DORMITORY BUILDINGS C & D

MANSFIELD UNIVERSITY, MANSFIELD PA

TECHNICAL REPORT NO. 3

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EXECUTIVE SUMMARY

In Technical Report 3, five main sections are discussed. The first section explores the LEED certification of the project. Mansfield University did not prioritize achieving a LEED certification for the project. Using the U.S. Green Building Council's (USGBC) LEED 2009 New Construction, the project was projected to meet a lot of requirements. The dormitory buildings are expected to earn 34 points; 40 points are required to gain LEED certification. After filling out the LEED scorecard, there were 47 possible points that could be achieved with very little design and construction change. There is more detailed information in this section of where the project management could gain these extra 6 points.

The second topic discusses the critical path of the schedule. The critical path was evaluated for each building and the schedule risks were found. One of the main schedule risks was crane logistics. In a perfect world, the steel erection crane will be finished and off site before the modular crane starts setting the modular units. Because of the schedule, this was not possible. The other schedule risk was MEP contractor manpower. The MEP's will have a lot of their work throughout the building all at the same time. They need to have the manpower to complete the required amount of work. There are two schedule acceleration techniques examined. The first required two modular cranes, so both buildings could set modular units at the same time. The second uses a different modular setting sequence that allows the MEP's to get into the hallways sooner.

The third topic discusses value engineering on the project. In the preconstruction phase, the owner asked the construction manager to provide enough value engineering to decrease the project budget $3 million. The construction manager got the project budget down to $39 million. This section shows how Wohlsen Construction cut almost $1 million in costs. There were also two value engineering techniques that were rejected by the owner, because the techniques did not meet the owner's goals.

The fourth section discusses critical industry issues. The Penn State 5th year construction management students attended the 21st Annual PACE Roundtable. At this event, the students attended two break-out sessions and an industry member feedback session. The first break-out session explored how BIM can be used to enable energy efficiency during a building's lifespan. At the second break-out session, modularization was discussed. Because the Mansfield University dorms are using modular construction, this session was found to be very helpful. At the final session, members of Forrester Construction were consulted about possible research topics for the thesis presentation in the spring.

The final section identifies problems with the construction process of the dormitories. The first problem for further research is the flooring system of the steel core. A structural breadth can be used for the redesigning of a concrete floor. The second problem for further analysis is the exterior façade. A new exterior façade can be preinstalled to the modular units in the modular facility. An architectural breadth can be used for the redesigning of the exterior façade. The last problem is modular setting accuracy. A construction process can be created to ensure accuracy and better quality.

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LEED EVALUATION

**See Appendix A for the LEED Scorecard*

The Mansfield University new dormitory buildings are not trying to achieve a LEED rating. LEED certification is not a priority of the university, although the project does meet a lot of the U.S. Green Building Council's (USGBC) LEED 2009 New Construction requirements. In order to achieve the lowest LEED certification, the dormitories must achieve 40 points on the LEED rating system.

After speaking with the project management team, the LEED scorecard was completed. The dormitory buildings are expected to earn 34 points. With minimal to moderate scope and project change, the project could add another 47 points. Table 1 shows the breakdown of the projected LEED points. Gaining the 6 points to achieve LEED certification would require very little change to the project. Each section provides possibilities to add more points. Below will explain where most of the points came from and point possibilities for each section.

Table 1: LEED Points

Category	Yes	?	No
Sustainable Sites	9	13	4
Water Efficiency	2	6	2
Energy and Atmosphere	12	12	11
Materials and Resources	3	5	6
Indoor Environmental Quality	3	9	3
Innovations in Operations	2	1	3
Regional Credits	3	1	0
Total	34	47	29

SUSTAINABLE SITES

Alternative transportation is a large part of this section. The Endless Mountains Transportation Authority (EMTA) provides public transit for Mansfield University students. EMTA has a stop within a quarter mile of the dorms, so that achieves 6 points. Other points come from site selection, site development and stormwater design. To add an easy point in this section, a public shower must be provided for bike riders and enough bike racks for 5% of the building's users. Another easy 3 points could be added by providing preferred parking spots for low-emitting and fuel-efficient vehicles. 5% of the preferred parking spots in the parking lots must be marked for these energy efficient vehicles.

WATER EFFICIENCY

Water efficiency has only one met requirement. The project comprises low water-use fixtures. This will decrease the water use by at least 20%. Other points can be achieved in this section by reducing the amount of potable water used for building sewage conveyance by 50%.

ENERGY AND ATMOSPHERE

Most of the points in this section are obtained by optimizing energy performance. This project uses ground source heat pumps and energy recovery units. These systems greatly decrease the energy needed for the mechanical systems. The project is expected to have about 30% energy cost savings. This gains the project 9 points in the LEED rating system. More points are gained by providing ongoing accountability of the building's energy consumption over time. Some other possible points can be obtained by engaging enhanced commissioning.

MATERIALS AND RESOURCES

The points in this section are gained by diverting 75% of disposal from landfills and using certified wood. More points can be gained in this section by using materials made of recycled content and using regional materials. Using 20% regional material may be achieved by the modular contractor alone. The modular contractor's facility is located outside of Scranton, PA. Scranton is approximately 100 miles away from Mansfield. If the modular units assembled in Scranton counts as materials, then 20% of the weight of all materials is easily obtained.

