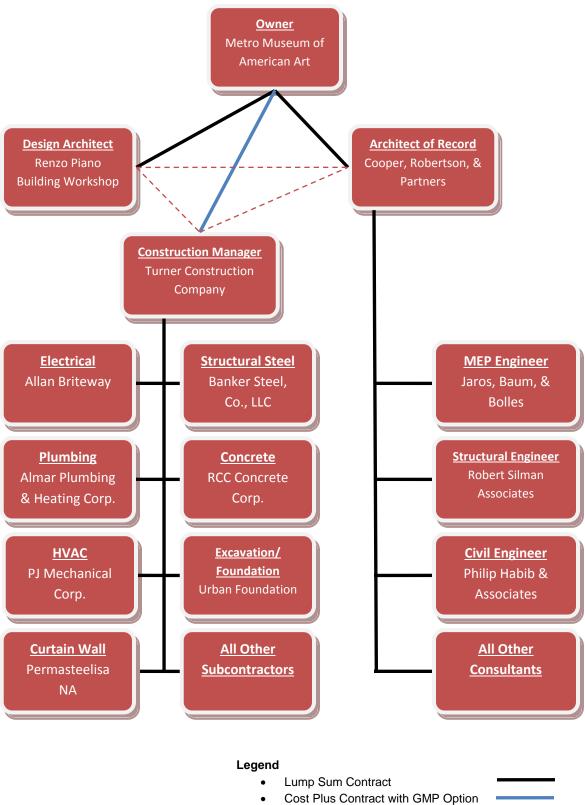
PROJECT DELIVERY SYSTEM

Turner Construction Company was awarded the work because of their high industry reputation and expertise. They are one of the premier contractors in the United States and are capable of successfully delivering large and complex projects like the Metro Museum of American Art. Before bidding, Turner provided some preconstruction services for the MMAA ownership. This included Turner's estimating department putting together design development estimate by obtaining proposals from subcontractors. This allowed the Metro Museum ownership to be confident that they had the proper financing in place for the job, and also gave Turner a leg up on the competition when bidding because they had already become familiar with the project conditions.

The project delivery method for the MMAA is Design-Bid-Build. As stated before, Turner Construction Company was awarded the work and entered into a cost plus contract with an option for a Guaranteed Maximum Price (GMP) for the owner. There are liquidated damages for completing the project late; however, those values are not public. Also, any bonus information for early completion and any savings sharing information are not public. Turner will bond all of the subcontractors through their subguard program. A subguard is used in lieu of traditional performance and payment bonds and covers all of the subcontractors on the project in one policy. In this policy if any of the subcontractors defaults the insurance company will step in and provide compensation. Turner also has a contractor controlled insurance policy (CCIP) which wraps the general contractor and all of the subcontractors under a single general liability / workers' compensation policy. Also, builders risk insurance is carried by the owner on this project.

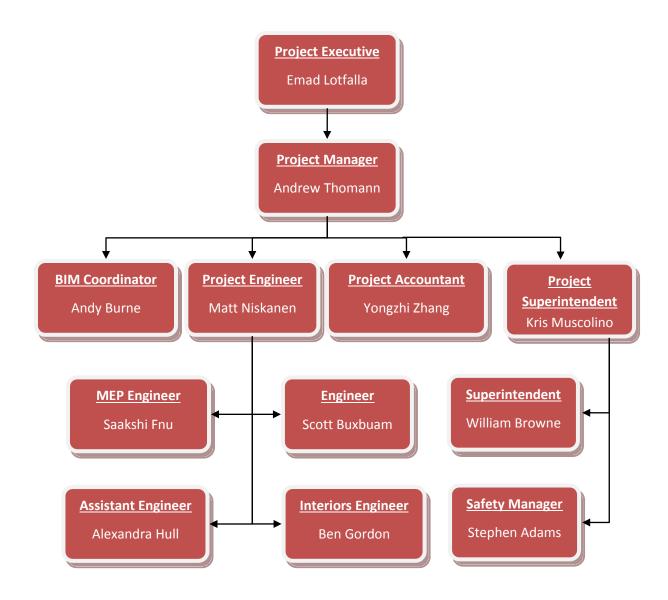
On the next page is an organizational chart for the project that details all of the main parties involved and their relationships by contract type. As mentioned earlier Turner is contracted with the owner through a cost plus contract that has an option for a GMP. The subcontractors are contracted directly with Turner with the approval of the Metro Museum ownership. Each of the work packages are hard bid to a minimum of three bidders with the scope being checked by Turners purchasing department to ensure that no scope coverage is missed. The contracts between the owner and the design architect and architect of record are listed as lump sum contracts. The contracts. Finally, there are lines of communication shown between all of the main design and building parties.

Project Organization Chart



STAFFING PLAN

The project staff is located a block north of the construction site. Here, they have established their office for the duration of the project. A project staffing plan can be seen below that was created using the project directory and consulting with the project team. Everybody in this staffing plan works out of the field office except for the project executive. The number of superintendents on site could be more than what is shown depending on the amount of work being done on site. Also, Turner has BIM capable team on site that is led by Andy Burne. Different individuals of the team will focus their efforts on one building system. For example, Ben Gordon is working on coordinating the interior work of the building especially the gallery spaces. This will allow the team to understand the entire building more intimately.



PROJECT SCHEDULE SUMMARY

The project schedule for the Metro Museum of American Art (MMAA) was made using Primavera P6 scheduling and can be found in Appendix C. This schedule breaks down the scope of the work by trade and details the work that will be performed by those different trades. The schedule consists of approximately 200 activities and milestones that starts with the installation of the cassions/piles and finishes with the issuance of the temporary certificate of occupancy for the building. The project 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. The level of detail in this schedule allows for the sequencing of the work to be understood without being too excessive in detail. The detailed schedule is organized by the different major trades / activites such as excavation and foundation, structural steel, and enclosure. Some of these phases that are driving the project will be discussed in detail in the following section. Below in Table 1, all of these major project phases are summarized in order to give a quick overview of the project.

DETAILED SCHEDULE OVERVIEW				
Phase	Start Date	Finish Date	Duration (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	

Table 1: Detailed Project Schedule Overview

* 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. This will be explained more in detail in the following section.

Excavation & Foundation

The first scheduled activity for the excavation/foundation phase is the drilling of the caissons/piles. After this the general excavation can begin. The access for equipment and trucks to the site/ramp is located at the southwest corner of the site. Due to this the excavation, soil retention, and foundation work will begin on the east side of the site and work its way west until the excavation and foundation are fully complete. This is why the entire excavation/foundation schedule is divided into two main sections; the west side and the east side. The west side activities will start approximately one week after the east side's do. Also,

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these main sections are broken down into sub-sections such as the north and the south/east sub-sections for the east side. This is done because the construction techniques for the excavation, soil retention and ultimately foundation construction are slightly different depending on the section of the site plan. For example, on the west side the north/south sub-section receives shotcrete, whalers, and cross lot bracing for its soil retention. Meanwhile the west subsection receives tiebacks and shotcrete to retain the soil.

Once this is complete the construction of the foundation can begin. This process will also progress from the east to the west side of the site starting with the pouring of the mud slab and waterproofing. The foundation consists of a 2.5' cast in place foundation wall that ties into a hydrostatic pressure concrete slab that is being supported by caissons/piles. There is also a 5" concrete wearing slab above a 19" gravel drainage layer that acts as the finish slab on grade for the cellar level.

Structural Steel

The important dates of the steel erection process can be seen in Table 2. As you can see once the excavation and foundation work is nearing completion the structural steel team will mobilize and start erecting the cranes that will be needed for the steel erection process. The crawler crane will be erected first, followed by the tower crane. From there the steel erection will start on the first floor.

	~	.		
labi	e 2:	Steel	Erection	Dates

IMPORTANT STEEL ERECTION DATES		
Description	Date	
Crane Mobilization	02-Aug-12	
Steel Erection Starts	14-Aug-12	
Foundation Complete	24-Aug-12	
Steel Erection Complete	14-Feb-13	

There is no special phasing for the steel erection; each floor's framing will be erected in its entirety before the erectors move up to the next building level. Once a floor is erected completely the raising gang can then move on to the next level and repeat until the steel is topped out. After the raising gang has moved on to the next level the steel detailing can begin. This includes tightening and plumbing the structure as well as laying the metal deck. See Table 3 for some of the typical durations for the steel erection process.

Table 3: Typical Steel Erection Durations			
TYPICAL STEEL ERECTION DURATIONS			
Description	Days		
	Days		
Average Erection Duration per Floor	11		
Average Detailing Duration per Floor	22		
Total Duration of Steel Erection / Detailing	129		

Superstructure Concrete

Following the completion and turnover of a floor by the steel erection team the cast-in-place concrete contractor will be responsible for installing their work. Typically, for this project, there will be a scheduling lag with an average of 14 working days between the steel turnover of a floor until the concrete workers start roughing in their work. This is to allow the structural steel team to work their way up a few floors so that there is a few layers of metal decking protecting any workers below from safety hazards such as falling debries. The cast-in-place concrete team

consists of two teams of workers; the first will rough-in each floor and the next team of workers will install the rebar/mesh and place the slab on deck. Once the workers start their work it will take the rough in crew five to ten days to complete their work and the reinforcing/placing crew five to ten days to complete their work depending on the size of the floor. Once a crew is finished with their work they will move on to the floor above until all floors are complete.

Enclosure

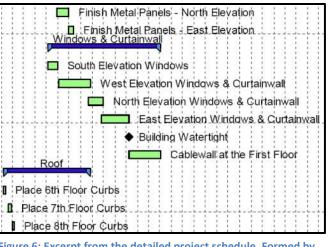
The enclosure for the MMAA consists mainly of precast concrete panels and a carbon steel rain cladding system. The schedule of activities for the wall enclosure starts with the erection of the metal panels followed by the precast concrete panels and the windows and curtainwall. Also the roof installation starts at approximately the same time as the metal panel erection. A detailed overview of the building enclosure start dates, finish dates, and durations can be seen in Table 4.

DETAILED ENCLOSURE SCHEDULE OVERVIEW				
Activity	Start Date	Finish Date	Duration (Days)	
Roofing Curb Placement	05-Feb-13	21-Mar-13	45	
Metal Panels	06-Feb-13	12-Aug-13	132	
Precast Concrete Panels	04-Mar-13	24-Apr-13	38	
Install Roofing	11-Apr-13	26-Sep-13	169	
Windows / Curtainwall	05-Jun-13	02-Apr-14	212	
Building Watertight	N/A	07-Jan-14	1	

Table 4: Enclosure Overview

As you can see from Tables 2 and 4 both the roofing curb placement and metal panel erection starts before the steel is topped out. Floors six an up all receive roof curbs due to the stepped nature of the building. The metal panel erection is split into two phases which include the erection of the back up system and then the finish metal panels themselves. The sequencing of

the metal panels will start with floors two through five of the south elevation of the building and move counterclockwise to the west, north, and finishing on the east elevation. Once the back up panels start to be erected on the lower west elevation the erection of the back up panels on floors six through the roof will begin on the south elevation and continue in the same order as the lower back up panels. The construction of the finish metal panels will begin once the back up panels start to be erected on the upper east side of the





building. The finish metal panels will also start on the south elevation and move counterclockwise.

An interesting note about the enclosure schedule is the fact that the building watertight milestone occurs before the end of the enclosure phase. This is atypical in building construction; however, it can be explained by looking at Figure 6 on the previous page. The windows and curtainwall sub-phase is the last to be completed in the enclosure phase. The building is watertight after the east elevation windows and curtainwall are complete but before the cablewall at the first floor is started. This is simply due to the fact that the cablewall at the first floor does not need to proctect the building from the elements outside and is mainly an aestetic element of the building enclosure.

Interior Fit-Out

The longest phase of the project as listed on the schedule is by far the interior fit-out. This is due mainly to the long durations for the gallery fit-outs. As you can see in Table 5, the average duration for a gallery fit-out is 416 working days which translates to approximately 19 months. The gallery fit-outs are really all inclusive and include everything from installing hangers in the above deck to completing punchlist items. A typical schedule of activities for a gallery fit out can be seen in Appendix C under the fifth floor gallery fit-out sub-phase. The sixth, seventh, and eighth floor galleries all have a similar scheduling of activities even though their durations are not exactly the same.

GALLERY FIT-OUT SCHEDULE OVERVIEW				
Gallery	Start Date	Finish Date	Duration (Days)	
1 st Floor Gallery	19-Dec-12	26-Jun-14	390	
5 th Floor Gallery	29-Jan-13	19-Aug-14	401	
6 th Floor Gallery	12-Feb-13	16-Sep-14	411	
7 th Floor Gallery	21-Feb-13	14-Oct-14	424	
8 th Floor Gallery	28-Feb-13	28-Nov-14	452	
Average	N/A	N/A	416	

Table 5: Gallery Fit-out Overview

PROJECT COST EVALUATION

In order to fully comprehend the costs associated with the Metro Museum of American Art, it was important to review the cost data for the project and to prepare some preliminary estimates. This includes reviewing the overall building cost data and the breakdown of the different systems within the building.

Building Cost Data

Here, the buildings cost is displayed in two forms; as the construction cost and as the total project cost. The construction cost is the costs associated with the physical construction of the building. This cost leaves out land costs, site work, permitting, general conditions, and fees. The total project cost is the cost associated with the delivery of the entire building. This cost data does include all of the aforementioned exclusions. This cost data can be seen in Table 6 below. As you can see from these tables the cost for this museum is very high per square foot, around \$1,200. This is due to the high end finishes, its unique design, and other factors which will be addressed in the coming sections.

Table 6: Building Cost Data

BUILDING COST DATA		
Description	Cost (\$)	Cost (\$/SF)
Construction Cost	\$213,690,741	\$958.46
Total Project Cost	\$266,345,323	\$1,194.63

Next, some of the main building system costs are highlighted. This can be seen in Table 7. The table breaks the cost down into total cost, cost per square foot, and percent of total building cost. As you can see the curtainwall system on the building is the highest priced system on the building. This is because the majority of the curtainwall system is constructed using a carbon steel rainscreen cladding system. This unique building material really drove up the cost of this building system.

BUILDING SYSTEMS COST DATA				
Building System	Cost (\$)	Cost (\$/SF)	% Of Total	
Excavation & Foundation	26,559,609	119.13	10.0	
Structural Steel	21,209,500	95.13	8.0	
Superstructure Concrete	5,300,831	23,78	2.0	
Drywall/Carpentry/Ceilings	17,723,026	79.49	6.7	
Curtainwall	30,637,767	137.42	11.5	
HVAC Work	24,432,743	109.59	9.2	
Electrical Work	24,845,611	111.44	9.3	

Table 7: Building Systems Cost Data

General Conditions

The general conditions estimate for the Metro Museum of American Art can be considered the operating costs for the job site. It include personnel, field offices, temporary utilities, insurance, bonding, and other miscellaneous costs. Personnel costs are the costs of the staff's salary and benefits. Insurance and bonding costs include builders risk insurance, general liability insurance, payment and performance bonds, permiting, and Turner's subguard program. Finally, the miscellaneous costs are associated with items such as the field office rent, supplies, temporary utilities, telephone bills, and job clean up. The general conditions estimate is based off of a 37 month construction schedule. Because of this a monthly cost for general conditions can be determined . This along with a summary of the general conditions estimate can be seen below in Table 8.

Table 8: General Conditions Summary

GENERAL CONDITIONS SUMMARY				
Section	Total Cost (\$)	Cost per Month		
General Conditions	\$15,722,000	\$424,919		
**Note that the estimate is ba	ased on a project duratio	on of 37 months.		

The general conditions on the MMAA were a significant part of the project budget. They were budgeted to cost \$15,722,000 which is approximately 6% of the total project budget. There are a few reasons why the general conditions cost is so high on this job. First off the project is large and complex which demands a large amount of personnel and facilities costs in order to manage the job properly. Also, managing the downtown site location and finding suitable space for management offices would be a costly endeavor. The project team has rented office space a block away from the project site so that they do not take up valuable space on construction site with job trailers.

The main takeaway from this exercise is showing that any schedule overruns would be extremely costly by themselves through added general conditions costs, let alone adding on the liquidated damages that would be incurred from turnover delays. On the other hand if Turner is able to deliver the project early it would be extremely beneficial and save a significant amount of money on the project.

ARCHITECTURE OVERVIEW

Interesting Architectural Features

One of the most attractive elements of the building is the large cantilevered entrance. This space gives the building an interesting appeal to people walking down the street and invites them into the space. It also will serve as an extension of the interior of the building giving the patrons a place to gather. This cantilever can be seen in Figure 7 in the bottom right portion of sectional rendering.



Figure 7 (Right): Sectional rendering of the Museum looking north. Note the cantilevered entrance and the stepped floors creating multiple terraces. Figure 8 (Left): View of Metro Museum from the north. Courtesy of Renzo Piano Building Workshop.

The building site has an abandoned above ground metro line that runs from the north east corner of the site and terminates at the south east corner of the site, which is the entrance of the building. This metro line has been turned into a green walkway / park that pedestrians can use. Figure 8 shows a view from this walkway looking south onto the Metro Museum. This element of the site will be one of the main reasons for the stepped nature of the building described below. The buildings architecture is defined in part by this abandoned metro line.

Another interesting feature of the Metro Museum is the stepped nature of the building which can also be seen in Figure 7. The east side of the building, which faces the elevated metro line, steps back with each floor creating an outdoor terrace on the roofs of each level. This terrace provides the opportunity for exterior gallery space and also provides excellent views of the metro park and the city itself.

Building Enclosure

The Metro Museum has ten different exterior wall types. However, the majority of the building enclosure is made up of a metal panel system. This wall type is an insulated stud wall with an exterior steel plate rain screen cladding system and punched in windows. A section of this wall type can be seen in Figure 9 on the next page. Other elements that make up the building enclosure include pre cast concrete planks, and various types of curtain wall glazing.

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Building Roofing

Multiple roofing systems make up the building enclosure. Here the primary systems will be described. First, the south roof has multiple clearstories running east to west that add natural light to the 8th floor gallery space. Around these clearstories the roofing consists of a gutter system with painted galvanized metal grating with snow melting cables where the gutter is less than five feet wide. Below the grating there is a layer of gravel followed by a composite drainage panel and waterproofing membrane.

Next the north side of the roof is made up of integrally footed pre-cast concrete pavers that are backed up with ridged insulation and a composite drainage panel. Located in the middle of the north roof and surrounded by these concrete pavers is a green roofing system. This system is made up of a 4" layer of growing medium, filter fabric, drainage tray and a moisture retention mat. Below this there is a root barrier, ridged insulation, and a waterproofing membrane.

Due to the stepped nature of the building a lot of the building's roof area has been turned into terraces. These terrace roofs consist of a 4" wearing course of cast in place concrete that is backed up with ridged insulation, a composite drainage mat, and a waterproofing membrane.

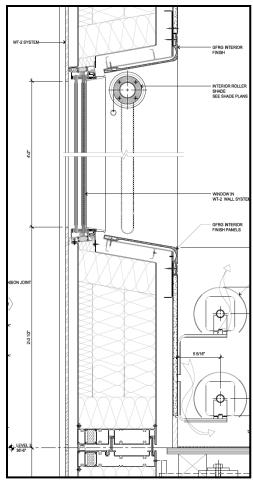


Figure 9: Section of the metal panel exterior wall type. Courtesy of Renzo Piano Building Workshop.

Sustainability Features

The goal for the Metro Museum is to achieve at least a LEED gold rating. To do this a LEED action plan was developed and the points worth pursuing were established. One of the main sustainability features is the green roof mentioned above. This along with other points such as construction waste management and enhanced commissioning will make the Metro Museum friendlier to the environment and to its occupants.

BUILDING SYSTEMS SUMMARY

The MMAA is a new construction building located downtown in a major US city 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. Table 9 outlines the major building systems associated with the construction of the MMAA. Each of these building systems will be discussed in detail in the following pages.

BUILDING SYSTEMS CHECKLIST			
Work Scope	Yes	No	
Demolition Required		Х	
Structural Steel Frame	Х		
Cast in Place Concrete	Х		
Precast Concrete	Х		
Mechanical System	Х		
Electrical System	Х		
Masonry	Х		
Curtain Wall	Х		
Support of Excavation	Х		

Structural Steel Frame

The structural system for the MMAA consists of a concrete slab on composite metal deck that bears on structural steel framing. The structural engineer, Robert Silman Associates (RSA), considered many structural systems such as a flat plate concrete system, post-tensioned concrete structure, and the system that would ultimately be used. RSA determined that the steel

frame with concrete on composite deck would be the most effective scheme because it is the lightest, most cost effective, and left the owner with most flexibility for future uses.

The structural system uses multiple concentrically braced frames to resist the horizontal forces on the building. These braced frames are located throughout the building and consist of mainly W shaped steel members; however a few of the braced frames utilize HSS shapes as well. There is also one large truss/braced frame that runs along the entire south side of the building between the fifth and sixth floors. This location is adjacent to where the largest column



Figure 10: Photo of the crawler crane on site. Photo taken by Vincent Rossi.

free gallery in the city is located.

The nine story building is framed with mainly with W shaped structural steel members that are connected with a mix of shear and moment connections. There is also horizontal bracing consisting of HSS and L shaped members within the floor framing where needed. The columns are almost all W12 or W14s with the exception of a few custom made pipe and bar columns.

There are two cranes on site during the steel erection. First there is a Liebherr LR 1200 crawler crane, shown in Figure 10, located on the south central perimeter location of the site. Also there is a Favelle Favco tower crane, shown in Figure 11, whose tower ascends through the

grand staircase of the museum. The locations of the

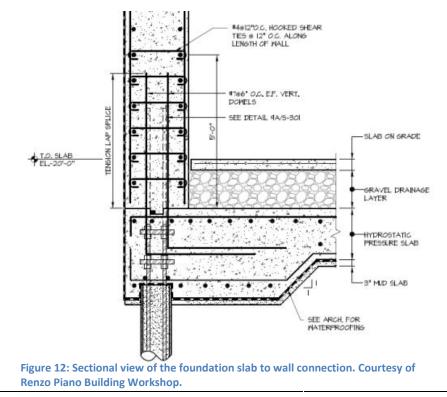


Figure 11: View of the tower crane on site. Photo taken by Vincent Rossi.

cranes can be better understood from looking at the site logistics plan located in Appendix B.

Cast in Place Concrete

Cast in place concrete was used throughout the Metro Museum. The foundation system is in effect a concrete bathtub because the cellar elevation is twenty feet below the water table. As shown in Figure 12, the foundation consists of a 2.5' cast in place foundation wall that ties into a hydrostatic pressure concrete slab that is being supported by caissons/piles. There is also a 5" concrete wearing slab above a 19" gravel drainage layer that acts as the finish slab on grade.



As mentioned previously the floor systems are composed of concrete slab on deck (SOD). There are multiple different variations of this floor system including the following examples.

- First, a 3-1/4" light weight concrete slab on 3"-18 gage composite metal deck is used for all of the gallery spaces.
- Another SOD system consists of a 6" normal weight concrete slab on 3"-18 gage composite metal deck that is used as the floor of the third floor theatre.

The methodology for the concrete placement is that the concrete will be pumped into place and the metal decking will act as the horizontal formwork. Also, for the vertical slab formwork, the slabs will have either a pour stop or a 3/8" bent plate along the slabs perimeter.

Precast Concrete

Precast concrete is used as in interior and exterior wall type for the Metro Museum. As an interior wall type it is used throughout the core of the building up through level five and acts as part of a two hour firewall for the stairs and elevator shafts. Beyond this level partition walls are used to obtain the necessary two hour fire rating. This type of pre-cast concrete is divided into vertical planks that are one story tall and have various widths. They are fastened to the structural steel HHS members with embedded anchors and the joints are then sealed. These pre cast members are erected using the onsite crane and are scheduled to be erected as steel erection is still proceeding on the upper floors. Their erection will proceed only after the concrete SOD has been poured on the corresponding level and allowed to cure for seven days. One interesting note about the erection of these interior precast members is that the tower crane's tower passes directly through the shaft of the grand stairway. Because of this the precast planks that are scheduled to line the grand stairway need to wait to be installed until after the steel is topped out and the tower crane is deconstructed and removed from the site. After this, a separate crane can then hoist the remaining interior precast panels into place.

Various sections of the exterior wall enclosure of the building are also pre-cast concrete panels. There are seventy panels on the north elevation, seventy four on the south elevation, forty two on the east elevation, and thirty two on the west elevation for a total of 218 exterior precast panels. These panels will be hoisted into place using the onsite crane. Similar to the interior panels, the exterior panels will be connected to the structural steel elements such as W & HSS shapes using an embedded anchor. An example of this type of connection can be seen on the next page in Figure 13.

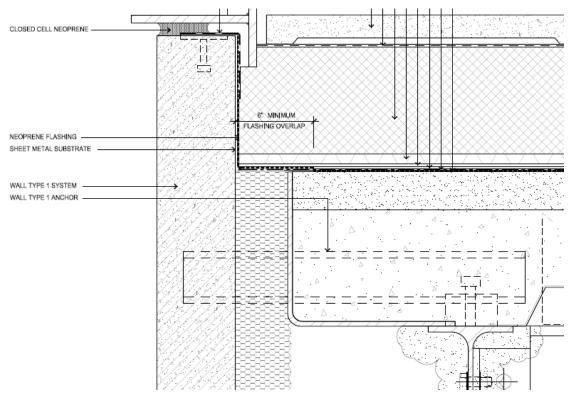


Figure 13: View of the support for the pre-cast panels. Courtesy of Renzo Piano Building Workshop.

Mechanical Systems

The mechanical makeup for the Metro Museum is complex and uses many different types of heating, ventilating, and air conditioning systems to make the building comfortable all year long. The air conditioning systems used for the galleries, office spaces, lobby, auditorium, and restaurant will be discussed here; including the feeds of the hot and cold water coils of these systems.

The gallery and office spaces will be served by an all-air, variable air volume conditioning system. This system will consist of a total of four air conditioning units. Three of the four units are located in the cellar fan room and will each handle one third of the load for the gallery/office spaces that are located between the cellar and seventh floors. The fourth unit is located in the fan room on the ninth floor and will serve the eighth floor spaces. Supply air to, and return air from, each floor will be carried through multiple mechanical riser shafts throughout the building. The supply air that will be going to the gallery spaces will be controlled by VAV units that are located adjacent to the air condition systems in the cellar or ninth floor fan rooms. Once the air is transferred to its destination it is delivered to and returned from the space by traditional diffusers and grilles in the office areas; or in the case of the galleries an open ceiling plenum is used for the return air. The lobby, auditorium, and restaurant are all conditioned by similar, but independent air conditioning systems. These systems are factory-assembled packaged all-air constant volume systems that are also located in the cellar fan room.

The chilled water for these mechanical systems originates from three electrically driven centrifugal refrigeration machines that are sized at 300 tons each. These are all located in the cellar of the building and each have an individual pump that will distribute the chilled water to its end users throughout the building. The building heat originates from a hot water boiler plant also located in the cellar that includes five condensing three million BTUh hot water boilers. Pumps then circulate the hot water to the air conditioning systems or finned tube radiators.

The fire protection system for the Metro Museum is a full building sprinkler system. The network consists of three different types of sprinkler systems; preaction, dry, and wet. The preaction system is used in sensitive areas of the Museum such as server rooms where accidental discharge of the system is critical to avoid. The dry system uses an air buffer in the lines so that the pipes do not burst in cold temperatures; this makes it an ideal system for areas such as the truck bay. Finally, the wet system is a generic sprinkler used in all other areas that the dry and preaction sprinklers are not being used.

Electrical System

Two electrical service lines enter the building's electrical room at the south west side of the cellar level from the vault / bus compartment of the service provider. Each line connects to a separate service switchboard that has a rating of 4,000A, 3ø, 4W, 208Y/120V. The two service switchboards also run a bus to two identical distribution switchboards that have the same rating of the service switchboards. From these four switchboards all of the power is distributed throughout the building.

An interesting idea that the project team had for the electrical service was to get at least partial service from the permanent electrical equipment up and running as early as possible on the project. In order to do this the masons would be directed to complete the interior electrical room first and then it would be made watertight before any other part of the building. Once this is done then the electrical equipment could be installed in the electrical room and the buildings permanent power source could be energized and distributed earlier than usual.

Masonry

The scope of the masonry work for this project is very small in comparison to the overall project size. In fact the unit masonry accounts for only 0.6% of the overall construction cost. A large portion of the masonry work is the construction of an insulated CMU exterior wall on the north elevation of the project where it edges up against the existing highline maintenance building. The rest of the masonry work is the construction of various interior partition walls throughout the building.

Curtain Wall

There are a total of ten different types of exterior wall systems that make up the building enclosure for the Metro Museum. However, only a few of them define the majority of the building; so those are the ones that will be discussed in detail. The wall type that is by far the most common on the building is the metal panel rain screen cladding system. It consists of a 5/16" thick steel plate cladding system with stainless steel fasteners and hardware attached to

custom extruded aluminum frames. Between these extruded aluminum frames is an aluminum liner sheet, galvanized steel sheet vapor barrier, and semi-rigid insulation. Anchor brackets connect the system to the structural frame of the building. The wall system is hoisted into place with the crane in two sections. First, the backup material for the metal panels is lifted into place. Then the metal panels themselves are lifted into place and the final connections are made. Figure 14 shows a horizontal section of this curtain wall.

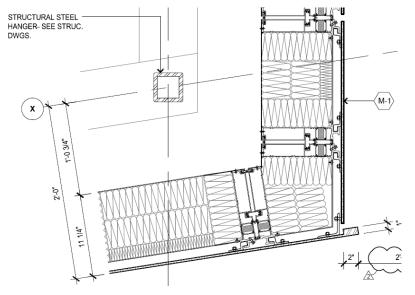


Figure 14: Horizontal section of the metal panel curtain wall. Courtesy of Renzo Piano Building Workshop.

Another curtain wall is the gallery storefront glazing system. It consists of a stick built system that has 3'4" wide insulated glass panels that are held vertically by extruded aluminum adapters and rest on custom mullions that are built-up steel tees. Once again, these are just two examples of the ten exterior wall types, but they are the most commonly found curtain walls on the building.

Excavation Support

As detailed before, the foundation for the MMAA is basically a concrete bathtub bearing on caissons/piles. Due to the downtown site location the excavation has to go vertically into the ground with no setbacks. There are a few different types of excavation support used for the construction of the MMAA foundations, including cross lot bracing, shotcrete and tiebacks, and soldier piles and walers.

As excavation progressed, the north and south sub sections of the west side received shotcrete treatment in order to retain the soil. Also, walers were used between the H piles to form a wall that would effectively retain the soil until the foundation walls were formed and poured. On the west sub section of the west side shotcrete was also used to initially resist the soil. Then tiebacks were installed in multiple tiers in order to retain the earth. The east side of the site also uses a mixture of shotcrete, tiebacks, and walers as excavation support.

Throughout the entire site cross lot bracing was installed as an earth retention system. It was generally installed in the north to south direction across the whole site. An example of the cross lot bracing can be seen in Figure 15. As you can see this photo was taken after the foundation walls had been cast and the structural steel erection had started. However, the cross lot bracing is still in place.

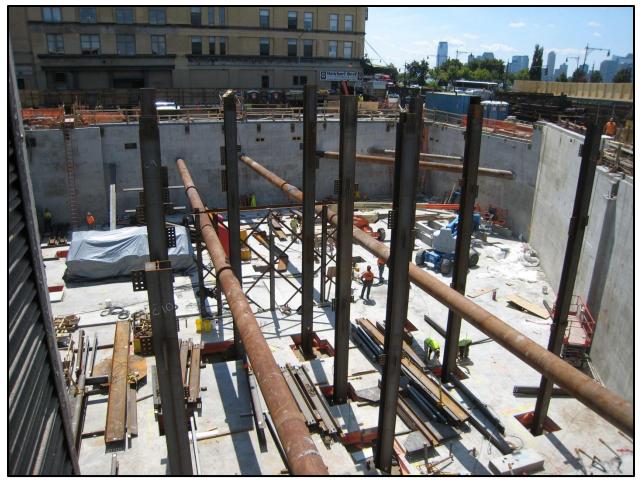


Figure 15: Photo of cross lot bracing located on the west side of the site looking south. Photo taken by Vincent Rossi

ANALYSIS 1A: GALLERY CEILING PREFABRICATION

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.

Analysis Goals

The main goal of this study is to investigate the cost benefit analysis of prefabricating the gallery ceiling. The driving factors of this analysis will determine if the benefits of prefabrication, such as increased productivity and shorter schedule time, outweigh the cons of prefabrication, such as accumulating increased trucking and warehouse rental costs. Determining how the prefabricated modules will be manufactured, transported, erected and installed into their final locations will complete this analysis. Then a schedule and cost analysis will be conducted to determine if this process is viable for the MMAA.

Background Information & Research

Preliminary research was completed and indicated that prefabricating the gallery ceiling was a viable option of study. 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 on the current schedule are listed as start to finish, which means one activity cannot start until the previous is fully complete. On the next page, Table 10, 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.

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 climatecontrolled 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

 Table 10: 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		

All of these benefits add value to the project. A cross section of the ceiling system can be seen in Figure 16 on the next page. As shown, 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. The problem was that the tight tolerances needed could not be achieved feasibly when manufacturing both the structural steel and the ceiling support system for prefabrication. These will have to be changed to a different type of connection such as a hanger in order to accommodate the needed tolerance for prefabrication.

The ceiling system consists of a grid of miscellaneous metal pieces bolted together. Running in the north-south direction are 10' W5 steel member sections. Figure 16 shows a cross section of the ceiling looking north. As you can see there are two W5 members that are approximately 11 inches apart from each other running parallel across the gallery space. These two members are connected together by the bent steel plate hanger. Supported by this hanger directly are the fire suppression system, electrical raceways, and the W5 members. This assembly is repeated in ten foot increments across the width of the gallery. Running in the east west direction between these assemblies is all of the lighting for the gallery spaces. It consists of track lighting strips that are enclosed by two steel angles, which are directly bolted to the W5 members using slotted connections. These strips are spaced every 3'4". All of the gallery space ceilings are designed in this manner. The only difference in the gallery spaces is the sixth and seventh floor spaces have a metal panel system enclosing the ceiling system, while the fifth floor leaves the above construction exposed. This can be seen in Figures 17 and 18 which are complete floor sections of the gallery spaces; note the ceiling panels are highlighted in red.

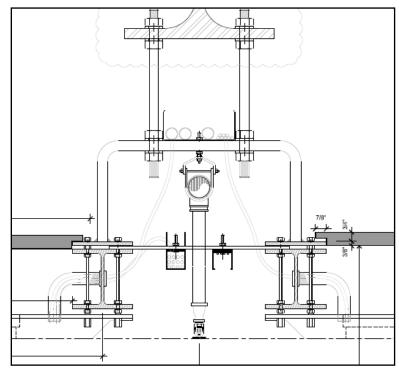


Figure 16: Section of the ceiling system looking north. Courtesy of Renzo Piano Building Workshop

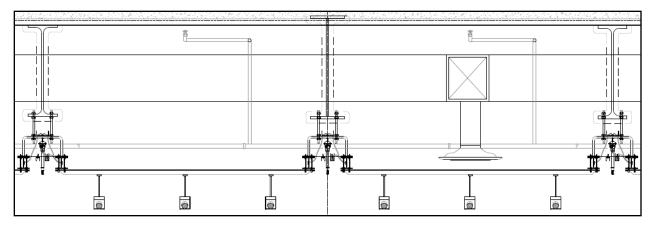


Figure 17: Fifth floor ceiling east west section showing the gallery ceiling system. Courtesy of Renzo Piano Building Workshop

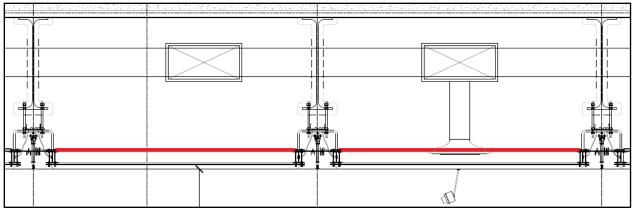


Figure 18: Sixth floor ceiling east west section showing the gallery ceiling system. Note the ceiling panels are highlighted in red. Courtesy of Renzo Piano Building Workshop.

Planning and Procurement

In order for a prefabrication process to run smoothly there must be a lot of coordination throughout the design and construction phases of the project. The MMAA gallery ceiling system consists of three main trades; miscellaneous metals, electrical, and fire protection. In order for the prefabrication process to run smoothly these contractors must work together along with the architect, general contractor, and the owner when planning for the prefabrication process. Typically, it is best for the prefabrication planning to begin before the project has even started. This allows for all of the parties to voice their concerns about the feasibility of the process and helps make it to be the most effective considering the individual project's constraints. Obviously, this means that the contractors would have to be on board with the project early on during the design phase.

This poses a potential problem when applying a prefabrication process to the MMAA. Typically due to the early involvement of the contractors a design-build project delivery method is preferred over the design-bid-build delivery method that the MMAA is being constructed under. A design-build delivery method gets the contractor involved in the design phase of the project so that they can provide their input to the owner and architect about what is feasible to construct and how the project can still meet the goals of the owner while providing the most value possible. This delivery method ties hand in hand with the prefabrication process because like the overall project it will benefit from having the contractors voice what problems could arise with the initial design of the prefabricated system in question. It is not to say that it is impossible to deliver a prefabricated system under a design-bid-build contract; it is simply more difficult to accomplish successfully.

The following are suggestions that should be implemented when attempting to plan for a prefabricated system under a design-bid-build project delivery method. The owner and architect must have very explicit wording in the contract documents that require the contractors bidding the work to prefabricate the systems. This becomes more complex when there is a multi-trade prefabrication process such as in the MMAA due to the fact that there will need to be increased coordination between the parties. Therefore, the contract documents would have to say what party is responsible for each process such as storing or transporting the prefabricated system. It would also be important to spell out how and where the system will be constructed. The prefabrication process will run more smoothly as the contract documents become more and more detailed. As you can see early planning is critical to any prefabrication process, especially one under a design-bid-build delivery method.

Designing for Prefabrication

The design and location of the MMAA creates several limiting factors that define how the prefabricated sections are divided so that they can be transported to the site and installed effectively. It is advantageous for the prefabricated sections to be as large as possible. This allows for the most work to be completed in the factory and limits the amount of final connections that need to be completed in the field where productivity is lower.

First, it is necessary to consider the size and layout of the MMAA gallery spaces. The fifth floor gallery ceiling is 66 feet long from north to south and approximately 260 feet wide from east to west. The pairs of W5 members run in the short direction while the steel angles that connect the W5 members run perpendicular in the east west direction. Figure 19 displays a typical layout of the gallery ceiling system; this depicts the east side of the fifth floor gallery space. The highlighted red lines represent the W5 members that run across the width of the gallery ceiling. As you can see there are two W5 members spaced close together (approximately 11") and these sets of two are repeated every 10 feet across the gallery. The dark lines connecting these highlighted members are the steel angle / lighting track system that repeat every 3'4". This is a typical design for the fifth, sixth, and seventh floor gallery ceilings.

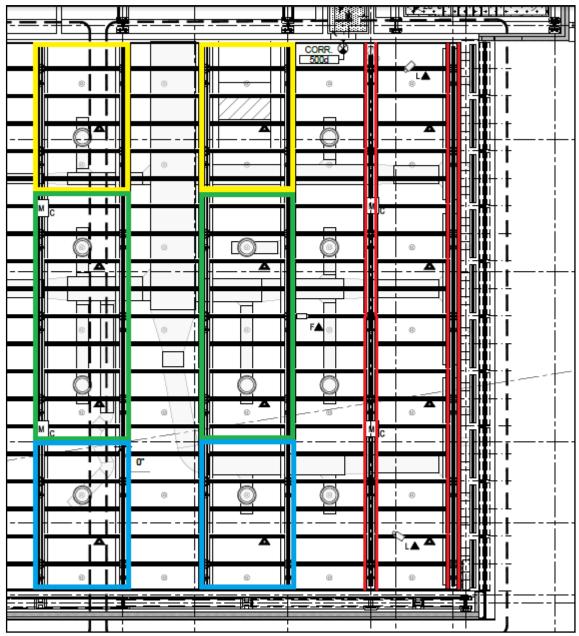


Figure 19: Typical layout of the gallery ceiling system. Original image Courtesy of Renzo Piano Building Workshop

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Now that the construction of the ceilings has been investigated they can be divided into modules for prefabrication. The first factor to consider when designing the prefabricated sections is how they will be transported to the job site. Fitting the prefabricated sections onto the bed of a truck is the main limiting factor for the size of the prefabricated sections. The city's limits on trailer size are displayed in Figure 20 below.

The maximum legal dimensions (overall, inclusive of load, bumpers, etc.) are:				
		State Highway	Qualifying or Access Highway	
Α.	Width of Vehicle, inclusive of load	8 feet 1	8 feet 6 inches	
В.	Height of vehicle from underside of tire to top of vehicle, inclusive of load	13 feet 6 inches	13 feet 6 inches	
C.	Length of single vehicle inclusive of load and bumpers	40 feet	40 feet	
D.	Length of a combination of vehicles inclusive of load and bumpers	65 feet²	Unlimited ²	
E.	Length of a single trailer	48 feet	53 feet ³	
F.	Length of a single twin trailer	28 feet 6 inches	28 feet 6 inches	

 Figure 20:
 State trucking dimension and weight limits. Taken from the State of
 Department of

 Transportation.
 Department of
 Department of

As you can see the applicable limits for length and width respectively are 48 and 8 feet. This is a problem because as stated before, the main assemblies that connect to the structural steel above are spaced every 10 feet, which in effect makes 10 feet the minimum width for the prefabricated sections. Further investigation revealed that it is possible to transport wider or longer trailers into the city by applying for a permit. The permit will allow the maximum dimensions to be increased to 16 feet wide by 160 feet long and 15'11" high (DOT), which provides more than enough room for the prefabricated sections. There is a small \$40 fee associated with applying for a permit that will be considered in final cost benefit analysis.

The optimum division of the ceiling would be to group all four of the red highlighted W5 members in Figure 19 along with the steel angles / lighting track that connects the two groups into one section. This would create a module that is 66 feet long by 11'9" wide. Although this conforms to the regulations with a permit noted above it would still be very difficult to find a way to navigate such a long trailer to the city jobsite. Therefore, it would be beneficial to shorten the trailer to the 48 foot maximum allowed without a permit. In order to do this the ceiling sections will not be able to be continuous throughout the gallery space and the W5 members will have to be split into sections. Splitting the W5 members at the center would allow them to fit onto the 48 foot trailer; however, that creates an awkward joint location because one of the bent steel plate supports is located in the center. It would be better to divide the 66 length into three sections; one central 30 foot section flanked on each side by an 18 foot section. Doing it this way allows all of the bent steel plate supports to remain undisturbed and allows the joints to be symmetrically spaced throughout the width of the gallery space. An example of this division of the ceiling space can be seen in Figure 19. Two examples of the main 30 foot section are enclosed in a highlighted green box, while the flanking 18 foot sections are enclosed in the yellow and blue boxes. These boxes will continue throughout the length of the fifth floor gallery.

This approach leaves gaps between the prefabricated modules. These gaps include the steel angles and lighting track assemblies that would not fit onto either of the prefabricated modules because they would make the whole section too wide. Due to this, these steel angles and lighting tracks will have to be installed in the field after the prefabricated sections were lifted into place. This means that only one half of the steel angles and lighting tracks will be prefabricated. This should not be a problem because the rest of the ceiling system that was prefabricated included the difficult components to handle and install that require the majority of the labor. The steel angle / lighting track assemblies simply have to be bolted onto the bottom of the two W5s that they span and connected to the electrical feed.