INDOOR ENVIRONMENTAL QUALITY

The 3 points earned in this section come from construction indoor air quality management plan and controllability of systems. The construction indoor air quality management plan requires protective on-site storage for absorptive materials and air handlers to filter the air in construction spaces. The air quality must meet requirements set by the SMACNA. More points can be gained by flushing out the mechanical system before building occupancy. Also, low emitting adhesives and sealants can be used to gain a point.

INNOVATIONS IN OPERATIONS

A point would be achieved in this section for the ground source heat pump system. There are 60 wells for each system. The ground source heat pump is expected to cut energy costs for the mechanical systems.

REGIONAL COSTS

The points counted as regional points for were mostly out of the sustainable sites section. Site selection, parking capacity, site development and stormwater design were all possible added regional points. Water efficient landscaping and on-site renewable energy are other potential regional points for Mansfield, PA.

SCHEDULE ACCELRATION SCENARIOS

CRITICAL PATH

**See Appendix B for the Detailed Schedule*

Dormitory buildings C and D have the same work flow. Building C has 21 critical path items over 400 days and Building D has 24 critical path items over 450 days. The shallow foundations and masonry basement walls will be completed by mid-December. The foundations are not on the critical path because of construction time needed for the modular units.

The modular mock up is expected to be finished by November 9th. Once the mock up is approved, the modular units can go into production. The critical path of each building relies heavily on modular unit placement. Because these buildings use modular construction, everything inside each dorm room is installed and finished. A phasing plan was created for the setting of the modular units to reduce onsite confusion.

Once the units are set, the MEP's must complete their rough-ins through the hallway on time. The critical path ends with some minor finishes. The structural steel in the core areas are to be finished before the modular units are set. This allows for more time for the finishes. The core also has a lot of MEP work including the elevators. The exterior façade is not along the critical path due to the length of the MEP's.

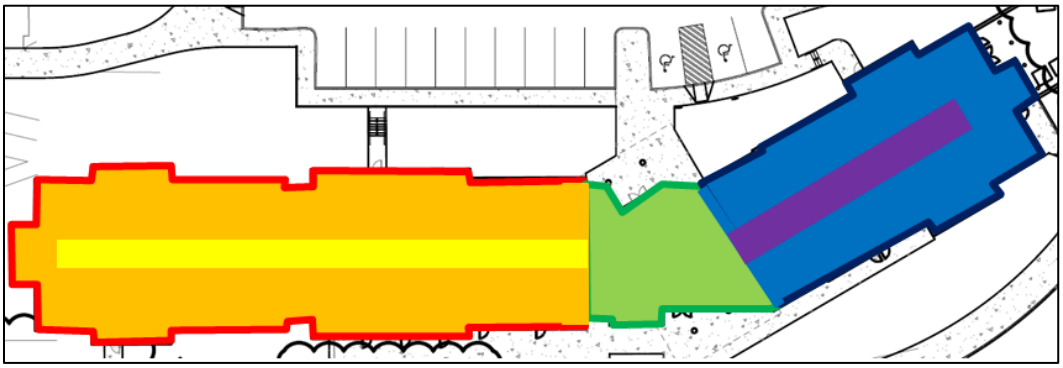


Figure 1 Building C Floor Phasing Plan

SCHEDULE RISKS

The focused items on the critical path include: steel core framing (light green in *Figure 1*), modular unit setting (orange and light blue), and MEP rough-ins (yellow and purple). The steel erection is the first of these sequences to begin and starts on the first floor going up to the fourth floor. Building C's core will be erected before Building D's. The crane for the structural steel will be in use, while the modular unit setting begins. There are five phases of modular unit setting: two in Building C and three in Building D. The units in each phase will be set on the first floor and move their way up to the fourth floor. Finally after the modular units are set in each phase, the MEP subcontractors have over two months to link all of the rooms to the mechanical, electrical and plumbing equipment.

CONSTRUCTION CRANES

The difficult part of the steel framing and the modular setting is crane logistics. The steel crane will be erecting steel in Building C as the modular units are being set in phase 1. The two cranes will need to be spaced properly so that there is as little threat as possible of collision. Also, deliveries for both cranes will be arriving onsite at the same time to add greater site congestion. The construction manager has created site logistic plans to reduce confusion and increase safety.

MEP MANPOWER

The MEP's are a threat to the schedule, because they will have multiple floors and multiple phases at the same time. They will need to increase manpower in order to meet the schedule demands. In each phase, the MEP's will have four floors and the basement level to finish. That is a lot of work all at one time. Then, another modular unit phases finishes before the MEP's are supposed to be finished with the phase they are on. Manpower will be key factor for the MEP subcontractors meeting the schedule.

ACCELERATION

There are two main ways to accelerate the schedule. Providing two modular cranes and two steel erection cranes will accelerate the schedule, but are associated with specific costs. Also, re-sequencing the setting of the modular units can increase productivity and schedule.

TWO MODULAR CRANES

To accelerate the completion of the project, the project could have 100 ton cranes stationed at each site. With the current schedule, Building C is scheduled to start modular setting on December 28, 2012. Once the crane is finished setting the two phases of modular units in Building C, it will move to Building D. With two modular cranes, Building D could also start setting units on December 28, 2012, shaving more than a month off of Building D's schedule.