1st Floor Gallery

After investigating the first floor gallery space it was determined that a prefabrication process would not be feasible for that particular floor. This ceiling construction is much different from the ones on the fifth through eighth floors. It consists of acoustic plaster that is backed up by metal studs filled with insulation as opposed to the structural steel assembly previously discussed. A typical detail of this ceiling type is shown below for reference in Figure 21.

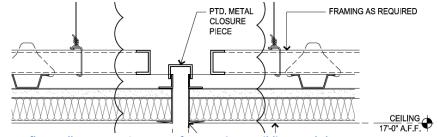
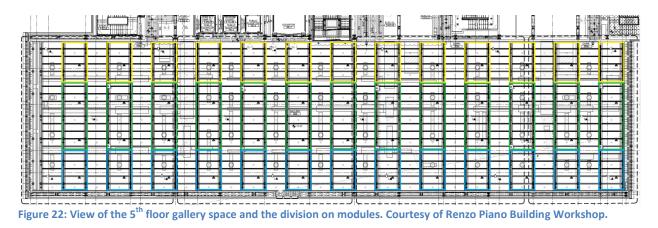


Figure 21: Section of the 1st floor gallery space. Courtesy of Renzo Piano Building Workshop.

5th Floor Gallery

The fifth floor gallery will have a total of 39 prefabricated modules. The gallery space in its entirety can be seen below in Figure 22. This figure highlights the plan for all of the prefabricated sections. The yellow and blue sections represent the twenty-six 18' prefabricated modules, and the green sections represent the thirteen 30' prefabricated modules. This layout allows for more than half of the total ceiling area to be prefabricated including 52 of the 54 total W5 steel members. The rectangular nature of this floors gallery allowed for the layout of the modules to be simple when considering the joint locations and separations.



6th Floor Gallery

The sixth floor gallery will have a total of 21 prefabricated modules. The gallery space in its entirety can be seen below in Figure 23. This gallery space is considerably smaller than the fifth floor space at 60' wide by 216' long at its largest points. The gallery spaces get smaller moving from the fifth floor up to the eighth. This is because there are outdoor terraces that act like steps going up the building that decrease the gallery square footage with each floor.

The layout for this ceiling's modules is different than on the fifth floor in that the W5 sections are divided roughly in half instead of into three sections. This was possible because there are five full 10' long bays with 1/3 of a bay on the far north end and 2/3 of a bay on the far south end of the gallery width. This means the center of the gallery is located approximately at the center of the third bay where there is not a bent steel hangar in conflict with the joint created by the prefabricated sections. The modules were designed so that the W5 members would be connected in the exact center of the third bay. The resulting design for the modules is highlighted in Figure 23 below. The yellow sections represent the ten 28'4" prefabricated modules, and the red sections represent the six 31'8" prefabricated modules along with the five modules in the southeast corner of the gallery that decrease in length from 26' down to 13'. This layout allows for more than half of the total ceiling area to be prefabricated and minimizes the amount of modules.



Figure 23: View of the 6th floor gallery space and the division on modules. Courtesy of Renzo Piano Building Workshop.

7th Floor Gallery

The seventh floor gallery's dimensions are 55'4" wide by 180'6" long at its largest points and will have a total of 17 prefabricated modules. The design and layout of the modules in this gallery space is very similar to the sixth floor except smaller in scale due to the square footage drop from the outdoor terraces. The modules on this floor will also span approximately half the width of the gallery space similar to the sixth floor. On the next page Figure 24 shows the gallery space in its entirety as well as the module layout. The yellow sections represent the eight 28'4" prefabricated modules, and the red sections represent the five 27' prefabricated modules along with the four modules in the southeast corner of the gallery that decrease in length from 24' down to 15'. This layout allows for more than half of the total ceiling area to be prefabricated and minimizes the amount of modules.

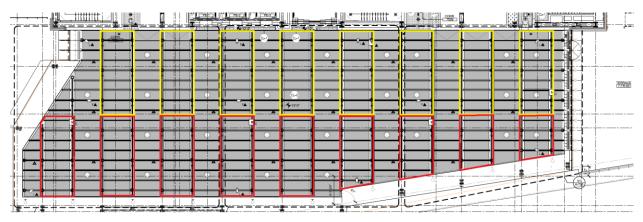


Figure 24: View of the 7th floor gallery space and the division on modules. Courtesy of Renzo Piano Building Workshop.

8th Floor Gallery

The ceiling for the eighth floor gallery is similar to the fifth through seventh floor galleries; however, there is one very important difference between the two. The difference is that there are no W5 steel members running the width of the space. Instead, the steel angle / lighting track assemblies are hung directly from the structural steel above. A section of this ceiling structure can be seen below in Figure 25. Due to the fact that all of the steel angle / lighting assemblies are only connected to the structural steel above and not each other the only way to prefabricate this ceiling would be to include the structural steel in the prefabrication process. Implementing this would not be practical because you are mixing two very different phases, building super structure and interior fit-out. Not only are the timeframes for installation completely different, but the coordination and implementation would almost be impossible and most likely economically unpractical. Due to all of this the eighth floor gallery ceiling will be built in the field. Although this is not preferred, it is acceptable because this ceiling is considerably less complex than ones on the fifth through seventh floors.

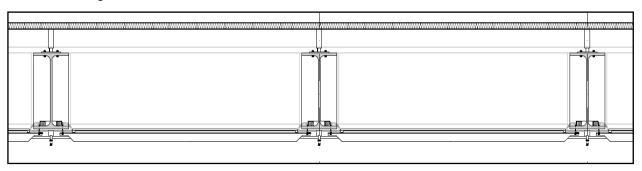


Figure 25: View of the 7th floor gallery space and the division on modules. Courtesy of Renzo Piano Building Workshop.

Design Summary

In order for the prefabrication of the gallery ceilings to be a viable option, two main concessions had to be made. They are as follows:

1. The design of the support system connecting the ceiling system to the structural steel above would have to be altered. The project team stated that the slotted connections that are currently called for in the project were one of the limiting factors that prevented the gallery ceilings from being prefabricated in the first place. The connections in

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question are highlighted below in Figure 26. These slotted connections would have to be switched to a hangar connection. This would eliminate any coordination needed with the structural steel mill order and allow the tradesmen installing the modules more flexibility in the field.

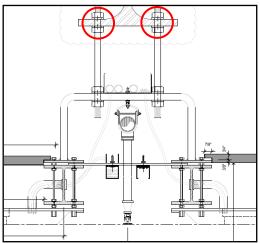


Figure 26: Section of the ceiling system looking north Note the highlighted slotted connections. Courtesy of Renzo Piano Building Workshop

2. Due to the trucking requirements, the W5 steel members had to be split creating joints that run down the length of the gallery. This is a concession purely in an aesthetic manner; although, it should not be a problem because the joints are placed symmetrically and in line with one another. The joints were designed to that they fell either in the center of the gallery (6th and 7th floors), or split the gallery into approximately thirds (5th floor). Note Figures 22 through 24 that show all of the joints between modules run the entire length of the gallery so that it is consistent and pleasing to the eye.

To sum up the design, there are a total of 77 prefabricated modules planned for the MMAA fifth, sixth, and seventh floor gallery spaces. Table 11 below summarizes the breakdown per floor and average module length. Note that the module lengths are significantly longer on the sixth and seventh floors due to the fact that they are split in half instead of thirds across the width of the gallery space.

Prefabricated Module Design Summary						
Floor	Number of Modules (ft)	Average Module Length (ft)				
5 th	39	22.0				
6 th	21	27.0				
7 th	17	26.0				
Total	77	24.25				

Table 11: Summary of the prefabricated modules by floor.

Manufacturing

The focal point of the prefabrication analysis is the manufacturing process. It is the reason that all the trouble was taken to design the system into modules; so that the work could be moved away from the construction site and into the manufacturing facility where the workforce can be safer and more productive. The obvious drive for the move is a reduction in project schedule that can hopefully reduce the overall project schedule. The increased labor productivity is not the only factor that reduces the project schedule. The fact that the prefabricated modules can be manufactured and stored in the warehouse, and then come to the jobsite already assembled; ready to be lifted into place when needed basically eliminates some lengthy schedule items. This is where significant schedule time can be saved, and with that savings there can be a massive cost reduction for the project through general conditions if the project is finished early.

In order to find a suitable warehouse, there are a few considerations that have to be made. First, the space should be large enough to allow for the work to be completed comfortably while providing ease of access to tools and the materials needed for the job. This study will provide enough room for three of the largest modules to be manufactured at the same time. Each of the trades (miscellaneous metals, electrical, and fire protection), will have one of the stations devoted to them. This will allow the prefabrication warehouse to act like an assembly line. This can be accomplished in approximately a 100' by 62' space, which equates to 6,200 square feet needed. There also needs to be enough room for the finished modules to be stored until they are ready for shipment to the jobsite. The modules will be stored in the warehouse in the same stacks in which they will be shipped. There will be a total of nine shipments on 48' long semi-trailers (This topic will be discussed in more detail in the transportation section). These result in 5,076 square feet of storage space needed. Together the production and storage spaces require that the storage space be a minimum of 11,276 square feet large.

Other important factors to consider include the rental rate of the space and the distance from the jobsite. There will be an increase in trucking costs as the distance from the job site increases. Also, another important factor is that the warehouse must be located on the ground floor and have adequate space so that the modules can be loaded on to the semitrailers for transit to the



site. Figure 27 to the right taken from Bing.com.

shows the warehouse that has been selected. The details regarding the property can be seen in Appendix D. As you can see there is ample room around the loading bays to maneuver a semi trailer and to load the modules. This property was found using <u>www.showcase.com</u>, and was listed as an industrial warehouse. The available space on this property includes three

continuous units that equal 12,420 square feet. There are no barriers between the units and there is plenty of ceiling height at 16'. This space will have three separate loading docks. The listing price was \$7.25/SF/Yr which is very reasonable for a space of this size and quality. Also, the warehouse is located 50 miles from the construction site. The trucking costs associated with that will be discussed more in detail in the transportation section.

Now it is time to consider how long the warehouse will need to be rented. This starts by looking at the original schedule which an excerpt of is reproduced below in Figure 28. This shows all of the activities that compose the gallery ceiling system. The ones that will be prefabricated are the drop rods, W5 members, infill pieces, lighting, and sprinkler activities. The ceiling panels and trim will have to be installed in the field because there is no safe and effective way to crane the modules up to the galleries with the loose ceiling panels resting in place. As you can see the miscellaneous metal installation is the most time consuming process of the bunch; and because of this it will be the basis for the production schedule at 35 days long per gallery. The lighting and fire protection crews will be adjusted so that their activity length will also be 35 days. This will allow the work to be fluid like an assembly line where the modules will turn over from each trade to the next with no costly downtime spent waiting. This creates an initial total of 105 working days needed for the production of the modules in all three gallery spaces.

INT-6-110	Ceiling layout and hang drop rods/unistrut	11-18-13	12-23-13	25	25	Ceiling layout and hang drop rods/unistrut
INT-6-111	Install W5 sections and infill pieces	12-24-13	02-12-14	35	35	Install W5 sections and infill pieces
INT-6-112	Rough-in lighting	02-13-14	02-27-14	10	10	Rough-in lighting
INT-6-113	Sprinkler heads	02-28-14	03-20-14	15	15	Sprinkler heads
INT-6-114	Install ceiling panels	03-21-14	04-07-14	12	12	Install ceiling panels
INT-6-115	Ceiling trim	04-08-14	04-14-14	5	5	Ceiling trim

Figure 28: Excerpt of the Gallery Schedule. Courtesy of Turner Construction Company.

Next, it is important to factor in the higher productivity rate that the workers will have in the factory setting. According to McGraw Hill's *Smart Market Report: Prefabrication and Modularization,* owners have seen project schedules be reduced by 10 to 30 percent when a prefabrication process is used (McGraw-Hill). The theory behind this productivity increase comes from multiple factors. First, the tradesmen are performing their work in a climate controlled warehouse as opposed to being exposed to the elements that exist on a construction site. Also, because this work deals with the gallery ceiling system, in the field all of this work would be completed overhead, which can strain the body especially the arms and the back. This discomfort is eliminated in the warehouse because the men can complete their work at a comfortable working level, approximately waist high. Other factors to include are having tools, adequate light, restrooms, and break rooms readily available, an increase in worker safety, and a reduction in material waste (McGraw-Hill).

So, applying a 20% productivity reduction to the 105 day duration equates to a savings of 21 days and it shortens the necessary rental time to 84 working days which is approximately four calendar months of work. So, in order to allow time for mobilizing the warehouse, a few weeks of storage, and loading the modules for shipment; the warehouse will have to be leased for a five month period. On the next page Table 12 summarizes the costs incurred through renting the warehouse. As you can see there will be an additional cost of \$37,518.75.

Table 12: Warehouse Lease Summary

Warehouse Lease Summary					
Square Feet Length of Lease Leasing Rate Cost (\$)					
Leased	(Years)	(\$/SF/Yr.)			
12,420	5/12	7.25	37,518.75		

The warehouse manufacturing plant is very beneficial to the project schedule. Most of the activities in Figure 28 are either eliminated from the onsite schedule or reduced in some form. The ceiling layout and drop rod installation will almost be completely eliminated for two reasons. First, all of the layout work will be simplified due to the use of the hangars instead of slotted connections. Second, the plan for the drop rods is to have them preassembled to the correct length and packaged with the individual modules so that they simply have to be screwed onto the bent steel supports when they are ready to be lifted into place. This will also allow the modules to be stacked when being transported to the jobsite. The next activity is the installation of the W5 members. Out of 7,446 linear feet of W5 members scheduled for the fifth, sixth, and seventh floor galleries 7,127 linear feet were prefabricated which is a 95.7% completion rate. Due to this, the W5 installation activity can be reduced from 35 to one and a half days per floor. Two days will be assumed in the new schedule due to the loss of the economies of scale associated with stick building the entire gallery. The lighting installation activity can be eliminated completely because approximately half of the lighting tracks are prefabricated on the modules. The other half of the tracks are to be prefabricated individually by attaching the steel angles that enclose the track and the track itself together. This will allow the complete lighting/steel angle assemblies to simply be lifted and screwed into place after the larger modules are already in place. A new activity will be included to reflect this in the updated project schedule that will be discussed in the schedule implications section. Finally, the fire protection installation activity can be deleted entirely because the modules contain the entire fire protection system located in the galleries. There will have to be final connections made to the electrical and fire protection systems between the prefabricated modules once they are lifted into place. This will also be reflected with a new schedule activity in the schedule section of this analysis.

Transportation

The next step in the prefabrication process is to transport the completed modules from the warehouse to the MMAA. In order to keep the trucking costs at a minimum an effort was made to use the least amount of trips as possible. Two steps were taken in order to accomplish this. First, the modules would be stacked on top of each other until the maximum allowable height that is regulated by the state department of transportation was reached. The maximum height of a semi trailer with its load is 13'6"; which can be seen in Figure 20 that is displayed previously on page 34. Second, the modules will be loaded so that the maximum amount of the 48' trailer can be used. For example, on the fifth floor gallery there are 30' sections and 18' sections that will be put in stacks next to each other so that the whole trailer is used. Obviously not all of the trailers will be filled to capacity due to the varying length of the modules. However, after studying module combinations on each floor it was determined that there will need to be nine trucking trips in order to deliver all of the modules to the MMAA.

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In order to be able to stack the modules custom wooden pallets must be inserted in between the different modules. The total module height from the bottom of the lighting assembly to the top of the next wooden pallet is 1' 5-1/2". An example of how the modules will be stacked can be seen below in Figure 29. This figure represents two modules stacked on each other. The highlighted red area represents one of the custom wooden pallets that are inserted between the modules. This pallet is set on the W5 members between the bent steel hangars and is approximately 1'

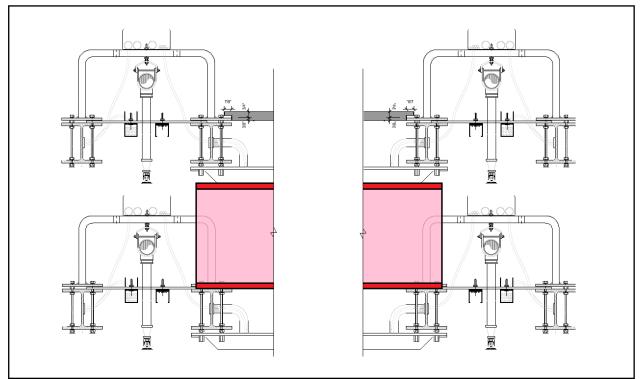


Figure 29: Section of a stacked set of modules. Original image Courtesy of Renzo Piano Building Workshop. deep. Note that that this image was appended and the overall width of these modules is 11'9".

In order to meet the maximum height restriction of 13.5' the module stacking must be studied. The bed of the truck is four feet off the ground which leaves nine and a half feet for the modules to be stacked. At 1' 5-1/2" with pallets, the modules can be stacked six high while complying with the state regulations. An image depicting the truck and its module stacking can be seen below in Figure 30.

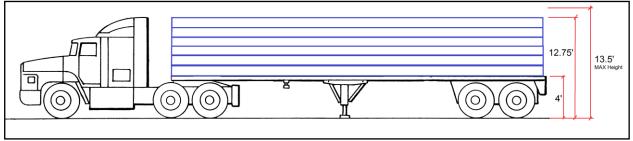


Figure 30: Example of a loaded truck. Original image taken from freepatentsonline.com.

There are three trucks dedicated to each of the fifth, sixth, and seventh floors (Trucks 1-3 are for the 5th, Trucks 4-6 are for the 6th, and Trucks 7-9 are for the 7th). The only exceptions are on trucks five and nine. These trucks each carry a module that is scheduled for the fifth floor. There was no room to fit them on the fifth floor trucks and it didn't make sense to schedule another truck when they could be fit on the trucks that carry the sixth and seventh floor modules. This only creates a minor issue when craning the modules to their appropriate floors because the crews accepting the module will have to move up and down the building slightly more. However, only three out of 77 modules need to be delivered out of sequence like this so it is still beneficial to group them this way. A detailed summary of each trucks load can be seen below.

- Truck 1: Fifth Floor Gallery
 - (6) 30', (6) 18' Sections
- Truck 2: Fifth Floor Gallery
 - (6) 30', (6) 18' Sections
- Truck 3: Fifth Floor Gallery
 - (12) 18' Sections
- Truck 4: Sixth Floor Gallery
 - (6) 31'8", (1) 16', (1) 13' Sections
- Truck 5: Sixth Floor Gallery
 - (6) 28'4", **(2) 18', (1) 19.5' Sections
- Truck 6: Sixth Floor Gallery
 - (4) 31'8", (1) 26', (1) 23.5' Sections
- Truck 7: Seventh Floor Gallery
 - (6) 27', (1) 21', (1) 18.5', (1) 15.5' Sections
- Truck 8: Seventh Floor Gallery
 - (6) 28'4", Sections
- Truck 9: Seventh Floor Gallery
 - (2) 28'4", **(1) 30' Sections

Note: ** represents modules from the first floor gallery

The costs associated with moving the modules from the warehouse to the MMAA site include the increased trucking costs, permits, extra expense due to the wooden pallets, and the labor involved with loading the material. The takeoffs and estimate summary for all of these items can be seen in Appendix E.

The increased trucking costs stem from the fact that instead of having the material delivered directly to the job site as they usually would be when they are stick built in the field; they are instead delivered to the warehouse. The contractor must then bear the costs associated with moving the prefabricated modules from the warehouse to the job site. As stated before the warehouse is located 50 miles from the jobsite. Research was conducted to determine an average cost per mile of trucking, and the website fairtran.com was discovered. They list the current trucking rates per mile for different types of trucks and haul lengths. They specify that a flatbed truck with a short haul will cost approximately \$2.72 per mile. This extrapolates to \$136

3

per haul and a total of \$1,224 for all nine shipments. This number seemed to be low to me so after consulting my advisor, Ray Sowers, he advised me that in his experience the trucking costs would be a minimum of \$400 regardless of the mileage. So, this analysis will estimate the trucking costs from the warehouse to the MMA to be \$400 per truck; this extrapolates to \$3,600 for all nine shipments.

The next item to factor in is the additional costs incurred due to driving a wide load into the city. This requires that a permit be filled out and approved by the State Department of Transportation. After conducting research on the subject it was determined that the wide load would not be a problem. This is because the MMAA project site is located directly next to one of the trucking access roads that serve the city. There would be a small \$40 fee payable to the Department of Transportation for processing each of the permits (DOT). The fees total to an additional cost of \$360 for all nine of the shipments.

Next, there are additional material and labor fees due to the wooden pallets that need to be constructed in order to ship the modules. The pallets need to be custom made due to the awkward shape of the modules and the fact that no standard palate would be feasible to use. The pallets need to be approximately 1'x9'x4' so that there will be enough separation between the modules so that the lighting assembly of one module does not come in contact with the bent steel hangars from the other module. The idea was to create a wooden box type pallet structure that consists of three nine foot long composite wooden I joists spaced two feet apart that are tied together on both sides by 1/2" plywood. The box

Pallet Count Per Truck						
Truck Number	Truck Designation	Number of Pallets				
1 st	А	15				
2 nd	В	15				
3 rd	С	15				
4 th	D	12				
5 th	А	14				
6 th	В	8				
7 th	С	13				
8 th	D	10				
9 th	А	2				
Max Total		57				

Table 13: Pallet Count Per Truck

would rest on the W5 members where there are no bent steel hangers. Figure 31 on the next page shows an example of how the pallets will be placed on a module so that the bent steel hangars are avoided and protected. The highlighted red areas represent the pallets and the green boxes show where the protruding bent steel hangars are located. Next, it is important to limit the amount of trucks so that the amount of pallets required can also be limited. It was determined through the sequencing schedule, shown in Appendix F, that there will need to be a minimum of four trucks running shipments in continuous loops. Therefore it is necessary to fabricate enough pallets for four full truckloads. Shipments five through nine can then reuse the pallets from previous shipments. Table 13 shows the number of pallets needed per truck. As you can see the maximum number of pallets needed on Truck A is 15, Truck B is 15, Truck C is 15, and on Truck D is 12. Summing these required maximums shows that there will need to be a minimum of 57 pallets fabricated in order to accommodate all of the modules. Pricing information for the pallets was obtained through RS Means Cost Data and Menard Inc's sales website which is reproduced in Appendix G & H respectively. The total cost of building all 108 pallets is \$10,614 which equates to \$186 per pallet.

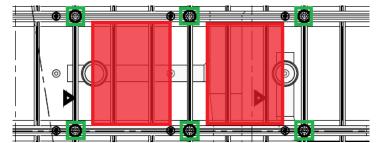


Figure 31: Pallet Placement Example. Original image courtesy of Renzo Piano Building Workshop.

The final costs associated with transporting the modules from the warehouse to the MMAA are the loading costs. The three main expenses that fall into this category are equipment rental, operating costs, and labor. The equipment needed includes something to load the units onto the back of the flatbed truck. I decided to use a flatbed mounted crane such as the one shown in Figure 32. This type of truck has a maximum load weight of 3 tons, which none of the modules exceed. The operating cost is an hourly fueling and maintaining the equipment. It



rate that represents the dollars spent Figure 32: Example of a flatbed mounted crane. Photo taken from fueling and maintaining the equipment. It Calworktrucks.com.

will take 12.8 hours to load all of the equipment onto the truck beds. This was determined using the sequencing schedule found below in Figure 33; or in Appendix F for a better view. It was assumed that it would take 10 minutes to crane each module onto the truck bed. The labor expense for loading the modules includes a crew of three men, one crane operator and two laborers. The rates for the equipment rental, operating costs, and the labor were all found using RS Means Construction Cost Data. The total cost for the equipment rental, operating costs, and labor comes out to be \$6,680.

Note that the RS Means reference material for the trucking estimates have been reproduced in Appendix G.

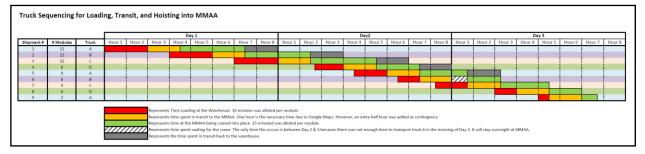


Figure 33: Truck Sequencing Schedule. Enlarged in Appendix F for a better view.

This sequencing schedule shown on the previous page was used mainly to determine how the loading, trucking, and craning operations would be coordinated. The red boxes represent the loading time spent at the warehouse. The gold boxes represent the time spent in transit to the MMAA. One hour is the necessary time according to Google Maps; however, an extra half hour was added to this time as a contingency. The green boxes represent the time spent craning the modules into their respective galleries. These timeframes were determined by assuming that each module needs fifteen minutes to be craned into place. This comes from the fact that five minutes was assumed for each of the following activities; hooking the modules to the crane line, lifting the modules to their respective galleries, and removing the modules from the crane line. Finally, the grey boxes represent the transit time back to the warehouse so that the trucks can be reloaded with modules. This timeframe is also one and a half hours due to the same reason mentioned previously. As you can see from the schedule only shipment numbers one through five need to go back to the warehouse. This is because there will be four trucks (A,B,C & D) running continuous loops until all the modules have been delivered, and the final four shipments will obviously not need to go back to the warehouse to pick up more modules as there will be none left. Also, it is worth noting that there are four truck running loops because that is the smallest number possible due to the time constraints of each delivery. The number of trucks was limited so that the number of pallets that needed to be fabricated was kept to a minimum.

Other benefits from making this schedule include finding out that the total crane time needed is approximately three full working days. Also, by summing up the warehouse loading time (red boxes) the hourly operating costs of the equipment could be determined which is reflected in the estimate details shown in Appendix E.

Hoisting and Installation

Once the modules arrive at the MMAA they have to be craned into their respective galleries. The plan is to crane the modules into the opening where the east side gallery curtain wall will be located. All of the craning of the prefabricated sections must occur before the curtain wall work on the east side begins because once they are in place there will be no opening large enough to fit the prefabricated modules. An excerpt from the overall project schedule is shown below in Figure 34. This shows that the east elevation windows and curtain wall work will begin on 10/25/13, which is a Friday. So, the goal will be to have all of the modules hoisted into place before that date. It is also necessary to complete the hoisting before this date so that there are no conflicts with any enclosure material being hoisted and installed on the east side of the building by the tower crane.

Windows & C	Curtainwall					
ENCL-123	South Elevation Windows	06-05-13	07-02-13	20	20	South Elevation Windows
ENCL-117	West Elevation Windows & Curtainwall	07-03-13	09-26-13	60	60	West Elevation Windows & Curtainwall
ENCL-118	North Elevation Windows & Curtainwall	09-20-13	10-31-13	30	30	North Elevation Windows & Curtainwall
ENCL-116	East Elevation Windows & Curtainwall	10-25-13	01-07-14	50	50	East Elevation Windows & Curtainwal
ENCL-119	Cablewall @ 1st Floor	01-08-14	04-02-14	60	60	Cablewall @ 1st Floor

Figure 34: MMAA Windows and Curtain Wall Schedule. Courtesy of Renzo Piano Building Workshop.

On the next page, Figure 35 shows the complete east side elevation of the MMAA. Note that the openings that will accept the modules for the 5th, 6th, and 7th floors are all highlighted. It is hard to tell by looking at the elevation, but the 6th and 7th floors both have outdoor terraces connected to the galleries that will make accepting the modules from the crane that much easier.

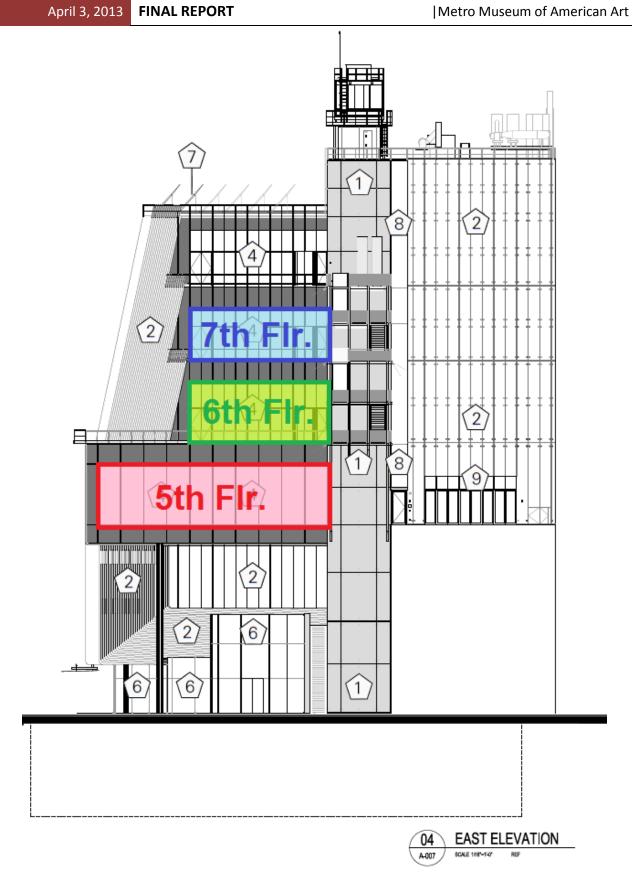


Figure 35: East Elevation of the MMAA. Courtesy of Renzo Piano Building Workshop.

These terraces can be seen in Figure 36 which is an isometric view of the MMAA looking at the southeast corner of the Museum. The terraces for the sixth and seventh floors are highlighted in orange. The fifth floor curtain wall is highlighted in red; the sixth floor curtain wall is highlighted in green; and the seventh floor curtain wall is highlighted in blue.

This timeframe matched up well with the interior fit out schedule. According to the gallery fit out schedule shown in Appendix C the fifth floor ceiling system was set to begin on 10/21/13 with the ceiling layout and hanging of drop rods

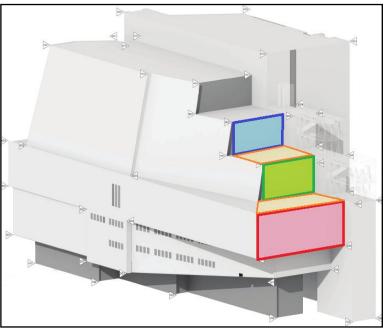


Figure 36: Isometric View of the MMAA. Courtesy of Renzo Piano Building Workshop.

(Note that this date is right before the east elevation curtain wall work begins). Because the timeframe is so tight the modules will be delivered a week early and stored in the gallery until they are ready to be installed on 10/21/13. Also, because the sixth and seventh floor fit out schedules lag the fifth floor schedule by about one and a half weeks each, those modules will be stored in their respective galleries for that time period until they are ready to be installed. The fifth floor gallery fit out schedule is reproduced in Figure 37 from the original project schedule which can be seen in Appendix C. This shows that all of the preceding activities to the ceiling layout deal with framing, hanging, or painting the gallery walls. This leaves the center of the galleries open for module storage. This will be important mostly for the sixth and seventh floor modules.

Gallery						
INT-5-100	Install hangers	01-29-13	02-11-13	10	10	
INT-5-101	Protect surface adjacent to steel	02-12-13	02-19-13	5	5	steel
INT-5-122	Cure SOFP (28 cal days)	03-06-13	04-02-13	20	20	iys)
INT-5-102	Paint metal deck & SOFP	04-03-13	04-16-13	10	10	SOFP
INT-5-103	Overhead MEP rough in	06-21-13	08-16-13	40	40	Overhead MEP rough in
INT-5-104	Layout and frame	08-19-13	09-04-13	12	12	Layout and frame
INT-5-105	Rough partitions	08-28-13	09-18-13	15	15	Rough partitions
INT-5-106	Sheetrock partitions	09-19-13	09-27-13	7	7	Sheetrock partitions
INT-5-107	Skim coat walls (3 coats) ring ceiling line	09-30-13	10-15-13	12	12	Skim coat walls (3 coats) ring ceiling line
INT-5-108	Paint ceiling line up	10-16-13	10-18-13	3	3	Paint ceiling line up
INT-5-109	Ceiling layout and hang drop rods/unistrut	10-21-13	11-22-13	25	25	Ceiling layout and hang drop rods/unistrut
INT-5-110	Install W5 sections and infill pieces	11-25-13	01-15-14	35	35	Install W5 sections and infill pieces
INT-5-111	Rough-in lighting	01-16-14	01-29-14	10	10	Rough-in lighting
INT-5-112	Sprinkler heads	01-30-14	02-20-14	15	15	Sprinkler heads
INT-5-113	Install ceiling panels	02-21-14	03-10-14	12	12	Install ceiling panels
INT-5-114	Ceiling trim	03-11-14	03-17-14	5	5	Ceiling trim
INT-5-115	Layout/frame/install sleepers	03-18-14	04-30-14	32	32	Layout/frame/install sleepers
INT-5-116	Plywood subfloor	05-01-14	05-16-14	12	12	Plywood subfloor
INT-5-117	Patch skim coat	05-19-14	05-23-14	5	5	Patch skim coat
INT-5-118	Paint	05-27-14	06-03-14	6	6	Paint
INT-5-119	Lights and MEP finish trim	06-04-14	06-17-14	10	10	Lights and MEP finish
INT-5-120	Wood flooring	06-19-14	07-15-14	18	18	Wood flooring
INT-5-123	Punchlist	07-16-14	08-19-14	25	25	Punchlist

Figure 37: Excerpt of the original 5th floor gallery fit out schedule. Courtesy of Turner Construction Company.

The type of crane that will be used to lift the modules into place is a truck mounted hydraulic crane. Considering the fact that the modules are relatively light when discussing construction loads this type of crane will do the job. The costs incurred from the crane include the three day rental price and the mobilization costs. Both of these were determined using RS Means Cost Date and the excerpts that were used are reproduced in Appendix G. The crane cost estimate can be seen in Appendix E. This cost estimate for the crane and mobilization totaled \$6,251.

The sequencing of the activities will remain the same as the original schedule until the ceiling layout activity. Next, all of the activities that deal with the construction of the modules can be changed or replaced with the new activities. The deleted or reduced activities are the ceiling layout and drop rod installation, W5 member installation, lighting installation, and the sprinkler installation. The sequence of new activities will be as follows:

- Module positioning and hoisting.
- W5 Installation (Reduced to 2 days per floor as described in the manufacturing section).
- Lighting Assembly Installation
- Electrical Connections.
- Fire Protection Connections.

The module positioning and hoisting includes moving the correct module to the spot where it needs to be hoisted. Note that all of the modules will be tagged with a specific module number and an erection plan would need to be made to ensure that each module gets to the correct final location. Then once the module is below its final location the drop rods will be screwed onto the bent steel hangars. Finally, the module will be hoisted up to its final position using a lift. Here the hangars will be clipped onto the structural steel above. It was estimated that it would take 20 minutes for each module to be moved into position and lifted into place. Table 14 below shows the breakdown of the module installation at this rate.

MODULE INSTALLATION BREAKDOWN							
Floor Number of Assemblies Hours Needed to Insta							
5 th	39	13.0					
6 th	21	7.0					
7 th	17	5.7					
Total	77	25.7					

Table 14: Module Installation Breakdown.

The lighting assembly installation activity includes the work involved with attaching the preassembled steel angle / lighting track assemblies to the prefabricated modules. Approximately half of the lighting assemblies would already be in place because they were part of the prefabricated modules. The other half will have to be lifted and screwed into place with a slotted connection. This is a relatively simple task due to the fact that a lot of the work was done in the prefabrication factory. These assemblies are almost all exactly the same and can be interchanged between one another. It was assumed that two men on ladders could install 12 an hour or one every five minutes. On the next page, Table 15 breaks down the installation timeframe based on these rates.

)

LIGHTING ASSEMBLY INSTALLATION BREAKDOWN								
Floor Number of Assemblies Hours Needed to Insta								
5 th	247	20.6						
6 th	163	13.6						
7 th	132	11.0						
Total	542	45.2						

 Table 15: Lighting Assembly Installation Breakdown.

The next activity is the electrical connections. This deals mainly with the intra module electrical connections such as completing conduit runs and busways. The conduits run in the north south direction are depicted in Figure 38 by the red highlighted lines. The conduit runs originate on the north side of the gallery and terminate when they get to the south wall of the gallery. All of the conduit lines are included in the prefabricated modules and each module carries two separate conduit lines. This means that each module will have two separate conduit connections that must be made. This gives a total of 154 conduit connections that must be made with 78 on the fifth floor, 42 on the sixth floor, and 34 on the seventh floor. It will be assumed that it will take 10 minutes per

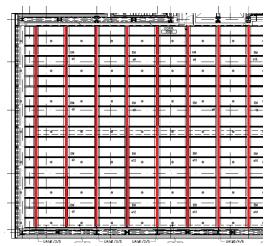


Figure 38: Conduit Runs Highlighted Red. Courtesy of Renzo Piano Building Workshop.

conduit connection. This extrapolates to 26 hours of work with 13 hours on the fifth floor (1.6 days), seven hours on the sixth floor, and 5.7 hours on the eighth floor. The only other work associated with this activity is the pulling of electrical wires through the connected conduits. The time needed to pull the wires was found using production values from RS Means. The number of fixtures and average distance from the pull boxes was calculated to determine the amount of wire needed for each gallery. These estimates can be seen in Appendix E. The result was that it would take 4 days to complete the fifth floor wire pulling and less than two days for the sixth and seventh floor galleries.

The final activity is the fire protection connections. Like the electrical connections this activity deals with the intra module connections that must be made. The fire protection lines are laid out almost exactly the same as the conduits are. In fact they are located directly below the conduit runs. This results in the same number of connections that need to be made on each floor. This results in a total of 154 connections with 78 on the fifth floor, 42 on the sixth floor, and 34 on the seventh floor. Like the electrical connections it will be assumed that it will take 10 minutes per conduit connection. This extrapolates to 26 hours of work with 13 hours on the fifth floor, seven hours on the sixth floor, and 5.7 hours on the eighth floor.

Schedule Analysis

The interior fit-out schedule will progress as originally scheduled until 6/21/13. This is the date that the MEP rough-in work can begin on the fifth floor gallery. As you can see from Figure 37 on page 48 there is a large gap between the end of the "Paint Metal Deck & SOFP" activity and the "Overhead MEP Rough-In" Activity. This is due to the fact that the MEP rough in is a more time consuming activity than the painting activity. This gap between activities grows bigger and bigger each floor as the lag builds up. This leaves the gallery space empty with no work going on for substantial amounts of time. Due to this, the MEP Rough-In activity drives the interior fit-out schedule. Table 16 below shows the gap between these activities that has built up for the fifth through eighth floors.

 Table 16: Schedule Activity Analysis

SCHEDULE ACTIVITY ANALYSIS							
Floor Date Painting Activity Date MEP Rough-Ir							
	Ends	Begins					
5 th	4/16/13	6/21/13					
6 th	4/24/13	7/22/13					
7 th	5/1/13	8/19/13					
8 th	5/8/13	9/17/13					

In order for the prefabrication process to save schedule time the eighth floor fit-out cannot be the last one to start (Note that its ceiling system is not being prefabricated). If the gallery fit-out simply starts on the first floor and works its way up to the eighth floor in order; the only benefit that would occur is that the fifth through seventh floor fit-outs would be completed early. The eighth floor would be completed on the same date as originally scheduled because the prefabrication processes below does not help it start any earlier. This is a problem because the eighth floor punchlist activity is tied directly to the turnover to the owner. So, it is imperative to re-sequence the gallery fit-outs so that the eight floor fit-out precedes the fifth through seventh floors. The gap created by the MEP Rough-In provides this opportunity because as you can see the eighth floor will be ready for MEP Rough-In after 5/8/13. The MEP Rough-In can begin on that floor starting on 6/21/13 if the fit-out of the fifth through eighth floors are re-sequenced. So, the plan will be to keep the fit-out schedule the same as planned for the first through fourth floors. Then starting with the MEP rough-in, the crews will move to the eighth floor before completing the fifth through seventh floors in order. This will allow the floors with prefabrication processes to tie directly into the turnover to the owner so that significant overall project schedule savings can be achieved. All of the gallery fit-out schedule activities will remain the same except for the ones that deal with the gallery ceiling. On the next page Table 17 summarizes the changes that will be made to each of the gallery fit-out schedules on the fifth through seventh floors.

ESTIMATED SCHED	ESTIMATED SCHEDULE REDUCTION									
Activity	Original Duration	Percentage Reduced	New Duration	Work Days Saved or Lost						
Ceiling Layout/ Drop Rods	25	100	0	25						
Install Remaining W5 Sections	35	95	2	33						
Rough-In Lighting	10	100	0	10						
Sprinkler System	15	100	0	15						
Module Positioning & Hoisting	0	n/a	2	2						
Lighting Assembly Installation	0	n/a	2	2						
Electrical Connections	0	n/a	6	6						
Fire Protection Connections	0	n/a	2	2						
Total	85		14	71						

Table 17: Estimated Schedule Reduction per Gallery

As you can see from this there is the opportunity for a significant schedule savings. The original gallery ceiling's scheduled work duration of 85 days was shortened by 71 days to 14 days. A new project schedule was created to calculate the potential schedule savings based on the new durations detailed in Table 17. This project schedule can be seen in Appendix I. This schedule starts with the fifth floor painting of the spray on fire proofing (SOFP) as this is the last item that is the same on both the new and old schedules. After this activity the schedules differ in that the old schedule progressed with the fifth floor MEP Rough-In while the new schedule starts with the eighth floor MEP Rough-In. When creating this schedule the same amount of lag time between floors was used. This lag time between floors in the original schedule was half of the 40 day MEP rough-in activity length (20 days). This lag time was also used between the start if the MEP rough-in activities for the new fit-out schedule as well.

There was only one conflict on the new schedule that was created due to the re-sequencing. Previously all of the fit-out schedules were approximately the same length per floor. However, because the eighth floor schedule was not shortened it ended up being a different overall length, while most of the individual activities were the same length. At first the eighth floor activities were ahead of the others due to the lag; however, the lag finally ran out when the seventh floor gallery floor sleepers were being installed. This created a schedule situation that had the seventh and eighth floor activities overlapping. Due to this a delay had to be put into the eighth floor sequence so that the crews could flow evenly without being overstrained. Before this sleeper activity all of the other activities flowed in this pattern:

- Eighth Floor
- Fifth Floor
- Sixth Floor
- Seventh Floor

Then starting with the sleeper activity they flowed in this pattern:

- Fifth Floor
- Sixth Floor

- Seventh Floor
- Eighth Floor.

This resulted in the critical path of the schedule to run through the seventh floor fit-out activities until the sleeper activity. Then the critical path switched to the eighth floor fit-out until the gallery fit-outs are complete. This can be shown in Appendix I with the red highlighted path.

Overall, according to the new interior fit-out schedule the project will be completed 41 working days prior to originally schedule. It shows that gallery fit-outs including the punchlist items will all be complete by October 2, 2014. This is an extremely significant savings in overall schedule. However, the overall project schedule will not be reduced by all 41 of those days. There are a few other independent activities that will not be complete until after that October 2nd date. They are displayed below in Table 18. As you can see from this table the earliest that the MMAA project can be finished based on these independent activities is October 23, 2014. When compared to the previously planned November 28, 2014 completion date the prefabrication process ends up saving 26 actual working days or just over 5 calendar weeks.

 Table 18: List of activities that end after October 2, 2014.

A	ACTIVITIES THAT END AFTER OCTOBER 2 ND , 2014							
Floor	Description	Date Complete						
8 th	Office & Conference/Trustee Rm. Fit-out	10/23/14						
8 th	Bookstore & Café Fit-Out	10/23/14						
9 th	Drywall & Interior Finishes	10/23/14						

The general conditions on the project were originally budgeted for a total of \$15,722,000. This total is spread out over approximately 37 months or 158 weeks to be more exact. The weekly cost of general conditions is equal to \$99,506. Therefore, shortening the schedule by five weeks will save the project approximately \$497,500.

Cost Analysis

The prefabrication of the gallery ceiling system is favorable in terms of reducing the project schedule. The next step is to determine whether or not the prefabrication process would save the project team any money. There are multiple different cost implications to consider including the ones outlined in the warehouse, transportation, installation, and schedule sections. On the next page Table 19 details and summarizes all of the costs incurred or saved when implementing the gallery ceiling prefabrication process.

The two costs that are listed in Table 19 that have not been discussed thus far are the additional manufacturing and installation labor. This comes from the fact that there will need to be a laborer moving the completed modules between each trade's station and eventually the storage space within the warehouse. This cost is necessary due to the fact that no trade union would want to move the modules themselves. The estimate for this additional labor can be seen in Appendix E and will include one union laborer and a forklift for the duration of the warehouse manufacturing period. The next labor cost will come from the labor required to install the

modules that was created due to the prefabrication process. The activities that were created due to the prefabrication process are the module hoisting, lighting assembly installation, and the electrical / fire protection final connections. The time required to complete all of these activities was covered in the hoisting an installation section of this analysis; however, the labor costs associated with that additional timeframe was not. The estimate for this additional installation labor can also be seen in Appendix E. It should be noted that there will be an electrical and a fire protection worker present as the modules are lifted into place due to the agreement covered in the union division of labor analysis. This is necessary because the electrical and fire protection unions would not want their work being installed without a representative present in case there was a problem. This topic will be covered in more detail in Analysis 3. The costs incurred due to the additional labor are as follows:

- Additional Manufacturing Labor: \$48,432.38
- Additional Installation Labor: \$33,987.76

As you can see from the Table 19 there is also a significant cost savings associated with prefabricating the gallery ceiling systems. If the process is implemented it could save the project up to \$345,500 mainly due to the large general conditions savings. Because this is such a large and complex project there are also large costs associated with keeping it running. However, keep in mind that this is a 266 million dollar project and that a savings of 345 thousand dollars translates to a 0.13% savings on the overall project budget. It is a significant sum of money but only a fraction of the overall project.

COST IMI	PLICATIONS OF THE PREFABRICATION PROC	ESS
Item	Description	Cost Impact (\$)
Manufacturing		
Warehouse Rental	Five months rent of 12,420 SF @ \$7.25/SF/Yr.	37,518.75
Additional Labor	Laborer to move modules between stations.	48,432.38
Transportation		
Trucking Costs	Nine Trucks at \$400/Truck.	3,600.00
Permits	Nine Permits at \$40/Permit.	360.00
Wood Pallets	57 Custom Pallets	10,613.65
Loading Costs	Crane, Labor, & Operating Costs at the Warehouse	6,680.56
Installation		
Hydraulic Crane	Three days rent, mobilization costs, and labor associated with receiving the modules.	10,739.56
Installation Labor	Labor outlined in hoisting and installation section.	33,987.76
General Conditions	Five weeks of general conditions savings.	497,500.00
Net Total		345,567.34

Table 19: Cost Implications of the Prefabrication Process

Conclusion & Recommendation

As shown in the schedule and costs analyses implementing the prefabrication process of the gallery ceiling system would be very beneficial to all of the parties involved in the construction of the MMAA. First, the owner would benefit due to the lower overall cost of the project and the shortened schedule would allow them to occupy the building five weeks sooner than anticipated. Also, due to the early finish the general contractor would be able to allocate their human and equipment resources to other jobs that need attention.

Even if implementing the prefabrication process turned out to cost the exact same amount of money and take the exact same amount of time to construct I would still recommend that it be implemented. This is because all of the important benefits of prefabrication would still be achieved such as providing a safer work environment for the workforce, reducing the material waste on the job, and an increase in worker comfort and productivity. So, for all of the above reasons I recommend that the prefabrication process for the gallery ceiling system be implemented on the MMAA project.

ANALYSIS 1B: GALLERY CEILING REDESIGN

Problem Identification

This analysis has similar problems as the first prefabrication analysis. The Metro Museum of American Art (MMAA) has gallery spaces located on the first, fifth, sixth, seventh, and eighth floors. The average duration for one of these gallery fit-outs is 416 working days, which translates to approximately 19 months. Currently it takes over 60 working days to complete just the structure of a single gallery ceiling. It is a custom designed grid of steel members that encloses the lighting and fire protection systems with it. As you can imagine, this significantly contributes to the high cost of the building.

There are also schedule concerns associated with the MMAA gallery fit out. The critical path of the schedule 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.

Analysis Goals

So, the goal of this analysis 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. Some initial possibilities include using an open grid ceiling that will expose the metal deck, structural members, and mechanical systems above. This analysis will be completed by redesigning the ceiling structure so that it will fit into the already present architecture of the MMAA. Then the new ceiling system will be compared to the existing ceiling system in order to determine any schedule or cost savings.

Background Information & Research

There are two steps of background research that were necessary. First, it was important to become familiar with the existing gallery ceiling system. Understanding the complexities of the existing system would allow for a more effective design of the new system that is to be proposed. The original gallery system design will be discussed in the following section, "*Original Ceiling Design*". Next, it was important to study the architecture that defines the MMAA. This will allow the new ceiling system to be integrated into the building without looking like it is out of place.

The architecture of the MMAA has a lot of industrial components. It uses mostly high quality yet simple materials in order to create a minimalistic look. This will allow the art showcased in the galleries to stand out from the building itself. This simple look can be seen on the next page in Figures 39 and 40. They are screenshots of a video walkthrough that was prepared by the

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MMAA. These images (Figures 39 and 40) are renderings of what the first floor gallery space will look like when it is complete. As you can see the potential exhibits really do stand out when compared to the simplistic nature of the building. The first floor gallery is even more simplistic than the rest of the building. The interior finishes in this first floor gallery consist of a stone floor, drywall ceiling, and precast concrete panels as the walls. The rest of the gallery spaces are more ornate due to the intricate gallery ceiling system that will be discussed further on in this section.



Figure 39: Rendering of the first floor gallery finishes. Courtesy of the MMAA & Renzo Piano **Building Workshop.**

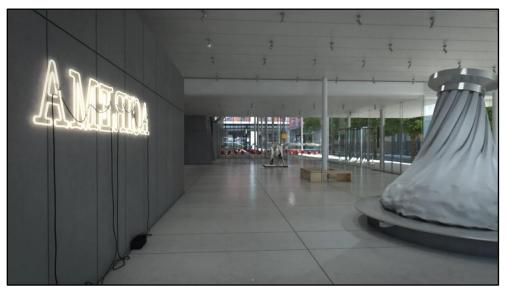


Figure 40: Rendering of the first floor gallery finishes. Courtesy of the MMAA & Renzo Piano **Building Workshop.**

The simplistic nature of the gallery spaces continues on the fifth through eight floors. These four galleries are the ones that this redesign analysis will focus on. As you can see from Figures 41 and 42 these galleries are very open airy spaces that are made up with a minimal amount of building components.



Figure 41: Rendering of the fifth floor gallery finishes. Courtesy of the MMAA & Renzo Piano Building Workshop.



Figure 42: Rendering of the sixth floor gallery finishes. Courtesy of the MMAA & Renzo Piano Building Workshop.

The finish materials for these gallery spaces consist of yellow pine wood flooring, drywall, and the grid of steel members that defines the ceiling. As you can see from Figures 41 and 42 the ceilings for the fifth and sixth floors are slightly different. This is because the sixth floor ceiling system has metal panels completely enclosing the gallery ceiling while the fifth floor system leaves the grid open to expose the mechanical and structural systems above. Also worth noting

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is that the fifth floor gallery is the largest column free gallery in the city. This provides a great empty canvas for an architectural redesign of the ceiling.

As minimalistic as the interior of the MMAA finishes are, the exterior architecture of the building is not for multiple reasons. First, as shown in Figure 43 the MMAA has a series of stepped terraces that contributes to the unique look of the MMAA and provides great views of the city. Next there is the cone shaped structure seen in Figure 44 that creates the top four floors of the building. The large curtainwall shown in Figure 44 is the mentioned cone structure above



west end of the 5th floor gallery and the Figure 43: View of the MMAA from the northeast. Courtesy of the cone structure mentioned above MMAA and Renzo Piano Building Workshop.

encloses the sixth through eighth floor galleries. Finally the last major architectural feature that defines the massing of the building is the large cantilevered entrance shown in Figure 45. This cantilever creates a grand space that is not quite outside or inside; it is a space of in between. So, to summarize the exterior of the MMAA is unique and elaborate while the interior spaces are simpler and minimalistic. The only elaborate elements in the MMAA galleries are the ceiling systems on the fifth through eight floors.



Figure 44 (Left): View of the MMAA from the southwest. Figure 45 (Right): View of the MMAA from the southeast looking at the cantilevered entrance. All images Courtesy of the MMAA and Renzo Piano Building Workshop.

Original Ceiling Design

The original ceiling system consists of a grid of miscellaneous metal pieces bolted together. Running in the north-south direction are 10' W5 steel member sections. On the next page, Figure 46 shows a rendering of the gallery ceiling system and Figure 47 shows a cross section of the ceiling system looking north. There are two W5 members that are approximately 11

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inches apart from each other running parallel across the gallery space. These two members are connected together by the bent steel plate Supported hanger. by this hanger directly are the fire suppression system, electrical raceways, and the W5 members. This assembly is repeated in ten foot increments across the width of the gallery. Running in the east west direction between these assemblies is all of the lighting for the gallery spaces. lt consists of track lighting strips that are enclosed by two steel



Figure 46: Rendering of the MMAA gallery ceiling system. Courtesy of Turner Construction Company.

angles, which are directly bolted to the W5 members using slotted connections. These angles are spaced every 3'4". The only difference in the gallery spaces is the sixth and seventh floor spaces have a metal panel system enclosing the ceiling system, while the fifth floor leaves the above construction exposed.

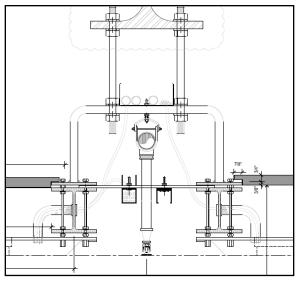


Figure 47: Section of the gallery ceiling system. Courtesy of Renzo Piano Building Workshop.

Original Ceiling Schedule

The construction of the original gallery ceiling system takes a very long time. This was one of the main reasons that a new ceiling system was investigated. On the next page Table 20 summarizes the construction schedule for a typical gallery ceiling system. As you can see the construction of the ceiling system alone (without the electrical or sprinkler activities) takes 77

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working days per gallery. This schedule is repeated on the fifth through eight floors. The reason that the schedule takes such a long time is due to the large amount of field connections that need to be made in order to install that intricate grid of structural steel members. It is important to note that the gallery fit out ties directly into the turnover to the owner. This and an overview of the original fit out schedule can be seen in Appendix C.

Table 20: Typical Gallery Ceiling Schedule of Activities

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				
	5				
Total	102				

Original Ceiling Costs

The project team could not provide any detailed cost information for the gallery ceilings. So, a cost estimate was made in order to compare the new system to the old system. The first step in this process was to complete takeoffs of all the ceiling components. The main components of the system and their takeoff estimates are displayed below in Table 21. The takeoff was limited to all of the structural steel members and not the electrical / fire protection systems because they will remain in the new ceiling system slightly modified. Then RS Means Construction Cost Data 2013 was used as a reference to price the material and labor required to complete the ceiling system. The reference sheets used for this estimate can be seen in Appendix J. Also, the final estimate can be seen separately in Appendix K. The final cost of the original 5th floor gallery ceiling is \$461,353 or \$26.89 per square foot. When this square foot price is extrapolated out to include the sixth through eighth galleries the final cost of all four galleries is \$1,157,146.

Table 2	21:	5th	Floor	Gallery	Ceiling	System	Takeoffs
1001010				Ganciy	B	.,	rancomo

ORIGINAL 5 th FLOOR GALLERY CEILING SYSTEM TAKEOFFS						
Item	Unit	Quantity				
W5x16 Members	LF	3,564				
2x2x1/4 Angle Members	LF	8,974				
C5x09 Members	LF	451				
Bent Steel Plate Hanger	EA	189				

Architectural Breadth: New Ceiling System Design

The goal of this breadth and analysis is to completely change the ceiling structure and so that it still fits in with the overarching architectural principles of the building but become easier and more cost effective to construct. As described earlier the galleries in the MMAA are very minimalistic. In the original design the ceiling system was the only component of the galleries that was not a simple flat surface. I wanted to incorporate that same kind of thinking into the redesign of the ceiling system. Another key element of my design was to use a ceiling system that would expose the structural and mechanical systems above without focusing on it. The structural and mechanical systems are being exposed because there are some very unique

elements in the plenum space. First the HVAC ductwork supply mains run east to west through the galleries and go directly through the structural steel using duct penetrations. The branch lines then run north to south in the galleries at the same level of structural beams. Integrating the the mechanical and structural systems at the same level leaves a lot of room for the other building components and contributes to the high ceiling heights that can be achieved in the galleries.

The ceiling system should be an interesting element of the galleries but at the same time Figure 48: Example of the ceiling shape that will be used in the it should not draw attention away from the art

that is being displayed in the space. In order to achieve all of those goals a multi tiered ceiling was developed using Armstrong ceiling products. First the lower layer of the ceiling would be composed of a tegular acoustical 2'x2' dropped ceiling. This lower layer would establish the perimeter of the gallery and allow for the center area of the gallery ceiling to be exposed to the structure and mechanical systems above. It would be shaped similarly to the ceiling shown in Figure 48; almost like a cloud. Then in the empty space left by the acoustical dropped ceiling a grid of 9/16" extruded metal pieces will be used to create a diamond pattern. This pattern will consist of 8" square sections that expose 90% of the ceiling structure above. An example of the grid that will be used in the MMAA can be seen in Figure 49. Installing this grid will allow the structure above the ceiling to be exposed without leaving it completely bare. The exposed ceiling will not dominate the room



MMAA. Taken from Armstrong.com



Figure 49: Example of the ceiling grid that will be used in the MMAA. Taken from Armstrong.com

when you walk in to the gallery because of this grid but the structure above still can be easily seen when wanted. Also, the structural and mechanical systems above the ceiling will be painted a dark blue color in order to achieve a consistent result from the new ceiling system.

Another goal of this redesign was make the ceiling system just as high as the original system. The original ceiling system was 17'6" above the finished floor. The original system had a lot more depth than the new system does and because of that the sprinkler mains run approximately one foot above the bottom piece of the ceiling system at 18'6" above the finished floor (Note this varies slightly due to the slope of the sprinkler line). The new ceiling system will set the acoustical grid level at 17'6" above the finished floor and have the open cell grid set six inches higher at 18' above the finished floor; Doing this will also give this ceiling some needed depth while staying away from any possible conflicts with the fire protection system. Due to this fact the fire protection system will not have to be redesigned significantly. Some of the sprinkler heads will be positioned at a slightly different height; but this difference will be negligible when considering any cost or schedule impacts.

The only component that will have to be adjusted due to the new ceiling system is the lighting system. The original lighting system consisted of 494 strips of 8' long lighting track that run in the east west direction. These strips were then offset from each other every 3'4" in the north south direction creating a matrix of lighting track. Doing this would allow the museum to create different lighting schemes as the exhibits changed throughout the years. Due to the importance of this the same scheme will be used in the new design with one minor exception. Where the acoustical ceiling is used the lighting track will be mounted flush with the grid at 17'6" above the finished floor. However, wherever the grid system is used the lighting track will be mounted above the ceiling just over 18' above the finished floor.

The ceiling plans for the fifth through seventh galleries can be seen below and on the next page in Figures 50 through 52. Note that in each of these figures the area that is shaded lighter is the tegular acoustical panel and the area that is crosshatched is the open cell grid. Each floor is slightly different in its layout due to the corresponding differences in gallery size and shape. Note that the eighth floor gallery is not represented. This is because that entire gallery will utilize the open cell grid ceiling system due to the clerestories that run across the gallery ceiling.

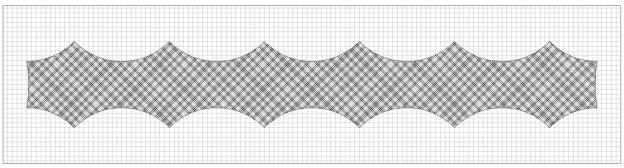


Figure 50: Fifth floor gallery reflected ceiling plan displaying the layout of the acoustical panels vs the open cell grid.

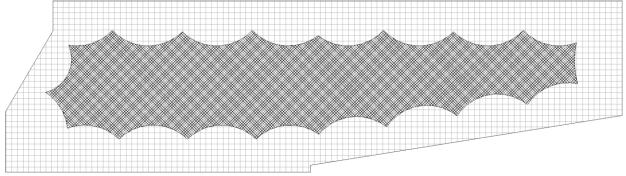


Figure 51: Sixth floor gallery reflected ceiling plan displaying the layout of the acoustical panels vs the open cell grid.

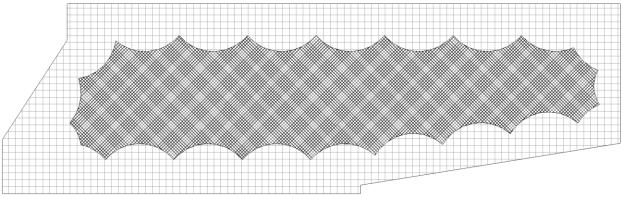


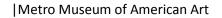
Figure 52: Seventh floor gallery reflected ceiling plan displaying the layout of the acoustical panels vs the open cell grid.

These ceiling plans were modeled using Revit; once they were completed the same program was used to takeoff the square footage of both ceiling system types. These takeoffs will be used in order to estimate the cost of the new design. A summary of the takeoffs by floor can be seen in Table 22 below.

CEILING SYSTEM TAKEOFFS BY FLOOR						
Floor	Total (SF)	Acoustical Ceiling (SF)	Open Cell Grid (SF)			
5 th	17,160	11,317	5,843			
6 th	11,353	6,574	4,779			
7 th	9,467	4,884	4,583			
8 TH	5,060	0	5,060			
Total	43,040	22,775	20,265			

Table 22: Ceiling Systems Taken off by Floor.

Over the course of all four floors the two types of ceiling system have approximately the same square footage. Finally, renderings of the redesigned ceiling system can be seen on the next page in Figures 53 and 54. As you can see the tegular acoustical panels line the perimeter of the gallery while the open cell grid appears throughout the center of the gallery. The dark blue above the ceiling systems represent the painted mechanical and structural systems.





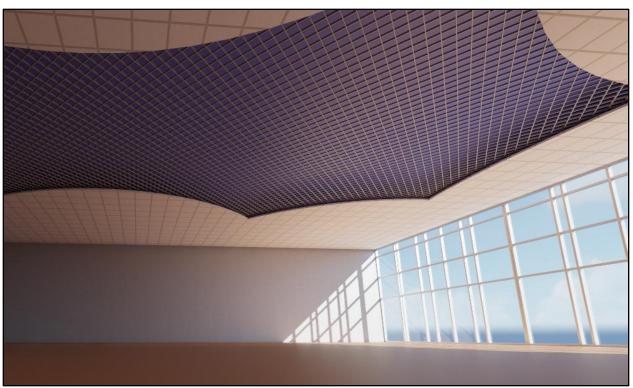


Figure 53: Rendering of the 5th floor gallery ceiling. Modeled by Vincent Rossi.

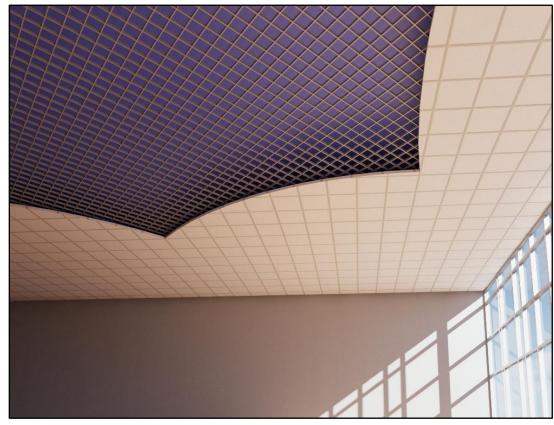


Figure 54: Rendering of the fifth floor gallery ceiling. Modeled by Vincent Rossi.

New Ceiling System Schedule

One of the biggest benefits of the redesigned ceiling system is the fact that it is simpler to construct and will take less time to construct. The original project schedule allocated approximately 77 days per gallery to install the original ceiling structure. Table 23 below summarizes how long it will take to install the redesigned gallery ceiling. Note that in order to complete this table the RS Means production rates were used. Those rates are based off what a single carpenter can complete. For the MMAA installation a team of four carpenters will be used for the acoustical ceiling and a team of two carpenters will be used for the open cell grid. These adjusted rates are also displayed in Table 23.

	CEILING SYSTEM TAKEOFFS BY FLOOR								
Floor	Acoustical Ceiling (SF)	Open Cell Grid (SF)	Production Rate of AC (SF/Day/Team(4Carp))	Production Rate of Grid (SF/Day/Team(2Carp))	Installation Time for AC (Days)	Installation Time for Grid (Days)			
5 th	11,317	5,843	1000	860	12	7			
6 th	6,574	4,779	1000	860	7	6			
7 th	4,884	4,583	1000	860	5	6			
8 ^{1H}	0	5,060	1000	860	0	6			
Total					24	25			

 Table 23: Gallery Installation Schedule Lengths

As you can see there is a fluxuation in schedule length for each of the activities between floors. A new fit out schedule was created using Primavera that implements these schedule changes in order to determine the schedule savings associated with redesigning the gallery ceiling. This fit out schedule will start with the Overhead MEP Rough-In activity in each gallery because this is the activity that drives the fit out schedule and starts the flow of activities. In summary the changes that were made to the fit out schedule are as follows:

- Activities eliminated from the project schedule.
 - o Ceiling Layout & Hang Drop Rods/Unistrut: 25 Days / Gallery
 - o Install W5 Sections and Infill Pieces: 35 Days / Gallery
 - Install Ceiling Panels: 12 Days / Gallery
 - Ceiling Trim: 5 Days/ Gallery
- Activities added to the project schedule:
 - o Open Cell Grid Installation: Varies
 - Acousticsal Panel installation: Varies

The new gallery fit out schedule can be seen in Appendix L. When compared to the fit out section of the original schedule (which can be seen in Appendix C) there is a significant amount of time that is saved due to the use of the redesigned ceiling system. Originally, the gallery fit out was scheduled to be complete by November 28, 2014. Now the gallery fit out is scheduled to be complete on August 4, 2014. This substantial savings is due to the fact that the average length of construction for the original gallery ceiling structure was 77 days per gallery; while the average length of construction for the redesigned ceiling system is approximately 12 days per

gallery. The ability for the gallery fit out to be complete on August 4, 2014 does not mean that the overall project schedule can be finished on that date. There are independent activities in the overall interior fit out that finish after this August 4, 2014 date. The most limiting activities are the Office & Conference/Trustee Rm. Fit-out, and the Bookstore / Café Fit-Out; which both finish on October 23, 2014. So these activities will be the final project activities and will tie directly into the turnover to the owner. The reduction in schedule from November 28, 2014 to October 23, 2014 allows the project to be reduced by 26 working days. This will ultimately save the owner money because the general conditions costs of the project will be reduced by a significant sum of money.

New Ceiling System Cost

The cost of the redesigned ceiling system was estimated using RS Means Construction Cost Data 2013. The pages of this text that were used for reference are reproduced in Appendix J. There are three main elements of the new ceiling system that had to be priced. First was the painting of the structural and mechanical systems above the ceiling. Second was the open cell extruded metal grid and finally, the last item was the tegular acoustical panels. None of the other building systems above the ceiling were priced up because the changes to those systems were negligible in terms of cost and schedule. Table 24 below summarizes the cost of the original ceiling system vs the redesigned system. The detailed estimate for the new ceiling system can be seen in Appendix K.

ORIGINAL VS REDESIGNED CEILING SYSTEM ESTIMATES								
Floor Original Estimate Redesigned Estimate Difference (\$) (\$) (\$)								
5 th	461,353	196,129	265,224					
Total	1,157,147	473,701	683,446					

 Table 24: Original vs Redesigned Ceiling System Estimates.

As you can see the redesigned ceiling system will provide a significant savings to the owner that is estimated to be approximately \$683K. This savings mainly comes from the decrease in labor associated with building the ceiling system. The original ceiling system was very labor intensive while this new ceiling system takes a much more conventional time to build. This decrease in labor also has positive schedule effects that were outlined in the previous section. Using the redesigned ceiling system would result in the project schedule being reduced by five weeks. This would provide a cost savings by reducing the general conditions on the project. The general conditions on the project were originally budgeted for a total of \$15,722,000. This total is spread out over approximately 37 months or 158 weeks to be more exact. The weekly cost of general conditions is equal to \$99,506. Therefore, shortening the schedule by five weeks will save the project approximately \$497,500. A summary of the overall costs saving can be seen on the next page in Table 25. This table shows that by implementing the redesigned ceiling system the owner can save \$1,180,946 on material, labor, and general conditions. Although this sum initially looks large it is really only 0.44% of the \$266M project budget.

Table 25: Redesigned Ceiling System Cost Savings.

REDESIGNED CEILING SYSTEM COST SAVINGS					
Description Cost Savings (\$)					
Material & Labor Savings	683,446				
General Conditions Savings	497,500				
Total	1,180,946				

Acoustical Breadth: Evaluating the New Gallery Ceiling System

One item that is often overlooked when designing a room or structure is the acoustical impacts that design has on the space and its occupants. The second breadth of this thesis report will focus on analyzing the fifth floor gallery space in the MMAA. This analysis will compare the original gallery design to the design that I authored in two areas. First the reverberation time (T60) will be calculated for each design, then the noise criteria (NC) will be determined for the two designs.

Reverberation Time

The first analysis that was run is the T60 calculation. This determines how long it will take the sound to decay 60 dB after the source of the noise has stopped. This is a very important calculation because if the T60 is too high or low for a space the noise will not have its desired effect and the occupants can become uncomfortable. In areas where speech will be the dominate noise the T60 time should be relatively low (below 1.3 seconds), and where music will be the main source of noise the T60 time should longer. The MMAA will be considered more speech oriented so that a speaker could be heard easily and so that there will not be an excessive amount of sound persisting in the space. The MMAA will be considered a "intimate drams" space as shown in Figure 55 on the next page. This means that the optimum reverberation time for the MMAA galleries is between 0.8 and 1.2 seconds. In order to complete this analysis the room dimensions and materials must be known. All of this was completed by completing a detailed takeoff of the square footage for each finish material in the fifth floor gallery. The detailed calculations for the T60 times for the original design and the redesign can be seen in Appendix M. The final reverberation time is calculated by averaging the reverberation at 500 and 1000 Hz. Table 26 below summarizes the reverberation times for the original design and the redesign.

Table 26: Reverberation Time Comparison

REVERBERATION TIME COMPARISON				
Design	T60 (s)			
Original Design	1.46			
Redesign	0.96			

As you can see the redesign has a lower reverberation time and one that it closer to the optimum reverberation time for this space. This is due to the fact that the redesigned ceiling uses much more absorptive materials than the original ceiling design did such as acoustical panels.

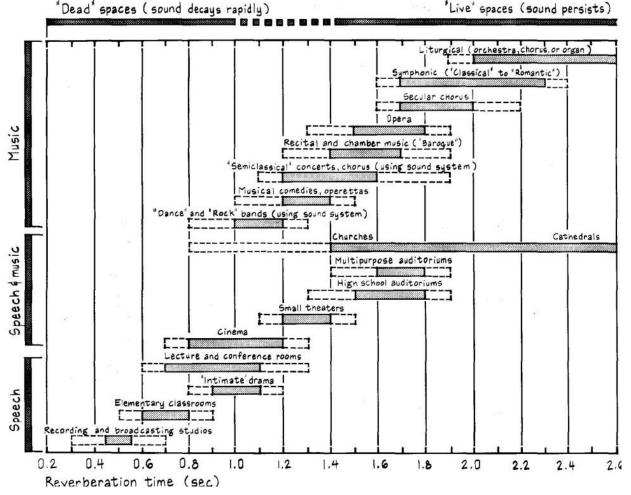


Figure 55: Optimum Reverberation Times for different spaces. Image taken from Architectural Acoustics.

Noise Criteria

Next, the noise criteria was determined. This value basically rates a space on how loud it will become during continuous use. In the case of the MMAA it was assumed that a typical gathering would include 100 people each speaking at 55 dB, which translates to a total of 95 dB. This amount is then compared to the total sound absorption available per octave band frequency in the room that will lower the overall noise in the room. This gives a dB value that can be charted to calculate the NC rating. The octave band frequency dB values for both the original and redesigned gallery systems can be seen below in Table 27. Note that the NC calculations can also be seen in Appendix M on the same sheet as the reverberation time calculations.

 Table 27: Comparison of decibels per octave band.

DECIBLE COMPARISON PER OCTAVE BAND FREQUENCY (dB)							
Design	125H	lz 250Hz	: 500Hz	1000Hz	2000Hz	4000Hz	
Original	55.	5 57.0	55.5	55.1	55.2	56.0	
Redesign	53.3	3 55.0	53.9	53.9	53.9	54.8	

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This table shows that the redesign has a slightly lower decible level per octave band frequency. It is surprising that the decibel level was not reduced even further than it was in the redesigned gallery considering the increase in sound absorptive materials. The next step in the process is to plot these decible levels on a NC chart in order to determine the NC value for the original and redesigned rooms. Figures 56 and 57 below chart the dB values on the NC chart in order to determine the NC value for each design of the gallery.

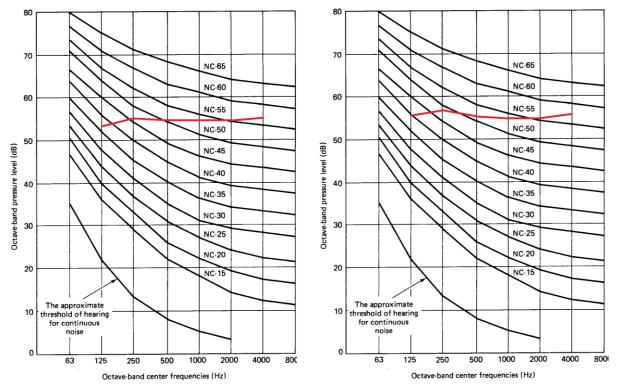


Figure 56(Left): NC Chart for the Original Design. Figure 57(Right): NC Chart for the Redesign Images taken from Architectural Acoustics.

These charts show that the NC values for both the original and redesigned gallery ceiling systems are NC60. This is because that NC line is the first one that is not intersected by the red dB line that represents the dB level per ocave band frequency. This is much higher than what would be desired for a space such as the MMAA galleries. This type of space would benefit from having a NC rating around 30 to 40. A NC60 space is classified as "Very Noisy" according to *Architectural Acoustics*.

Conclusion and Recommendations

The redesigned ceiling system eliminates the grid of structural steel members that originally defined the gallery ceiling and replaced it with a network of acoustical panels, open cell grid, and exposed ceiling structure. This ceiling system provided a lot of benefits to the MMAA. First, if this ceiling system is implemented then the project schedule could be reduced by up to five weeks. Next, there would be significant cost savings associated with implementing this system that comes from two different areas. First, the cost of the labor and materials will be \$683K less than the original system with the bulk of the savings coming from the decrease in labor.

Secondly, there will be a general conditions savings of \$497K due to the shortened project schedule. All of this money goes directly into the pocket of the owner and because of this it is ultimately their decision to make. If they believe that the new ceiling system still meets their needs and adds value to the project they should implement this design of the gallery ceiling system. The redesigned gallery system also had a slower reverberation time that would make it more comfortable for the occupants. Unfortunately, the NC value is a bit high at NC60 but it is no different from the original design. This is one area where the MMAA gallery could be improved even further. All things considered my recommendation would be to implement the redesigned gallery ceiling system due to all of these savings.

ANALYSIS 2: 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.

Analysis Goals

The main goal of this study is to investigate if implementing a short interval production schedule (SIPS) would be beneficial to the Metro Museum of American Art (MMAA) construction project. The main driving factor of a SIPS is that it shortens the overall schedule length of the project. Because the gallery fit-out schedule ties directly into the turnover to the owner implementing a successful SIPS will indeed shorten the overall project schedule. The main savings from implementing a SIPS comes from the general conditions that are saved due to the shorter construction period. This analysis will be completed by researching a relevant case study and applying the learned principles to the MMAA.

The original plan was to use a SIPS in conjunction with the prefabrication of the gallery ceiling system, that was detailed in the first analysis, in order to make the gallery fit-out schedule as efficient as possible. However, because the first analysis worked so well, shortening the gallery fit-out schedule by any more would not result in the overall schedule being shortened. This is because there are independent activities that restrict the project from being turned over to the owner before October 23, 2014. The prefabrication process alone allowed the gallery fit-out schedule to be completed by October 2, 2014. So, as you can see shortening the gallery fit-out schedule even further with a SIPS would not shorten the overall project schedule and no additional dollars would be saved. Due to this, the goal of this analysis is to compare any savings that the SIPS schedule creates to the savings we know the prefabrication process will create in order to determine what process should be implemented.

Background Research Performed

A SIPS breaks down a project sequence into more detail than a typical project schedule would. It defines durations 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 or high rise office building,

but all of the gallery spaces are all constructed with the exact same gallery fit-out schedule. This provides the potential for the galleries to act as zones for the work crews to move sequentially through. Currently the gallery fit-out schedules have an 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 10 to 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. These include the MEP rough-in, ceiling installation, and the sleeper layout and installation. These activities may have to be broken down into smaller tasks to allow the SIPS to flow evenly and not diminish the crew size on the other activities too much. Doing 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 progress through the zones. Their productivity will start relatively low and then increase as the project progresses.

Pentagon Case Study

The renovation of the Pentagon utilized a SIPS schedule. That schedule divided the Pentagon interior into thirty eight 10,000 square foot zones (Pentagon). Each trade or activity was given one week to complete their scope of the work and move on to the next zone. They used a total of 26 activities which means that it would take 26 weeks for a zone to be delivered fully complete. After this first zone was finished an additional zone would be completed each subsequent week until all 38 zones were finished (Pentagon). The schedule allows for all 38 zones to be completed in 63 work weeks. This can be seen on the next page in Figure 58 which displays the SIPS schedule that was used during the renovation of the pentagon.

As you can see from this image a SIPS schedule creates a continuous flow of trades throughout the different zones. The horizontal axis represents the timeframe in which the schedule is completed. Each line or box in this direction represents a week of schedule time. The vertical axis represents the order in which the zones will be completed. The first zone is listed at the top left and each subsequent zone is listed below the first. Each colored box represents one of the trades. For example, the first activity was the installation of the sprinkler main and branch lines and it is represented by the yellow colored boxes that flow from the top left of the schedule to the bottom right. The final activities were the furniture install and clean up of the space. This clean up activity is colored box within the flow of trades represents three things; the date, location, and the trade that is there performing work. This assures that all of the workers know exactly where they need to be at all times during the project schedule. This elimination of confusion allows the workers to become more productive and lowers the stress level on the project. Also, as you can see there are no work stoppages in any of the zones due to implementing a SIPS schedule.

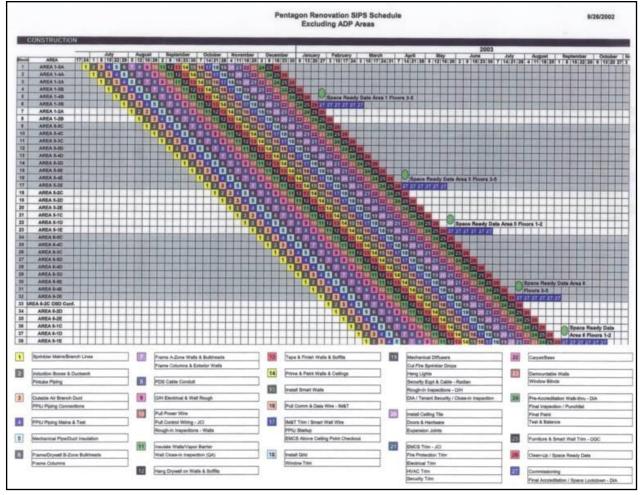


Figure 58: SIPS Schedule used during the pentagon construction. Image taken from http://renovation.pentagon.mil/wedge2-5/sips.htm

MMAA Activity Analysis

The next step is to identify all of the activities that will be used in the SIPS schedule for the MMAA. The schedule will focus on the gallery fit-outs of the fifth through eighth floors because they are all very similar in nature. Note that the first floor gallery will be left out because its ceiling structure is completely different than the fifth through eighth floors. Figure 59 below shows a typical gallery fit-out schedule.

Gallery						
INT-5-100	Install hangers	01-29-13	02-11-13	10	10	🗖 Install hangers
INT-5-101	Protect surface adjacent to steel	02-12-13	02-19-13	5	5	Protect surface adjacent to steel
INT-5-122	Cure SOFP (28 cal days)	03-06-13	04-02-13	20	20	Cure SOFP (28 cal days)
INT-5-102	Paint metal deck & SOFP	04-03-13	04-16-13	10	10	Paint metal deck & SOFP
INT-5-103	Overhead MEP rough in	06-21-13	08-16-13	40	40	Overhead ME
INT-5-104	Layout and frame	08-19-13	09-04-13	12	12	🗖 Layout and
INT-5-105	Rough partitions	08-28-13	09-18-13	15	15	Rough p
INT-5-106	Sheetrock partitions	09-19-13	09-27-13	7	7	Sheetr
INT-5-107	Skim coat walls (3 coats) ring ceiling line	09-30-13	10-15-13	12	12	Ski
INT-5-108	Paint ceiling line up	10-16-13	10-18-13	3	3	D Pai
INT-5-109	Ceiling layout and hang drop rods/unistrut	10-21-13	11-22-13	25	25	
INT-5-110	Install W5 sections and infill pieces	11-25-13	01-15-14	35	35	
INT-5-111	Rough-in lighting	01-16-14	01-29-14	10	10	
INT-5-112	Sprinkler heads	01-30-14	02-20-14	15	15	
INT-5-113	Install ceiling panels	02-21-14	03-10-14	12	12	
INT-5-114	Ceiling trim	03-11-14	03-17-14	5	5	
INT-5-115	Layout/frame/install sleepers	03-18-14	04-30-14	32	32	
INT-5-116	Plywood subfloor	05-01-14	05-16-14	12	12	
INT-5-117	Patch skim coat	05-19-14	05-23-14	5	5	
INT-5-118	Paint	05-27-14	06-03-14	6	6	
INT-5-119	Lights and MEP finish trim	06-04-14	06-17-14	10	10	
INT-5-120	Wood flooring	06-19-14	07-15-14	18	18	
INT-5-123	Punchlist	07-16-14	08-19-14	25	25	

Figure 59: Excerpt of the original 5th floor gallery fit out schedule. Courtesy of Turner Construction Company.

As you can see from Figure 59 there is a large gap between the end of the "Paint Metal Deck & SOFP" activity and the "Overhead MEP Rough-In" Activity. This is due to the fact that the MEP rough in is a more time consuming activity than the painting activity. This gap between activities grows bigger and bigger each floor as the lag builds up. This leaves the gallery space empty with no work going on for substantial amounts of time. Due to this, the MEP Rough-In activity drives the interior fit-out schedule. So, the gallery SIPS schedule will commence with the "Overhead MEP Rough-In" activity and continue all the way through to the "Punchlist". The MEP rough-in activity starts on 6/21/13 in the fifth floor gallery; which is a Friday. So the SIPS schedule will start on the following Monday 6/24/13. The interior fit-out schedule will progress as originally scheduled until 6/24/13. After that date all activities in the gallery fit-out schedule will become part of the SIPS.

Tables 28 and 29 displayed on the next page are lists of all of the activities from the original gallery fit-out schedule along with their original durations and how they will be adjusted to fit the SIPS schedule. Some of the shorter activities will have to be combined with similar activities while some of the longer activities will have to be broken down in to more detailed activities. The major changes to the schedule of activities are as follows:

 First, the MEP Rough In activity was broken down into separate Mechanical Rough-In and Electrical Rough-In activities. Plumbing is not included in the breakdown because the limited amounts of plumbing lines that exist in the gallery spaces serve the mechanical system anyways. Separating these activities will allow the activity length to

be cut in half from 40 to 20 days. Because this is the longest schedule length it will become the target for all of the other activities.

- Next, the rough and sheetrock partition activities will be combined together. This will create an activity with a length of 22 days. As you can see this is longer than the target activity length of twenty days. However, this activity can be accelerated rather easily by adding a small amount of additional manpower. In contrast, it would be difficult to accelerate the installation of the MEP systems.
- The skim coat walls (3 coats) and the paint ceiling line up activities will be combined into one 15 day long activity. This along with any other activity that is below the target 20 day activity length will have to scale back its crew size in order to come as close as possible to the 20 day schedule length. Although this seems like the overall gallery fit-out productivity is going down, hopefully, the flow of trades that the SIPS creates will counter this by mitigating any schedule delays.
- The ceiling system had to be split into four activities instead of two. First, the ceiling layout and drop rod installation were separated into two separate activities under 20 days long. Second, the W5 sections and infill pieces activity was separated into 2 separate activities are now both under 20 days long.

ORIGINAL					
GALLERY FIT-OUT ACTIVITIES					
Activity	(Days)				
Overhead MEP Rough-In	40				
Layout and frame	12				
Rough partitions	15				
Sheetrock partitions	7				
Skim coat walls (3 coats)	12				
Paint ceiling line up	3				
Ceiling layout/hang drop rods	25				
Install W5 sections & Infill pieces	35				
Rough-in lighting	10				
Sprinkler heads	15				
Install ceiling panels	12				
Ceiling trim	5				
Layout/frame/install Sleepers	32				
Plywood subfloor	12				
Patch skim coat	5				
Paint	6				
Lights and MEP finish trim	10				
Wood flooring	18				
Punchlist	25				

Tables 28 & 29: Original and Adjusted Gallery Fit-Out Activities

ADJUSTED				
GALLERY FIT-OUT ACTIVITIES				
Activity	Duration (Days)			
Mechanical Rough-In	20			
Electrical Rough-In	20			
Layout and frame	12			
Rough & Sheetrock Partitions	22			
Skim coat walls (3 coats) & Paint Ceiling Line Up	15			
Ceiling Layout	13			
Hang Drop Rods	12			
Install W5 sections	18			
Install Infill pieces	17			
Rough-in lighting	10			
Sprinkler heads	15			
Install ceiling panels/ Ceiling Trim	17			
Layout/frame Sleepers	16			
Install Sleepers	16			
Plywood subfloor	12			
Patch skim coat/ Paint	11			
Lights and MEP finish trim	10			
Wood flooring	18			
Punchlist	25			

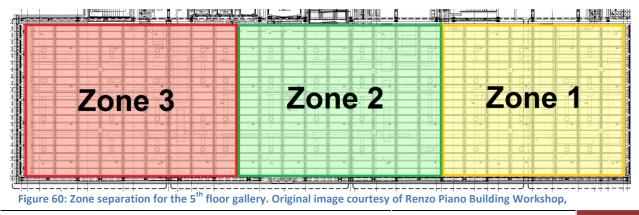
- Next, the ceiling panel and ceiling trim activities were combined into one 17 day long sequence.
- Finally, the last activity that was combined was the patch skim coat and final painting activities. Note that the total amount of scheduled days for both the original schedule and the adjusted schedule is 299 days. Also, remember that there is 4 times the amount of work because these totals are for only one of the gallery spaces.

Zone Definition

Now the work zones need to be established. The fifth through eighth floors all have different square footages. Table 30 below shows a summary of the total square footage per floor. Table 30: Square footage per gallery.