To properly analyze this acceleration method, the predecessor to the first phase of setting modular units was examined. The date of the December 28th was chosen, because it was the quickest the modular units could be assembled. The mock up is due to be complete November 9th, and it takes approximately 30 working days to build and ship the units to the jobsite. After speaking with the Project Manager, it was determined that the modular facility can only make the units fast enough to set one phase at a time. In order to accommodate two phases at one time, the facility would have to work two shifts. This is assuming that the modular facility has the personnel and capabilities to work at twice the regular capacity. The modular contractor, Simplex Industries Inc, has a contract value of $11.8 million. Assuming that about 30% of the contract value is labor costs, the labor is approximately $3.5 million. If shift differential and overtime is needed, because of the increased pace of completion of modular units, the labor cost would jump to $4.4 million. That is an increase of $900,000.

The accelerated pace of the modular setting would also affect the steel erecting sequence. The steel core is scheduled to be mostly complete before the setting of the modular units. In order to keep the same sequence, the steel contractor will need so they can complete the steel erection in Building C and D at the same time. The crane costs were estimated in Technical Report 2. According to *RS Means*, a 100-ton crane costs $3,625/day. This equates to an added cost of $54,000 for the crane and crew. That does not include the added crane setup costs.

Along with added equipment costs, more labor will be required onsite to complete the added work. With the modular units setting faster, all the money spent on the extra cranes and modular facility labor will be for nothing, if the MEP subcontractors do not have enough manpower to keep up with the accelerated pace. The subcontractors following the modular unit setting will need to keep the same pace of work that was projected before the acceleration, only with more work at one time. If the schedule slips due to lack of subcontractor manpower, the project just got a lot more expensive with no real schedule benefits.

In order for this acceleration method to work, all of the subcontractors have to buy in to the increased pace. The modular contractor has to have the labor available at their facility to run increased hours. The steel contractor must be able to get another crane for steel erection, and all of the subcontractors must have the manpower required to keep up with the compact schedule. Finally, the construction manager must have updated crane logistics plans, and extra safety personnel onsite to ensure deadly corners are not cut. With a larger work force, there is a greater risk for accidents.

Figure 2 Example of Crane Setting Modular Units
Picture Courtesy of TexasConstruction.com

MODULAR SETTING SEQUENCE

The modular sequence with in a phase is currently floor by floor. By changing the sequencing, the subcontractors that follow the modular setting can get into the units sooner. The main issue is crane safety. When the crane is swinging and setting modular units overhead, no one is allowed underneath.

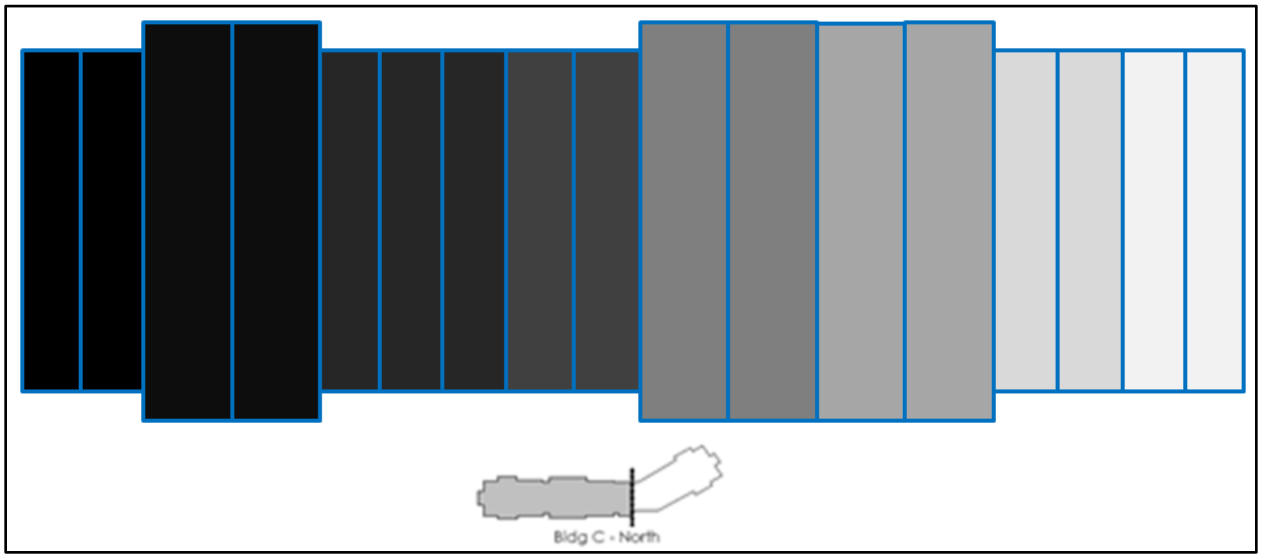


Figure 3 Building C Modular Setting Plan

The proposed sequence is described in Figure 3. The steel core is supposed to be mostly erected before the modular units are beginning to be set. The sequence starts with the closest room to the core, which is indicated with the lightest grey color. There are two modular units in that make one room. The first floor through fourth floor of this room will be set before moving on to the next lightest shade of grey room. Floors one through four will once again be set before moving to the next room. This process is continued from the lightest grey to the darkest grey. This sequence would be used for all five phases of modular construction.