SQUARE FOOTAGE PER GALLERY					
Floor	Square Footage	Number of Zones	Square Footage Per Zone		
5 th	17,160	3	5,700		
6 th	11,353	2	5,675		
7 th	9,467	2	4,734		
8 th	5,060	1	5,060		
Total	43,040	8	5,380		

As you can see the fifth floor gallery is significantly larger than any of the other galleries. This is a problem because the zones need to be equal. So, the solution will be to split the fifth floor gallery in to three equal sizes zone. Next the sixth and seventh floor galleries will be split in half to make two equal sized zones. Finally the eighth floor gallery will not be split at all and will be its own zone. This will allow all of the zones to equal approximately 5,000 square feet of space. The zones will be split so that each zone has the same amount of perimeter as well as interior square footage. This is important because the amount work that takes place on the perimeter of the gallery such as partitions and painting needs to be the same in each zone in order for the SIPS to work effectively. This is really only a problem on the fifth floor gallery where there is a center zone with no side walls. However, upon looking at the drawings further this will not be a problem because the side walls of the fifth floor gallery are almost completely curtain wall glazing. Figures 60 - 63 below and on the next page display the zone distributions per gallery.



Penn State AE Senior Thesis

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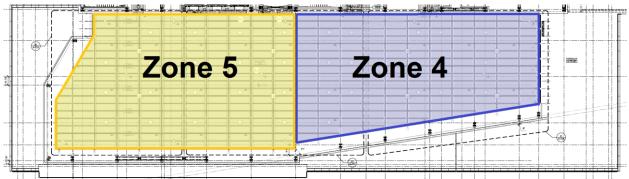


Figure 61: Zone separation for the 6th floor gallery. Original image courtesy of Renzo Piano Building Workshop,



Figure 62: Zone separation for the 7th floor gallery. Original image courtesy of Renzo Piano Building Workshop,

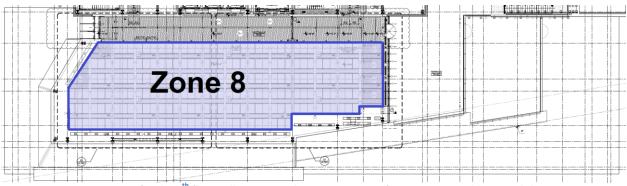


Figure 63: Zone separation for the 8th floor gallery. Original image courtesy of Renzo Piano Building Workshop,

The best way to distribute the workload between the zones is to make sure that the total amount of work is split between the eight zones evenly. For example, the mechanical rough-in activity is listed as a 20 day activity per gallery space. So, that equals a total of 80 work days for all four galleries in question. These eighty days will be split evenly across all eight zones to give a 10 day zone time. Also, one of the main requirements of a successful SIPS is that all of the activities have the same duration. This fact is what gives the SIPS the ability to flow without any downtime between the trades. This will be accomplished by adjusting workforce of all of the activities that take less than 20 days so that they are as close to the 20 day schedule length per gallery as possible. This will allow all of the activities to be completed in 10 days per zone or 80 days overall.

SIPS Schedule Creation

Now that the start date, typical activity length, and the amount of activities have been established; the SIPS schedule can be generated. A SIPS does not need to be created using a special scheduling program. Rather, it can be made using simple software such as Microsoft Excel; which is how the MMAA's prospective SIPS was made. The MMAA SIPS can be seen below in Figure 64 and in full size in Appendix N.

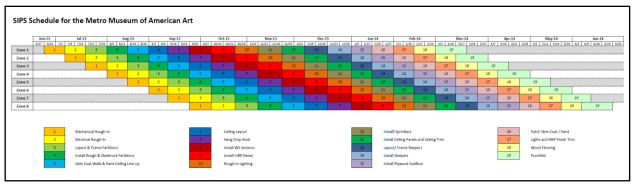


Figure 64: MMAA SIPS

As you can see from this schedule it is very similar in nature to the Pentagon SIPS discussed earlier. Once again the horizontal axis represents the timeline, the vertical axis represents the different zones, and each individual colored box represents the trade that occupies each zone at each specific time. The only difference between these schedules is that the MMAA SIPS used 10 work day activities as opposed to the 5 work day activities that were used on the Pentagon.

The MMAA SIPS cut down the overall project schedule from approximately 17 months to 12 months. At first this seemed to be an excessive reduction to me. However, after evaluating the original schedule and the SIPS it became clear that this reduction was in fact possible. One of the main reasons that the SIPS created so much schedule savings was that it allowed more than one trade to be working in each gallery space at a time. The original gallery fit-out was scheduled so that each activity had the entire gallery devoted to them and their work. Also, all of the activities had start to finish relationships which means that one activity cannot begin in the space until the preceding is complete. While the start to finish relationship did not change with the implementation of a SIPS, the fact that each activity had a gallery to themselves did. Separating the galleries into zones allowed the amount of work being done in a gallery to be double or tripled depending on the floor in question. This greatly increased the amount of work going on inside the MMAA which fueled the schedule savings.

Looking into this further the fifth floor gallery would be completed after the third zone was completed. The first zone would be complete 195 days after the 6/24/13 start date (18 activities at 10 days per zone, plus the punchlist at 15 days). Each additional zone would then be completed 10 days after. This means that the third zone and subsequently the fifth floor gallery would be completed 215 days after the 6/24/13 start date. This is significantly faster than the original schedule that took 299 days to be completed. Table 31 on the next page shows the when each gallery space will be started and completed.

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Table 31: SIPS Summary

SIPS SUMMARY						
Gallery	Start Date	Finish Date	SIPS Schedule Length (Weeks)			
5 th	6/24/13	4/18/14	43			
6 th	8/5/13	5/16/14	41			
7 th	9/2/13	6/13/14	41			
8 th	9/30/13	6/27/14	39			
Overall	6/24/13	6/27/14	53			

While the overall work days went down (299 to 215 work days) the amount of days worked by the sum of the trades in that time goes up. This is because the manpower was scaled back in order to accommodate the 20 day target schedule length. For example, on the sixth floor there were 390 trade days worked. All 18 of the trades each worked 10 days in the fourth and fifth zones respectively and the punchlist took a total of 30 trade days for both zones combined. It needs to be emphasized that there were no extra man hours worked when making the SIPS. The increase in trade days is simply due to the scaling of the manpower. Doing this allowed the best qualities of a SIPS to be brought out; a constant flow of different work and trades through the zones. While the original schedule also had mostly constant flow through the galleries, it was not nearly as efficient as the SIPS. This flow of trades coupled with the fact that the SIPS allowed multiple trades in the galleries at one time are the main factors that reduced the project schedule by so much.

Overall, by ending on June 27, 2014, the SIPS allowed the gallery fit-out schedule to be reduced by 22 work weeks or approximately five months. However, similar to the prefabrication process the overall project schedule cannot be reduced by the complete five months due to independent activities that are displayed below in Table 32. As you can see from this table the earliest that the MMAA project can be finished based on these independent activities is October 23, 2014. When compared to the previously planned November 28, 2014 completion date the prefabrication process ends up saving 26 actual working days or just over 5 calendar weeks. Table 32: List of relevant activities that end after the completion of the SIPS

ACTIVITIES THAT END AFTER JUNE 27 TH , 2014					
Floor	Description	Date Complete			
8 th	Office & Conference/Trustee Rm. Fit-out	10/23/14			
8 th	Bookstore & Café Fit-Out	10/23/14			
9 th	Drywall & Interior Finishes	10/23/14			

The general conditions on the project were originally budgeted for a total of \$15,722,000. This total is spread out over approximately 37 months or 158 weeks to be more exact. The weekly

cost of general conditions is equal to \$99,506. Therefore, shortening the schedule by five weeks will save the project approximately \$497,500.

Cost Implications

Implementing the SIPS does not really incur any additional costs which is a huge benefit. As stated before the total amount of manpower stays the same. It was simply scaled to a different level and reschedule. There are no more material or equipment costs because the exact same product is being created. Finally, there may be some additional management costs associated with creating the SIPS. However, once the SIPS is in place those costs will eventually be outweighed by the positive impact that the SIPS has on the project. The positive impact of the SIPS includes the fact that because all of the trades know exactly where they need to be and where they will be for the duration of the fit-out less time will be spent managing them. This clarity of procedure and sequencing is very valuable to the construction process and the management team. There will be cost savings established from the general conditions that are saved by shortening the project schedule by five weeks. So, overall the cost implications for implementing the gallery fit-out SIPS is a savings of \$497,500.

Conclusion & Recommendation

Using a SIPS will accelerate the interior gallery fit-out construction length by five months and the overall project schedule by five weeks. 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.

Because of the significant cost saving I would recommend that the SIPS be implemented on the MMAA project. It is also important to consider whether to implement the prefabrication process discussed earlier or the SIPS, as implementing both would not add any additional benefit to the project. When comparing the two it is easy to identify the SIPS as the more attractive option. They both save the same amount of general conditions costs. However, the SIPS does not have any other additional significant costs associated with it. The prefabrication process on the other hand has additional costs such as transportation and warehousing costs that eat into the general conditions from the management team. The SIPS creates more monetary benefit while providing the easiest path to implement, and due to that the SIPS should be implemented before the prefabrication process.

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.

Analysis Goals

The goal of this analysis is to discover and analyze any union division of labor issues that could arise from the use of a prefabrication process on the MMAA project. This analysis will be completed by researching case studies of projects that used a prefabrication process and had a union related issue. Next, this analysis will walk through the MMAA's prefabrication process in order to discover the union issues that could arise. Finally, a possible solution that will satisfy all of the parties involved will be outlined.

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 which 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 which trade will be responsible for lifting the final prefabricated modules into place. This work is 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 the individual modules are constructed, where each trade will be constructing their scope of the work, and how these modules will 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.

Case Studies

The first case study that will be examined is the Atlantic Yards project located in Brooklyn, New York. A rendering of the project can be seen in Figure 65 to the right. This project is part of a development program that was meant to revitalize the Brooklyn area by bringing jobs and affordable housing into the area. The Atlantic Yards project is part of the development that saw the Barclays Center be constructed, which is the new arena for the Brooklyn Nets NBA basketball team and the New York Islanders NHL hockey team. The Atlantic Yards is utilizing prefabricated modules to expedite the construction of the building. It is planned to be the tallest building ever constructed using prefabricated modules at 32 stories high. It will be constructed using 930 prefabricated steel boxes that are basically stacked and bolted together once they arrive at the jobsite. The use of the prefabricated modules will save the project months of schedule time and cut costs by up to 25% (Bush).



Figure 65: Rendering of the Atlantic Yards project. Image taken from brooklynpaper.com.

Although these time and cost savings sound great, a lot of them were at the expense of the unions. By implementing the modular construction a lot of the construction work was moved from the field into the factory where the workers make less than half of what they would make in the field (Bush). This was a point of contention for the union, but they ultimately backed the plan due to the fact that the developer promised to use entirely union labor for the construction work related to the development. In the end this would still bring a substantial amount of jobs to the area even though it would be less than if the building was built traditionally in the field.

The good news about applying this case study to the MMAA is that the MMAA's prefabrication is much simpler. The proposed prefabrication process that was discussed in Analysis 1A is not sending the work to a factory to be made. Instead the same union workers will still be building the prefabricated modules; they will simply be in a warehouse as opposed to on a construction site. This means that no union jobs will be lost due to the MMAA prefabrication process. There may be a productivity increase that would reduce the time needed to construct the modules, but no union should be opposed to a system that increases the power of the workforce.

Through my research it seemed as though the critical issue was not the division of labor during a prefabrication process. Instead it was just the fact that implementing a prefabrication process takes away jobs from the workers a lot of the time. They tend to believe that the prefabrication process devalues the use of union labor and that almost anybody could work in one of those

prefabrication factories with little training. Take for example this excerpt from an article published by *Electrical Contractor Magazine:*

"Using prefabricated and preassembled electrical components often can bring substantial cost savings, especially on large projects such as hotels and hospitals that have a large number of identical layouts. Some contractors have used preassembled products for years; others are trying them for the first time, while there are some who have yet to do so. And while labor issues that once restrained the practice of assembling electrical parts off the job site are less an issue today, some contractors say many electricians in the field are not happy when prefabricated assemblies are used, feeling that they devalue their skills and experience and ultimately could threaten jobs. "Prefab stuff?" snorted one union electrician. "They don't need us for that. A monkey can do that work." Even so, suppliers of prefabricated components and the contractors who install them say that their use is growing steadily and that the trend will continue"

This passage is just one example of why some union representatives are opposed to prefabrication and the shifting of the work from the field to the factory. One could argue that using the prefabrication factories would reduce the quality of the end product due the cheaper cost but I am not convinced. I believe that using an assembly line type of work environment with specialized workers can create a very high quality product. As long as the intra module connections are done properly in the field, the process can be very successful and therefore valuable to the project.

The MMAA Case Study

This section will walk through the MMAA prefabrication process to determine any issues that the unions might raise. Thankfully after reviewing the MMAA there were not a lot of points that could cause contention.

The first step in the prefabrication was moving the work from the construction site to the warehouse. Unlike the previous case study, I planned on having the same union workers complete the prefabricated modules. They would simply be completing the work in a different and more comfortable location. As you can see from Analysis 1A their wage rates were not changed; so there should not be any contention from the unions on this front.

The prefabricated units were planned on being completed in an assembly line fashion. All three of the trades would have a station set up for them in the warehouse with ample room around the module to work and once each trade is complete with a module a laborer will be responsible for moving the module to the next trade or to the storage pile if it is finished. All of their tools and materials could be stored nearby their station and they would be working in a climate controlled environment that is much more comfortable than your typical job site. Since the prefabricated modules create the ceiling system, if they were stick built in the field the workers would spend the majority of their time working overhead which can be straining to the body quickly. However, by prefabricating the modules in the warehouse they can work at a comfortable height where they are less prone to injury and more productive. All of these points are benefits to the workers that are derived from the prefabrication process.

There is one issue that could possibly occur during the warehouse phase of the prefabrication process. Once a trade is complete with their work on a particular module somebody will have to transport said module to the next trade's station; or when fully complete, to the storage pile. None of the trades will want to do this work themselves because it is out of their scope. Therefore a laborer will have to be hired to be responsible for moving the modules around the warehouse. This adds a substantial additional cost to the project. The prefabrication analysis showed that when applied over all 84 working days that the warehouse will be in operation it will add an additional cost of approximately \$48,000. Although this seems like a very high price to pay it was worth it in the case of the MMAA due to the general conditions saved.

The next step in the process is to transport the modules to the jobsite. All of the materials needed for the gallery ceiling systems would be delivered directly to the warehouse instead of the construction site. Then it would be the general contractor's responsibility to bear the costs associated with transporting the modules from the warehouse to the jobsite. I initially thought this would be a problem area when dividing up the labor due to the liability of moving the fully complete units. However, after consulting my advisor, Ray Sowers, he advised that the Teamsters union would handle the transport of the modules from the warehouse to the jobsite in time for placement.

Next, after the modules are craned into place they will need to be lifted into their final positions in the galleries. This is the one step where I anticipated the largest issue when considering the union division of labor for the prefabrication process. My suspicions were confirmed when I contacted the project team. They confirmed that this would be one task that could be problematic for the prefabrication process. Because the completed modules include work from the miscellaneous metals, electrical, and fire protection trades they will all claim this is their work to install. However, since the modules have a higher percentage of iron work than any other trade, they should be the ones to lift the modules into place. They have the most experience in this type of work and the connection deals solely with miscellaneous metal and the structural steel. The electrical and fire protection unions would most likely have an issue with this due to their work being installed while they are not around. They would want to be present in case there is a problem regarding their system or in case part of their system was damaged in the process. So, one way to compensate them is to allow one worker from each trade to be present while the modules are lifted into place. This would allow all concerns regarding the proper installation of their work to be alleviated and all parties to be satisfied. Although this is an extra expense to the project that is not completely necessary it would serve as a suitable solution to the division of labor issue. Plus, as shown in Analysis 1A there are considerable savings that result from the prefabrication process so they can afford to pay the trades these monies.

Conclusion and Recommendations

After reviewing the union division of labor issue it seems as though it will not be as large of a roadblock as initially thought. Through research and reviewing case studies it was evident that the critical issue was not the division of labor during a prefabrication process. Instead it was just the fact that implementing a prefabrication process takes away jobs from the union workers a lot of the time and gives them to the factory workers. They tend to believe that the prefabrication process devalues the use of skilled union labor and that they can produce a much higher quality product than the factory workers can.

The MMAA case study proved that the only two problem areas during the prefabrication process would occur when the modules needed to be transported around the warehouse and when they needed to be hoisted into place once they arrived at the jobsite. However, both of those situations could be resolved rather easily. The problem of transporting modules around the warehouse can be resolved through adding a laborer to move the modules. The issue of hoisting the modules into place can be determined by which trade has the higher percentage of work in the modules and whose scope the connections to the structure fall under. Also, a representative from each other trade would be allowed to be present during the hoisting in case of any problems. Even with the added cost I would recommend that the solutions be implemented as outlined in this analysis and that the prefabrication process be completed on the MMAA construction project.

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.

Analysis Goals

This goal of this analysis is to investigate what BIM uses would be the most beneficial to the MMAA and to estimate the value of these uses. This analysis will be completed by creating a BIM execution plan that is modeled after the *BIM Project Execution Planning Guide Version 2.1* that was researched and developed by the Computer Integrated Construction Research Program at the Pennsylvania State University. This analysis will be completed by performing background research, summarizing the *BIM Project Execution Planning Guide Version 2,* applying the guide to the MMAA, and estimating the benefits provided from the selected BIM uses.

Background Research Performed

Using BIM for clash detection purposes only does not have to be the stopping point for BIM use 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.

BIM Project Execution Planning Guide Version 2.1 Summary

The *BIM Project Execution Planning Guide Version 2.1* (henceforth referred to as "the guide") was developed by the Computer Integrated Construction Research Program at the Pennsylvania State University in order to create a "structured procedure for creating and implementing a BIM project execution plan" (CIC). It does this by providing four important steps to take which are reproduced here:

- 1. "Identify high value BIM uses during project planning, design, construction and operational phases.
- 2. Design the BIM execution process by creating process maps.
- 3. Define the BIM deliverables in the form of information exchanges.
- 4. Develop the infrastructure in the form of contracts, communication procedures, technology and quality control to support the implementation".

The idea is that by following these four steps a BIM can be planned for and effectively used on the job in question. This is important because in order to receive the full benefits of a BIM it needs to be planned for and used effectively. It also will ensure that all of the parties involved in the BIM process know exactly what their responsibilities are and how one party's shortcomings or failures can affect both the project team and the BIM use in question. The guide goes on to say that when a BIM is properly implemented it can provide savings to the project in the form of increased design quality, predictable field conditions which allow more effective prefabrication, improved field efficiency due to the visualization of the construction sequence, and even more (CIC). However, if a project team implements BIM without properly planning for it the results can be troublesome. They will still incur the costs associated with developing the BIM uses but they may not receive the benefits mentioned above to the fullest extent. This can make the BIM use add little or even no value to the project. However, by following the four steps suggested by the guide a project team can be confident that implementing BIM uses on their project will be a success.

It should be noted that when applying the guide to the MMAA, I will be acting as a general contractor that has experience in BIM similar to a larger general contractor such as Turner Construction Company, the actual contractor on the job. This is necessary because the capabilities of different types of contractors are vastly different.

Step 1: Identify BIM Uses

The first step outlined in the guide is to select the BIM uses that will be the most effective based on the specific project conditions. The guide outlines twenty five possible uses for BIM that occur throughout all stages of the project from planning the building to operating it. These BIM uses can be seen in Figure 66 below which is an image taken from the guide that displays all of the proposed uses and the phase or phases in which they occur.

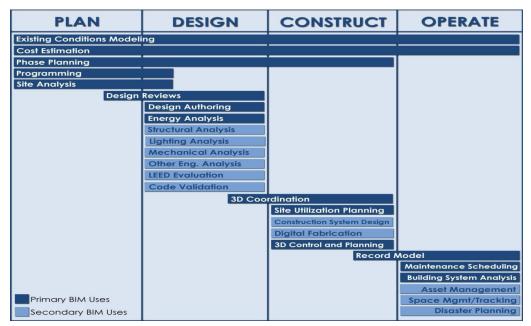


Figure 66: BIM uses based on project phase. Image taken from *BIM Project Execution Planning Guide Version 2.1.*

As mentioned previously the MMAA is already using BIM for 3D coordination purposes which, as you can see from Figure 66, occurs in the late design phase and throughout the construction phase. The other uses vary from lasting one phase such as site utilization planning in the construction phase or cost estimation that spans all four phases. As mentioned in the background research some of the uses that will be initially targeted are site utilization planning and 4D modeling (listed as phase planning in Figure 66). Site utilization planning would be beneficial to the MMAA project due to the constricted construction site and the fact that the utilization of this site is constantly changing with the different phases of construction. 4D modeling would be useful to the MMAA because it would allow the project team to fully understand how this building will be constructed and it will highlight any sequencing conflicts that may not have been initially evident.

Next, it is important to define the goals that can be reached by implementing the BIM uses. All of the goals that will be included in this analysis deal with improving the construction sequence. The MMAA would benefit from things such as increased productivity in the field, eliminating conflicts in the field, ensuring the constricted site is used properly, and ensuring an on time project delivery. On the next page, Figure 67 summarizes these goals and the potential BIM uses that apply to them. As you can see from this the main BIM uses that can aid these goals are 3D coordination, 4D modeling, and Site Utilization Planning. Figure 67 also prioritizes the

goals. Preventing any schedule overruns is listed as the top priority because it would be very costly through increased general conditions and liquidated damages. However, other goals such as increased productivity in the field and proper usage of the site can directly affect the project schedule and therefore are also important.

Priority (1-3)	Goal Description	Potential BIM Uses
1- Most		
Important	Value added objectives	
2	Increased Productivity in the Field	3D Coordination
2	Eliminating Conflicts in the Field	3D Coordination, 4D Modeling
	Proper Usage of the Constricted City Site	4D Modeiling, Site Utilization
2	Proper usage of the constructed city site	Planning
1	No Project Schedule Overruns	4D Modeiling

BIM Goals Worksheet

Figure 67: Project goals and their potential BIM uses prioritized. Template courtesy of the BIM Project Execution Planning

One important factor to consider when developing the information for the BIM uses is to "begin with the end in mind," as the guide says. This means that when the BIM uses are being developed it is important to make sure that the end use of the information is fully understood. This will allow the developer of the model to add the appropriate information to the model so that when it comes time to utilize the BIM the results will be as accurate as possible. To relate this to the MMAA lets consider the 4D modeling BIM use. It will be important for the developer of the model to consider the sequencing of how the MMAA will be built. A 4D model in effect allows the team members to virtually see the building being constructed on the screen in front of them; which is done by adding the element of time by attaching the project schedule to the model. As time elapses, different building elements will appear on the screen in the order in which they will be built. So, it is important to model the building elements in a way that reflects how they will be built. This means that the structural steel system should be split up into logical segments such as by floor or by certain bays. Perhaps a better example is that the concrete slab on deck should be grouped and modeled by each individual pour. This will allow the 4D model to be the most useful to the project team and therefore provide the most value to the project.

The next step is to select the BIM uses that will be used in the project. The guide has a matrix that considered each BIM use in the following categories:

- Value to the Project
- Responsible Party
- Value to Responsible Party
- Capability of the Responsible Party
- Additional Resources / Competencies Required to Implement the Use
- Decision to Proceed or Not

This matrix will not be completed in this analysis because it is mainly meant to rate the benefit to the project and to determine if all of the parties involved are capable of completing their tasks. As stated before for the purposes of this analysis, it will be assumed that the general contractor

completing the project will be a contractor similar to Turner Construction Company who is capable of developing and utilizing these BIM uses. Also, all three of the prospective uses (3D coordination, 4D modeling, and site utilization planning) are considered to be valuable to the project and to the general contractor, who is the responsible party for all of the BIM uses. So, all three of these uses will be included in the BIM execution plan.

Step 2: Designing the BIM Project Execution Process

Now that the potential BIM uses have been identified the process for implementing them into the project can be defined. This is important because this is a step that a lot of project teams do not take. This defines structure for the BIM uses and allows all of the parties to know what they are responsible for and how their work will affect the work of others. The guide suggests that this be completed by mapping out the BIM execution using process maps.

These process maps are visual representations of the BIM uses, how they are interconnected with one another, their inputs, outputs, and information exchanges. There are two levels of process maps. The first level is a "BIM Overview Map." This map is a high level process map that provides an overview of the entire use of BIM on the project. This map displays the relationships between the different BIM uses that will be implemented on the project such as how the 3D coordination and 4D modeling are related to one another. The guide provides a four step process for creating the BIM overview map. They are as follows (CIC):

- 1. Place the potential BIM uses into a BIM overview map.
- 2. Arrange the BIM uses according to the phase in which they will be implemented.
- 3. Identify the responsible party for each process.
- 4. Determine the information exchanges required to implement each BIM use.

The BIM overview map for the MMAA can be seen in Figure 69 on the next page or in Appendix O for a larger view. As you can see this shows how the BIM uses progress through all three phases of the design (Schematic Design, Design Development, and Construction Documents). Figure 68 to the right displays the 4D modeling process from the Level 1 Process Map. The name of the process is bolded in the center; the phase of the process is listed in the top left; the responsible party is listed on the

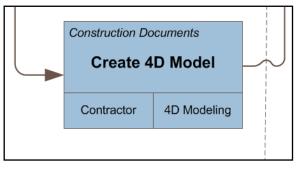
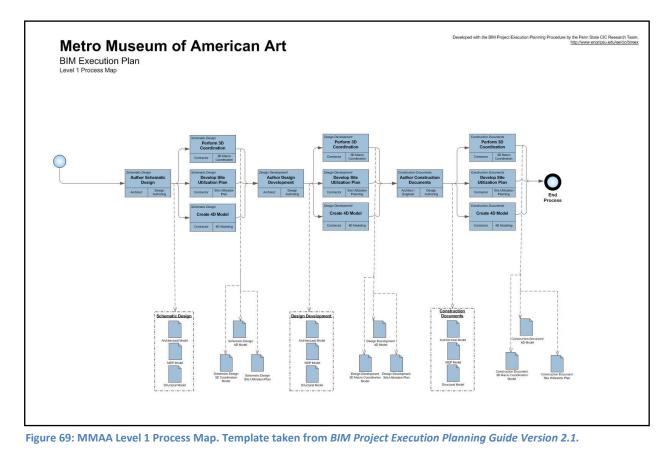


Figure 68: Example of a BIM use from the Level 1 process map. Template taken from *BIM Project Execution Planning Guide Version 2.1.*

bottom left; and the reference to the detailed process map is listed in the bottom right. Looking at the overall process map, each design phase has the same general flow of work. First, the architect will author the design documents. Then the contractor can utilize the new design in order to run clash detection, 4D modeling, and site utilization planning. The 3D coordination is very important to developing the design because it will give feedback to the architect and engineers on where there are space defined conflicts in the building. It is important to continue running 3D coordination checks as the design is developed so that any modifications of the

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building systems do not create new clashes of their own. This will ensure that the final design and construction documents are clash free. The 4D modeling and site utilization planning uses will become most useful during the construction phase of the project. However, they will be modeled throughout all three of the design phases in order to determine where there will be sequencing or construction issues due to the specific design of the building and site conditions.



Now that the level one process map is complete the detailed process maps can be made. The level one process map shows the flow of the "large picture" of the BIM implementation. The detailed process maps will display the interworking of the individual processes displayed on the level one map. There are three detailed process maps that are the responsibility of the contractor, which can be seen in Appendix P; one for the 3D coordination, 4D modeling, and site-utilization planning. Note that these three processes are repeated in each of the three design phases. The process for completing the 4D modeling is the same in the schematic design phase as it is in the final construction documents phase. So, therefore all of the 4D modeling processes in the level one process map will reference the same detailed 4D modeling map. This is applied to all three of the detailed process maps.

The guide also provides step by step instructions to create the detailed process maps. It is as follows (CIC):

- 1. Decompose the BIM use into its core internal processes and place them in sequential order.
- 2. Define the dependency between these core processes.

- 3. Develop the detailed process map to include reference information, information exchanges, and responsible parties.
- 4. Add goal verification gateways at critical points in the process. If the goals meet the defined criteria then the process can continue through, if not one or more of the previous activities are repeated until the goals are satisfied.
- 5. Document, review, and refine the process for continued use on this or future projects. This step aims to create the most efficient process possible. As the project progresses the detailed process maps should be updated to reflect the actual workflow of the process and refined to eliminate any inefficiency.

The detailed process map for the 4D modeling is shown below in Figure 70 or in Appendix P for a larger view. As you can see this process breaks down the 4D modeling process into smaller, more detailed activities. The reference information needed to complete this process includes the 3D model supplied from the architect, the productivity information, and lead times. The ultimate outputs of this process are the 4D model and the optimized construction schedule. Also, note that there are two gateways in this process that check to ensure that the 4D model is made correctly and being utilized to create the most efficient schedule possible.

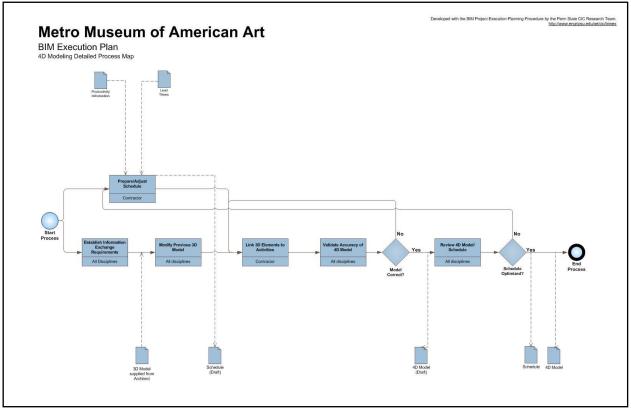


Figure 70: Detailed 4D Modeling Process Map. Template taken from *BIM Project Execution Planning Guide Version 2.1*.

Figures 71 & 72 on the next page display the detailed process maps for the 3D coordination and site utilization planning processes. All of the BIM process maps can be seen in Appendix P for a larger version.

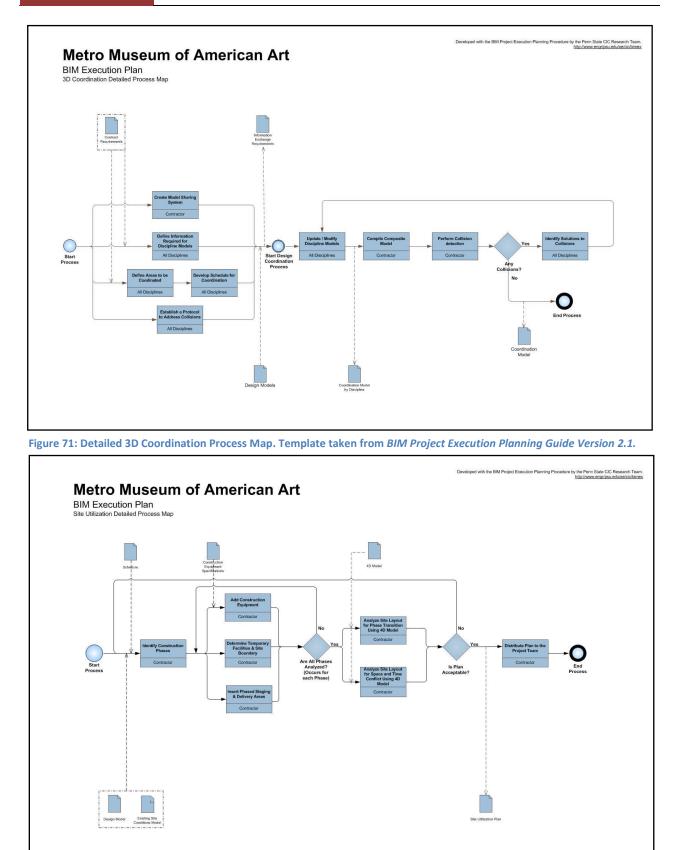


Figure 72: Detailed Site Utilization Process Map. Template taken from BIM Project Execution Planning Guide Version 2.1.

These detailed process maps will eliminate any confusion when implementing the BIM uses on the MMAA. Every activity within the process maps has a responsible party and all of the outputs of the activities are defined. The different BIM uses can also be used to assist in creating other BIM uses. For example, the 4D modeling use would be helpful in determining the site utilization during phase transitions and for time conflicts in general. This is shown in the detailed site utilization process map when the 4D model is used as a resource.

Step 3: Develop Information Exchanges

Now that the process maps have been developed the next step is to clearly define the information exchanges necessary to successfully implement each BIM use. These information exchanges were outlined in the process maps as resources and outputs but now they need to be refined. There must be a responsible party (author), receiver, level of detail, and file type associated with each information exchange (CIC). In order to apply this step to the MMAA Tables 33, 34, and 35 were created. These tables, which can be seen below and on the next page, list all of the pertinent information exchanges required to complete the 3D Coordination, 4D modeling, and site utilization BIM uses respectively as well as the refined details listed above. Note that the tables below will be utilizing the naming convention in Figure 73 when specifying the level of detail required for that piece of information.

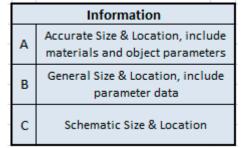


Figure 73: Naming convention for the level of detail required from an information exchange. Taken from *BIM Project Execution Planning Guide Version*

Table 33: 3D Coordination Required Information Exchanges

3D COORDINATION REQUIRED INFORMATION EXCHANGES					
Description	Responsible Party	Receiver	Level of Detail	File Type	
3D Model					
MEP Models	MEP Engineer	Contractor	A	Revit/Navisworks	
Arch Model	Architect	Contractor	В	Revit/Navisworks	
Structural Model	Structural Engineer	Contractor	А	Revit/Navisworks	

Table 34: 4D Modeling Required Information Exchanges

4D MODELING REQUIRED INFORMATION EXCHANGES					
Description	Responsible Party	Receiver	Level of Detail	File Type	
3D Model					
MEP Models	MEP Engineer	Contractor	В	Revit/Navisworks	
Arch Model	Architect	Contractor	В	Revit/Navisworks	
Structural Model	Structural Engineer	Contractor	В	Revit/Navisworks	

Table 35: Site Utilization Required Information Exchanges

SITE UTILIZATION REQUIRED INFORMATION EXCHANGES					
Description	Responsible Party	Receiver	Level of Detail	File Type	
3D Model					
MEP Models	MEP Engineer	Contractor	В	Revit/Navisworks	
Arch Model	Architect	Contractor	В	Revit/Navisworks	
Structural Model	Structural Engineer	Contractor	В	Revit/Navisworks	
Equipment Models	Contractor	Contractor	В	Revit/Navisworks	
Temporary Facility Models	Contractor	Contractor	В	Revit/Navisworks	

As you can see from the tables the architect / engineers are the authors of the majority of the building's models. The contractor is then responsible to take this information and run the BIM analyses. The downstream uses of the models depend on the accuracy and detail of the original

design made by the architect and engineers. The level of detail required for the MMAA models is mostly "B" rated. However, when it comes to the 3D coordination there must be a higher level of detail due to needing to know exactly where the building components will be located. The 3D coordination will mainly by run between the MEP and structural systems; because of this the models of these systems must be created to an "A" level of detail.

Step 4: Define Supporting Infrastructure

The final step when implementing a BIM process is to define the infrastructure that will be necessary to support the execution plan. The guide has come up with a list of fourteen key categories that provide an outline of infrastructure items that are needed when implementing any BIM execution plan. A summary of the categories has been reproduced from the guide in Figure 74 to the right. As you can see this list had a lot of general information such as project and contact information that are commonly

BIM Project Execution Plan Categories
BIM Project Execution Plan Overview
Project Information
Key Project Contacts
Project Goals / BIM Uses
Organizational Roles / Staffing
BIM Process Design
BIM Information Exchanges
BIM and Facility Data Requirements
Collaboration Procedures
Quality Control
Technological Infrastructure Needs
Model Structure
Project Deliverables
Delivery Strategy / Contract

Figure 74: Infrastructure Categories. Taken from *BIM Project Execution Planning Guide*.

found at jobs across the country. A lot of these categories deal with the conveying the information that has already been completed in the previous three steps such as the organizational roles, BIM process design, and BIM information exchanges categories.

Here are some of the categories that the guide covers that would have been important to the MMAA (CIC):

- The first new category deals with the collaboration procedures which define how the model will be managed, and what the standard BIM project meeting will cover. This includes defining how the team will communicate, how the documents will be managed and stored, and how the information exchanges will be scheduled and conducted between parties.
- Another category that will be important to consider is the technology infrastructure needs required to implement the BIM use. This includes the hardware, software, and reference information. The MMAA will require software such as Revit and Navisworks (or similar) in order to complete the proposed BIM uses on the project.
- Other items to consider are creating a consistent naming convention to use when authoring the models in order to limit confusion. Also, it is important, especially for the 4D modeling use, to determine how the building elements will be separated within the model (i.e. by concrete pour or floor of structural steel).

Finally, it is important to consider the project delivery method and the contract structure. The BIM execution plan that has been created for the MMAA focuses on a lot of early planning in the design phase of the project. This would obviously be the most successful under a design-build or an integrated project delivery system due to the early contractor involvement and focus on collaboration. Although those are the ideal project delivery methods, BIM uses can be successfully implemented with all different types of delivery methods (CIC). When using a design-bid-build project delivery system like the MMAA does, it becomes even more important to work through the BIM execution process. According to the guide, one item that cannot be stressed enough is the importance for there to be complete "buy-in" from all of the team members so that the highest quality BIM can be produced. If everybody believes in the process it will allow the implementation to be much smoother and the final product much more useful.

Benefits of Expanding the BIM Use

There are many benefits associated with expanding the BIM uses on the MMAA. The most notable benefits are the time and money saved due to investing in the BIM uses. By discovering and eliminating unforeseen errors in the construction documents the project team can realize these savings and avoid possible schedule delays. As shown in Figure 75 on the next page, as the project progresses from design to construction the ability to alter to project drops while the cost of making these alterations increases dramatically. Therefore, by implementing these BIM uses and discovering the majority of the project errors in the design phase, the cost of fixing these problems can be kept to a minimum. This is beneficial because if major errors are found during the construction phase the cost to fix them can be substantial and crippling to a project budget.

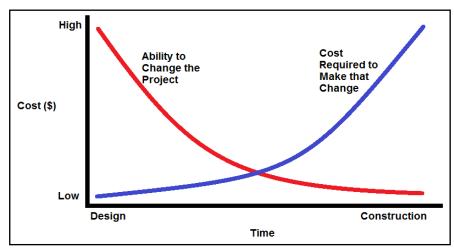


Figure 75: Graph displaying the cost implications due to project alterations.

Another benefit that expanding the BIM use creates is that the project managers, foreman, and even the tradesmen will not have to spend as much time in the field solving problems. This allows them all to devote their time to other matters at hand and be a more productive workforce overall. For example, say that the BIM uses save the project manager and foreman four hours of coordination time per week; over the total project duration of 158 weeks that equates to a total of 632 hours saved per man. Table 36 below summarizes the possible savings that could be realized from the BIM expansion.

POTENTIAL LABOR SAVINGS FROM BIM EXPANSION					
Description	Hourly Wage (w/benefits)	Hours Saved per Week	Duration of Project (Weeks)	Total Hours Saved	Total Savings
Project Manager	\$150	4	158	632	\$94,800
Foreman	\$75	4	158	632	\$47,400
Total					\$142,200

Table 36: Potential Labor Savings from BIM Expansion

As you can see expanding the BIM use could very easily save a lot of project management labor monies. However, it should be noted that these savings will not be directly cut from the project. Instead that dollar amount of management labor would be distributed to other important tasks. This will allow the MMAA to be managed more efficiently than if the BIM uses were not expanded. Finally, another item to consider is the fact that eliminating these conflicts in the field will mitigate any risk of the project experiencing any setbacks that delay the turnover to the owner. Any delay would be costly due to the increased general conditions costs which are approximately \$19,900 per day along with the unspecified liquidated damages that the contractor would incur for every day they are late turning over the MMAA. It is possible that the BIM uses could create enough schedule savings to save some schedule time. However, that should not be depended on when expanding the BIM use on the project.

Perhaps the most important factor to consider is the fact that the project is already using BIM for 3D coordination. So, expanding the BIM use to include 4D modeling and site utilization planning would not incur as much additional cost as if the project was not using BIM at all. There is already a model developed for the 3D coordination and a lot of the infrastructure required to expand the BIM uses is already in place. Therefore, the costs that would be incurred in order to expand the BIM use would be relatively low in comparison to the possible savings.

Conclusion & Recommendations

Expanding the BIM use to include 4D modeling and site utilization planning would be beneficial to the project. After completing the BIM execution plan it is evident that adding these two BIM uses to the already in place 3D coordination would provide the most benefit to the project. Using 4D modeling will enable the project team to understand how the building will be constructed and allow problem areas to be identified early on in the project so that they can be fixed easier and more economically. The site utilization planning will also prove to be useful due to the constricted downtown site location. It will be especially useful when planning for all of the temporary facilities and equipment phasing. The project is already using BIM for 3D coordination purposes and will have a model and the majority of the infrastructure required in place. This will keep the implementation costs low in comparison to the possible savings and because of that, I recommend that the MMAA expand the BIM use to include 4D modeling and site utilization planning.