The advantage of this sequence is the MEP rough-ins can start in the first room on all four floors 36 days earlier. As long as the crane does not swing the units over the completed four floors of units, there is no longer a safety issue. There is access to all of four floors from the steel core. By getting a jump start on the MEP's, the schedule should decrease by approximately 20 working days or 4 weeks for both buildings. This will give the finish subcontractors more time to complete their work, ensuring better quality.

Also by sequencing the modular setting this way, the MEP's don't have a large amount of work open up at one time. These contractors will have steady work for the length of the project. This saves the contractors from laying off workers for short periods of time when they are waiting for work.

VALUE ENGINEERING TOPICS

MAIN VALUE ENGINEERING TOPICS

Changing the Exterior Façade to E.F.I.S: Total Deduct: $ 0 (Owner Rejected)

Brick Veneer	$ 780,000
Cast Stone	$ 425,000
Total	$ 1,205,000

Changing Cast Stone Façade to Split Face CMU: Total Deduct: $ 138,000

Split Face 16" x 8" CMU	$ 138,000

Changing to CPVC Sprinkler System: Total Deduct: $ 498,450

Blazemaster Sprinkler System	$ 498,450

Relax STC Rating in Floor: Total Deduct: $ 580,000 (Pending)

Thicker Acoustical Mat	$ 580,000

Delete Fresh Air Make-up: Total Deduct: $ 0 (Owner Rejected)

Operable Windows	$ 850,000

Use 30 kW Emergency Generator: Total Deduct: $ 209,000

30kW Generator	$ 209,000

Eliminate Crawl Space in Steel Core: Total Deduct: $ 100,000

Eliminate Crawl Space	$ 100,000

VALUE ENGINEERING ANALYSIS

At the beginning of the project, the owner asked the Construction Manager to perform value engineering on their bid project cost to decrease the price. The CM's bid price was approximately $41 million. The owner asked the CM to decrease the project price to $38 million in order to be able to close on their financing. The value engineering process took three months and the CM got the price of the project down to $39 million. On August 17, 2012, the funding finally was approved, and the CM got their notice to proceed. The following are the techniques and prices that Construction Manager value engineered to decrease the price.

EFIS EXTERIOR FAÇADE

The CM looked at the façade first and thought that it would be an easy way to decrease the price. The façade specified in the drawings was masonry brick and stone cast units. An alternative EFIS façade was investigated. The cost would decrease $1.2 million. The owner saw samples and rejected this technique of value engineering, because of the appearance. The owner wanted these dormitories to have the same architectural style as the surrounding buildings on campus.

SPLIT-FACE CMU VENEER FAÇADE

The cast stone masonry façade provided an possible area for value engineering. Split-face CMU veneer was proposed instead of the expensive stone. The savings from the CMU would be $138,000. The owner saw samples of the split-face CMU and approved the change. The CMU's style met the owner's appearance requirements.

CPVC SPRINKLER SYSTEM

Inside the modular units, the specifications state that the sprinkler pipe should be metal pipe. The CM found a $498,450 savings by switching to a CPVC sprinkler system. This CPVC system uses CPVC pipe instead of metal, figure 4. There are issues with stress cracking with this system. The joints are glued together instead of soldered. If the pipe moves over time, stress is forced upon the glued joints, resulting in leaks. The owner and architect only approved this system in the modular units, due to all of the risks. The system will also decrease the weight of the modular units for shipping reasons. The risks will be minimized by third party inspection.

Figure 4 CPVC Sprinkler System
Image from www.exponent.com

STC RATING

The acoustic rating of the dormitories was specified to have a high STC rating. If the STC rating was relaxed, less acoustic panels and mats will be needed to absorb sound. The relaxed STC rating will save $580,000. This includes reduced thickness of the acoustical mat in the flooring and no resilient clips between the drywall ceiling and the wood ceiling joists. The owner has not approved this option yet. They are waiting to for further information to make a decision.

FRESH AIR MAKE-UP

The mechanical contractor did not include fresh air make-up in their bid. After awarded the project, the contractor was informed that there needed to be fresh air make-up. This created a large cost of $850,000 to the contractor. The construction manager proposed using operable windows as the fresh air make-up instead of installing the upgraded mechanical system. It was presented as a value engineering technique and the owner and engineer rejected it. The owner valued the upgraded mechanical system higher than the need to cut the price. The students' comfort was the main reason for the rejection.

30KW GENERATOR

The project was bid to have a 250 kW emergency generator for the buildings. After doing electrical calculations, it was proposed to use a 30kW generator. The owner and engineers approved the change. The change of generator saved $209,000.

CRAWL SPACE

There was a crawl space located under the first floor of the structural steel core section. With coordination of all of the MEP's, the crawl space could be deleted. A lot of the savings would be in concrete. The MEP's agreed to coordinate all of their piping to underneath the slab. The deletion of the crawl space saves approximately $100,000. The owner approved this change.

CRITICAL INDUSTRY ISSUES

The 21st annual PACE Roundtable was themed "Improving Efficiency through Innovation." It was on November 6, 2012 at the Penn Stater Conference Center and Hotel. There were four main sections of the Roundtable. First, there was a presentation on integrated educational experiences, then there were two break-out sessions. Finally the day concluded with focus groups on the student's research topics. The purpose of the Roundtable is to gather information and feedback on key construction research topics. The fifth year construction management students were supposed to be exposed to possible research topics for their thesis presentation in the spring.