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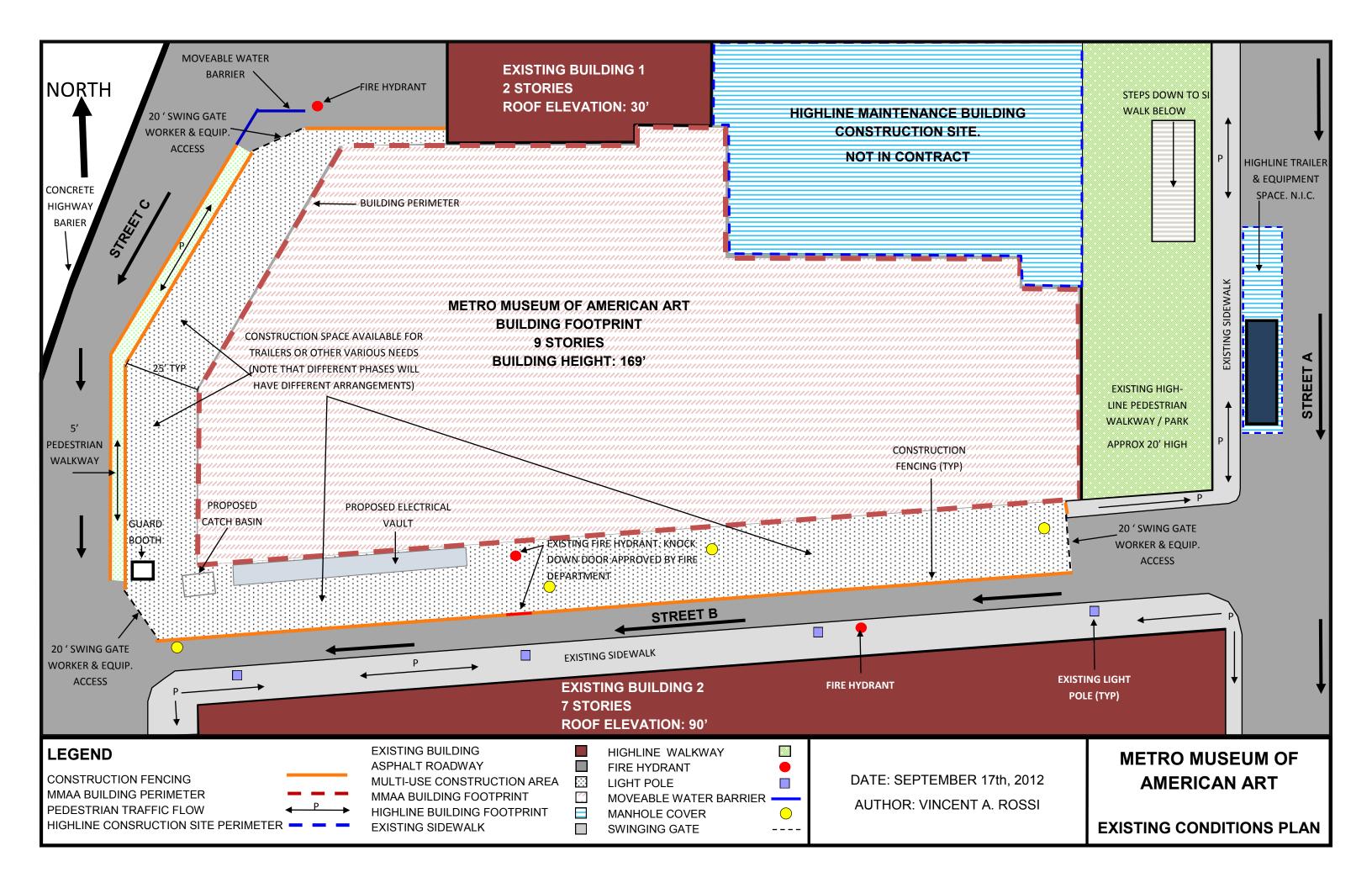
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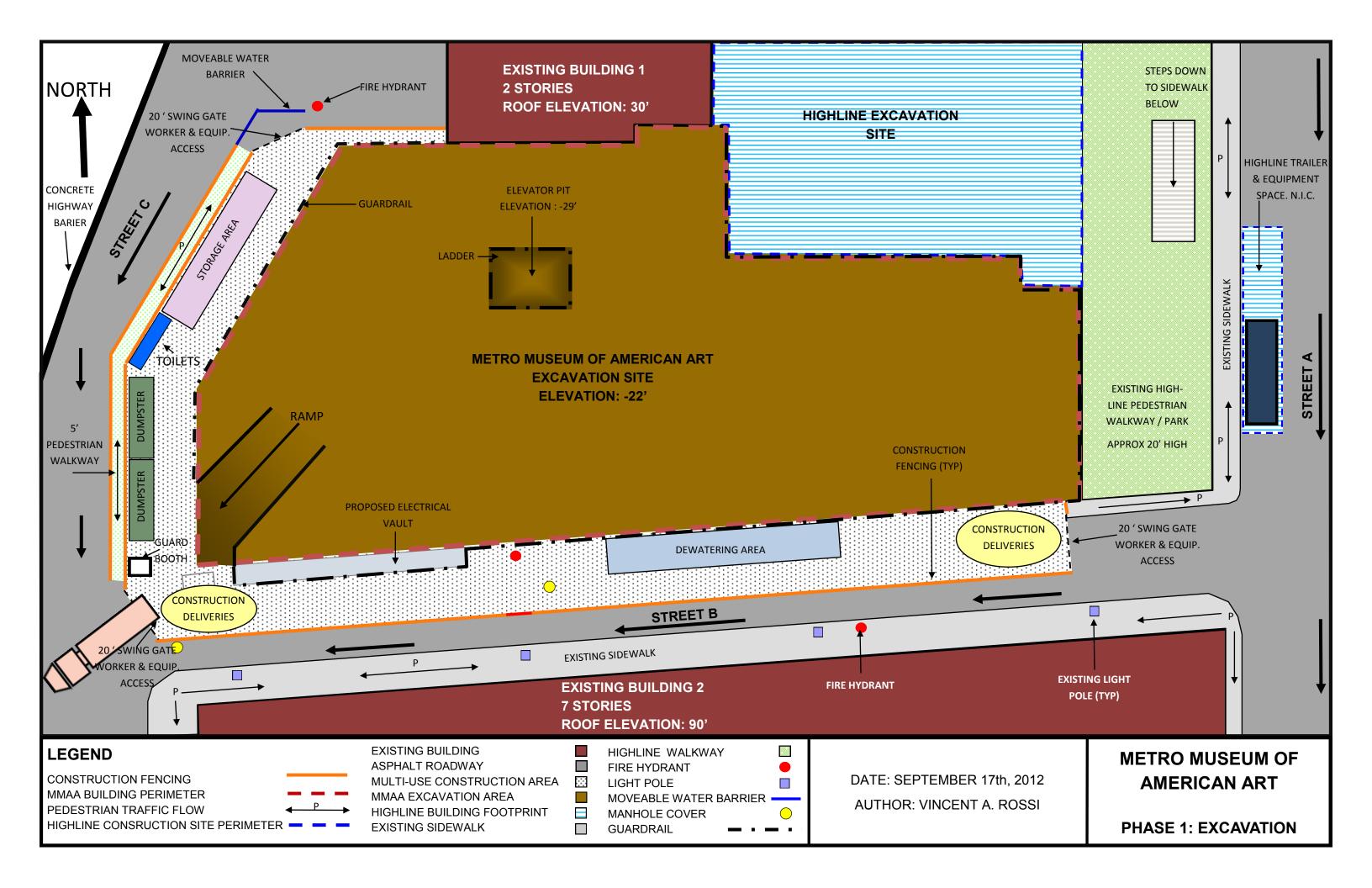
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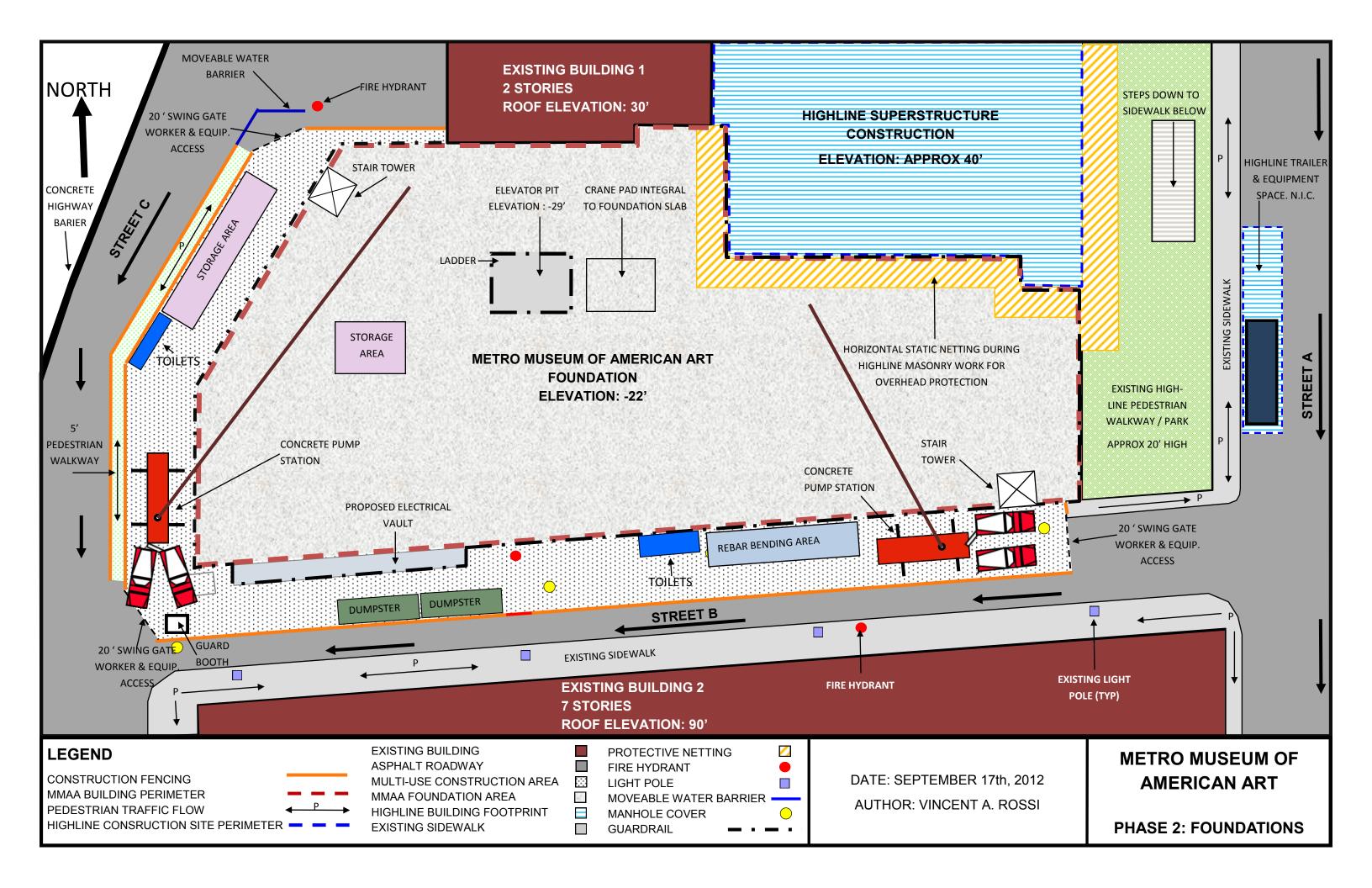


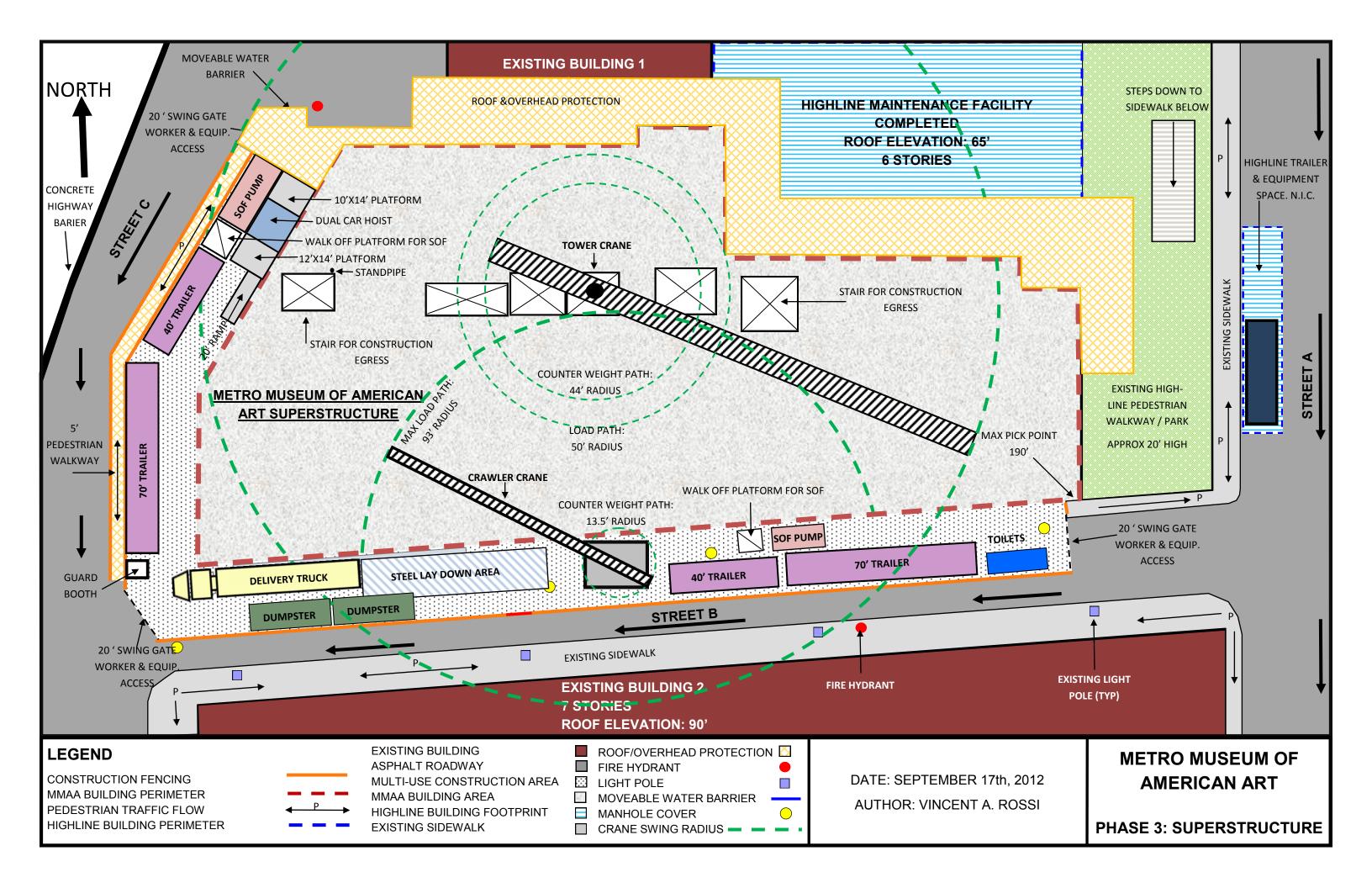


Phased Site Logistics Plans

3









Original Project Schedule

	of American Art: Detailed Project Schedule		Liniah		Bamaining	
y ID	Activity Name	Start	Finish	Original Duration	Remaining Duration	2012 2013 2014 2015 2016 Q4 Q1 Q2 Q3 Q4
Netro Muse	um of American Art: Detailed Project Schedule	13-Oct-11	28-Nov-14	803	803	Metro Museum of American Art: Detailed Project Schedule
	, Foundation & Superstructure	13-Oct-11	25-Jul-13	455	455	Excavation, Foundation & Superstructure
	A Foundation	13-Oct-11	24-Aug-12	222	222	Excavation & Foundation
EX010	Install Cassions/Piles		17-Feb-12	89	89	
EX020	Install Dewatering System		24-Feb-12	39	39	Install Cassions/Piles
West Side			24-Aug-12	138	138	Jnstall Dewatering System
EXW10			16-Mar-12	25	25	
EXW10			30-Mar-12	25	25	General Excavation & Shotcrete: -5' N&S
EXW10			27-Apr-12	35	35	Install Top Tier; Wale & Cross Lot Bracing N&\$
EXW10			11-May-12	30	30	Excavate & Shotcrete: -15! N&\$
EXW10		· ·	25-May-12	25	25	Install Lower Tier Wale & Cross Lot Bracing N&S
			-			🔲 Exçavate & Shotcrete to Subgrade: N&S
EXW10			08-Jun-12	24	24	Perimeter Mud Slab/Waterproofing/Pour Perimeter Mat N&S
EXW10		04-Jun-12		29	29	📖 Waterproof & Pour Lower Walls N&S
EXW10		18-Jun-12		29	29	🖽 Waterproof & Pour Upper Walls N&S
EXW11		14-May-12		38	38	Excavate Center Matto Subgrade and Prep Pile Caps
EXW11		04-Jun-12		39	39	Center Mat Mud Slab/Waterproofing/Pour
EXW12	21 Excavate/Install Tiebacks (21 ea): -5' W	21-Feb-12	09-Mar-12	14	14	Excavate/Install/Tiebacks (21 ea): -5'W
EXW13	31 Shotcrete to -5' & Install Tieback Heads & Lock Off: W	05-Mar-12	23-Mar-12	15	15	■ Shotcrete to -5' & Install Tieback Heads & Lock Off: W
EXW14	41 Excavate & Shotcrete: -15' W	19-Mar-12	13-Apr-12	20	20	Excavate & Shotcrete: -15' W
EXW15	51 Install Lower Tier Tiebacks (42 ea) with Heads & Lock Off: W	02-Apr-12	04-May-12	25	25	Install Lower Tier, Tiebacks (42 ea) with Heads & Lock Off: W
EXW16	61 Excavate & Shotcrete to Subgrade: W	30-Apr-12	25-May-12	20	20	□ Excavate & Shotcrete to Subgrade: W
EXW17	71 Mud Slab/Waterproofing/Pour Perimeter Mat: W	14-May-12	15-Jun-12	24	24	Mud Slab/Waterproofing/Pour Perimeter Matt W
EXW18	81 Waterproof & Pour Lower Walls W	04-Jun-12	06-Jul-12	24	24	Waterproof & Pour Lower Walls W
EXW19	91 Waterproof & Pour Upper Walls W	25-Jun-12	27-Jul-12	24	24	
EXW20		16-Jul-12	03-Aug-12	15	15	🔲 Waterproof & Pour Upper Walls W
EXW21	11 Place 19" Stone Backfill & 5" Conc Wearing Slab	30-Jul-12	24-Aug-12	20	20	
East Side	-		24-Aug-12	167	167	East SideEast Side
EXE002	2 Install Dewatering System	03-Jan-12	24-Feb-12	39	39	install Dewatering System
EXE100	0 Install Top Tier Cross Lot Braces	23-Jan-12	17-Feb-12	20	20	Install Top Tier Cross Lot Braces
EXE110	0 Excavate North Side & Wales: -17' N	06-Feb-12	16-Mar-12	30	30	
EXE120			30-Mar-12	20	20	Excavate North Side & Wales - 17' N
EXE130			20-Apr-12	15	15	Excavate North Side & Install Inclined Braces & Heel Blocks: N
EXE140	, in the second s	· ·	18-May-12	25	25	Excavate North Berm to Subgrade
EXE150		· ·	01-Jun-12	9	23	🔲 Install Mud Slab/Waterproofing/Pour Perim Mat: N
EXE160	5	29-May-12		28	28	Remove Lower Bracing: N
		-				🔲 . Waterproof & Pour Lower Walls N
EXE170		18-Jun-12		29	29	🔲 Waterproof & Pour Upper Walls N
EXE180			30-Mar-12	35	35	Excavate to Subgrade & Install Tiebacks: S&E
EXE190			20-Apr-12	25	25	🛄 Install Mud Slab/Waterproofing/Pour Perimeter Mat: S&E
EXE191		· · ·	04-May-12	25	25	Install Mud Slab/Waterproofing/Pour Center of Mat: S&E
EXE200			22-Jun-12	39	39	Pour Lower / Upper Tier Walls: S&E
EXE210	0 Waterproof & Backfill Lower / Upper Tier Walls: S&E	18-Jun-12		24	24	🔲 Waterproof & Backfill Lower / Upper Tier Walls: S&E
EXE220	0 Install Underslab MEP	09-Jul-12	03-Aug-12	20	20	🔲 Install Understab MEP
	0 Place 19" Stone Backfill & 5" Conc Wearing Slab	24-Jul-12	24-Aug-12	24	24	
EXE230		02-Jul-12	25-Jul-13	272	272	Place 19" Stone Backfill & 5" Cono Wearing Slab
EXE230	Steel				202	Stairs
		02-Oct-12	25-Jul-13	208	208	
Structural S			25-Jul-13 05-Nov-12	208 25	208	
Structural Stairs	0 Install Steel Stairs Celler to 5th Floors	02-Oct-12				· ↓···································

D		American Art: Detailed Project Schedule	Start	Finish	Original	Remaining			201	12				2013					2014					2015	5			2	016		-
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	ST3020	Install Exterior Stairs 6th to 8th Floors	25-Apr-13*	15-May-13	15	15								IInsta	II Ext	erior St	airs 6	6th to	8th Fl	oors											L
	ST3030	Install Struct/Precast - Grand Staircase	01-May-13*	25-Jul-13	60	60										al Struc	1 I I I	- I - I -	1.1.1.	1.1	aircas	e !									
	Crane Setup			30-Apr-13	212	212			.		r <u>ane Set</u>	tup								!!-					+					+	
	ST1000	Erect, Detail, & Pour Conc.for Crane Platform		01-Aug-12	22	22				Erec	ct, Detai	uil, & F	Pour	Conc.	for C	ane Pla	atforn	n													ł
	ST1010	Erect Crawler Crane & Tower Crane		13-Aug-12	8	8				Ere	ct Craw	wler C	Cran	e & To	wer C	rane															ł
	ST1020	Remove Tower Crane	·	30-Apr-13	12	12								Remo	ve to	wer ¢ı	rane														
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	ST2150	9th Floor Steel Erection		14-Jan-13	11	11	•						1 1	oor Ste		1 1 1								·	+-+						
	ST2100	9th Floor Steel Detailing		11-Feb-13	20	20						1.1.	1 1	or Stee	1.1	1.1.1.1															
	ST2170	Roof Steel Erection		17-Jan-13	3						i i i	i i	i i	loor Ste	i i	i i i															
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	SOD	e concrete		14-Mar-13	101	101	·			-+-+	SO											÷-+-		·							
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		0 Rough In, Install Rebar/Mesh, & Place Concrete - 1st Floor		16-Nov-12	15	15				1 1 1	Rou	1 1	1 1		1.1	1 1 1	1.1	1 1	1 1 1	1.1	1.1	1.1.									ł
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		0 Rough In, Install Rebar/Mesh, & Place Concrete - 3rd Floor		26-Dec-12	20	20					1 1 1	1 1	1 1	nstall F			1 1	1 1	1 1 1	- 1 - 1		1 1									
		0 Rough In, Install Rebar/Mesh, & Place Concrete - 4th Floor		08-Jan-13	17	17	· J - J				1 1 1	1.1		, Instal	1.1	1 1 1	1.1	1.1	1 1 1	1.1	1.1	1.1					 	J L			¦
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		0 Rough In, Install Rebar/Mesh, & Place Concrete - 6th Floor		30-Jan-13	10	10							1 1	In, Inst	1 1	1 1 1	1 1	1 1	1 1 1		1 1	1 1									; ;
		0 Rough In, Install Rebar/Mesh, & Place Concrete - 7th Floor		19-Feb-13	14	14					i i i	i i	1 1	n In, Ins	i i	-i i i	- i - i -	i i	i i i	i i	i i	i i	i i i								-
		0 Rough In, Install Rebar/Mesh, & Place Concrete - 8th Floor		28-Feb-13	11	11							1.1.	gh ln, li			1 1	1 1				1.1									
		0 Rough In, Install Rebar/Mesh, & Place Concrete - 9th Floor		07-Mar-13	10	10						1.1	1 1	ugh In, I	1.1	1 1 1	1.1	1.1	1 1 1	1.1	1.1	1.1	1 1 1								
		0 Rough In, Install Rebar/Mesh, & Place Concrete - Roof		14-Mar-13	10	10						i i	i i	ugh In,	i i	i i i	i i	i i	i i i	i i	i i	i i	i i i								
Enc	losure		05-Feb-13		297	297							Ro	ugh In Er	insta Indlosi	all Reba ute : : :	ar/Me	sh, ð	Place	Con	crete	- Ro									i.
				24-Apr-13	38	20					Pi	reoas	st P	anels	: :																
-	ecast Panel					16							-1																		1
	E1000 E1010	Erect Precast Panels - North Elevation (70 Panels) Erect Precast Panels - West Elevation (32 Panels)		25-Mar-13	16 5				+!!-			i i	i i	ect Pr	i i	i i i	i i	i i	i i i	- i i i	i i	1.1		· - +	+						;
				01-Apr-13 15-Apr-13	-	0 10							-i -i	rect Pr				1 1	1 1 1	- i i		1 i i									
	E1020	Erect Precast Panels - South Elevation (74 Panels)			10									Erect F																	ł.
	E1030	Erect Precast Panels - East Elevation (42 Panels)	· ·	24-Apr-13	· · ·	(М	letal	Érect l Panels	Preca	ıst Pan	els - I	East	Elevat	ion (4	12 Pai	nels)									1
(VI)	etal Panels		00-rep-13	12-Aug-13	132	132		<u> </u>								1 1 1			<u> </u>												<u>!</u>
	ctual Work	Critical Remaining Work				Page 2 of	6							TAS	SK filt	er: All	Activit	ities													

ID	Activity Name	Start	Finish	Original	Remaining			2012			2	2013				2014				2015				201	6	
				Duration	Duration	Q4	Q1 (Q2 Q3	Q4	Q1	Q2	2 Q	3 (Q4 C	ຊ1 (ຊ2 (23 Q	4 C	1 (ຊ2 (23	Q4	Q1	Q2	Q3	Q4
E2000	Back Up Metal panel System - Whole Building (Flrs2-5)	06-Feb-13*	08-Apr-13	44	44						Ba	ack Up	Meta	panel	System	Who	e Buildir	ng (Flrs	2-5)							
E2010	Back Up Metal panel System - Whole Building (Flrs6-Roof)	11-Mar-13*	30-Apr-13	37	37						i i	Back L	Jp Me	alpane	el Syste	m - Wh	ole Buik	ding (Fl	rs6-R	oof)						
E2020	Finish Metal Panels - South Elevation	25-Apr-13*	04-Jun-13	28	28] Finis	sh Me	al Pane	els - So	outh Elev	vation									
E2030	Finish Metal Panels - West Elevation	05-Jun-13*	27-Jun-13	17	17							🗖 Fir	inish M	etal Pa	inels - V	Nest El	evation									
E2040	Finish Metal Panels - North Elevation	28-Jun-13*	30-Jul-13	22	22								Finish	Metal	Panels	- North	Elevatio	on i								
E2050	Finish Metal Panels - East Elevation	31-Jul-13*	12-Aug-13	9	9																					
Windows & Cu	irtainwall	05-Jun-13	02-Apr-14	212	212							Wind	lows 8	Curta	inwall		Elevatio									
E3000	South Elevation Windows	05-Jun-13*	02-Jul-13	20	20						Í	Sc	outh E	evation	h Windo	าพร										
E3010	West Elevation Windows & Curtainwall	03-Jul-13*	26-Sep-13	60	60								1 1 1				w\$& Cu	irtainwa	all							į
E3020	North Elevation Windows & Curtainwall	20-Sep-13*	31-Oct-13	30	30								i i i	- i i i		- i i i	dóws &	-i i i								
E3030	East Elevation Windows & Curtainwall	25-Oct-13*	07-Jan-14	51	51												Window									
E3035	Building Watertight		07-Jan-14	0	0	L _ J L 				-!				1 1 1	Building	1 1 1	1 1 1		ILUUUW			-lL-J	. In a b a al a 1 1 1 1			
E3040	Cablewall at the First Floor	08-Jan-14*	02-Apr-14	61	61											- i i i	i i i	The second	-							
Roof		05-Feb-13		165	165						R	oof				Cablewa	all at the									
E4000	Place 6th Floor Curbs	05-Feb-13*		5	5						1 1 1		111													
E4010	Place 7th Floor Curbs	20-Feb-13*		5							Place 6															
E4020	Place 8th Floor Curbs	01-Mar-13*		5	5	L - JI L				1.1.1.	Place															
E4030	Place 9th Floor Curbs	08-Mar-13*		5	5					1 1 1	Place															
E4040	Place Roof Curbs	15-Mar-13*		5	5					1 1 1	Place															
E4040	Install Roofing on 6th Floor - Hot Mop Only	11-Apr-13*			30] Plac		1 1 1													
E4050		02-May-13*	-		20							Insta	all Roof	ing ọn	6th Floo	or - Hot	Mop Or	ηλ								
	Install Roofing on 7th Floor - Hot Mop Only				12							Insta	all Roo	fing on	7th Flo	or - Ho	t Mop O	nly								
E4070	Install Roofing on 8th Floor - Hot Mop Only	23-May-13*		12							📫	lnst	tall Ro	ofing or	n 8th Fl	oor - Ho	ot Mop C	Dnly								
E4080	Install Roofing on Roof - Hot Mop Only	31-May-13*		23	23							🔲 In	stall R	oofing	on Roo	f - Hot I	Nop Onl	y l								
E4090	Install Roof Pavers & Green Roof	03-Jul-13*	· ·		60						,	Vertica		nstall R	oof Pav	/ers & (Green R	oof								
Vertical Trans	portation	01-May-13	03-Apr-14	237	237							: :	: : :													
PE-1-2		01-May-13	24-Jan-14	188	188							: : : F	PE-1-2	 Q												
VT1000	Shaft Construction PE1/2	01-May-13*	22-Aug-13	80	80						1] Sha	ft Cons	struction	n PE1/2										
VT1010	Install Rails/Brackets/Car Frame/Counterweight/Rope PE1/2	23-Aug-13*	11-Oct-13	35	35								i i	Install I	Rails/Br	rackets	/Car Fra	ame/Co	unterv	veight/F	Rope F	PE1/2				
VT1020	Entrances/Doors/Fixtures/Cabs/Testing/Punchlist PE1/2	14-Oct-13*	24-Jan-14	73	73										Ėntrar	nces/Do	oors/Fix	tures/C	abs/T	esting/F	Punch	ist PE1/	2			
PE-3		01-May-13	14-Feb-14	203	203								PE-3													-
VT2000	Shaft Construction PE3	01-May-13*	22-Aug-13	80	80					1 1 1 1 1 1 1 1 1	1 i-i	: :	l [,] Sha	ftCons	struction	n PF3	1 1 1 1 1 1 II + -									
VT2010	Install Rails/Brackets/Car Frame/Counterweight/Rope PE3	23-Aug-13*	11-Oct-13	35	35												/Car Fra					PE3				
VT2020	Entrances/Doors/Fixtures/Cabs/Testing/Punchlist PE3	14-Oct-13*	14-Feb-14	88	88								- i 📊				Doors/F				1 1		3			
AE-1		20-Jun-13	03-Apr-14	202	202								A	E <u>-1;</u> ;		un000/1				i coung						
VT3000	Shaft Construction AE1	20-Jun-13*	22-Aug-13	45	45								1: Shà	ft Cone	truction	ο Δ Ξ 1										
VT3010	Install Rails/Brackets/Car Frame/Counterweight/Rope AE1	23-Aug-13*	11-Oct-13	35	35							1 1	1 1 1				/Car Fta		unterv	voight/F	2000 A					
VT3020	Entrances/Doors/Fixtures/Cabs/Testing/Punchlist AE1	14-Oct-13*	03-Apr-14	122	122	+ + 		!! #!		-1+-+-			┟╴╷┍┷				es/Door	1 1 1			1.1	1 1 1	·/\ = 1		+-	
MEP Equipme	ent & Risers	07-Aug-12	03-Jul-14	489	489					M	EP Edu	uipme	nt & R	sers :		Entranç	es/µoøi	SIFIXIU	iles/Ca		sung/r	unomist	AEI			
MEP Risers		21-Jan-13	21-May-13	87	87					MEP	Riser	s														
R1000	MEP Risers at West Shaft	21-Jan-13*			81																					
R1000	MEP Risers at Mid Shaft	21-Jan-13*	-		81						1 1 1		1 1 1		st Shaf	1 1 1										
	MEP Risers at East Shaft	29-Jan-13*	,								i i i	- i i			d Shaft	- i i i										
R1020		29-Jan-13" 07-Aug-12	-		81				(Celler: M	LEP P	MEP	Riser	s at Ea	st Shaf	t										
Celler MEP Eq					368			F																		
ME Room	Set AC Units ACS-C-4 thru C8	07-Aug-12 07-Aug-12								;;;	; ; ;	; ;	;;;													
	Set HV Units HV-C-1 through C3	23-Oct-12*	-		2				Set AC U	i i i	i i i	i i	-i i i													
	Set PFHX-C1 through C3 Set PFHX-C1 thru C-4 Heat Exchangers	23-Oct-12*		2	2				1 1 1	t HV U																
IVIEP 1020		23-001-12	24-001-12	2					l Se	et PFHX	<u> </u>								: : :							<u> </u>
Actual Work	Critical Remaining Work	I	1		Page 3 o	f 6			<u> </u>	<u>a pph</u> y	<u>\-U'I tr</u>				ctivities								<u></u>		-	

ID	Activity Name	Start	Finish	Original Duration	Remaining Duration		ļ,	201				2013				2014				201			4		2016		
			40 Dec 40			Q4	Q1	Q2	Q3	Q4	Q1 Q	2 Q3	Q4	Q1	Q2	Q	3 6	24 G	Q1	Q2	Q3	Q4	Q1	Q2	2 Q:	3 (C
	Pipe, Duct, & Wire All AC, HV, & PFHX Units			231	231					1				Pipe	Duct,	& Wir	≑AllA	C, HV,	& PFI	HX Un	its						ł
	Start-Up / Commission All Units	17-Dec-13* 23-Oct-12		314	21 314						Boile	er Room		🗖 St	art-Up	/ Com	missio	n All Ur	nits								
Boiler Room	Set Boilers B-C1 - 5	23-Oct-12*		2							1 1 1 1 1 1 1 1																
	Pipe, Duct, & Wire All Boilers	23-001-12 22-Jan-13*		231	231					Set B	oilers_B-9	C1_5		+													
	Start-Up / Commission All Boilers	17-Dec-13*		201	231					[1 1 1 1	1 1 1 1	: : :	1 1 1	Duct,	1 1	1 1 1										
Chiller Room	· ·	07-Aug-12		368							Chiller I	Room		St	art-Up	/ Com	missio	n All Bo	oilers								ł
	Set Chillers CH-C-1 thru C-3	07-Aug-12									: : : :	; ; ; ;		-													
	Pipe, Duct, & Wire All Chillers	22-Jan-13*	-	231	231				l Se	t Chillers	CH-C-1	thru C-3															
	Start-Up / Commission All Chillers	17-Dec-13*		21	21		L - Jll								, Duct,	1 1	1 1 1					J					
Fire Pump Ro		23-Oct-12		314							Fire P	ump Roon	n ¦	St	art-Up	/ Com	missio	n All Ch	nillers								
	Set Fire Pumps	23-Oct-12*		2	2																						
	Connect Fire Pumps	04-Nov-13*		30	30					Set F	ire Pump)\$															
	Start Up / Commission Fire Pumps	17-Dec-13*		21	21								i i	1 1 1	nect Fil	- i i	1 I I										
Electrical Roo		30-Oct-12		253							Electrica	Room	·	St	art Up /	/ Com	missio	n Fire F	Shubb	\$¦				· '			
	Set Switchboards	30-Oct-12*		2	2																						ł
MEP5010	Conduit & Wire Switchboards	05-Feb-13*	27-Sep-13	166	166					i Set s	Switchboa	aros															
MEP5020	Test Switchboards	30-Sep-13*		20	20										Mire Sv	1 1	paras										ł
2nd Floor MEP	Equipment	11-Jan-13		380	380						2	nd Floor N	AEP Equ	st Swi uipme	ichboa ht	ras											
ME Rooms 20		11-Jan-13	26-Mar-14	309	309					/		Rooms 2															
	Set PFHX-2-1 thru 2-3 Heat Exchangers	11-Jan-13*		2							CatiDE					o #o											
	Connect PFHX-2-1 thru 2-3 Heat Exchangers	02-Dec-13*	26-Feb-14	62	62			111		u	SelPFr	HX-2-1 thr	1.1.1.1.1	1.1.1	- i - 1	1.1		A 44 4 4			-						ł
	Start Up / Commission Heat Exchangers	27-Feb-14*	26-Mar-14	20	20													1 thru 2									
	Generator Room	29-Jan-13	03-Jul-14	368							<u>; ; ; E</u>	mergency	Genera	ator R	j Stai	rt Up /	Comn	nission	Heat	Excna	ngers						
	Set Emergency Generator/ATS	29-Jan-13*		2				-++				nergency	1-1-6-	7													
	Conduit & Wire Emergency Generator	13-Sep-13*	07-May-14	167	167						BelEn		Genera			Candu		; ; ; ; ; ;									
MEP7020	Test/Commission Emergency Generator	08-May-14*	03-Jul-14	41	41								: : :	: : :			1 1 1	ire Eme				enerato					ł
9th Floor MEP	Equipment	04-Apr-13	22-May-14	291	291							9th Floor	MEPE	quipm	ent		SILCO	mmissi	SU EU	lergen	cy Ge	inerato	л				
ME Room		04-Apr-13	22-May-14	291	291							N	<u>/IE Roor</u>	ή¦													ł
MEP8000	Set AC Units ACS-9-1 & 2	04-Apr-13*	05-Apr-13	2	2			- 4!!-			1 9	et AC Unit		0-1 8	2			!! 4							<u></u>		
MEP8010	Set HV Units HV-9-1 & 9-2	04-Apr-13*	05-Apr-13	2	2			111				et HV Uhi		1 1 1													
MEP8020	Set PFHX-9-1 Heat Exchanger	04-Apr-13*	05-Apr-13	2	2							et PFHX-9		1 1 1	1 1 1												
MEP8030	Pipe, Duct, & Wire All Units	29-Aug-13*	25-Feb-14	126	126										- E - E - E		W/irc	All Unit	ite								
MEP8040	Start Up / Commission All Units	26-Feb-14*	22-May-14	62	62													ommis									
Cooling Tow	ers	12-Apr-13	15-Jan-14	194	194	L - J! ! ! ! !		- 4!!-			· · · · · · · · ·	Cooling 1	Towers	+ -							>	J L - L -			L - L! 		
MEP9000	Set, Build, & Connect Cooling Towers	12-Apr-13*	12-Aug-13	85	85								Set, Build	d & c	onnect	Coolir		/ers									ł
MEP9010	Start Up / Commissioning Cooling Towers	17-Dec-13*	15-Jan-14	21	21														odlina	Tower	rs						
Interior Fit Ou	it	25-Oct-12	28-Nov-14	539	539			111				lint	terior Fit	ťOuť		çom			, oin ig		Ŭ						
Celler/Mezz		25-Oct-12	26-Jun-14	428	428							Celler/N	Viezz			-											
IFO00	Interior Masonry Work	25-Oct-12*		60	60									1-1-1		.											
	MEP Rough In	05-Feb-13*		131	131						Interior	Masonry	1.1.1	1.1.1													ł
	Drywall, Core and Toilet, & Interior Finishes	08-Jan-14*		122	122								1EP Rou	igh in		_											
1st Floor		19-Dec-12		401	401							1:st	t Floor		1 1 1	Dr	ywall,	Core ar	nd Ioi	let, & I	nterior	or Finish	nės				÷.
Gallery		19-Dec-12		390								Ġa	allery														
	Install Hangers and Protect Surface Adjacent to Steel	19-Dec-12*		15	15						Inetell	angers an	d Broke		face A	diooo			- 4								
	Cure Spray on Fireproofing (28 Days) / Paint Deck & SOFP	21-Jan-13*		31	31	, , , , , , , , , , , , , , , , ,	, ,			- i i i -	i i i i			i i i	-i i i	- i - i -		- i i i	en=1								
	Overhead MEP Rough-in	05-Mar-13*		40	40							e Spray or	1 1 1	1 1 1		ay6)/l	aint L	HOCK &	SOFF								
	Layout & Frame/ Rough Partitions/ Sheetrock Partitions	30-Apr-13*	· ·	29	29						1 1 1 1	Overhead	1 I I	1 1 1	- i - i - i				De	6							
	Critical Remaining Work Summary				Page 4 c	f 6		1 1 1	1 1 1		[t <u>∙& ⊢rar</u> filter: All			alution	5/ SNE	UCCK	rartit						<u> </u>		_

y ID		American Art: Detailed Project Schedule	Start	Finish	Original	Remaining	2012	2013 2014
,					Duration	Duration	Q4 Q1 Q2 Q3 Q4	
	IFO-1040	Skim Coat Walls (3 Coats) & Paint from ceiling line up.	11-Jun-13*	01-Jul-13	15	15		
	IFO-1050	Ceiling Layout/ Install of W5 Sections and Infill Pieces	02-Jul-13*	25-Sep-13	60	60		Ceiling Layout/Install o
	IFO-1060	Rough In Lighting	26-Sep-13*	09-Oct-13	10	10		
	IFO-1070	Sprinkler Heads	10-Oct-13*	30-Oct-13	15	15		Sprinkler Heads
	IFO-1080	Install Ceiling Panels & Ceiling Trim	31-Oct-13*	22-Nov-13	17	17		□ Install Ceiling Pan
	IFO-1090	Patch Skim Coat & Paint	25-Nov-13*	10-Dec-13	11	11		
	IFO-1100	Lights & MEP Finish Trim	11-Dec-13*	24-Dec-13	10	10		□ Lights & MEP F
	IFO-1110	Stone Flooring	24-Apr-14*	21-May-14	20	20		
	IFO-1120	Punchlist	22-May-14*	26-Jun-14	26	26		
	Other Spaces		12-Feb-13	11-Jul-14	364	364		Other Spaces
	IFO-A-100	MEP Rough In; Drywall Framing; In-wall MEP	12-Feb-13*	05-Jun-13	81	81		MEP Rough In; Drywall Framin
	IFO-A-101	1st Floor Lobby/Museum Shop/Resturant Fit-out	23-Dec-13*	11-Jul-14	144	144		
2	nd Floor		31-Jan-13	18-Jul-14	377	377		2nd Floot
	IFO2000	Install Masonry Walls & MEP Rough In	31-Jan-13*	23-May-13	81	81		Install Masonry Walls & MEP Ro
	IFO2010	Drywall & Interior Finishes	22-May-14*	18-Jul-14	42	42		
3	rd Floor		25-Apr-13	25-Jul-14	322	322		3rd Floor
	IFO3000	MEP Rough In / Drywall Framing/ In-Wall MEP	25-Apr-13*	28-Oct-13	130	130		MEP Rough In / Dr
	IFO3010	Drywall & Interior Finishes (inc. Core and Toilet, & Theatre/Lobby)	22-Jan-14*	25-Jul-14	133	133		
4	th Floor		23-May-13	01-Aug-14	307	307		4th Floor
	IFO4000	MEP Rough In / Drywall Framing/ In-Wall MEP	23-May-13*	10-Dec-13	140	140		MEP Rough In /
	IFO4010	Drywall & Interior Finishes (inc. Core and Toilet, & Theatre/Lobby)	29-Jan-14*	01-Aug-14	133	133		
5	th Floor		29-Jan-13	19-Aug-14	401	401		5th Floor
	Gallery		29-Jan-13	19-Aug-14	401	401		Gallery
		Install Hangers and Protect Surface Adjacent to Steel	29-Jan-13*	19-Feb-13	16	16		Install Hangers and Protect Surface Ad
	IFO-5010	Cure Spray on Fireproofing (28 Days) / Paint Deck & SOFP	06-Mar-13*	16-Apr-13	30	30		Cure Spray on Fireproofing (28 Da
	IFO-5020	Overhead MEP Rough-in	21-Jun-13*	16-Aug-13	40	40		Qverhead MEP Rough-in
	IFO-5030	Layout & Frame/ Rough Partitions/ Sheetrock Partitions	19-Aug-13*	27-Sep-13	29	29		📛 Layout & Frame/ Rou
	IFO-5040	Skim Coat Walls (3 Coats) & Paint from ceiling line up.	30-Sep-13*	18-Oct-13	15	15		Skim Coat Walls (3
	IFO-5050	Ceiling Layout/ Install of W5 Sections and Infill Pieces	21-Oct-13*	15-Jan-14	61	61		Ceiling Layou
	IFO-5060	Rough In Lighting	16-Jan-14*	29-Jan-14	10	10		🛛 Rough In Lic
		Sprinkler Heads		20-Feb-14	16	16		🗖 Sprinklet F
	IFO-5080	Install Ceiling Panels & Ceiling Trim	21-Feb-14*	17-Mar-14	17	17		🗖 Install C
	IFO-5090	Install Sleepers and Plywood Subfloor	18-Mar-14*	,	44	44		inst
				03-Jun-14	12	12		
		Lights/ MEP/ Wood Flooring Finish Work	04-Jun-14*		30	30		
	IFO-5120		16-Jul-14*	19-Aug-14	25	25		
	Other Spaces		17-Apr-14	19-Aug-14	89			Uther Sp
		Core & Toilet Finishes	· ·	12-Jun-14	41	41		
		Film & Video Theatre/ Office Fit Out		19-Aug-14	82	82		
6	th Floor		12-Feb-13	16-Sep-14	411	411		0 6th Floor
	IFO6000	GALLERY SPACE - Detail Similar to 5th Floor Gallery		16-Sep-14	411	411		
	IFO6010	Core & Toilet Finishes	-	26-Jun-14	41	41		
	IFO6020	Laboratory/Study Center Fit-out		11-Aug-14	62	62		
7	th Floor		21-Feb-13	14-Oct-14	424	424		7th Floor
	IFO7000	GALLERY SPACE - Details Similar to 5th Floor Gallery		14-Oct-14	424	424		
	IFO7010	Core & Toilet Finishes	15-May-14*		42	42	· · · · · · · · · · · · · · · · · · ·	
	IFO7020	Office Space Fit-Out		09-Sep-14	62	62		

03-Oct-12 19:30

		20	15			20	16		2017
Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
ftom	eiling li	ne up.							
Sectio	ns and	Infill Pi	eces						
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Ceilind	Trim								
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/all & Ii	nterior I	Finishes	s : : :						
ramin	g/ In-W	all MEP							
wall & I	nterior	Finishe	s (inc.	Core a	nd Toile	t, & The	eatre/Lo	bby)	
all Fra	ming/ Ir	-Wall M	1EP						
wall &	Interior	Finishe	es (inc.	Core_a	nd Toile	et, &Th	eatre/L	oppa) -	
t to Ste									
1.1	eck & S	OFP							
titions	/ Sheet	rock Pa	rtitions						
) & Pa	int from	ceiling	line up						
all of V	V5 Sec	tions an	id Infill I	Pieces					
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Toilet	Finishe	s							
1 1		eatre/ 0	Office F	it Out					
GALL	ERY SF	ACE -	Detail S	imilar to	5.5th Fl	oor Ga	lery		
& Toilet	Finish	es							
borato	rv/Stud	v Cente	r Fit-ou	it					
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Jttice	Space	Fit-Out	<u> </u>	<u> i i </u>			i	<u> </u>	<u>. i i</u>
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Metro	Museum o	f American Art: Detailed Project Schedule			(Classic Scheo	dule Lay	out																		03-0	Oct-12 19):30
Activity ID)	Activity Name	Start	Finish	Original	Remaining				2012				2013			2	2014				2015			20	16	20	017
					Duration	Duration	Q4	Q1	Q2	Q3	Q4	Q1		02 Q	3	Q4 Q1	Q2	Q3	Q4	Q1	Q	2 Q3	3 Q4	4 Q1	Q2	Q3	Q4 (1ג
	8th Floor		28-Feb-13	28-Nov-14	452	452										8th Floo	or											
	IFO8000	GALLERY SPACE - Details Similar to 5th Floor Gallery	28-Feb-13*	28-Nov-14	452	452						f		<u> </u>	<u> i i </u>					GALL	ERY	SPACE	Detail	s Similar	to 5th Fl	oor Gal	lerv	
	IFO8010	Core & Toilet Finishes	30-May-14*	25-Jul-14	41	41												C C				1 1 1			· · · · ·			
	IFO8020	Kitchen Fit-Out	02-Jul-14*	23-Oct-14	82	82														tchen F								
	IFO8030	Bookstore & Cafe Fit Out	02-Jul-14*	23-Oct-14	82	82							+						1 1 1	1.1.1.1.		afe Fit (Dut					
	IFO8040	Office Space & Conference/Trustee Rm Fit-out	31-Jul-14*	23-Oct-14	61	61														ffice Sc	ace 8	Confe	rence/1	rustee R	m Fit-ou	t		
	9th Floor		15-Oct-13	23-Oct-14	266	266												or	÷.									
	IFO9000	MEP Rough In; Drywall Framing; In-wall MEP	15-Oct-13*	06-Feb-14	81	81												ough In;		ll Frami	in'a: Ir	i-wall M	EP					
	IFO9010	Drywall & Interior Finishes	18-Jun-14*	23-Oct-14	92	92							: : :			1 1 1 1 1	1 1 1					ior Finis						
	Site Work		03-Mar-14	29-Jul-14	107	107											Site V	/ork										
	SW1000	Largo (Plaza) Work	03-Mar-14*	29-Jul-14	107	107													arao (P		Vork			1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1				
-	Festing, Insp	pections, & TCO	06-May-14	28-Nov-14	149	149											Testing.	Inspec	tions, 8	ŤĊÓ								
	TCO1000	Systems Testing & Commissioning	06-May-14*	23-Oct-14	123	123														/stems	Testi		mmissi	oning				
	TCO1010	Start Owner Furniture Delivery	25-Jul-14*		0	0													1 1 1		1 1	Delive	1 1 1					
	TCO1020	TCO Inspections Cellar, Lobby, 2nd, 3rd, 4th, Roof	11-Aug-14*	08-Sep-14	21	21							+											nd, 3rd,	4th Roo	f		1
	TCO1030	TCO - Cellar, Lobby, 2nd, 3rd, 4th, Roof		08-Sep-14	0	0												1 1 1	1 1 1		1 1	1 1 1	1 1 1	h, Roof	-,, r.oo			-
	TCO1040	TCO Inspections All Areas	24-Oct-14*	20-Nov-14	20	20																tions Al						
	TCO1050	TCO - Full Building		28-Nov-14	0	0																1 1 1	1 1 1					

Actual Work Critical Remaining Work Summary	Page 6 of 6	TASK filter: All Activities
Remaining Work Milestone		

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Warehouse Details

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For Lease

Equipark



101-125 Comac Street



90 Thirteenth Avenue



1 Comac Loop

Contact Information:

Jay Silver Vice President of Leasing jay@realtagroup.com Luis Castellanos Leasing Agent luis@realtagroup.com



80 Thirteenth Avenue



200 Thirteenth Avenue



33 Comac Loop



www.realtagroup.com

Although the information provided above regarding property for sale, rental or financing is from sources deemed reliable, such information has not been verified and no express representation is made nor is any to be implied as to the accuracy thereof and it is submitted subject to errors, omissions, change of price, rental or other conditions prior to sale, lease or financing or withdrawal without notice.

For Lease

Equipark

Industrial Suites

<u>Address</u>	Bldg/Unit	<u>Size</u>	Office	Loading	Ceiling Power	Lease Price	
				<u>Height</u>		<u>(Gross)</u>	
1 Comac Loop	4/Unit 3	4,140 SF	10%	1 Drive-In	16'	100 Amps	\$7.25 PSF
1 Comac Loop	4/Unit 6	4,140 SF	10%	1 Drive-In	16'	200 Amps	\$7.25 PSF
1 Comac Loop	4/Unit 7	4,140 SF	10%	1 Drive-In	16'	200 Amps	\$7.25 PSF
1 Comac Loop	4/Unit 8	4,000 SF	10%	1 Drive-In	16'	200 Amps	\$7.25 PSF
1 Comac Loop	4/Units 9/10/11	12,420 SF	10%	3 Drive-Ins	16'	200 Amps	\$7.25 PSF
33 Comac Loop	8/Unit 9	4,140 SF	10%	1 Drive-In	16'	200 Amps	\$7.25 PSF
33 Comac Loop	8/Unit 14	4,140 SF	15%	1 Drive-In	16'	200 Amps	\$7.25 PSF
33 Comac Loop	8/Unit 15	4,140 SF	10%	1 Drive-In	16'	200 Amps	\$7.25 PSF
33 Comac Loop	8/Units 14/15	8,280 SF	12%	2 Drive-Ins	16'	400 Amps	\$7.25 PSF
80 13th Avenue	5/Unit 4	8,405 SF	15%	1 Dock/Drive-In	18'	200 Amps	\$7.25 PSF
90 13th Avenue	7/Unit 7	5,642 SF	10%	1 Dock	16'	200 Amps	\$7.25 PSF
90 13th Avenue	7/Unit 8	5,642 SF	35%	2 Docks	16'	200 Amps	\$7.25 PSF
200 13th Avenue	2/Unit 5	4,140 SF	10% BTS	1 Dock	16'	200 Amps	\$7.25 PSF
200 13th Avenue	2/Unit 10-13	16,560 SF	10%	4 Docks	16'	600 Amps	\$7.25 PSF

Comments:

Gross rental includes base rent, base year real estate taxes and common area maintenance charges year 1.

All buildings have gas heat and are fully sprinklered.

Units are separately metered for heat and electric.

The properties are owned and operated by Long Island Industrial.

Contact Information:

Jay Silver Vice President of Leasing jay@realtagroup.com Luis Castellanos Leasing Agent luis@realtagroup.com



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For Lease

Equipark

R&D Suite

<u>Address</u>	Bldg/Unit	<u>Size</u>	Loading	<u>Power</u>		<u>Utilities</u>	Lease Price (Gross)
101-125 Comac St	9/Unit 2A	3,250 SF	Double Door	200 Amps @ 480 Volt	ts	Separate Meter	\$12.00 PSF
101-125 Comac St	9/Unit 11-12	13,250 SF	Double Door	400 Amps		Separate Meter	\$12.00 PSF
Office Suites							
<u>Address</u>	Bldg/Unit	<u>Size</u>	<u>Floor</u>	<u>Utilities</u>	Lease	Price (Gross)	
1 Comac Loop	4/Unit 1B1	1,300 SF	2nd	Included	\$12.0	0 PSF	
1 Comac Loop	4/Unit 14B3	1,530 SF	2nd	Included	\$12.0	0 PSF	
1 Comac Loop	4/Unit 1B4	900 SF	2nd	Included	\$12.0	0 PSF	
*1 Comac Loop	4/Unit 14B1	885 SF	2nd	Included	\$12.0	0 PSF	
*Available 3rd Qt	r 2012						
33 Comac Loop	8/Unit 1B1	2,100 SF	2nd	Included	\$12.0	0 PSF	
33 Comac Loop	8/Unit 16B1	2,000 SF	2nd	Included	\$12.0	0 PSF	
33 Comac Loop	8/Unit 16B3	1,200 SF	2nd	Included	\$12.0	0 PSF	
200 13th Avenue	2/Unit 16A1	2,300 SF	1st	Included	\$12.0	0 PSF	
200 13th Avenue	2/Unit 16B1	1,674 SF	2nd	Included	\$12.0	0 PSF	

Comments:

Gross rental includes base rent, base year real estate taxes and common area maintenance charges year 1. Cleaning by tenant.

All buildings have gas heat and are fully sprinklered.

Units are separately metered for heat and electric.

The properties are owned and operated by Long Island Industrial.

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Prefabrication Estimates

Estimate Summary: Wood Pallets and Trucking Costs

REFERENCE MATERIAL

Taken from one of the following.

RS Means Construction Cost Estimating 2013 (RS Means Book) RS Means Online Database (RS Means Online) Menards, Inc.

WOOD PALLETS

Description	Reference Source	Unit	Crew	Daily Output	Labor Hours	Bare Material	Bare Labor	Bare Equip.	Bare Total	Total O&P
Subfloors, plywood, CDX, 1/2, pneumatic	RS Means Book	SF	2 Carp	1860.00	0.01	0.58	0.39	0.00	0.97	1.23
Wood I Joists 2-1/2" x 9-1/2" x 18'	Menards, Inc.	Ea	2 Carp	n/a	0.00	26.82	0.00	0.00	25.02	34.87
WAREHOUSE LOADING EQUIPMENT										

Description	Reference Source	Unit	Crew	Daily Output	Labor Hours	Hourly Opp Cost	Rent (day)	Rent (Week)
Crane, flatbed mounted, 3 ton	RS Means Online	Ea	n/a	n/a	n/a	16.00	192.00	575.00
				<u>Hourly Rate</u>	<u>Daily Rate</u>	Hourly Rate O&P	Daily Rate O&P	
Laborer	RS Means Book	Ea		35.45	283.60	54.60	436.80	
Crane Operator	RS Means Book	Ea		48.40	390.40	69.20	553.60	

COST ESTIMATE

WOOD PALLETS

Total

Description	Unit	Quantity	Cost/Unit	Cost	Location Factor	Adjusted Cost	
Plywood Subfloor 57: 4'x9' Units Both Sides	SF	4104.00	1.23	5047.92	1.32	6,658.21	
Wood I Joists 2-1/2" x 9-1/2" x 18': (27' needed per Pallet)	EA	86.00	34.87	2998.82	1.32	3,955.44	
Total						10,613.65	
WAREHOUSE LOADING EQUIPMENT							
Description	Unit	Quantity	Cost/Unit	Cost	Location Factor	Adjusted Cost	
Crane, flatbed mounted, 3 ton	Day	3.00	192.00	576.00	1.32	759.74	
Operating Cost	Hr.	12.83	16.00	205.28	1.32	270.76	
Crane Operator	Day	3.00	553.60	1660.80	1.32	2,190.60	
Laborer (2 Laborers for 3 Days Each)	Day	6.00	436.80	2620.80	1.32	3,459.46	
Total						6,680.56	
TRUCKING							
Description	Unit	Quantity	Cost/Unit	Cost	Location Factor	Adjusted Cost	
Shipment of Modules	Ea	9.00	400.00	3600.00	1.00	3,600.00	
Permits	Ea	9.00	40.00	360.00	1.00	360.00	

3,960.00

Rent (Month)

1725.00

Estimate Summary: Crane Rental for Installation

REFERENCE MATERIAL

Taken from one of the following.

RS Means Construction Cost Estimating 2013 (RS Means Book) RS Means Online Database (RS Means Online)

TEMPORARY CRANES

Description	Reference Source	Unit	Crew	Daily Output	Labor Hours	Bare Material	Bare Labor	Bare Equip.	Bare Total	Total O&P
12 Ton Truck Mounted Hydraulic Crane	RS Means Book	Day	A-3H	1.00	8.00	0.00	390.00	855.00	1245.00	1525.00
Mobilization of above Crane	RS Means Book	Ea	1 Eqhv	7.20	1.11	0.00	54.00	0.00	54.00	82.00
		Ea	<u>Hourly Rate</u>	<u>Daily Rate</u>	lourly Rate O&P	Daily Rate O&P				
Laborer	RS Means Book	Ea	35.45	283.60	54.60	436.80				

COST ESTIMATE

TEMPORARY CRANES

DescriptionUnitQuantityCost/UnitCostLocation FactorAdjusted CostCrane RentalDay3.001525.004575.001.326,034.43Mobilization to and fromEA2.0082.00164.001.32216.32Labor to Receive Modules in the Galleries (4 men for 3 full days)EA12.00283.603403.201.324,488.82TotalID,739.56	TEMPORARY CRANES						
Mobilization to and from EA 2.00 82.00 164.00 1.32 216.32 Labor to Receive Modules in the Galleries (4 men for 3 full days) EA 12.00 283.60 3403.20 1.32 4,488.82	Description	Unit	Quantity	Cost/Unit	Cost	Location Factor	Adjusted Cost
Labor to Receive Modules in the Galleries (4 men for 3 full days) EA 12.00 283.60 3403.20 1.32 4,488.82	Crane Rental	Day	3.00	1525.00	4575.00	1.32	6,034.43
	Mobilization to and from	EA	2.00	82.00	164.00	1.32	216.32
Total 10,739.56	Labor to Receive Modules in the Galleries (4 men for 3 full days)	EA	12.00	283.60	3403.20	1.32	4,488.82
	Total						10,739.56

TOTAL CRANE RENTAL COST

10,739.56

REFERENCE MATERIAL

Taken from RS Means Construction Cost Data 2013

LABOR & EQUIPMENT RATES

	Base Rate	Base Rate	O&P Rate	
Description	Hourly	Daily	Hourly	O&P Rate Daily
Laborer	35.45	283.60	54.60	436.80
Skilled Worker	46.20	369.60	71.45	571.60
Electriciam	52.40	419.20	78.40	627.20
Sprinkler Installer	54.65	437.20	82.35	658.80

COST ESTIMATE

WAREHOUSE LABOR AND EQUIPMENT

Description	Unit	Quantity	Men Needed	Cost/Man	Cost	Location Factor	Adjusted Cost
One Laborer	Day	84.00	1.00	436.80	36691.20	1.32	48,432.38
Total							48,432.38

INSTALLATION LABOR

Description	Unit	Quantity	Men Needed	Cost/Man	Cost	Location Factor	Adjusted Cost
Module Positioning and Hoisting							
Iron Workers	Hour	26.00	4.00	71.45	7430.80	1.32	9,808.66
Electrician	Hour	26.00	1.00	78.40	2038.40	1.32	2,690.69
Sprinkler Installer	Hour	26.00	1.00	82.35	2141.10	1.32	2,826.25
Lighting Assembly Installation							
Iron Workers	Hour	45.00	2.00	71.45	6430.50	1.32	8,488.26
Electrician	Hour	45.00	1.00	78.40	3528.00	1.32	4,656.96
Electrical & Fire Protection Connections							
Electrician	Hour	26.00	1.00	78.4	2038.40	1.32	2,690.69
Sprinkler Installer	Hour	26.00	1.00	82.35	2141.10	1.32	2,826.25
Total							33,987.76

TOTAL ADDITIONAL LABOR

82,420.14

Estimate Summary: Wire Pull

REFERENCE MATERIAL

Taken from one of the following.

RS Means Construction Cost Estimating 2013 (RS Means Book)

WIRE All lighting circuits in the galleries is #10AWG

Floor	Number of Lighting	Average Distance	Total Linear	Productivity Rate	Number of Workers	Totak Productivity	Total Duration to
FIOOI	Asemblies	from Pull Box	Feet of Wire	(LF/ Day/Worker)	Assumed	Rate (LF/ Day)	Pull Wire (Day)
5th	494	33	16302	1,000	4	4,000	4.08
6th	312	25	7800	1,000	4	4,000	1.95
7th	267	25	6675	1,000	4	4,000	1.67



Truck Sequencing Schedule

Truck Sequencing for Loading, Transit, and Hoisting into MMAA

						Da	ay 1							Da	ay2							Da	у З			
Shipment #	# Modules	Truck	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8
1	12	А																								
2	12	В													1	1		1			1				1	
3	12	С		1			1							1		1		1		1	1				1	
4	8	D																								
5	9	А		I I		1	 			 			1	-			1	1		1	:	: :			1 1	1
6	6	В					1			1																
7	9	С										i			1	1	i	·							1	
8	6	D										1			1			1		 						
9	3	A										!	1	ļ			1									

Represents Time Loading at the Warehouse. 10 minutes was alloted per module.

Represents time spent in transit to the MMAA. One hour is the necessary time due to Google Maps. However, an extra half hour was added as contingency.

Represents time at the MMAA being craned into place. 15 minuted was alloted per module.

Repre Repre Repre

Represents time spent waiting for the crane. The only time this occurs is between Day 2 & 3 because there was not enough time to transport truck 6 in the morning of Day 3. It will stay overnight at MMAA.

Appendix G:

Prefabrication RS Means Reference Material

01 54 Construction Aids

18 1

01 54 09 - Protection Equipment

OK E	100 40 Entony biots	(row	Daily Output	Labor-		Matorial		Bare Costs	Total	Total
J1 54	4 09.60 Safety Nets	Crew	UUIPUI	nours	Unit	Material	Labor	Equipment	Tota	incl O&P
0010	SAFETY NETS									
020	No supports, stock sizes, nylon, 3 1/2" mesh	1			S.F.	2.96			2.96	3.2
100	Polypropylene, 6" mesh					1.59			1.59	1.7
200	Small mesh debris nets, 1/4" mesh, stock sizes		l i	139.1		.74			.74	.8
220	Combined 3 1/2" mesh and 1/4" mesh, stock sizes					4.67			4.67	5.1
300	Monthly rental, 4" mesh, stock sizes, 1st month					.50			.50	
)320	2nd month rental					.25			.25	.2
340	Maximum rental/year	and the second	180 an 10		V.	1.15			1.15	1.2
and the second sec	54 16 - Temporary Hoists						1. (a)	<u> Kennen i</u>		
01 54 0010	4 16.50 Weekly Forklift Crew WEEKLY FORKLIFT CREW		1223		401-67			1.2.2.5	100000	1
)100		1 20	20	10	Weak	a Providence and	1 005	2,550	1 975	5 400
Description	All-terrain forklift, 45' lift, 35' reach, 9000 lb. capacity	A-3P	.20	40	Week		1,825	2,550	4,375	5,600
and a second	54 19 – Temporary Cranes									
010	4 19.50 Daily Crane Crews DAILY CRANE CREWS for small jobs, portal to portal		- Cardina	16.0		1		1		0707
100	12-ton truck-mounted hydraulic crane	A-3H	1	8	Day		390	855	1,245	1,525
200	25-ton	A-31	1	8	Duy		390	980	1,245	1,525
300	40-ton	A-31	1	8		in the following the	390	1,225	1,615	1,875
400	55-ton	A-3K	1201935	16	and and a	1012482.84	730	1,225	2,380	2,900
500	80-ton	A-3L	1	16			730	2,350	3,080	3,675
500	100-ton	A-3M	1	16	11		730	2,350	3,080	3,675
000	If crane is needed on a Saturday, Sunday or Holiday	MOM		10	v		100	2,000	0,000	0,075
10	At time-and-a-half, add	exessed	STATES IN	1952487	Day	STANDAR	50%	ALE SHIRE SH	(and the second	N. S. S. S. S.
720	At double time, add						100%	Contraction of the	leater 1	Carlos and
	4 19.60 Monthly Tower Crane Crew	ALC: NO. 1	105, 12,04		1. Sector	Contraction of the		1.27.107.20.0010		
010	MONTHLY TOWER CRANE CREW, excludes concrete footing		19.12	19.3				4382.0		
100	Static tower crane, 130' high, 106' jib, 6200 lb. capacity	A-3N	.05	176	Month	1 Alert	8,600	23,600	32,200	38,900
)1 !	54 23 – Temporary Scaffolding and Platform	IS						A States		
	4 23.60 Pump Staging					Constanting of the second s	<u></u>			
010	PUMP STAGING, Aluminum R015423-20			Case of		and the second		A State of the sta	and the seal	Distantin 1
200	24' long pole section, buy	A P	Control of		Ea.	330			330	365
300	18' long pole section, buy			(ale)		257			257	282
00	12' long pole section, buy		Sec. 1	AS O		173			173	190
500	6' long pole section, buy					97			97	107
600	6' long splice joint section, buy	[]]				69			69	75
00	Pump jack, buy	[]		1		140			140	154
900	Foldable brace, buy		Longer and	Lunger and		55			55	61
000	Workbench/back safety rail support, buy	11 250		Contraction of the		74		and the second s	- 74	81
100	Scaffolding planks/workbench, 14" wide x 24' long, buy	1	Concern of	Contraction of the second		680		1 States 1	680	745
200	Plank end safety rail, buy	119.7		1		288			288	315
250	Safety net, 22' long, buy	133	123	1. 4	V	330			330	365
300	System in place, 50' working height, per use based on 50 uses	2 Carp			C.S.F.	5.80	8.45		14.25	19
400	100 uses	1 1 1	84.80			2.90	8.45		11.35	16
500	150 uses	W	84.80	.189	V	1.94	8.45		10.39	15
	4 23.70 Scaffolding		100.03	T T AT I	1					
010	SCAFFOLDING R015423-10	13				Sector 1			Star 1	$\beta = -\frac{1}{2}$
015	Steel tube, regular, no plank, labor only to erect & dismantle	1		Res .				14.20		
090		3 Carp		3	C.S.F.		135	1530.1	135	207
		1	0	1 1	1.1.7	Provide Contractor	100	Asterior	180	277
0200 0301	6 to 12 stories	4 Carp	8	4	424 1	and the state	180	A Band State	100	211

01 54 36 - Equipment Mobilization

01 54	36.50 Mobilization		Crew	Daily Output	Labor- Hours	Unit	Materia	2013 Bo Labor	re Costs Equipment	Total	Total Incl 0&P
1100	Small equipment, placed in rear of, or towed by pickup truck		A-3A	8	1	Ea.		35.50	20.50	56	77.50
1150	Equip up to 70 HP, on flatbed trailer behind pickup truck		A-3D	4	2			71.50	69.50	141	186
2000	Crane, truck-mounted, up to 75 ton, (driver only, one-way)		1 Eghv	7.20	1.111			54		54	82
2100	Crane, truck-mounted, over 75 ton		A-3E	2.50	6.400			273	66	339	490
2200	Crawler-mounted, up to 75 ton		A-3F	2	8			340	500	840	1,075
2300	Over 75 ton		A-3G	1.50	10.667	*		455	750	1,205	1,525
2500	For each additional 5 miles haul distance, add							10%	10%		
3000	For large pieces of equipment, allow for assembly/knockdown										
3001	For mob/demob of vibrofloatation equip, see Section 31 45 13.10										
3100	For mob/demob of micro-tunneling equip, see Section 33 05 23.19										•
3200	For mob/demob of pile driving equip, see Section 31 62 19.10										
3300	For mob/demob of caisson drilling equip, see Section 31 63 26.13										
and the second se	64 39 - Construction Equipment										
	39.70 Small Tools										
0010	SMALL TOOLS	R013113-50	1.1								
0020	As % of contractor's bare labor cost for project, minimum					Total		.50%			
0100	Maximum		1.10			"		2%	1		

0010	ROADS AND SIDEWALKS Temporary		S. Pr							
0050	Roads, gravel fill, no surfacing, 4" gravel depth	B-14	715	.067	S.Y.	4.35	2.52	.51	7.38	9.20
0100	8" gravel depth	"	615	.078	"	8.70	2.93	.60	12.23	14.75
1000	Ramp, 3/4" plywood on 2" x 6" joists, 16" O.C.	2 Carp	300	.053	S.F.	1.33	2.39	1204	3.72	5.15 ~
1100	On 2" x 10" joists, 16" 0.C.	"	275	.058	"	1.85	2.61		4.46	6.05

01 56 Temporary Barriers and Enclosures

01 56 13 - Temporary Air Barriers

01 56 13.60 Tarpaulins TARPAULINS 0010 0020 Cotton duck, 10 oz. to 13.13 oz. per S.Y., 6'x8' S.F. .79 .79 .87 0050 30'x30' 1.65 1.50 1.50 1.31 0100 Polyvinyl coated nylon, 14 oz. to 18 oz., minimum 1.19 1.19 0150 1.19 1.19 1.31 Maximum 0200 Reinforced polyethylene 3 mils thick, white .03 .03 .03 .09 0300 4 mils thick, white, clear or black .09 .10 .18 0400 5.5 mils thick, clear .16 .16 .45 0500 White, fire retardant .41 .41 0600 12 mils, oil resistant, fire retardant .27 .27 .30 8.5 mils, black .57 .57 .63 0700 .16 0710 Woven polyethylene, 6 mils thick .16 .18 0730 .24 .26 Polyester reinforced w/integral fastening system 11 mils thick .24 0740 Mylar polyester, non-reinforced, 7 mils thick 1.17 1.17 1.29 01 56 13.90 Winter Protection 0010 WINTER PROTECTION 0100 Framing to close openings 2 Clab S.F. .40 1.13 1.53 2.19 500 .032 0200 Tarpaulins hung over scaffolding, 8 uses, not incl. scaffolding 1500 .011 .25 .38 .63 .86

Wood Decking 06 15 23 - Laminated Wood Decking

06 15	23.10 Laminated Roof	Deck	Crew	Daily Output	Labor- Hours	Unit	Material	2013 Bo Labor	re Costs Equipment	Total	Total
0300	Cedar, 3" thick		2 Carp	425	.038	S.F.	4.45	1.69		6.14	7.50
0400	4" thick			325	.049		5.65	2.21		7.86	9.65
0600	Fir, 3" thick			425	.038		4.11	1.69		5.80	7.10
0700	4" thick		*	325	.049	T.	5.50	2.21		7.71	9.45

1.76

2.11

2.3

1.36

1.67

1.85

1.05

.57

.62

.65

.48

.79

1.05

1.20

.57

16 Sheathing

06 16 23 - Subflooring

0010	SUBFLOOR	DO LO DO	104212	67	Sur as	STREET	10000000	1 and the last	84 S 18 8 8 8 8		
0010	Plywood, CDX, 1/2" thick	R061636-20	2 Carp	1600	.011	SF Flr.	.58	.48	Arrento de la	1.06	1.
015	Pneumatic nailed			1860	.009	SF FIL	.58	.40		.97	1.3
100	5/8" thick			1350	.007		.30	.53		1.26	1.2
105	Pneumatic nailed		521833	1674	.012	103-03	.73	.43	Mar Pala West	1.16	1.0
200	3/4" thick			1250	.013		.73	.57		1.34	1.4
205	Pneumatic nailed			1550	.010		.77	.46		1.23	1.5
300	1-1/8" thick, 2-4-1 including underlayment			1050	.015		1.53	.68		2.21	2.7
440	With boards, 1" x 6", S4S, laid regular		No an	900	.018	1373	1.80	.80	NOT THE OWNER	2.60	3.2
450	1" x 8", laid regular			1000	.016		1.81	.72	Carl and Th	2.53	3.1
460	Laid diagonal			850	.019		1.81	.85		2.66	3.2
)500	1" x 10", laid regular			1100	.015		1.84	.65	a series and the	2.49	3.0
0600	Laid diagonal	and service of the service of the	+	900	.018	+	1.84	.80	Constant and a second second	2.64	3.2
990	Subfloor adhesive, 3/8" bead		1 Carp	2300	.003	L.F.	.12	.16		.28	.3
	6 26.10 Wood Product Underlayment										
6 1	6 26.10 Wood Product Underlayment										
010	WOOD PRODUCT UNDERLAYMENT	R061636-20						San Sarah			12 2
030	Plywood, underlayment grade, 3/8" thick		2 Carp	1500	.011	SF Flr.	.81	.48		1.29	1.6
070	Pneumatic nailed			1860	.009		.81 *	.39	Specific States	1.20	1.4
100	1/2" thick			1450	.011		.94	.50		1.44	1,7
105	Pneumatic nailed			1798	.009		.94	.40		1.34	1.6
200	5/8" thick			1400	.011		1.09	.51		1.60	1.9
)205	Pneumatic nailed			1736	.009		1.09	.41		1.50	1.8
0300	3/4" thick		CONTRACT	1300	.012	1235 18-839	1.24	.55	Contra Charlennander - P	1.79	2.2 2.0
0305	Pneumatic nailed			1612	.010		1.24	.45		1.69	
)500	Particle board, 3/8" thick	G		1500	.011		.37	.48		.85	1.15
)505	Pneumatic nailed	G		1860	.009		.37	.39		.76	1.21
)600)605	1/2" thick Pneumatic nailed	G		1450 1798	.011	(1941)23	.41	.50 .40		.91	1.07
0080	5/8" thick	G		1/98	.009		.41 .50	.40		1.01	1.34
805	Pneumatic nailed	G		1736	.001		.50	.41		.91	1.19
900	3/4" thick	G		1300	.007		.50	.55	i i i	1.23	1.60
905	Pneumatic nailed	G	100	1612	.012	1.157	.00.	.55	te official cars official	1.13	1.4
J905 J955	Particleboard, 100% recycled straw/wheat, 4' x 8' x 1/4"	G		1450	.010	S.F.	.00	.45		.78	1.0/
0960	4' x 8' x 3/8"	G		1450	.011	J.F.	.20	.50		.70	1.2
	4 x 0 x 3/0 4' x 8' x 1/2"	G	See. Sty	1450	.011		.41	.50	STREET,	1.10	1.6
)965	4' v 8' v 1//"	Charles and the second states of the second s									

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.011 SF Flr.

4' x 8' x 3/4"

4' x 8' x 1-1/4"

Hardboard, underlayment grade, 4' x 4', .215" thick

4′ x 8′ x 1″

	×	 -	Daily	Labor-			2013 E	Bare Costs		To
26 05 19.35	Cable Terminations	Crew	Output	Hours	Unit	Material	Labor	Equipment	Total	Inc
800	500 kcmil	1 Elec	6	1.333	Ea.	21	70		91	
6 05 19.50	Mineral Insulated Cable									
010 MINERAL	INSULATED CABLE 600 volt	1.1					and and a second			1
100 1 0	onductor, #12	1 Elec	1.60	5	C.L.F.	385	262	Mar 14	647	1
200	#10		1.60	5	1	495	262		757	1.10
400	#8	300	1.50	5.333	24	550	279	- A Start	829	1,
500	#6		1.40	5.714		655	299		954	1,
600	#4	2 Elec	2.40	6.667		880	350		1,230	1,
0800	#2		2.20	7.273		1.250	380		1,630	1,

2.10 7.619

8.421

8.889

1.90

1.80

1.60

*

1,425

1,675

2,000

2,400

2,775

1410	250 kcmil	3 Elec	2.40	10	1990 1990	3,125	525	3,650	4,225
1420	350 kcmil		1.95	12.308		3,575	645	4,220	4,900
1430	500 kcmil	+	1.95	12.308	*	4,600	645	5,245	6,025
26 0	5 19.55 Non-Metallic Sheathed Cable								
0010	NON-METALLIC SHEATHED CABLE 600 volt		Store -			and the second sec			
0100	Copper with ground wire, (Romex)		Sant.					A CAR DE LA	
0150	#14, 2 conductor	1 Elec	2.70	2.963	C.L.F.	25	155	180	260
0200	3 conductor	74	2.40	3.333		35	175	210	300
0250	#12, 2 conductor		2.50	3.200		38	168	206	293
0300	3 conductor		2.20	3.636		53.50	191	244.50	345
0350	#10, 2 conductor		2.20	3.636		60.50	191	251.50	350
0400	3 conductor		1.80	4.444		85.50	233	318.50	445
0430	#8, 2 conductor		1.60	5		92.50	262	354.50	490
0450	3 conductor		1.50	5.333		136	279	415	570
0500	#6, 3 conductor		1.40	5.714		220	299	519	695
0550	SE type SER aluminum cable, 3 RHW and								and the second
0600	1 bare neutral, 3 #8 & 1 #8	1 Elec	1.60	5	C.L.F.	162	262	424	570
0650	3 #6 & 1 #6	"	1.40	5.714		183	299	482	650
0700	3 #4 & 1 #6	2 Elec	2.40	6.667		169	350	519	710
0750	3 #2 & 1 #4		2.20	7.273		300	380	680	905
0800	3#1/0 & 1 #2		2	8		460	420	880	1,125
0850	3 #2/0 & 1 #1		1.80	8.889		540	465	1,005	1,300
0900	3 #4/0 & 1 #2/0		1.60	10		770	525	1,295	1,625

010	WIRE	60519-92		Mar 1				Constant of the A	
0020	600 volt, copper type THW, solid, #14	The Party Support of the Vice of the	Elec	13	.615	C.L.F.	8.25	32.50	40.75 57.50
0030	#12		13	11	.727		12.45	38	50.45 70.50
040	#10		13	10	.800		19.70	42	61.70 84
0050	Stranded, #14 R2	60533-22		13	.615		9.30	32.50	41.80 58.50
0100	#12 -			11	.727		14.25	38	52.25 72.50
0120	#10			10	.800		22.50	42	64.50 87
0140	#8			8	1		37	52.50	89.50 120
0160	#6			6.50	1.231		63	64.50	127.50 166
0180	#4	. 2	Elec	10.60	1.509		99	79	178 227
0200	#3		12	10	1.600		125	84	209 262
0220	#2	Constant of		9	1.778		157	93	250 310
0240	#1	and the second		8	2		199	105	304 375
0260	1/0			6.60	2.424		248	127	375 465

#1

1/0

2/0

3/0

4/0

26 05 19

1,950

2,175

2,475

2,850

3,350

3,825

1,825

2,095

2,440

2,865

3,300

Appendix H:

I Joist Pricing from Menards, Inc.

/19/13	2 1/2" :	x 9 1/2" x 18' I-Joist	at Menards		
ogin or Register	Rebate Center	Order Tracker	Store Locator	My Account	My Ca
Dedicated to Service & Quality*	Promotions 👻 Services	✓ Project Cente	er How-To Center 💌 Cre	dit Center ✔ Gift Regis	stry Gift Card
Departments	Search All	Enter SKU	, Model # or Keyword	We	ekly Ad
			Home » Building N	Aterials » Engineered Prod	ducts » I-Joist
	2 1/2" x 9 1/2" x 18'	I-Joist		Online Availability	
	Model Number: 1065905 Menar			X Ship to Guest Not eligible for Ship to	
	Online Price ⑦ \$25.02			Ship to Store - Free	e!
				Quantity 1	
				Select a Store	& Buy
				Store Availability	
				Enter Your ZIP Code for	Store Information
			hases, or take advantage of BIG CARD. Learn More >		
Click image for a larger view . Hover to zoom in.	 2% Year End Rebate 12 Month Special Financia	ng on Purchases Ove	er \$299 💿		
▶ View Videos	Add to Wish List Add to Com	pare Printer Friendly	Share	-	
Product Description					-
This I-joist can be used for floor joists or	r roof rafters. NI-40x Joist, 2-1/2"solid sa	wn flange with 3/8"hi	gh density OSB web stock.		
• Lightweight, dimensionally stable					
Uses 50% less wood fiber than tradi	itional lumber joists				
Dimensions: 2-1/2" x 9-1/2" x 18'					
Brand Name: NI-40 Vendor: Nordic					
NORDIC					
Product Documents					•
Technical Specifications: view PDF file MSDS Document: 100833 001.pdf					
To read PDF files, you need the Adobe Acroba	at Reader 6.0 or higher. If vou don't have it. cli	ck here and download it	for free from Adobe's site.		
ease Note: Prices, promotions, styles ar ock status and availability as item quanti erefore online purchases do not qualify t	ities are constantly changing throughout				

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	Flooring	Register Protection Plan	Privacy & Terms
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www.menards.com/main/building-materials/engineered-products/i-joists/2-1-2-x-9-1-2-x-18-i-joist/p-1319266-c-5662.htm

2 1/2" x 9 1/2" x 18' I-Joist at Menards

We Are Here To Help You! Your comments, suggestions and questions are important to us. Help > Let us know w hat you think > Home & Decor Kitchen Lighting & Ceiling Fans Outdoor Paint Plumbing Storage & Organization Sterling Home and Patio Sterling Home and Patio Cools & Hardware Window Treatments See More MSDS Lookup Local Utility Rebates

How-To Center How-To Videos Garden Center

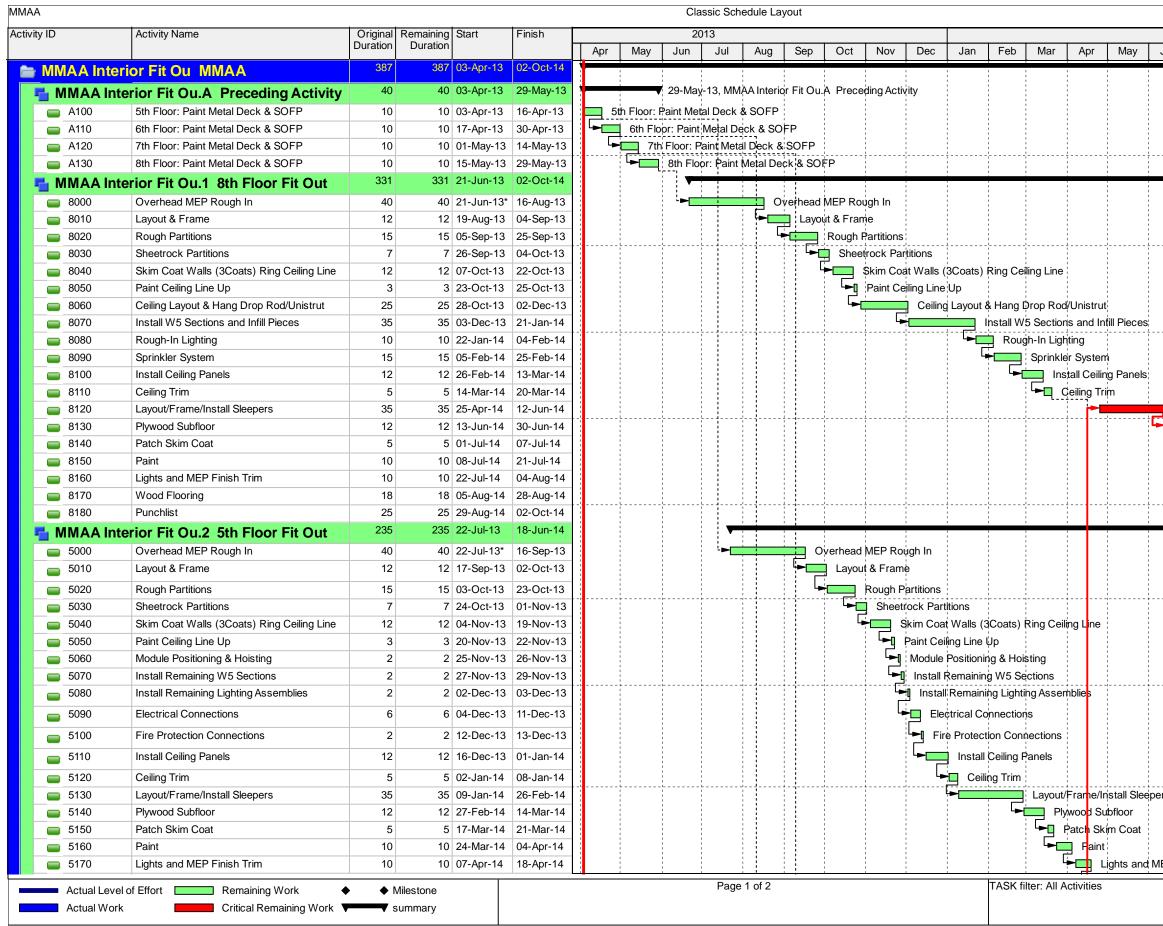
Forms Contractor Hauling Form Supplier Form Security

Affiliated Websites Midwest Manufacturing Menards Racing Real Estate

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Appendix I:

New Interior Fit-Out Schedule for Prefabrication



						25-Feb	o-13 19:4	15
	14						2015	,
Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	þ
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IEP Fin	ish Trim			 		1 1 1	1 1 1	1
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5100 Wood Planing 16 10 21 April 4 14 April 4 <th< th=""><th>ity ID</th><th>Activity Name</th><th>Original</th><th></th><th></th><th>Finish</th><th></th><th></th><th>20</th><th>013</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></th<>	ity ID	Activity Name	Original			Finish			20	013										
Biolog Panciel 25 15 Marcu M 15 Juil 44 MMAA lateior Fit Out. 288 289 14 Marcu M 14 Juil 44 MMAA lateior Fit Out. 288 289 14 Juil 44 15 Juil 44 MMAA lateior Fit Out. 288 289 14 Juil 44 15 Juil 44				ļ	ļ		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
MAA Interior Fit Out 250 228. 20.40.913 17.04/44 5000 Ownhord MEP Rough In 40 40.20.40.011 60.60.41.01 60.01 40.00.41.01 60.01.01 40.00.41.01 60.01.01 40.00.41.01 70.01.10		Wood Flooring	18	18	21-Apr-14	14-May-14		-	1	1 1 1								1		
6000 Ourseward MP Rough In 40 40 20 20 Common Second			25		-				1											له الع
0010 Lupuk A Former 12 12 14-0e-113 14-0e-13 0020 Roug-Paritime 16 15 10-0e-13 10-0e-13 10-0e-13 0030 Sheencok Nariticos 7 7 2-Nor-13 10-0e-13 10-0e-13 0040 Sheencok Nariticos 7 7 2-Nor-13 10-0e-13 10-0e-13 0040 Sheencok Nariticos 7 7 2-Nor-13 10-0e-13 10-0e-13 0050 Reside Pariticos 2 2-0-0e-13 10-0e-13 10-0e-13 0050 Reside Pariticos 2 2-0-0e-13 10-0e-13 10-0e-13 0050 Reside Pariticos 2 2-0-0e-13 10-0e-14 10-0e-14 0050 Reside Camp Pariticos 2 2-0-0e-13 10-0e-14 10-0e-14 0100 Instal Remaining Using Socialis 2 2-0-0e-13 10-0e-14 10-0e-17 0100 Instal Remaining Using Socialis 2 10-0e-17 10-0e-17 10-0e-0e-13 0100	💾 MMAA In	terior Fit Ou.3 6th Floor Fit Out	235	235	20-Aug-13	17-Jul-14							1				· · ·	1		
8020 Roogh Partitions 15 15 17 Mon-10 2 Mon-10 Mo	— 6000	Overhead MEP Rough In	40	40	20-Aug-13*	15-Oct-13								verhead	MEP Rou	igh In		1		
Biological Partitione T< T< <tht<< th=""> T< <tht<< th=""></tht<<></tht<<>	6010	Layout & Frame	12	12	16-Oct-13	31-Oct-13			1	1				Layou	ut & Frame	\$				1
ex040 Skm Coxt Wals (Schas) Ring Caling Line 12 12 14 Deben 3 32 Deben 3 24 Deben 3	6020	Rough Partitions	15	15	01-Nov-13	21-Nov-13		1 1 1					- L-			artitions	· · · · ·			
Biolon Part Celling Line Up India Subsection Subsec	6030	Sheetrock Partitions	7	7	22-Nov-13	03-Dec-13				1	-				📥 Sheet	rock Part	titions			
B000 Module Preaming & Hatting 2 2 2-Dec-13 2-Dec-14	6040	Skim Coat Walls (3Coats) Ring Ceiling Line	12	12	04-Dec-13	19-Dec-13				1				ļ	+ S	kim Coat	Walls (BCoats) F	ling Ceili	ng Line
6070 Insul Remaining Light Assembles 2 2 Differentiation 3 Decretal 3 Decretal Comparison Comparison <thcomparison< th=""> <thcomparison< th=""> <thco< td=""><td>6050</td><td>Paint Ceiling Line Up</td><td>3</td><td>3</td><td>20-Dec-13</td><td>24-Dec-13</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>└►]</td><td>Paint Cei</td><td>ling Line</td><td>Up</td><td></td><td></td></thco<></thcomparison<></thcomparison<>	6050	Paint Ceiling Line Up	3	3	20-Dec-13	24-Dec-13									└►]	Paint Cei	ling Line	Up		
0 6000 Install Remaining Lighting Assembles 2 2 0 1/2 m1-14 0 2/2 m1-14 0 6000 Electrical Connections 6 6 0 3/2 m1-14 0 3/2 m1/2 0 3/	6060	Module Positioning & Hoisting	2	2	26-Dec-13	27-Dec-13				1						Module	Positioni	ng & Hois	ting	1
6 0909 Ellicital Connections 6 6 0 0.3an-14 10 Jan-14 6 1000 Fire Protection Connections 2 2 13 Jan-14 10 Jan-14 30 Jan-14 <td>6070</td> <td>Install Remaining W5 Sections</td> <td>2</td> <td>2</td> <td>30-Dec-13</td> <td>31-Dec-13</td> <td></td> <td></td> <td>·!</td> <td>L</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Install I</td> <td>Remainir</td> <td>ng W5 Se</td> <td>ctions</td> <td></td>	6070	Install Remaining W5 Sections	2	2	30-Dec-13	31-Dec-13			·!	L						Install I	Remainir	ng W5 Se	ctions	
6100 File Protection Connectons 2 2 13-Jan-14 14-Jan-14 6110 Instal Ceiling Panels 12 12 15-Jan-14 30-Jan-14 6120 Ceiling Tim 5 5 31-Jan-14 30-Jan-14 6130 Loyout/Frame/Install Steppers 35 35 07-Feb-14 27-Mar-14 6160 Paint 6 5 15-Apr-14 22-Apr-14 14-Apr-14 6180 Paint 10 01 02-Mar-14 14-Apr-14 6180 Paint 10 01 02-Mar-14 12-Jan-14 12-Jan-14 6180 Paint 10 01 02-Mar-14 12-Jan-14 12-Jan-14 12-Jan-14 6180 Wood Flooring 18 22-Mor-14 12-Jan-14 12-J	6080	Install Remaining Lighting Assemblies	2	2	01-Jan-14	02-Jan-14			1	1						Install	Remaini	ng Lightin	gAssen	blies
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Appendix J:

Gallery Redesign RS Means Reference Material

05 12 Structural Steel Framing 05 12 23 – Structural Steel for Buildings

05 10	23.17 Columns, Structural		Crew	Daily Output	Labor- Hours	Unit	Material	2013 Bare Labor E	Costs quipment	Total	Total Incl O&P
6800	W Shape, A992 steel, 2 tier, W8 x 24	G	E-2	1080	.052	L.F.	34.50	2.54	1.41	38.45	44
6850	W8 x 31	G	L-Z	1080	.052	L.I.	44.50	2.54	1.41	48.45	55
6900	W8 x 48	G	1	1032	.052	T	68.50	2.66	1.48	72.64	81.50
6950	W8 x 67	G		984	.057		96	2.79	1.55	100.34	111
7000	W10 x 45	G		1032	.054		64.50	2.66	1.48	68.64	77
7050	W10 x 43	G		984	.057		97	2.79	1.55	101.34	113
7100	W10 x 85	G	1	960	.058		160	2.86	1.59	164.45	183
7150	W10 x 112 W12 x 50	G		1032	.054	2	71.50	2.66	1.48	75.64	84.50
7200	W12 x 30	G		984	.054		124	2.00	1.55	128.34	143
7250	W12 x 07 W12 x 120	G		960	.057		124	2.77	1.55	176.45	145
	W12 x 120 W12 x 190	G	T	912	.058		272	3.01	1.57	276.68	305
7300	W12 x 190 W14 x 74	G			.001		106	2.79		110.34	122
7350		G		984					1.55		
7400	W14 x 120	G		960	.058		172	2.86	1.59	176.45	196
7450	W14 x 176	G	*	912	.061	*	252	3.01	1.67	256.68	284
8090	For projects 75 to 99 tons, add					All	10%				
8092	50 to 74 tons, add						20%	1.00/			
8094	25 to 49 tons, add						30%	10%			
8096	10 to 24 tons, add						50%	25%			
8098	2 to 9 tons, add						75%	50%			
8099	Less than 2 tons, add			1	-	*	100%	100%			
05 12	23.20 Curb Edging					_					
0010	CURB EDGING										
0020	Steel angle w/anchors, shop fabricated, on forms, 1" x 1", 0.8#/L.F.	G	E-4	350	.091	L.F.	1.65	4.62	.41	6.68	10.50
0100	2" x 2" angles, 3.92#/L.F.	G		330	.097		6.50	4.90	.44	11.84	16.40
0200	3" x 3" angles, 6.1#/L.F.	G		300	.107		10.25	5.40	.48	16.13	21.50
0300	4" x 4" angles, 8.2#/L.F.	G		275	.116		13.55	5.90	.52	19.97	26
1000	6" x 4" angles, 12.3#/L.F.	G		250	.128		19.95	6.45	.58	26.98	34
1050	Steel channels with anchors, on forms, 3" channel, 5#/L.F.	G		290	.110		8.20	5.60	.50	14.30	19.50
1100	4" channel, 5.4#/L.F.	G		270	.119		8.80	6	.53	15.33	21
1200	6" channel, 8.2#/L.F.	G		255	.125		13.55	6.35	.56	20.46	27
1300	8" chonnel, 11.5#/L.F.	G		225	.142		18.70	7.20	.64	26.54	34
1400	10" channel, 15.3#/L.F.	G		180	.178		24.50	9	.80	34.30	44
1500	12" channel, 20.7#/L.F.	G	4	140	.229		33	11.55	1.03	45.58	58
2000	For curved edging, add						35%	10%			
05 12	23.40 Lightweight Framing							3			
	LIGHTWEIGHT FRAMING	R051223-35	1	1	1			-			
0015	Made from recycled materials	G									
0200	For load-bearing steel studs see Section 05 41 13.30										
0400	Angle framing, field fabricated, 4" and larger R051223-45	G	E-3	440	.055	Lb.	.75	2.77	.33	3.85	6.15
0450	Less than 4" angles	G		265	1.091	"	.78	4.59	.54	5.91	9.65
0460	1/2" x 1/2" x 1/8"	G		200	.120	L.F.	.16	6.10	.72	6.98	11.80
0462	3/4" x 3/4" x 1/8"	G		160	.150		.44	7.60	.90	8.94	15
0464	1" x 1" x 1/8"	G		135	.178		.62	9	1.07	10.69	17.95
0466	1-1/4" x 1-1/4" x 3/16"	G		115	.209	1 1	1.15	10.60	1.25	13	21.50
0468	1-1/2" x 1-1/2" x 3/16"	G		100	.240		1.40	12.15	1.44	14.99	24.50
0400	2" x 2" x 1/4"	G		90	.267		2.49	13.55	1.60	17.64	28.50
0470	2-1/2" x 2-1/2" x 1/4"	G		72	.333		3.20	16.90	2	22.10	35.50
		G		65	.369		4.60	18.75	2.22	25.57	41
0474	3" x 2" x 3/8" 3" x 3" x 3/8"	G		57	.307		4.60	21.50	2.53	29.63	41
0476	,	G				W.					
0600	Channel framing, field fabricated, 8" and larger	G		500	.048	Lb.	.78	2.43	.29	3.50	5.50
0650	Less than 8" channels	G	-	335	.072		.78	3.63	.43	4.84	7.85
0660	C2 x 1.78	G	· ·	115	.209	L.F.	1.39	10.60	1.25	13.24	22

	2 23 - Structural Steel for Buildin			Deile	Labor		
05 12	23.40 Lightweight Framing		Crew	Daily Output	Labor- Hours	Unit	Materia
0662	C3 x 4.1	G	E-3	80	.300	L.F.	3.20
0664	C4 x 5.4	G		66	.364		4.21
0666	C5 x 6.7	G		57	.421	ł	5.25
668	C6 x 8.2	G		55	.436		6.20
670	C7 x 9.8	G		40	.600		7.65
0672	C8 x 11.5	G		36	.667		8.95
710	Structural bar tee, field fabricated, 3/4" x 3/4" x 1/8"	G		160	.150		.44
0712	1" x 1" x 1/8"	G	+	135	.178	2	.62
714	1-1/2" x 1-1/2" x 1/4"	G		114	.211		1.83
716	2" x 2" x 1/4"	G		89	.270		2.49
718	2.1 /2" x 2.1 /2" x 3 /8"	G		72	333		4.60

5 12	23.40 Lightweight Framing		Crew	Daily Output	Labor- Hours	Unit	Materia	2013 Ba Labor	re Costs Equipment	Total	Total Incl O&P
662	C3 x 4.1	G	E-3	80	.300	L.F.	3.20	15.20	1.80	20.20	32.50
664	C4 x 5.4	G		66	.364		4.21	18.45	2.18	24.84	40
666	C5 x 6.7	G	3	57	.421	ł	5.25	21.50	2.53	29.28	46.50
668	C6 x 8.2	G		55	.436		6.20	22	2.62	30.82	49
670	C7 x 9.8	G		40	.600		7.65	30.50	3.60	41.75	67
672	C8 x 11.5	G		36	.667		8.95	34	4	46.95	75
710	Structural bar tee, field fabricated, 3/4" x 3/4" x 1/8"	G		160	.150		.44	7.60	.90	8.94	15
712	1" x 1" x 1/8"	G	-	135	.178	2	.62	9	1.07	10.69	17.95
714	1-1/2" x 1-1/2" x 1/4"	G		114	.211		1.83	10.70	1.26	13.79	22.50
716	2" x 2" x 1/4"	G		89	.270		2.49	13.70	1.62	17.81	29
718	2-1/2" x 2-1/2" x 3/8"	G		72 .	.333		4.60	16.90	2	23.50	37.50
720	3" x 3" x 3/8"	G	F	57	.421	Ĭ	5.60	21.50	2.53	29.63	47
730	Structural zee, field fabricated, 1-1/4" x 1-3/4" x 1-3/4"	G		114	.211		.59	10.70	1.26	12.55	21
732	2-11/16" x 3" x 2-11/16"	G		114	.211		1.39	10.70	1.26	13.35	22
734	3-1/16" x 4" x 3-1/16"	G		133	.180		2.10	9.15	1.08	12.33	19.85
736	3-1/4" x 5" x 3-1/4"	G		133	.180		2.86	9.15	1.08	13.09	20.50
738	3-1/2" × 6" × 3-1/2"	G		160	.150		4.31	7.60	.90	12.81	19.30
740	Juniar beam, field fabricated, 3″	G		80	.300		4.45	15.20	1.80	21.45	34
742	4"	G		72	.333		6	16.90	2	24.90	39
744	5″	G	T	67	.358	T	7.80	18.15	2.15	28.10	43.50
746	6"	G		62	.387		9.75	19.65	2.32	31.72	48.50
748	7"	G		57	.421		11.95	21.50	2.53	35.98	54
750	8″	G		53	.453	4	14.35	23	2.72	40.07	60
000	Continuous slotted channel framing system, shop fab, minimum	G	2 Sswk	2400	.007	Lb.	4.03	.33	2.11 2	4.36	5.05
200	Maximum	G	11	1600	.010	ED.	4.55	.50		5.05	5.90
300	Cross bracing, rods, shop fabricated, 3/4" diameter	G	E-3	700	.034		1.56	1.74	.21	3.51	5.05
310	7/8" diameter	G	LU	850	.028		1.56	1.43	.17	3.16	4.47
320	1" diameter	G	T	1000	.024		1.56	1.40	.14	2.92	4.05
330	Angle, 5" x 5" x 3/8"	G		2800	.009		1.56	.43	.05	2.04	2.56
350	Hanging lintels, shop fabricated, average	G		850	.028		1.56	1.43	.17	3.16	4.47
380	Roof frames, shop fabricated, 3'-O" square, 5' span	G	E-2	4200	.013		1.56	.65	.36	2.57	3.24
400	Tie rod, not upset, 1-1/2" to 4" diameter, with turnbuckle	G	2 Sswk	800	.020		1.69	1	.00	2.69	3.65
420	No turnbuckle	G	L JOYAK	700	.020		1.63	1.14		2.77	3.83
500	Upset, 1-3/4" to 4" diameter, with turnbuckle	G		800	.023		1.65	1.14		2.69	3.65
520	No turnbuckle	G		700	.020	}	1.63	1.14		2.09	3.83
š	2 23.45 Lintels		I. Y.	700	.020	Y	1.00	1.17	A A A A A A A A A A A A A A A A A A A	4.11	
	LINTELS		1								-
015	Made from recycled materials	G									
)20	Plain steel angles, shop fabricated, under 500 lb.	G	1 Bric	550	.015	Lb.	1	.65		1.65	2.09
100	500 to 1000 lb.	G	1 DHC	640	.013	20.	.98	.56		1.65	1.92
200	1,000 to 2,000 lb.	G		640	.013	T	.95	.56		1.54	1.72
300	2,000 to 4,000 lb.	G		640	.013		.95	.50		1.51	1.07
500	For built-up angles and plates, add to above	G	V	UNIO	.015		.72	.50			.36
00	For engineering, add to above	0					.33			.33	
00	For galvanizing, add to above For galvanizing, add to above, under 500 lb.									.13	.14
50	500 to 2,000 lb.						.30			.30	.33
							.28			.28	.30
000	Over 2,000 lb.		1.0.	47	170	*	.25	7.15		.25	.28
000	Steel angles, 3-1/2" x 3", 1/4" thick, 2'-6" long	G	1 Bric	47	.170	Ea.	14.05	7.65		21.70	27
00	4'-6" long	G		26	.308		25.50	13.80		39.30	49
600	4" x 3-1/2", 1/4" thick, 5'-0" long	G		21	.381		32	17.05		49.05	61.50
700	9'-0" long	G		12	.667	¥	58	30		88	109

05 12 Structural Steel Framing 05 12 23 – Structural Steel for Buildings

C 12	23.60 Pipe Support Framing		Crew	Daily Output	Labor- Hours	Unit	Material	2013 Bare Labor E	Costs quipment	Total	Total Incl O&P
	PIPE SUPPORT FRAMING								J-1		
0020	Under 10#/L.F., shop fabricated	G	E-4	3900	.008	Lb.	1.74	.42	.04	2.20	2.7
0200	10.1 to 15#/L.F.	G		4300	.007	-0.	1.72	.38	.04	2.13	2.6
0400	15.1 to 20#/L.F.	G		4800	.007		1.69	.34	.03	2.06	2.4
0600	Over 20#/L.F.	G	1	5400	.007		1.66	.30	.03	1.99	2.3
	23.65 Plates		1.4	5100	.000		1.00	.00	.00	1.77	2.0
	PLATES	00 00 00 00	-								
0015	Made from recycled materials	R051223-80									
0020	For connections & stiffener plates, shop fabricated										
0050	1/8" thick (5.1 lb./S.F.)	G				S.F.	6.65			6.65	7.
0100	1/4" thick (10.2 lb./S.F.)	G	-				13.25			13.25	14.
0300	3/8" thick (15.3 lb./S.F.)	G					19.90			19.90	22
0400	1/2" thick (20.4 lb./S.F.)	G					26.50			26.50	29
0450	3/4" thick (30.6 lb./S.F.)	G					40			40	44
0500	1" thick (40.8 lb./S.F.)	G	-			-	53			53	58
2000	Steel plate, warehouse prices, no shop fabricatian	_				1					
2100	1/4" thick (10.2 lb./S.F.)	G				S.F.	8.50			8.50	9
	23.70 Stressed Skin Steel Roof and Ceiling										
	STRESSED SKIN STEEL ROOF & CEILING SYSTEM					-		-			
0020	Double panel flat roof, spans to 100'	G	E-2	1150	.049	S.F.	10.40	2.39	1.33	14.12	17
0100	Double panel convex roof, spans to 200'	G		960	.058	0	16.90	2.86	1.59	21.35	25
	Deuble panel arched roof, spans to 300'	G	11	760	.074		26	3.61	2.01	31.62	37
05 12	23.75 Structural Steel Members		V	1					and the second s		
	STRUCTURAL STEEL MEMBERS	R051223-10	1		1						
0015	Made from recycled materials	G									
0020	Shop fab'd for 100-ton, 1-2 story project, bolted connections										
0100	Beam or girder, W 6 x 9	G	E-2	600	.093	L.F.	12.85	4.58	2.54	19.97	25
0120	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0140	x 20	G		600	.093		28.50	4.58	2.54	35.62	42
0300	W 8 x 10	G		600	.093		14.30	4.58	2.54	21.42	26
0320	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0350	x 21	G		600	.093	2	30	4.58	2.54	37.12	43
0360	x 24	G		550	.102		34.50	4.99	2.77	42.26	49
0370	x 28	G		550	.102		40	4.99	2.77	47.76	55
0500	x 31	G		550	.102		44.50	4.99	2.77	52.26	60
0520	x 35	G		550	.102		50	4.99	2.77	57.76	66
0540	x 48	G		550	.102		68.50	4.99	2.77	76.26	87
0600	W 10 x 12	G		600	.093		17.15	4.58	2.54	24.27	29
0620	x 15	G		600	.093		21.50	4.58	2.54	28.62	34
0700	x 22	G		600	.093		31.50	4.58	2.54	38.62	45
0720	x 26	G		600	.093		37	4.58	2.54	44.12	51
0740	x 33	G		550	.102		47	4.99	2.77	54.76	63
0900	x 49	G		550	.102		70	4.99	2.77	77.76	88
1100	W 12 x 16	G		880	.064		23	3.12	1.73	27.85	32
1300	x 22	G		880	.064		31.50	3.12	1.73	36.35	42
1500	x 26	G		880	.064		37	3.12	1.73	41.85	48
1520	x 35	G		810	.069		50	3.39	1.88	55.27	63
1560	x 50	G		750	.075		71.50	3.66	2.03	77.19	87
1580	x 58	G		750	.075		83	3.66	2.03	88.69	99
1700	x 72	G		640	.088		103	4.29	2.38	109.67	123
1740	x 87	G		640	.088	1	124	4.29	2.38	130.67	147

09 30 Tiling

09 30 29.10 Metal Tile		30 29.10 Metal Tile		0 29.10 Metal Tile		Daily Output	Labor- Hours	Unit	Material	2013 Bo Labor	ire Costs Equipment	Total	Total Incl O&P
0010 METAL TILE 4' x 4' sheet, 24 ga., tile pattern, nailed	1							-					
0200 Stainless steel	2 Carp	512	.031	S.F.	27	1.40		28.40	31.50				
0400 Aluminized steel	"	512	.031	"	14.50	1.40		15.90	18.10				

09 34 Waterproofing-Membrane Tiling

09 34 13 - Waterproofing-Membrane Ceramic Tiling

09 34 13.10 Ceramic Tile Waterproofing Membrane

0010	CERAMIC TILE WATERPROOFING MEMBRANE									
0020	On floors, including thinset									
0030	Fleece laminated polyethylene grid, 1/8" thick	D-7	250	.064	S.F.	2.24	2.37		4.61	5.95
0040	5/16" thick	11	250	.064	"	2.60	2.37		4.97	6.35
0050	On walls, including thinset							1.000		
0060	Fleece laminated polyethylene sheet, 8 mil thick	D-7	480	.033	S.F.	2.24	1.23		3.47	4.27
0070	Accessories, including thinset									
0080	Joint and corner sheet, 4 mils thick, 5" wide	1 Tilf	240	.033	L.F.	1.45	1.37		2.82	3.61
0090	7-1/4" wide		180	.044		1.84	1.83		3.67	4.71
0100	10" wide		120	.067	· .	2.24	2.75		4.99	6.50
0110	Pre-formed corners, inside		32	.250	Ea.	4.73	10.30		15.03	20.50
0120	Outside		32	.250		7.40	10.30		17.70	23.50
0130	2" flanged floor drain with 6" stainless steel grate		16	.500		355	20.50		375.50	420
0140	EPS, sloped shower floor		480	.017	S.F.	4.82	.69		5.51	6.30
0150	Curb	v	32	.250	L.F.	13.55	10.30		23.85	30

09 51 Acoustical Ceilings

09 51 23 - Acoustical Tile Ceilings

09 51 23.10	Suspended	Acoustic	Ceiling	Tiles
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0010 0100	SUSPENDED ACOUSTIC CEILING TILES, not including suspension system								
0300	Fiberglass boards, film faced, 2' x 2' or 2' x 4', 5/8" thick	1 Carp	625	.013	S.F.	.96	.57	1.53	1.95
0400	3/4" thick	1 corp	600	.013	J.1.	1.54	.60	2.14	2.61
0500	3" thick, thermal, R11		450	.018		1.88	.80	2.68	3.30
0600	Glass cloth faced fiberglass, 3/4" thick		500	.016		2.14	.72	2.86	3.46
0700	1" thick		485	.016		2.82	.74	3.56	4.24
0820	1-1/2" thick, nubby face		475	.017		2.45	.76	3.21	3.86
1110	Mineral fiber tile, lay-in, 2' x 2' or 2' x 4', 5/8" thick, fine texture		625	.013		.76	.57	1.33	1.73
1115	Rough textured		625	.013		1.32	.57	1.89	2.34
1125	3/4" thick, fine textured		600	.013		1.61	.60	2.21	2.69
1130	Rough textured	1	600	.013		1.76	.60	2.36	2.86
1135	Fissured		600	.013		2.33	.60	2.93	3.48
1150	Tegular, 5/8" thick, fine textured		470	.017		1.58	.76	2.34	2.92
1155	Rough textured		470	.017		1.86	.76	2.62	3.23
1165	3/4" thick, fine textured		450	.018		2.08	.80	2.88	3.52
1170	Rough textured		450	.018	-	1.86	.80	2.66	3.28
1175	Fissured		450	.018		3.28	.80	4.08	4.84
1185	For plastic film face, add					.94		.94	1.03
1190	For fire rating, add					.45		.45	.50
1300	Mirror tile, acrylic, 2' x 2'	1 Carp	500	.016		10.10	.72	10.82	12.20
1900	Eggcrate, acrylic, 1/2" x 1/2" x 1/2" cubes		500	.016		1.82	.72	2.54	3.11
2100	Polystyrene eggcrate, 3/8" x 3/8" x 1/2" cubes		510	.016		1.53	.70	2.23	2.77

30.50 30.50 30.50 42.50 42.50 3.50 3.01 11.40

Total Incl O&P 5

	51 23 - Acoustical Tile Ceilings	0	p. d	4.1					Tabl
9 5	1 23.10 Suspended Acoustic Ceiling Tiles	Crew	Daily Output		Unit	Material	2013 Bare (Labor Ec	osts juipment Total	Total Incl O&P
200	1/2" x 1/2" x 1/2" cubes	1 Carp	No. of Concession, Name and Address of Street, or other	.016	S.F.	2.04	.72	2.76	3.35
400	Luminous panels, prismatic, acrylic		400	.020		2.22	.90	3.12	3.82
500	Polystyrene		400	.020		1.14	.90	2.04	2.63
700	Flat white acrylic		400	.020		3.86	.90	4.76	5.65
800	Polystyrene		400	.020		2.65	.90	3.55	4.30
1000	Drop pan, white, acrylic	T	400	.020	T	5.65	.90	6.55	7.65
100	Polystyrene		400	.020		4.73	.90	5.63	6.60
3600	Perforated aluminum sheets, .024" thick, corrugated, painted		490	.016		2.29	.73	3.02	3.65
3700	Plain		500	.016		3.78	.70	4.50	5.25
720	Mineral fiber, 24" x 24" or 48", reveal edge, painted, 5/8" thick		600	.013	1	1.86	.60	2.46	2.97
3740	3/4" thick		575	.013		1.95	.62	2.57	3.11
5020	66 – 78% recycled content, 3/4" thick	1	600	.014		1.82	.60	2.42	2.92
5020	Mylar, 42% recycled content, 3/4" thick		600	.013		4.28	.60	4.88	
	1 , ,		000	010		4.20	.00	4,08	¥:
	1 23.30 Suspended Ceilings, Complete	_			_				
010	SUSPENDED CEILINGS, COMPLETE, including standard								
0100	suspension system but not incl. 1-1/2" carrier channels								
600	Fiberglass ceiling board, $2' \times 4' \times 5/8''$, plain faced	1 Carp		.016	S.F.	1.63	.72	2.35	2.91
700	Offices, 2' x 4' x 3/4"		380	.021		2.21	.95	3.16	3.90
800	Mineral fiber, on 15/16" T bar susp. 2' x 2' x 3/4" lay-in board		345	.023		2.47	1.04	3.51	4.31
810	2' x 4' x 5/8" tile		380	.021		1.43	.95	2.38	3.04
820	Tegular, 2′ x 2′ x 5/8″ tile on 9/16″ grid		250	.032		2.60	1.44	4.04	5.05
830	2' x 4' x 3/4" tile		275	.029		2.91	1.31	4.22	5.20
900	Luminous panels, prismatic, acrylic		255	.031		2.89	1.41	4.30	5.35
200	Metal pan with acoustic pad, steel		75	.107		4.45	4.79	9.24	12.30
300	Painted aluminum		75	.107		2.96	4.79	7.75	10.65
500	Aluminum, degreased finish		75	.107	-	5.15	4.79	9.94	13.05
1600	Stainless steel		75	.107		9.65	4.79	14.44	18.05
1800	Tile, Z bar suspension, 5/8" mineral fiber tile		150	.053		2.32	2.39	4.71	6.25
1900	3/4" mineral fiber tile		150	.053	+	2.48	2.39	4.87	6.40
2400	For strip lighting, see Section 26 51 13.50								
2500	For rooms under 500 S.F., add		1		S.F.	1	25%		-
09	51 53 - Direct-Applied Acoustical Ceilings								
9 5				-					
010	CEILING TILE, stapled or cemented	1	1			1			1
)100	12" x 12" or 12" x 24", not including furring								
)600	Mineral fiber, vinyl coated, 5/8" thick	1 Car	300	.027	S.F.	1.98	1.20	3.18	4.02
700	3/4" thick	i cui	300	.027	5.F.	1.78	1.20	2.98	3.80
		Т	300	.027	1	1.78	1.20	2.55	3.33
900	Fire rated, 3/4" thick, plain faced							2.55	3.25
000	Plastic coated face		300	.027		1.28	1.20		3.25
200	Aluminum faced, 5/8" thick, plain		300	.027		1.56	1.20	2.76	
3700	Wall application of above, add		1000	.008	-	10	.36	.36	.55
3900 4000	For ceiling primer, add					.13		.13	.14
armiti	For ceiling cement, add				444	.38		.38	.42

09 53 Acoustical Ceiling Suspension Assemblies 09 53 23 – Metal Acoustical Ceiling Suspension Assemblies

				Labor-			2013 Ba			Total
09 53	23.30 Ceiling Suspension Systems	Crew	Output	Hours	Unit	Material	Labor	Equipment	Total	Incl 0&P
0100	CEILING SUSPENSION SYSTEMS for boards and tile									
0050	Class A suspension system, 15/16" T bar, 2' x 4' grid	1 Carp	800	.010	S.F.	.67	.45		1.12	1.43
0300	2' x 2' grid		650	.012		.86	.55		1.41	1.79
0310	25% recycled steel, 2' x 4' grid		800	.010		.71	.45		1.16	1.47
0320	2' x 2' grid G	4	650	.012		.91	.55		1.46	1.85
0350	For 9/16" grid, add					.16			.16	.18
0360	For fire rated grid, add					.09			.09	.10
0370	For colored grid, add	-				.21			.21	.23
0400	Concealed Z bar suspension system, 12" module	1 Carp	520	.015		.78	.69		1.47	1.92
0600	1-1/2" carrier channels, 4' O.C., add	"	470	.017	*	.11	.76		.87	1.3
0700	Carrier channels for ceilings with									
0900	recessed lighting fixtures, add	1 Carp	460	.017	S.F.	.20	.78		.98	1.4
1040	Hanging wire, 12 ga., 4' long	T	65	.123	C.S.F.	2.67	5.55		8.22	11.4
1080	8' long	+	65	.123	"	5.35	5.55		10.90	14.3
3000	Seismic ceiling bracing, IBC Site Class D, Occupancy Category II									
3050	For ceilings less than 2500 S.F.									
3060	Seismic clips at attached walls	1 Carp	180	.044	Ea.	1.12	2		3.12	4.3
3100	Far ceilings greater than 2500 S.F., add									
3120	Seismic clips, joints at cross tees	1 Carp	120	.067	Éa.	2.47	2.99		5.46	7.3
3140	At cross tees and mains, mains field cut	"	60	.133	"	2.47	6		8.47	11.9
3200	Compression posts, telescopic, attached to structure above									
3210	To 30" high	1 Carp	26	.308	Ea.	36	13.80		49.80	61
3220	30" to 48" high		25.50	.314		39.50	14.10		53.60	65
3230	48" to 84" high		25	.320		47.50	14.35		61.85	74.5
3240	84" to 102" high	1	24.50	.327		54.50	14.65		69.15	82.5
3250	102" to 120" high		24	.333		81.50	14.95		96.45	113
3260	120" to 144" high	14	24	.333		92.50	14.95		107.45	125
3300	Stabilizer bars									
3310	12" long	1 Carp	240	.033	Ea.	.78	1.50		2.28	3.1
3320	24" long		235	.034		.77	1.53		2.30	3.2
3330	36" long		230	.035		.72	1.56		2.28	3.2
3340	48" long	+	220	.036	+	.73	1.63		2.36	3.3
3400	Wire support for light fixtures, per L.F. height to structure above	u.J.			-1 ·					
3410	Less than 10 lb.	1 Carp	400	.020	L.F.	.27	.90		1.17	1.6
3420	10 lb. to 56 lb.	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	240	.033	"	.53	1.50		2.03	2.8

.14 .42

Total Incl O&P 3.35 3.82 2.63 5.65 4.30 7.65 6.60 3.65 5.25 2.97 3.11 2.92 5.65

> 2.91 3.90 4.31 3.04 5.05 5.20 5.35 12.30 10.65 13.05 18.05 6.25 6.40

09 54 Specialty Ceilings

09 54 33 - Decorative Panel Ceilings

0010	METAL PANEL CEILINGS								
0020	Lay-in or screwed to furring, not including grid								
0100	Tin ceilings, 2' x 2' or 2' x 4', bare steel finish	2 Carp	300	.053	S.F.	2.46	2.39	4.85	6.40
0120	Painted white finish		300	.053	"	3.67	2.39	6.06	7.75
0140	Copper, chrome or brass finish		300	.053	L.F.	6.45	2.39	8.84	10.80
0200	Cornice molding, 2-1/2" to 3-1/2" wide, 4' long, bare steel finish		200	.080	S.F.	2.12	3.59	5.71	7.90
0220	Painted white finish		200	.080		2.85	3.59	6.44	8.70
0240	Copper, chrome or brass finish		200	.080		3.87	3.59	7.46	9.80
0320	5" to $6-1/2$ " wide, 4' long, bare steel finish		150	.107		3.06	4.79	7.85	10.75
0340	Painted white finish		150	.107		4.20	4.79	8.99	12
0360	Copper, chrome or brass finish		150	.107		6.40	4.79	11.19	14.45
0420	Flat molding, 3-1/2" to 5" wide, 4' long, bare steel finish		250	.064		3.43	2.87	6.30	8.20

327

09 91 Painting

			Daily	Labor-			2013 Ba	re Costs		Total
09 91	23.75 Dry Fall Painting	Crew Ou	Output	Hours	Unit	Material	Labor	Equipment	Total	Incl O&P
0560	Two coats	1 Pord	1300	.006	S.F.	.11	.24		.35	.48
0570	Structural steel, bar joists or metal deck, one coat		1560	.005		.05	.20		.25	.36
0580	Two coats	1.4	1040	.008	+	.11	.30		.41	.57

09 09

0010

0310 0320

09 93 Staining and Transparent Finishing

09 93 23 - Interior Staining and Finishing

09 93	3 23.10 Varnish								
0010	VARNISH								
0012	1 caat + sealer, on wood trim, brush, no sanding included	1 Pord	400	.020	S.F.	.07	.77	.84	1.24
0100	Hardwood floors, 2 coats, no sanding included, roller	"	1890	.004	17	.15	.16	.31	.42

09 96 High-Performance Coatings 09 96 23 – Graffiti-Resistant Coatings

96	5 23.10 Graffiti Resistant Treatments								
010	GRAFFITI RESISTANT TREATMENTS, sprayed on walls								
100	Non-sacrificial, permanent non-stick coating, clear, on metals	1 Pord	2000	.004	S.F.	2.06	.15	2.21	2.50
200	Concrete		2000	.004		2.35	.15	2.50	2.81
300	Concrete block		2000	.004		3.03	.15	3.18	3.57
)400	Brick		2000	.004		3.44	.15	3.59	4.01
0500	Stone		2000	.004		3.44	.15	3.59	4,01
0600	Unpainted wood		2000	.004		3.97	.15	4.12	4.60
2000	Semi-permanent cross linking polymer primer, on metals		2000	.004		.67	.15	.82	.96
2100	Concrete		2000	.004		.80	.15	.95	1.11
2200	Concrete block		2000	.004		1	.15	1.15	1.33
2300	Brick		2000	.004		.80	.15	.95	1.11
2400	Stone		2000	.004		.80	.15	.95	1.11
2500	Unpainted wood		2000	.004		1.11	.15	1.26	1.45
3000	Top coat, on metals		2000	.004		.55	.15	.70	.83
3100	Concrete		2000	.004		.62	.15	.77	.92
3200	Concrete block		2000	.004		.87	.15	1.02	1.19
3300	Brick		2000	.004		.73	.15	.88	1.03
3400	Stone		2000	.004		.73	.15	.88	1.03
3500	Unpainted wood		2000	.004		.87	.15	1.02	1.19
5000	Sacrificial, water based, on metal		2000	.004		.32	.15	.47	.59
5100	Concrete		2000	.004		.32	.15	.47	.59
5200	Concrete block		2000	.004		.32	.15	.47	.59
5300	Brick		2000	.004		.32	.15	.47	.59
5400	Stone		2000	.004		.32	.15	.47	.59
5500	Unpainted wood	7	2000	.004	*	.32	.15	.47	.59
8000	Cleaner for use after treatment								
8100	Towels or wipes, per package of 30				Ea.	.63		.63	.70
8200	Aerosol spray, 24 oz. can				"	18		18	19.80
09 9	96 46 – Intumescent Coatings								
09 90	5 46.10 Coatings, Intumescent								
0010	COATINGS, INTUMESCENT, spray applied			1					
0100	On exterior structural steel, 0.25" d.f.t.	1 Pord	475	.017	S.F.	.41	.65	1.06	1.43
0150	0.51" d.f.t.		350	.023		.41	.88	1.29	1.78
0200	0.98″ d.f.t.		14	.571		.41	22	22.41	33.50
			7						

300 .027

.41

1.03

1.44

2

On interior structural steel, 0.108" d.f.t.

	6 46 – Intumescent Coatings	6		Labor-	11.11		2013 Bare Costs	Tel	Total
09 90	46.10 Coatings, Intumescent 0.310" d.f.t.	Crew 1 Pord	Output 150	Hours	Unit S.F.	Material .41	Labor Equipment 2.06	Total 2.47	Incl 0&P 3.55
0400	0.510 0.1.1. 0.670″ d.f.t.		100	.033	э.г. ↓	.41	3.10	3.51	5.10
	6 53 – Elastomeric Coatings		100	.000		.41	5.10	0.31	5.10
_	53.10 Coatings, Elastomeric								
	COATINGS, ELASTOMERIC	-	-		1				
0010	High build, water proof, one coat system								
0100	Concrete, brush	1 Pord	650	.012	S.F.	.31	.48	.79	1.05
0110	Roll	TTOIL	1650	.005	2.1.	.31	.19	.50	.62
0120	Spray		2600	.003		.31	.12	.43	.52
0200	Concrete block, brush		600	.003		.37	.52	.89	1.17
0210	Roll		1400	.006		.37	.22	.59	.73
0220	Spray		1900	.000		.37	.16	.53	.64
0300	Stucco, brush		400	.020		.57	.77	1.27	1.71
0310	Roll	1	1000	.020		.50	.31	.81	1.01
0320	Spray		1500	.005		.50	.21	.71	.86
	6 56 - Epoxy Coatings		1500	.005	- V	.50	.21		.00
_									
	56.20 Wall Coatings		7.			_			
	WALL COATINGS	10	505	015			70		1.00
0100	Acrylic glazed coatings, minimum	1 Pord		.015	S.F.	.31	.59	.90	1.22
0200	Maximum		305	.026		.65	1.02	1.67	2.24
0300	Epoxy coatings, minimum		525	.015		.40	.59	.99	1.32
0400	Maximum		170	.047		1.20	1.82	3.02	4.05
0600	Exposed aggregate, troweled on, $1/16''$ to $1/4''$, minimum		235	.034		.61	1.32	1.93	2.65
0700	Maximum (epoxy or polyacrylate)		130	.062		1.31	2.38	3.69	5
0900	1/2" to 5/8" aggregate, minimum		130	.062		1.19	2.38	3.57	4.88
1000	Maximum		80	.100		2.06	3.87	5.93	8.05
1500	Exposed aggregate, sprayed on, $1/8''$ aggregate, minimum		295	.027		.56	1.05	1.61	2.19
1600	Maximum		145	.055		1.04	2.14	3.18	4.34
1800	High build epoxy, 50 mil, minimum	1 1	390	.021	T	.67	.79	1.46	1.93
1900	Maximum		95	.084		1.14	3.26	4.40	6.15
2100	Laminated epoxy with fiberglass, minimum		295	.027		.72	1.05	1.77	2.36
2200	Maximum		145	.055		1.30	2.14	3.44	4.63
2400	Sprayed perlite or vermiculite, 1/16" thick, minimum		2935	.003		.27	.11	.38	.46
2500	Maximum		640	.013		.73	.48	1.21	1.53
2700	Vinyl plastic wall coating, minimum		735	.011		.33	.42	.75	.99
2800	Maximum		240	.033		.81	1.29	2.10	2.82
3000	Urethane on smooth surface, 2 coats, minimum		1135	.007	T	.27	.27	.54	.71
3100	Maximum		665	.012		.58	.47	1.05	1.34
3600	Ceramic-like glazed coating, cementitious, minimum		440	.018		.47	.70	1.17	1.58
3700	Maximum		345	.023		.80	.90	1.70	2.23
3900	Resin base, minimum		640	.013		.33	.48	.81	1.09
4000	Maximum		330	.024		.53	.94	1.47	1.99

.70 19.80

Total incl 0&P .48 .36 .57

1.43 1.78 33.50 2



Gallery Redesign Estimates

REFERENCE MATERIAL

Taken from one of the following.

RS Means Construction Cost Estimating 2013

HomeDepot.com

MATERIAL REFERENCE DATA

Description	Unit	Bare Material	Bare Labor	Bare Equip.	Bare Total	Material O&P	Total O&P
Beam or Girder W6x15 (Closest to MMAA)	LF	21.50	4.58	2.54	28.62	26.23	34.00
Channel framing C6x8.2 (Closest to MMAA)	LF	6.20	22.00	2.62	30.82	7.56	49.00
Angle Framing 2x2x1/4	LF	2.49	13.55	1.60	17.64	3.04	28.50
Angle Framing 3"x3"x3/8"	LF	5.60	21.50	2.53	29.63	6.83	47.00
Plate 7/8" Thick (extrapolated btw 3/4" and 1")	SF	46.50	n/a	n/a	46.50	56.73	51.25
Bent Steel Plate Hanger (50% added to above for Bending)	SF	69.75	n/a	n/a	69.75	85.10	85.10
Each Hanger is 2'1-1/4" x 4" OR 0.70 SF	EA	48.89	n/a	n/a	0.00	59.65	59.65
Plate 3/8" Thick	SF	19.90	n/a	n/a	19.90	22.00	22.00
Plate 1/4" Thick	SF	13.25	n/a	n/a	13.25	14.60	14.60
Weld Single Pass 3/16" Thick	LF	0.44	5.55	1.92	7.91	0.54	12.50
Tin Ceiling Lay In Painted Finish	SF	3.67	2.39	0.00	6.06	4.48	7.75
3/8" Hex Nuts (Home Depot)	100CT	9.57	n/a	n/a	9.57	11.68	11.68
3/4" Hex Nut (Home Depot)	50CT	20.37	n/a	n/a	20.37	24.85	24.85

LABOR REFERENCE DATA	Base Rate	Rate with O%P		
Description	Hourly	Daily	Hourly	Daily
Steel Worker	\$50.05	\$400.40	\$89.30	\$714.40
Laborer	\$35.45	\$283.60	\$54.60	\$436.80

COST ESTIMATE

5th FLOOR CEILING SYSTEM

	Linit	Quantity	Material Cost	Labor Cost	Equipment Cost	Material Cost	Labor Cost (\$)	Equipment	Total Cost (\$)	Location	Final Cost (\$)
Description	Unit	Quantity	(\$/Unit)	(\$/Unit)	(\$/Unit)	(\$)		Cost (\$)	Total Cost (3)	Factor	Final Cost (3)
Material											
W5x16 Members Material	LF	3,564.00	26.23	0.00	0.00	93,483.72	0.00	0.00	93,483.72	1.32	123,398.51
C5x09 Members Material	LF	450.67	7.56	0.00	0.00	3,407.07	0.00	0.00	3,407.07	1.32	4,497.33
Bent Plate Connecting W5 to C5 3"x3"x3/8 (4" Wide)	LF	34.66	8.83	0.00	0.00	306.05	0.00	0.00	306.05	1.32	403.98
2x2x1/4 Angle Members Material	LF	8,974.33	3.04	0.00	0.00	27,281.96	0.00	0.00	27,281.96	1.32	36,012.19
Plate Connecting the Angles 2-3/4x2-3/4x1/4 (1482 EA)	SF	77.83	14.60	0.00	0.00	1,136.32	0.00	0.00	1,136.32	1.32	1,499.94
Weld Plate to Angle 5.5" Weld /Plate (1482 EA)	LF	679.25	0.44	5.55	1.92	298.87	3,769.84	1,304.16	5,372.87	1.31	7,038.46
Bent Steel Plate Hanger	EA	189.00	59.65	0.00	0.00	11,273.85	0.00	0.00	11,273.85	1.32	14,881.48

Plate connected to Hanger 5"x5"x3/8" Material (375 EA)	SF	65.62	22.00	0.00	0.00	1,443.64	0.00
Weld Plate to Hanger 8" Weld /Plate (375 EA)	LF	250.00	0.44	5.55	1.92	110.00	1,387.50
Metal Ceiling (260 EA @27.8SF)	SF	7,238.00	4.48	0.00	0.00	32,426.24	0.00
3/8" Hex Nuts (15,300 EA)	100CT	153.00	11.68	0.00	0.00	1,787.04	0.00
3/4" Hex Nuts (1512 EA)	50CT	31.00	24.85	0.00	0.00	770.35	0.00
Labor (Installation)							
Layout /Hand Drop Rods & Hanger (3 Steel Workers 25 Day EA)	Day	75.00	0.00	714.40	0.00	0.00	53,580.00
Install w% Sections and Infill Pieces							
3 Steel Workers 35 Days EA for W5	Day	70.00	0.00	714.40	0.00	0.00	50,008.00
3 Steel Workers 35 Days EA for Infill / Angles	Day	70.00	0.00	714.40	0.00	0.00	50,008.00
1 Laborer 35 Days	Day	35.00	0.00	436.80	0.00	0.00	15,288.00
TOTAL COST (5th FLOOR GALLERY)							
COST PER SQUARE FOOT		17,160.00 SF					
COMPLETE GALLERY COST (5th-8th FLOORS)		43,040.00 SF					

0.00	1,443.64	1.32	1,905.60
480.00	1,977.50	1.32	2,610.30
0.00	32,426.24	1.32	42,802.64
0.00	1,787.04	1.32	2,358.89
0.00	770.35	1.32	1,016.86
0.00	53,580.00	1.32	70,725.60
0.00	50,008.00	1.32	66,010.56
0.00	50,008.00	1.32	66,010.56
0.00	15,288.00	1.32	20,180.16

\$461,353.07

\$26.89 \$1,157,146.62

REFERENCE MATERIAL

Taken from one of the following.