Each year, the PACE advisory board detects important current construction topics in the industry. Table 2 shows the topics for this year.

Table 2: Break-Out Session Topics

	Supply Chain	Delivery of Services	Operations and Maintenance
Break-Out Session 1	Integrating Strategies and Technologies	Efficient use of Integrated Design	Energy and BIM
Break-Out Session 2	Modularization	Measuring Effective Collaboration	Model Handover

**See Appendix C for notes taken during the PACE Roundtable*

BREAK-OUT SESSION 1

The first break-out session attended focused on Energy and BIM. The key point of this discussion was to examine how BIM can be used in the operations and maintenance of a building after construction is completed. The discussion started with the owner's perspective of the energy consumption and virtual models. The owners stated that buildings are getting more and more complex. It is becoming more difficult to operate the buildings. They are always looking for things that will help them with maintenance and operations.

One of the ways to simplify building maintenance is combine the BIM model and the building automation system. Most of the technicians that are using the building automation system are older and may not be as tech savvy as the new generation. Companies will need to invest in training sessions for this new program. The training sessions will cost money and the company will need to evaluate if the costs are worth the value of a new program.

The owners seemed to agree that the costs outweigh the benefits. So owners are not the ones that are driving the BIM development. It was stated that as young professionals begin to be hired as management, BIM will begin to gain momentum.

There is no program out there currently to link a virtual model with energy consumption. Right now, there are two screens: one for the model and another for the building automation system. The program that would link the two would simplify operation processes. Many industry members do not think that this program would accurately calculate the energy consumption anyway. There are assumptions used in the program that would need to be kept constant. One example is the computer lab that is designed for 10 computers actually contains 45 computers. The program will underestimate the design for this room because of the assumptions in design. The building operators may switch the uses of rooms to meet their needs. To accurately test for the energy consumption, the owner could easily measure each floor's consumption without the model. This technology seems to be years out, but according to the industry members; there may be no real reason to develop it.

RESERCH IDEAS

1. **Finding the Value of the Program that Links BIM and Operations Systems**

   Research the advantages and disadvantages of the program, compute the costs of program licenses and training the staff. Develop the level of detail that the program would need in order to accurately calculate the expected energy consumption of each room in a building. Evaluate the model's level of detail and see if the benefits outweigh the added design time.

2. **Recognition of Energy Consumption**

   Research how knowing other building's energy consumption affects the building user's energy consumption. The competitive nature of people could be examined. Can this tactic persuade people to reduce their energy usage? There are other types of visual energy notices to persuade energy usage. The USGBC could use some of these tactics in their LEED points system.

BREAK-OUT SESSION 2

The second break-out session focused on modularization. Because the Mansfield University dormitories project uses modular units, this session directly related to this construction project. One of the main topics covered in this session were prefabricated MEP systems. There were industry members from Southland Industries and Truland Systems. They spoke about the added quality and time savings they achieve by prefabbing their MEP systems before they get onsite. Both companies have fully integrated prefabrication into their company's construction process, even if the owner doesn't specify it. One new development in prefabrication is more trades are getting involved. The drywall contractor, for example, is now installing drywall and taping on the pre-built walls after the mechanical and electrical systems are fully installed. By installing more trades' work before the units get onsite, there will be less congestion in the building.

With less congestion, the construction site safer. One of the industry members spoke about engineering out hazards. Engineering out the hazards means inventing ways to reduce the risky items. His example was climbing a ladder. By prefabbing a section of pipe, the plumbing worker only has to climb the ladder once to install it, instead of 10 or 20 times. The factories that these units are created in provide a controlled environment to work. This also increases safety. Because the factory has a finished floor, workers try to keep the floor cleaner. Material waste is picked up more frequently and reused, instead of being thrown out.

In order to properly use modular construction, a lot of planning must be accomplished. Subcontractors must be brought into the design phase. This usually happens with design-build project types. Modular construction would be hard to execute, if the project was fully designed and then the subcontractors were brought in. The owner has a lot of control in the modular construction process. By making the project a design-build project, with heavy preconstruction, the owner is creating a positive modular environment that will allow the most opportunity to succeed.

RESEARCH IDEAS

1. **Modular Preconstruction**

   Research the amount of planning needed for modular construction. Find lead times and calculate schedule impact. Compare the saved time during the schedule to the amount of time needed for planning. Investigate how many different trades can be integrated into the modular construction process.

2. **Price Difference in Modular Construction**

   Research the difference in price between modular construction and stick-built. If both types of construction have equal costs, what are the advantages and disadvantages of picking modular construction? Compare the quality of modular construction to stick-built. Investigate other reasons to pick modular construction and the potential costs associated with them.

KEY FEEDBACK

During the feedback session, I spoke with Mike from Forrester Construction. It was a brief conversation. I had told him about the modular construction that was going on in my project and he said that he had never experienced anything like it. I talked about my modular construction issues. He thought that I was on the right track. He said that one topic that he thought would be worth looking into is incentive based contracts. Incentive based contractors give subcontractors a reason to finish their work sooner.

PROBLEM IDENTIFICATION

Research of construction management topics is considered depth. Research pertaining to other options is called a breadth topic. The following will discuss some possible depth topics and breadth topics that can be associated with them.

FLOORING SYSTEM ANALYSIS

DEPTH

Schedule Delay and Value Engineering

In the structural steel core of the buildings, the engineer designed 2x10 lumber joists covered with wood sheathing. This is an uncommon flooring system for a steel structure. There will be investigation into the reason why the engineer picked this system. The flooring of the modular units are wood sheathing with lumber joist also. There may be interest from the owner in keeping the flooring system the same throughout the building. There are other concerns that needed to be considered when building an unfamiliar flooring system. The learning curve of the laborers is one concern. There is potential to delay the schedule. Other methods of constructing the flooring will be examined.

BREADTH

Structural: Flooring System Redesign

The traditional flooring system for a steel structure is metal deck with shear studs and a concrete topping. There will be a redesign of the flooring system with the loads provided in the IBC codebook. The cost estimate will be calculated for both systems and compared. The time required to complete each system will also be analyzed.

EXTERIOR FAÇADE REDESIGN

DEPTH

Value Engineering and Schedule Acceleration

The exterior façade is currently brick and cast stone masonry. As pointed out in the value engineering section, the façade provides a great place to cut costs on the project. Types of other façades will be investigated. The quality of the exterior appearance will also be considered. A look into installing the exterior façade while in the modular facility will be made. This may increase the speed of the construction project and increase quality. The structure of the modular unit may need to be changed in order to ensure that the mortor does not crack during shipment and installation.

BREADTH

Architectural: Redesign the Exterior Façade

The owner put a large emphasis on the appearance of the façade. They did not accept certain value engineering techniques, because the appearance did not match the surrounding buildings on campus. A brick veneer will be examined along with a split face CMU veneer. They will be installed in the modular factory which will increase the quality.

DEPTH

Quality and Constructability

There was a presentation by Whiting Turner's Ted Border given in Prof. Dubler's AE 473 class that exposed potential problems with the quality of constructing a modular building. The bottom floor of the modular units must be set with close accuracy. If the bottom modular unit is set with a little bit of error, by the time the top unit is being set, the error will exponentially increase, figure 5. There will be investigation into the procedure for accurately the setting modular units. Once the units are set, the expansion joints in between each unit will be examined. The precision of setting the units will help keep the expansion joints consistent throughout the building. The different types of connections between the modular units will be looked at and other techniques will be compared. The quality inside each modular unit will be increased because of modularization. The connections between the units must have the same quality, in order for the owner to completely happy.

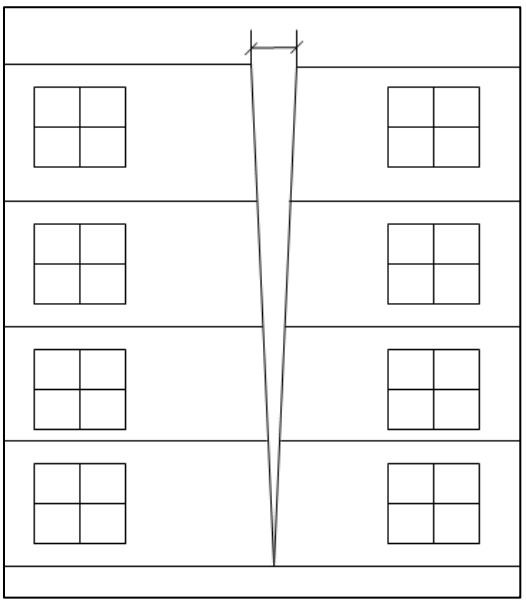


Figure 5 Example of Setting the First Floor Wrong
The smallest error could result in large gaps at the top.

APPENDIX A

LEED SCORECARD

LEED for New Construction and Major Renovation 2009
Project Scorecard

Project Name:
Project Address:

Yes	?	No			
			Sustainable Sites	**26**	**Points**
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
Regional			Credit 1	**Site Selection**	1
			Credit 2	**Development Density & Community Connectivity**	5
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation,** Public Transportation Access	6
			Credit 4.2	**Alternative Transportation,** Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation,** Low-Emitting & Fuel-Efficient Vehicles	3
Regional			Credit 4.4	**Alternative Transportation,** Parking Capacity	2
Regional			Credit 5.1	**Site Development,** Protect or Restore Habitat	1
			Credit 5.2	**Site Development,** Maximize Open Space	1
Regional			Credit 6.1	**Stormwater Design,** Quantity Control	1
			Credit 6.2	**Stormwater Design,** Quality Control	1
			Credit 7.1	**Heat Island Effect,** Non-Roof	1
			Credit 7.2	**Heat Island Effect,** Roof	1
			Credit 8	**Light Pollution Reduction**	1
Yes	?	No			
			Water Efficiency	**10**	**Points**
			Prereq 1	**Water Use Reduction,** 20% Reduction	Required
Regional			Credit 1.1	**Water Efficient Landscaping,** Reduce by 50%	2
Regional			Credit 1.2	**Water Efficient Landscaping,** No Potable Use or No Irrigation	2
			Credit 2	**Innovative Wastewater Technologies**	2
			Credit 3.1	**Water Use Reduction,** 30% Reduction	2
			Credit 3.2	**Water Use Reduction**, 40% Reduction	2
Yes	?	No			
			Energy & Atmosphere	**35**	**Points**
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance:** 10% New Bldgs or 5% Existing Bldg Renovations	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
			Credit 1	**Optimize Energy Performance**	1 to 19
				12% New Buildings or 8% Existing Building Renovations	1
				16% New Buildings or 12% Existing Building Renovations	3
				20% New Buildings or 16% Existing Building Renovations	5
				24% New Buildings or 20% Existing Building Renovations	7
				28% New Buildings or 24% Existing Building Renovations	9
				32% New Buildings or 28% Existing Building Renovations	11
				36% New Buildings or 32% Existing Building Renovations	13
				40% New Buildings or 36% Existing Building Renovations	15
				44% New Buildings or 40% Existing Building Renovations	17
				48% New Buildings or 44% Existing Building Renovations	19
Regional			Credit 2	**On-Site Renewable Energy**	1 to 7
				1% Renewable Energy	1
				5% Renewable Energy	3
				9% Renewable Energy	5
				13% Renewable Energy	7
			Credit 3	**Enhanced Commissioning**	2
			Credit 4	**Enhanced Refrigerant Management**	2
			Credit 5	**Measurement & Verification**	3
			Credit 6	**Green Power**	2
Yes	?	No			