RS Means Construction Cost Estimating 2013

MATERIAL REFERENCE DATA

Suspended Ceiling, Complete Tegular 2x2, 5/8" tile, 9/16 gridSF1 CarpCeiling System: 9/16" Grid Tbar, 2x2, ColoredSF1 CarpCeiling System: 9/16" Grid Tbar, 8" Cell Colored **SF1 Carp*** NOTE: In oreder to estimate the Metal Works 8" Cell Lay In the 2x2 grid shown in RS MEANS was scThe Daily Output was reduced to 66% of the original due to the increased number of grid attackThe Bare Material was increased by 50% due to the increased about od grid needeaThe Bare Labor was increased by 50% due to the increased amount of connections needed.Intumescent Paint on interior steel w/ 0.31" DFTSF1 Prod	ments needed to	2.60 1.28 1.92 get to a 8" square	1.44 0.55 0.83 e instead of a 2' so	0.00 0.00 0.00 quare	4.04 1.83 2.75	5.05 2.23 3.35
Ceiling System: 9/16" Grid Tbar, 8" Cell Colored ** SF 1 Carp ** NOTE: In oreder to estimate the Metal Works 8" Cell Lay In the 2x2 grid shown in RS MEANS was so The Daily Output was reduced to 66% of the original due to the increased number of grid attack The Bare Material was increased by 50% due to the increased about od grid needea The Bare Labor was increased by 50% due to the increased amount of connections needed.	430.00 aled as follows ments needed to	1.92	0.83	0.00		-
** NOTE: In oreder to estimate the Metal Works 8" Cell Lay In the 2x2 grid shown in RS MEANS was so The Daily Output was reduced to 66% of the original due to the increased number of grid attack The Bare Material was increased by 50% due to the increased about od grid needea The Bare Labor was increased by 50% due to the increased amount of connections needed.	aled as follows ments needed to	_			2.75	3.35
The Daily Output was reduced to 66% of the original due to the increased number of grid attach The Bare Material was increased by 50% due to the increased about od grid needea The Bare Labor was increased by 50% due to the increased amount of connections needed.	ments needed to	get to a 8" square	e instead of a 2' so	quare		
The Bare Material was increased by 50% due to the increased about od grid needea The Bare Labor was increased by 50% due to the increased amount of connections needed.		get to a 8" square	e instead of a 2' so	quare		
The Bare Labor was increased by 50% due to the increased amount of connections needed.						
Intumescent Paint on interior steel w/ 0.31" DFT SF 1 Prod						
	150.00	0.41	2.06	0.00	2.47	3.55
LABOR REFERENCE DATA	Base Rate	nc. Fringes	Rate with	n O%P		
Description	Hourly	Daily	Hourly	Daily		

COST ESTIMATE

5th FLOOR CEILING SYSTEM

	Unit	Quantity	Material Cost	Labor Cost	Equipment Cost	t Total Cost	Material Cost	Labor Cost (\$)	Equipment	Total Cost (\$)	Total Cost Inc	Location Factor	Final Cost (\$)
Description	Unit	Quantity	(\$/Unit)	(\$/Unit)	(\$/Unit)	O&P (\$/Unit)	(\$)		Cost (\$)	Total Cost (3)	O&P (\$)		Filial Cost (3)
Paint Steel and HVAC Equip Above Ceiling (1.25 Time Area ceiling)	SF	21,450.00	0.41	2.06	0.00) 3.35	8,794.50	44,187.00	0.00	52,981.50	71,857.50	1.32	94,851.90
Suspended Ceiling, Complete Tegular 2x2, 5/8" tile, 9/16 grid	SF	11,317.00	2.60	1.44	0.00) 5.05	29,424.20	16,296.48	0.00	45,720.68	57,150.85	1.32	75,439.12
Ceiling System: 9/16" Grid Tbar, 8" Cell Colored **	SF	5,843.00	1.92	0.83	0.00) 3.35	11,218.56	4,820.48	0.00	16,039.04	19,574.05	1.32	25,837.75

TOTAL COST (5th FLOOR GALLERY)

5th-8th FLOORS CEILING SYSTEM

Description	Unit	Quantity	Material Cost (\$/Unit)	Labor Cost (\$/Unit)	Equipment Cost (\$/Unit)	Total Cost O&P (\$/Unit)	Material Cost (\$)	Labor Cost (\$)	Equipment Cost (\$)	Total Cost (\$)	Total Cost Inc O&P (\$)	Location Factor	Final Cost (\$)
Paint Steel and HVAC Equip Above Ceiling (1.25 Time Area ceiling)	SF	53,800.00	0.41	2.06	0.00	3.35	22,058.00	110,828.00	0.00	132,886.00	180,230.00	1.32	237,903.60
Suspended Ceiling, Complete Tegular 2x2, 5/8" tile, 9/16 grid	SF	20,265.00	2.60	1.44	0.00	5.05	52,689.00	29,181.60	0.00	81,870.60	102,338.25	1.32	135,086.49
Ceiling System: 9/16" Grid Tbar, 8" Cell Colored **	SF	22,775.00	1.92	0.83	0.00	3.35	43,728.00	18,789.38	0.00	62,517.38	76,296.25	1.32	100,711.05

TOTAL COST (5th-8th FLOOR GALLERIES)

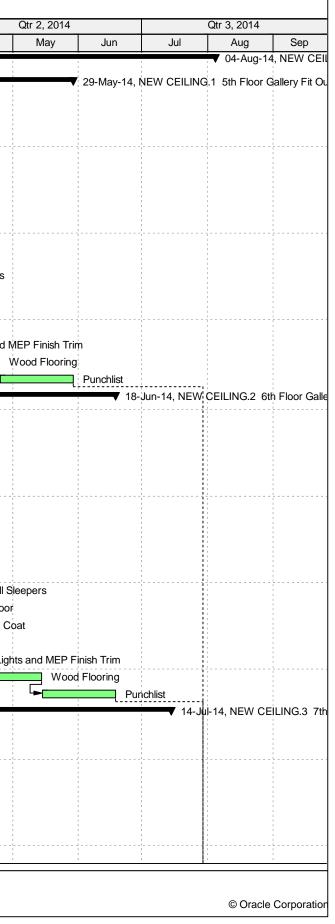
\$196,128.77

\$473,701.14

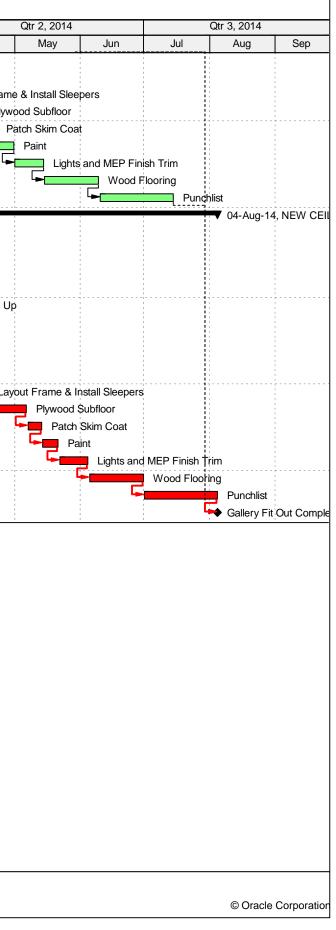
Appendix L:

New Interior Fit-Out Schedule for the Redesign

/ ID	Activity Name	Original	Start	Finish	3		Qtr 3, 2013			Qtr 4, 2013			Qtr 1, 2014		
		Duration			Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	A
NEW CEILI	NG MMAA	288	21-Jun-13	04-Aug-14		1	1	1	1	1	1	1	1	1	
🛓 NEW CEIL	LING.1 5th Floor Ga	241	21-Jun-13	29-May-14	-	1	1		1	1 - - -		1 1			
= 5000	Overhead MEP Rough-In	40	21-Jun-13*	16-Aug-13		:	Over	head MEP Ro	ough-In	1		: :	1		
= 5010	Layout & Frame	12	19-Aug-13	04-Sep-13	1	: : :		Layout &	Frame	- - 		1			-
= 5020	Rough Partitions	15	05-Sep-13	25-Sep-13	1 1 1				Rough Partition	ns		1			-
= 5030	Sheetrock Partitions	7	26-Sep-13	04-Oct-13				└►∎	Sheetrock	Partitions			·		
= 5040	Skim Coat Walls (3Coats) I	12	07-Oct-13	22-Oct-13			• • •		SI SI	im Coat Wall	s (3Coats) Rin	g Ceiling Line	Up		
= 5050	Paint Ceiling Line Up	3	23-Oct-13	25-Oct-13			: : :	1	l ⊢ ∎ F	Paint Ceiling L	ine Up	1			-
= 5060	Rough-In Lighting	10	28-Oct-13	08-Nov-13			:			Rough-	In Lighting	:			-
= 5070	Sprinkler System	15	11-Nov-13	02-Dec-13	1		: : :	1	-		Sprinkler S	ystem			-
5080	Install Open Cell Grid	7	03-Dec-13	11-Dec-13						Ц	Install	Open Cell Grid	4		
= 5090	Install Acoustical Ceiling	12	12-Dec-13	30-Dec-13	1					• • •		Install Acou	stical Ceiling		-
= 5100	Layout Frame & Install Slee	32	31-Dec-13	12-Feb-14			: : :		* * *	1 1 1		•	Layo	out Frame & I	Install Sl
= 5110	Plywood Subfloor	12	13-Feb-14	28-Feb-14				1	1	1		:	L=	Plywood S	Subfloor
5120	Patch Skim Coat	5	03-Mar-14	07-Mar-14	1 1 1				-	· · ·			G	Patch S	Skim Co
5130	Paint	6	10-Mar-14	17-Mar-14										🕞 🗖 Pa	aint
= 5140	Lights and MEP Finish Trim	10	18-Mar-14	31-Mar-14			: : :	1	: : :	1	1	1 1 1	1		Ligh
= 5150	Wood Flooring	18	01-Apr-14	24-Apr-14	: :		:	1	- - -	: : :		:		l	
= 5160	Punchlist	25	25-Apr-14	29-May-14	1 1 1	1	1 1 1	1	: :	1	1	1			-
NEW CEIL	LING.2 6th Floor Ga	235	22-Jul-13	18-Jun-14	1	-	1	1	1	a a	1	1	1		
— 6000	Overhead MEP Rough-In	40	22-Jul-13	16-Sep-13				Ove	rhead MEP Ro	ugh-In					
6010	Layout & Frame	12	17-Sep-13	02-Oct-13	1 1 1		:		Layout & Fi		1 1 1	1 1 1			
6020	Rough Partitions	15	03-Oct-13	23-Oct-13	1 1 1	1		E	R	ough Partitior	าร	2 2 2			-
6030	Sheetrock Partitions		24-Oct-13	01-Nov-13				1		Sheetrock	1	1 2 1			-
6040	Skim Coat Walls (3Coats) I	12	04-Nov-13	19-Nov-13		1			<u> </u>	Sk	im Coat Walls	(3Coats) Ring	Ceiling Line	Up	-
6050	Paint Ceiling Line Up	3	20-Nov-13	22-Nov-13	1		<u>+</u>				aint Ceiling Lir	1	·		
6060	Rough-In Lighting	10	25-Nov-13	09-Dec-13	1 1	: :	:	1 1 1	- - -		1	In Lighting	1 1 1	1	
6070	Sprinkler System	15	10-Dec-13	31-Dec-13	1 1 1	1		1	: : :	1 1 1		Sprinkler S	ystem		:
6080	Install Open Cell Grid	6	01-Jan-14	08-Jan-14					-	: : :	-	Install C	Open Cell Grid	1	-
6090	Install Acoustical Ceiling	7	09-Jan-14	17-Jan-14	! !		-	- - -		•	- - -	Ins	tall Acoustical	Ceiling	
6100	Layout Frame & Install Slee	32	20-Jan-14	04-Mar-14			· · · · · · · · · · · · · · · · · · ·							Layout F	Frame &
6110	Plywood Subfloor		05-Mar-14	20-Mar-14					: :			:			Plywood
6120	Patch Skim Coat	5	21-Mar-14	27-Mar-14		: : :		- - 	- - - -	: :	- - 	- - - -			Patch
6130	Paint		28-Mar-14	04-Apr-14	: : :				: : :			-		5	_, ► <mark>—</mark> ———————————————————————————————————
6140	Lights and MEP Finish Trim	10	07-Apr-14	18-Apr-14					1 1 1	 		1			
6150	Wood Flooring		21-Apr-14	14-May-14			• • • • • • • • • • • • • • • • • • •								
6160	Punchlist	25	15-May-14					1	1 1 1			:			:
	LING.3 7th Floor Ga		19-Aug-13						-					-	
7000	Overhead MEP Rough-In		19-Aug-13	14-Oct-13	1 1 1	: : :		: 	; Overh	ead MEP Ro	uah-In	: : :			
7010	Layout & Frame		15-Oct-13	30-Oct-13						Layout & Fr		1 1 1			-
7020	Rough Partitions		31-Oct-13	20-Nov-13	· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · · · · · · · · ·				ough Partitions				
7020	Sheetrock Partitions		21-Nov-13	02-Dec-13	1 1 1		1 : :		-		Sheetrock	:			-
7040	Skim Coat Walls (3Coats) F		03-Dec-13	18-Dec-13				1 1 1	:	G		m Coat Walls	(3Coats) Rino	Ceilina Line	e Up
7050	Paint Ceiling Line Up		19-Dec-13		1 1 1		1 1 1		1 1 1	1 1 1		aint Ceiling Li	· . · ·	, _ c	-
7060	Rough-In Lighting		24-Dec-13	07-Jan-14		: : :	:		: : :	1 1 1		-	In Lighting		-
— 7070	Sprinkler System		08-Jan-14	28-Jan-14		·				L			Sprinkler Sy	vstem	
					1	1	1	4 I	1	1	1		,	· · · · ·	:



ctivity ID	Activity Name	Original	Start	Finish	13			Qtr 3, 2013			Qtr 4, 2013			Qtr 1, 2014		
		Duration				Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
7080	Install Open Cell Grid	6	29-Jan-14	05-Feb-14						: : :			-	Install Op	pen Cell Grid	-
— 7090	Install Acoustical Ceiling	5	06-Feb-14	12-Feb-14			1	1	1 1 1	1		1		- Instal	Acoustical Ce	eiling
— 7100	Layout Frame & Install Slee	32	13-Feb-14	28-Mar-14	1		1	1 2 1		:	1 1 1	1 1 1	1 1 1			Layout Frame
— 7110	Plywood Subfloor	12	31-Mar-14	15-Apr-14	1		:	: : :		:	: : :			: : :	L 🕨	Plywo
— 7120	Patch Skim Coat	5	16-Apr-14	22-Apr-14	1		1	1	1 1 1	1	1				1 1 1	P
— 7130	Paint	6	23-Apr-14	30-Apr-14	1		2 2 2	2 2 2	2 2 2	: : :	: : :				: : :	
— 7140	Lights and MEP Finish Trim	10	01-May-14	14-May-14	1		1	1	1 1 1	1	1 1 1	1		1 1 1	1 1 1	: L e
— 7150	Wood Flooring	18	15-May-14	09-Jun-14	-		1	1		1	1 1 1	1 2 1		1 1 1	1 1 1	-
— 7160	Punchlist	25	10-Jun-14	14-Jul-14	1		1	1		1	1				1	-
🐴 NEW CE	ILING.4 8th Floor Ga	228	17-Sep-13	04-Aug-14			1		—	1	1		1		1	1
8000	Overhead MEP Rough-In	40	17-Sep-13	11-Nov-13	1		: : :	: : :		:	Overhe	ead MEP Roug	h-In	1 	: : :	: : :
a 8010	Layout & Frame	12	12-Nov-13	27-Nov-13	1		1	1	1	:		Layout & Frar	ne	1 1 1	1 1 1	:
8020	Rough Partitions	15	29-Nov-13	19-Dec-13	-		1	1	1	:	-		igh Partitions	2 2 2	2 2 2	: : :
a 8030	Sheetrock Partitions	7	20-Dec-13	31-Dec-13			1	1	1	1	1	ᄃ	Sheetrock P	artitions	1 5 5	: : :
a 8040	Skim Coat Walls (3Coats) F	12	01-Jan-14	16-Jan-14				•				L.	Skim	Coat Walls (3Coats) Ring	Ceiling Line Up
= 8050	Paint Ceiling Line Up	3	17-Jan-14	21-Jan-14			1	1	1	:	1 1 1	1 1 1	두 📕 Pa	int Ceiling Lir	ie Up	:
a 8060	Rough-In Lighting	10	22-Jan-14	04-Feb-14	-		1	1	1	:		: : :		Rough-Ir	Lighting	-
= 8070	Sprinkler System	15	05-Feb-14	25-Feb-14			1	1	1		1	- - 			Sprinkler Sys	tem
a 8080	Install Open Cell Grid	6	26-Feb-14	05-Mar-14			1	1 1 1	1	1					Install Op	en Cell Grid
= 8090	Layout Frame & Install Slee	32	06-Mar-14	18-Apr-14				•		• • • • • • • • • • • • • • • • • • •		,			>	Lay
= 8100	Plywood Subfloor	12	21-Apr-14	06-May-14			1	1	1	1	1 1 1	1		1	1	
= 8110	Patch Skim Coat	5	07-May-14	13-May-14	-		1			:		1		: :	: : :	-
= 8120	Paint	6	14-May-14	21-May-14			• • •	•	• • •		1 1	• 1 1		• 1 1	1 1	
= 8130	Lights and MEP Finish Trim	10	22-May-14	04-Jun-14	1		1		1	: : :					1 1 1	- - -
a 8140	Wood Flooring	18	05-Jun-14	30-Jun-14				•		•		r		,	,	
e 8150	Punchlist		01-Jul-14	04-Aug-14			1	1 2 1 2	1	1		1 2 1		1 1 1	1 1 1	1 1 1
8160	Gallery Fit Out Complete	0		04-Aug-14			1		1			: :		: :	1 1	-





Acoustics Calculations

MMAA - Reverberation Time & NC Calculations for the Original Gallery Design

Volume: (ft³) Total Surface Area: (ft²)

Expected Sound Level (Lp): 100 people speaking at 55dB

V = 300,300.00 S_{tot} = 45,730.00

W (ft)	260.00
L (ft)	66.00
H (ft)	17.50

	Surface Area,		Sound Absorption Coefficient, α									
Surface Description	S (ft ²)	Material Description			Frequer	ncy (Hz)						
			125	250	500	1000	2000	4000	125			
Wood Flooring	17160.00	Wood Flooring	0.15	0.11	0.10	0.07	0.06	0.07	2574.00			
North Wall Drywall	4183.00	Gypsum Board	0.55	0.14	0.08	0.04	0.12	0.11	2300.65			
North Wall Elevator Doors	241.00	Metal Doors	0.05	0.10	0.10	0.10	0.07	0.02	12.05			
North Wall Wood Doors	126.00	Wood Doors	0.42	0.21	0.10	0.08	0.06	0.06	52.92			
South Wall Drywall	4403.00	Gypsum Board	0.55	0.14	0.08	0.04	0.12	0.11	2421.65			
South Wall Glass	147.00	Glass Ordinary	0.35	0.25	0.18	0.12	0.07	0.04	51.45			
East Wall Curtainwall	1155.00	Glass Large Panes	0.18	0.06	0.04	0.03	0.02	0.02	207.90			
West Wall Curtainwall	1155.00	Glass Large Panes	0.18	0.06	0.04	0.03	0.02	0.02	207.90			
Ceiling Steel Members	2967.00	Steel	0.05	0.10	0.10	0.10	0.07	0.02	148.35			
Ceiling Insulated Metal Deck	7096.50	Insulated Metal Deck	0.08	0.29	0.75	0.98	0.93	0.76	567.72			
Ceiling Mechanical Equip/Structural	7096.50	Metal Equipment/Structral Steel	0.05	0.10	0.10	0.10	0.07	0.02	354.83			
								ΣSα=	8899.42			

Avg. α = 0.19

Air absorption constant for 20 °C and 40% RH, m

Sabine Reverb Time: (s) RT = 1.65 Norris-Eyring Reverb Time: (s) RT = ERROR Calculated RT (s) 1.6 Lp=55+log(100) Lp = q

dB=Lp-10log(α)

55.5063

dB =

		S*α (s	abins)		
		Frequer	ncy (Hz)		
	250	500	1000	2000	4000
00	1887.60	1716.00	1201.20	1029.60	1201.20
65	585.62	334.64	167.32	501.96	460.13
)5	24.10	24.10	24.10	16.87	4.82
92	26.46	12.60	10.08	7.56	7.56
65	616.42	352.24	176.12	528.36	484.33
45	36.75	26.46	17.64	10.29	5.88
90	69.30	46.20	34.65	23.10	23.10
90	69.30	46.20	34.65	23.10	23.10
35	296.70	296.70	296.70	207.69	59.34
72	2057.99	5322.38	6954.57	6599.75	5393.34
83	709.65	709.65	709.65	496.76	141.93
42	6379.89	8887.17	9626.68	9445.03	7804.73
19	0.14	0.19	0.21	0.21	0.17
0	0	1.83E-04	3.26E-04	7.86E-04	2.56E-03
65	2.31	1.62	ERROR	ERROR	1.35
	ERROR	ERROR	1.31	1.28	ERROR
65	2.31	1.62	1.31	1.28	1.35
95	95	95	95	95	95
	_		_		_
20		FF F4337			
39	56.95187	55.51237	55.16523	55.24797	56.07642

MMAA - Reverberation Time & NC Calculations for the Redesigned Gallery

Volume: (ft³) Total Surface Area: (ft²)

V = 300300.00 S_{tot} = 45730.00

W (ft)	260.00
L (ft)	66.00
H (ft)	17.50

	Surface Area,			Sour	nd Absorptio	on Coefficie	nt, α							
Surface Description	S (ft ²)	Material Description		Frequency (Hz)										
	, , , , , , , , , , , , , , , , , , ,		125	250	500	1000	2000	4000	125					
Wood Flooring	17160.00	Wood Flooring	0.15	0.11	0.10	0.07	0.06	0.07	2574.					
North Wall Drywall	4183.00	Gypsum Board	0.55	0.14	0.08	0.04	0.12	0.11	2300					
North Wall Elevator Doors	241.00	Metal Doors	0.05	0.10	0.10	0.10	0.07	0.02	12					
North Wall Wood Doors	126.00	Wood Doors	0.42	0.21	0.10	0.08	0.06	0.06	52					
South Wall Drywall	4403.00	Gypsum Board	0.55	0.14	0.08	0.04	0.12	0.11	2421					
South Wall Glass	147.00	Glass Ordinary	0.35	0.25	0.18	0.12	0.07	0.04	51					
East Wall Curtainwall	1155.00	Glass Large Panes	0.18	0.06	0.04	0.03	0.02	0.02	207					
West Wall Curtainwall	1155.00	Glass Large Panes	0.18	0.06	0.04	0.03	0.02	0.02	207					
Acoustical Panel Ceiling	8580.00	Acoustical Ceiling	0.10	0.60	0.80	0.82	0.78	0.60	858					
Grid Ceiling	858.00	Extruded Metal Grid	0.05	0.10	0.10	0.10	0.07	0.02	42					
Ceiling Insulated Metal Deck	3861.00	Insulated Metal Deck	0.08	0.29	0.75	0.98	0.93	0.76	308					
Ceiling Mechanical Equip/Structural	3861.00	Metal Equipment/Structral Steel	0.05	0.10	0.10	0.10	0.07	0.02	193					
								ΣSα=	9231					

Avg. α = - () Air absorption constant for 20 °C and 40% RH, m Sabine Reverb Time: (s) RT = ERROR Norris-Eyring Reverb Time: (s) RT =

Calculated RT (s)

Lp=55+log(100) Lp =

dB=Lp-10log(α) dB = 55.347

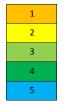
		S*α (s	abins)		
		Frequei	ncy (Hz)		
5	250	500	1000	2000	4000
4.00	1887.60	1716.00	1201.20	1029.60	1201.20
0.65	585.62	334.64	167.32	501.96	460.13
2.05	24.10	24.10	24.10	16.87	4.82
2.92	26.46	12.60	10.08	7.56	7.56
1.65	616.42	352.24	176.12	528.36	484.33
1.45	36.75	26.46	17.64	10.29	5.88
7.90	69.30	46.20	34.65	23.10	23.10
7.90	69.30	46.20	34.65	23.10	23.10
8.00	5148.00	6864.00	7035.60	6692.40	5148.00
2.90	85.80	85.80	85.80	60.06	17.16
8.88	1119.69	2895.75	3783.78	3590.73	2934.36
3.05	386.10	386.10	386.10	270.27	77.22
1.35	10055.14	12790.09	12957.04	12754.30	10386.86
0.20	0.22	0.28	0.28	0.28	0.23
0	0	1.83E-04	3.26E-04	7.86E-04	2.56E-03
ł	ERROR	ERROR	ERROR	ERROR	ERROR
1.43	1.30	0.97	0.94	0.93	0.99
1.43	1.30	0.97	0.94	0.93	0.99
95	95	95	95	95	95
735	54.97612	53.93126	53.87494	53.94343	54.83516
		_			-

Appendix N:

Short Interval Production Schedule

SIPS Schedule for the Metro Museum of American Art

Ì	Jun	า-13			Jul-13			Au	ıg-13			Se	ep-13		Oct-13		Nov-13		Dec	-13	Ja	n-14	F	eb-14		Mar-14	1		Apr-14		May-14		Jun-14
	6/17	6/24	7/1	7/8	7/15	7/22 7/2	9 8/5	5 8/12	8/19	8/26	9/2 9/	9 9/	/16 9/23	9/30 10/7	10/14 10/21	10/28 11/4	11/11 11/18	11/25 1	2/2 12/9 12/1	6 12/23 12/30	1/6 1/13	1/20 1/27	2/3 2/10	2/17 2/24	3/3 3/10	3/17	3/24 3/31	4/7	4/14 4/21	4/28 5/5	5/12 5/19	/26 6/2 6	/9 6/16 6/23
Zone 1		1	L	2		3		4		5	6		7	8	9	10	11	12	13	14	15	16	17	18	19								
Zone 2				1		2		3		4	5		6	7	8	9	10	11	12	13	14	15	16	17	18		19						
Zone 3						1		2		3	4		5	6	7	8	9	10	11	12	13	14	15	16	17	1	8	19					
Zone 4								1		2	3		4	5	6	7	8	9	10	11	12	13	14	15	16	1	7	18	19				
Zone 5										1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	1	6	17	18	19			
Zone 6											1		2	3	4	5	6	7	8	9	10	11	12	13	14	1	5	16	17	18	19		
Zone 7													1	2	3	4	5	6	7	8	9	10	11	12	13	14	4	15	16	17	18	19	
Zone 8														1	2	3	4	5	6	7	8	9	10	11	12	1	3	14	15	16	17	18	19



Mechanical Rough-In Electrical Rough-In

Layout & Frame Partitions

Install Rough & Sheetrock Partitions Skim Coat Walls & Paint Ceiling Line Up

6	
7	
8	
9	
10	

Ceiling Layout Hang Drop Rods Install W5 Sections Install Infill Pieces Rough-In Lighting



Installl Sprinklers

Install Ceiling Panels and Ceiling Trim Layout/ Frame Sleepers Install Sleepers

Install Plywood Subfloor

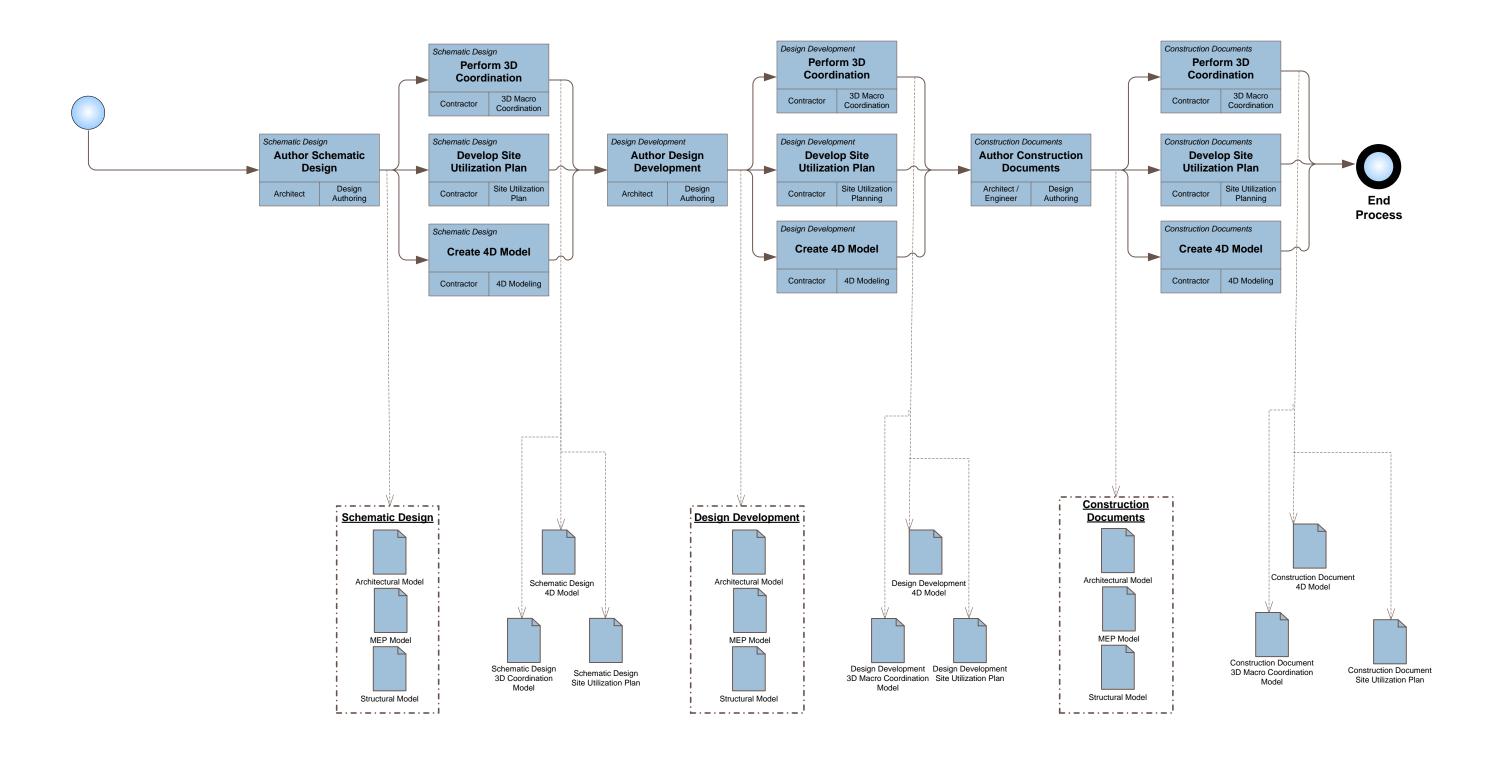
16
17
18
19

Patch Skim Coat / Paint Lights and MEP Finish Trim Wood Flooring Punchlist



BIM Level 1 Process Map

BIM Execution Plan Level 1 Process Map

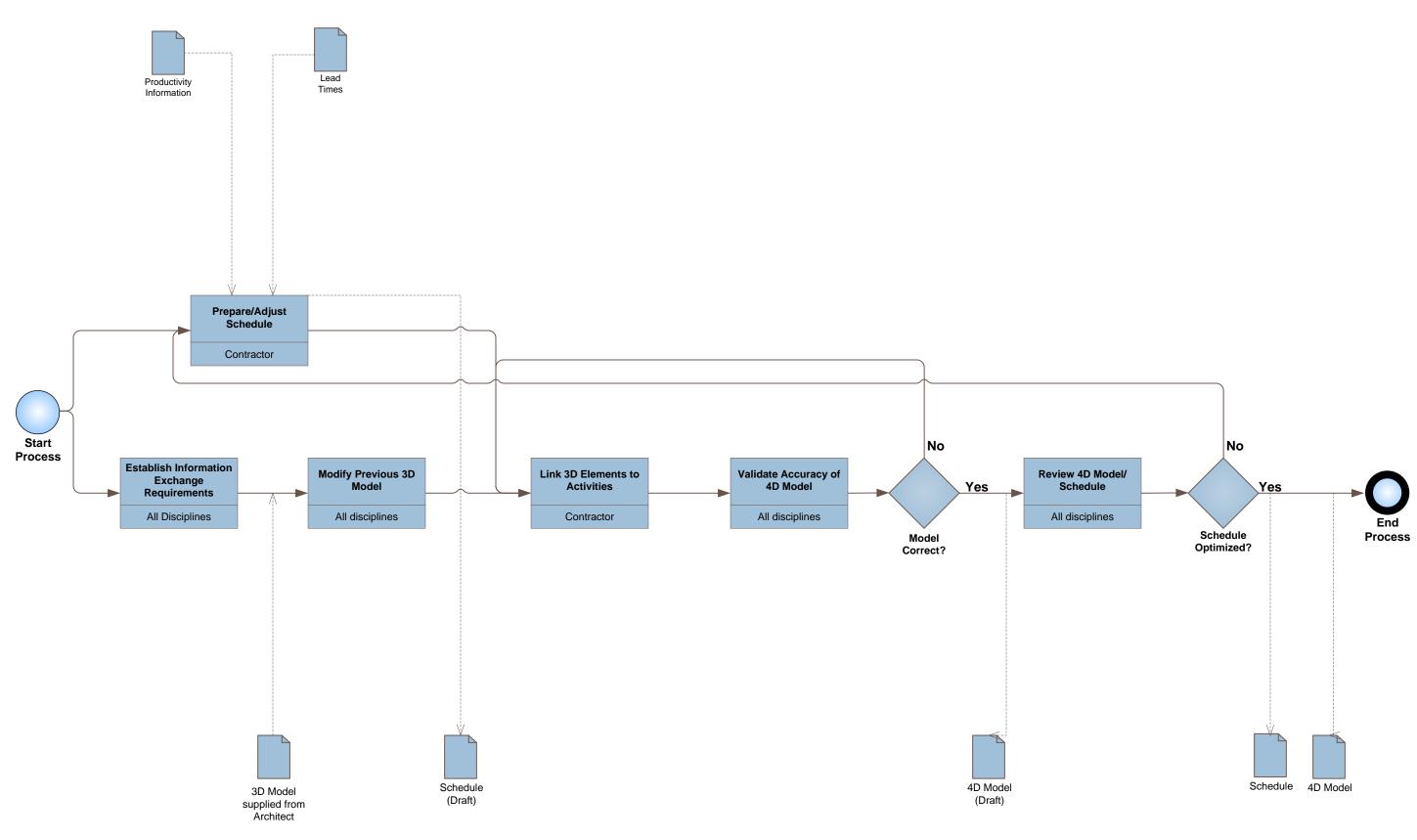




BIM Detailed Process Maps

BIM Execution Plan

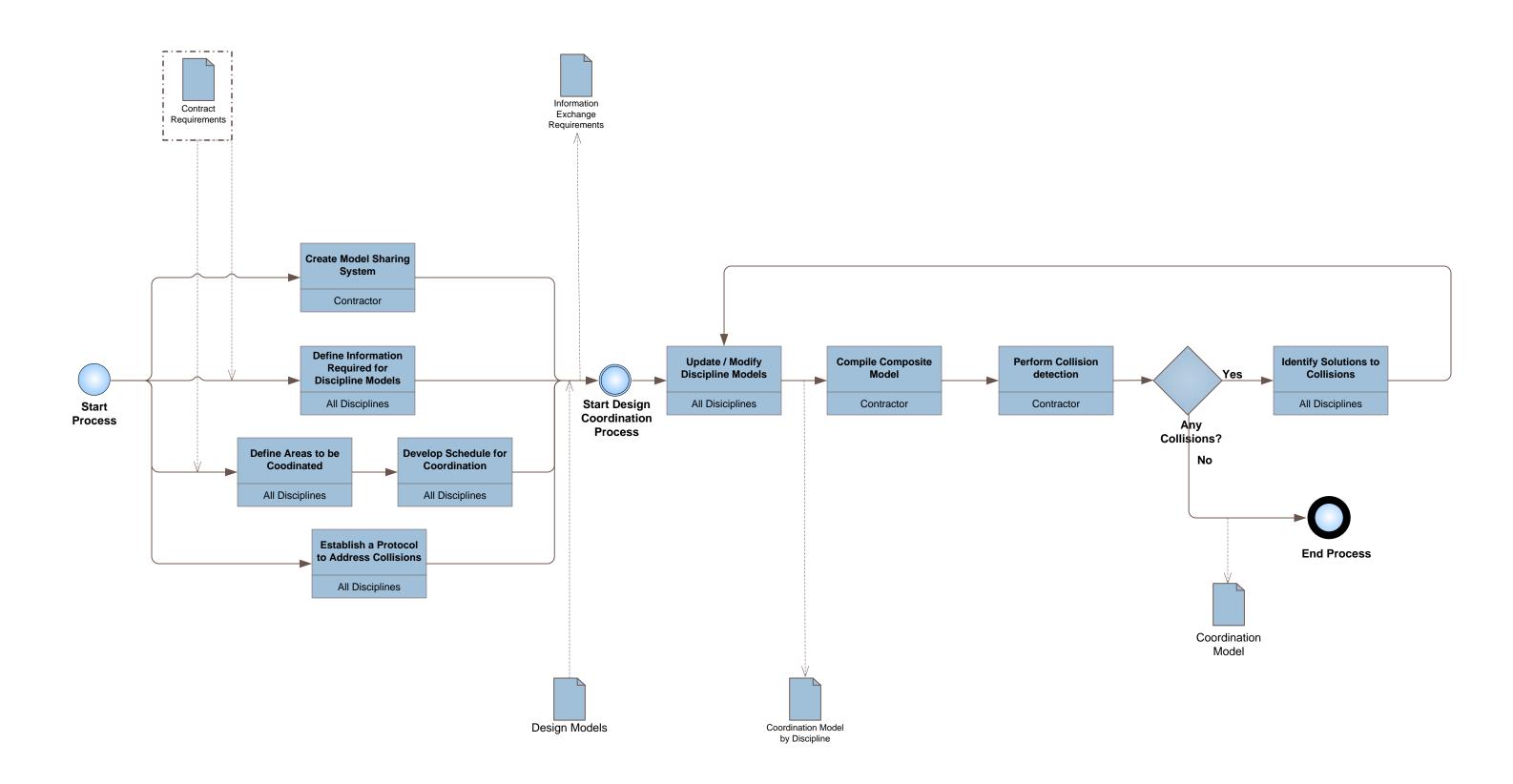
4D Modeling Detailed Process Map



Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team. http://www.engr/psu.edu/ae/cic/bimex

BIM Execution Plan

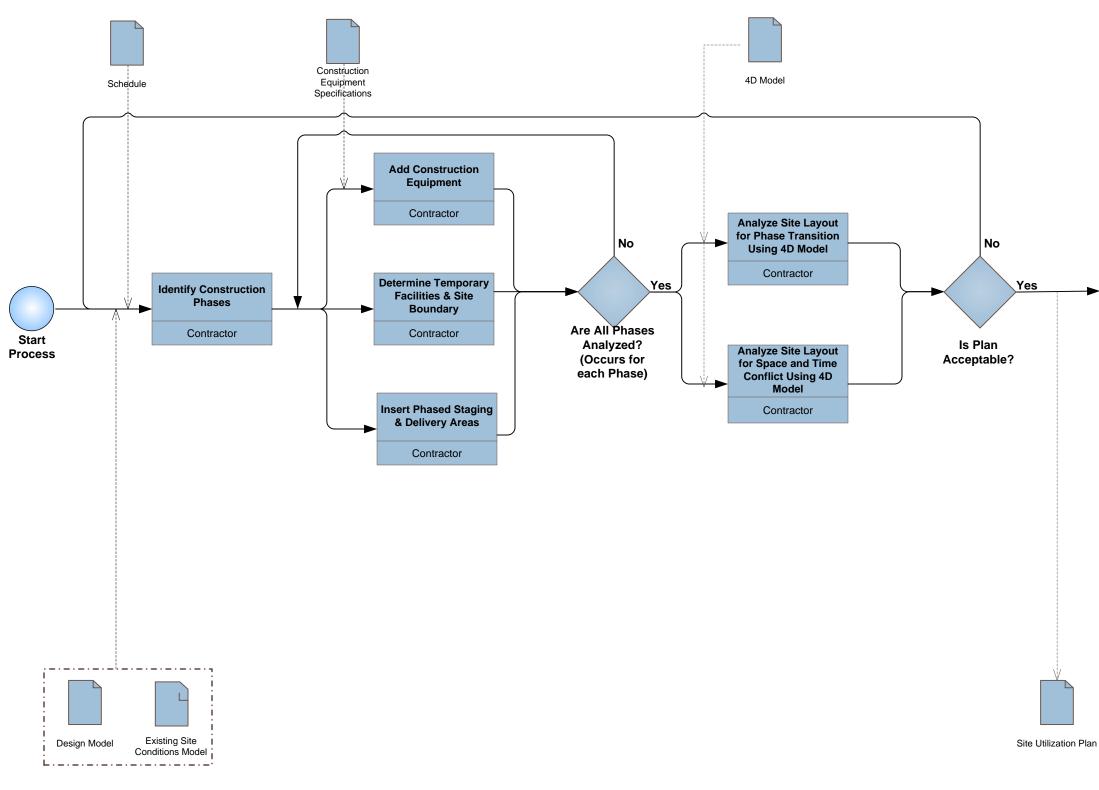
3D Coordination Detailed Process Map



Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team. http://www.engr/psu.edu/ae/cic/bimex

BIM Execution Plan

Site Utilization Detailed Process Map



Developed with the BIM Project Execution Planning Procedure by the Penn State CIC Research Team. http://www.engr/psu.edu/ae/cic/bimex