Materials & Resources — 14 Points

Y					
			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	2
			Credit 1.2	**Building Reuse,** Maintain 95% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1
			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse,** 5%	1
			Credit 3.2	**Materials Reuse,** 10%	1
			Credit 4.1	**Recycled Content,** 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content,** 20% (post-consumer + ½ pre-consumer)	1
			Credit 5.1	**Regional Materials,** 10% Extracted, Processed & Manufactured Regionally	1
			Credit 5.2	**Regional Materials,** 20% Extracted, Processed & Manufactured Regionally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes ? No

Indoor Environmental Quality — 15 Points

Y					
Y			Prereq 1	**Minimum IAQ Performance**	Required
			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan,** During Construction	1
			Credit 3.2	**Construction IAQ Management Plan,** Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials,** Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials,** Paints & Coatings	1
			Credit 4.3	**Low-Emitting Materials,** Flooring Systems	1
			Credit 4.4	**Low-Emitting Materials,** Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems,** Lighting	1
			Credit 6.2	**Controllability of Systems,** Thermal Comfort	1
			Credit 7.1	**Thermal Comfort,** Design	1
			Credit 7.2	**Thermal Comfort,** Verification	1
			Credit 8.1	**Daylight & Views,** Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views,** Views for 90% of Spaces	1

Yes ? No

Innovation & Design Process — 6 Points

			Credit 1.1	**Innovation in Design:** Provide Specific Title	1
			Credit 1.2	**Innovation in Design:** Provide Specific Title	1
			Credit 1.3	**Innovation in Design:** Provide Specific Title	1
			Credit 1.4	**Innovation in Design:** Provide Specific Title	1
			Credit 1.5	**Innovation in Design:** Provide Specific Title	1
			Credit 2	**LEED® Accredited Professional**	1

Yes ? No

Regional Bonus Credits — 4 Points

			Credit 1.1	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.2	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.3	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.4	**Region Specific Environmental Priority:** Region Defined	1

Yes ? No

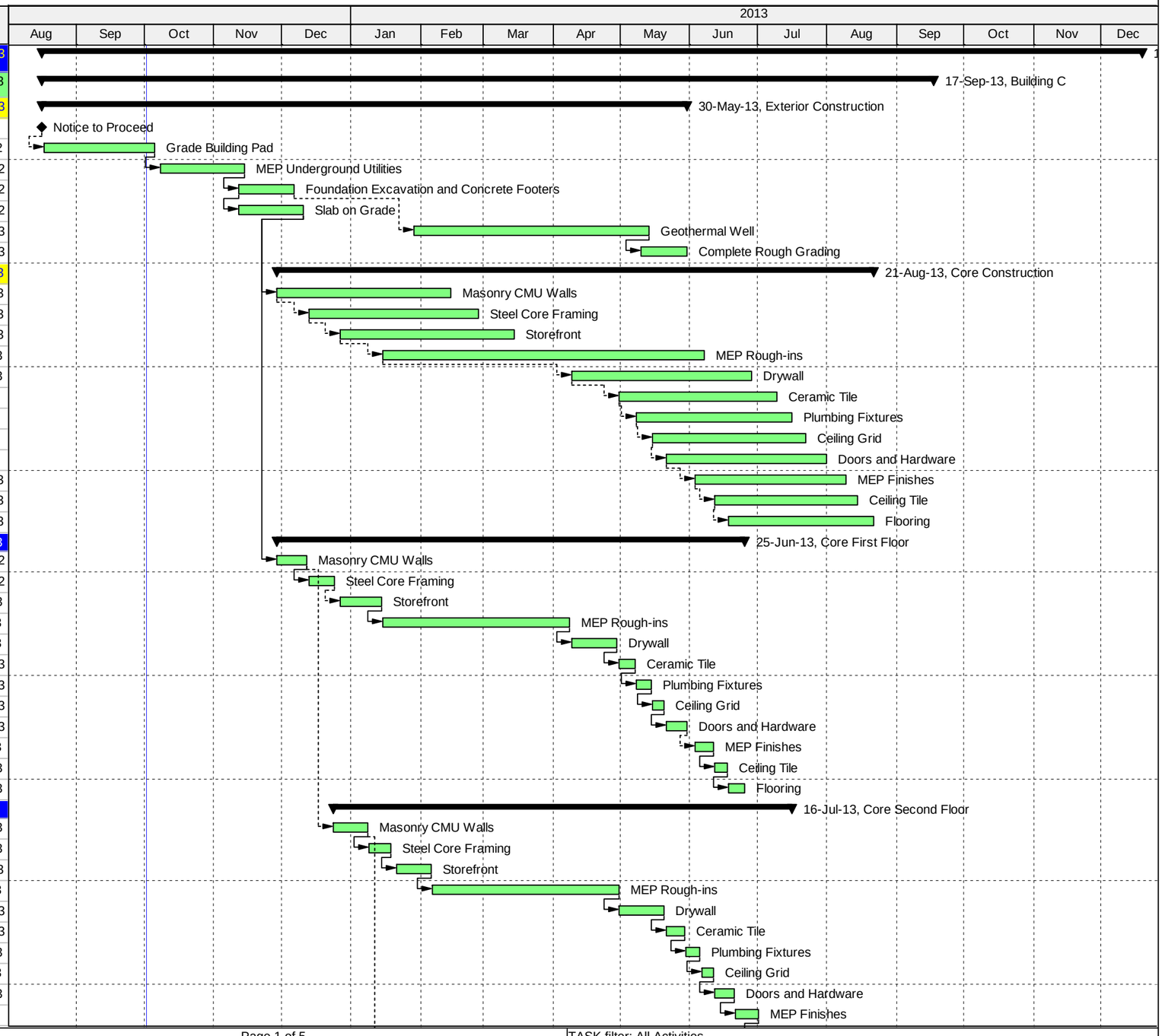
Project Totals (Certification Estimates) — 110 Points

Not Certified **Certified:** 40-49 points **Silver:** 50-59 points **Gold:** 60-79 points **Platinum:** 80+ points

APPENDIX B

DETAILED SCHEDULE

Activity ID	Activity Name	Original Duration	Start	Finish
Detailed Project Schedule1		343	16-Aug-12	19-Dec-13
Building C		277	16-Aug-12	17-Sep-13
Exterior Construction		201	16-Aug-12	30-May-13
E-000	Notice to Proceed	0	16-Aug-12	
E-001	Grade Building Pad	35	17-Aug-12	05-Oct-12
E-002	MEP Underground Utilities	28	08-Oct-1	14-Nov-12
E-003	Foundation Excavation and Concrete Foote	18	12-Nov-1	06-Dec-12
E-004	Slab on Grade	20	12-Nov-1	10-Dec-12
E-005	Geothermal Well	75	29-Jan-1	13-May-13
E-006	Complete Rough Grading	14	10-May-1	30-May-13
Core Construction		186	29-Nov-12	21-Aug-13
C-001	Masonry CMU Walls	54	29-Nov-1	14-Feb-13
C-002	Steel Core Framing	52	13-Dec-1	26-Feb-13
C-003	Storefront	55	27-Dec-1	14-Mar-13
C-004	MEP Rough-ins	103	15-Jan-1	07-Jun-13
C-005	Drywall	58	09-Apr-1	28-Jun-13
C-006	Ceramic Tile	49	30-Apr-1	09-Jul-13
C-007	Plumbing Fixtures	48	08-May-1	16-Jul-13
C-008	Ceiling Grid	47	15-May-1	22-Jul-13
C-009	Doors and Hardware	50	21-May-1	31-Jul-13
C-010	MEP Finishes	49	03-Jun-1	09-Aug-13
C-011	Ceiling Tile	45	12-Jun-1	14-Aug-13
C-012	Flooring	46	18-Jun-1	21-Aug-13
Core First Floor		146	29-Nov-12	25-Jun-13
C1-001	Masonry CMU Walls	10	29-Nov-1	12-Dec-12
C1-002	Steel Core Framing	8	13-Dec-1	24-Dec-12
C1-003	Storefront	12	27-Dec-1	14-Jan-13
C1-004	MEP Rough-ins	60	15-Jan-1	08-Apr-13
C1-005	Drywall	15	09-Apr-1	29-Apr-13
C1-006	Ceramic Tile	6	30-Apr-1	07-May-13
C1-007	Plumbing Fixtures	5	08-May-1	14-May-13
C1-008	Ceiling Grid	4	15-May-1	20-May-13
C1-009	Doors and Hardware	7	21-May-1	30-May-13
C1-010	MEP Finishes	7	03-Jun-1	11-Jun-13
C1-011	Ceiling Tile	4	12-Jun-1	17-Jun-13
C1-012	Flooring	6	18-Jun-1	25-Jun-13
Core Second Floor		143	24-Dec-12	16-Jul-13
C2-001	Masonry CMU Walls	10	24-Dec-1	08-Jan-13
C2-002	Steel Core Framing	8	09-Jan-1	18-Jan-13
C2-003	Storefront	12	21-Jan-1	05-Feb-13
C2-004	MEP Rough-ins	60	06-Feb-1	30-Apr-13
C2-005	Drywall	15	30-Apr-1	20-May-13
C2-006	Ceramic Tile	6	21-May-1	29-May-13
C2-007	Plumbing Fixtures	5	30-May-1	05-Jun-13
C2-008	Ceiling Grid	4	06-Jun-1	11-Jun-13
C2-009	Doors and Hardware	7	12-Jun-1	20-Jun-13
C2-010	MEP Finishes	7	21-Jun-1	01-Jul-13

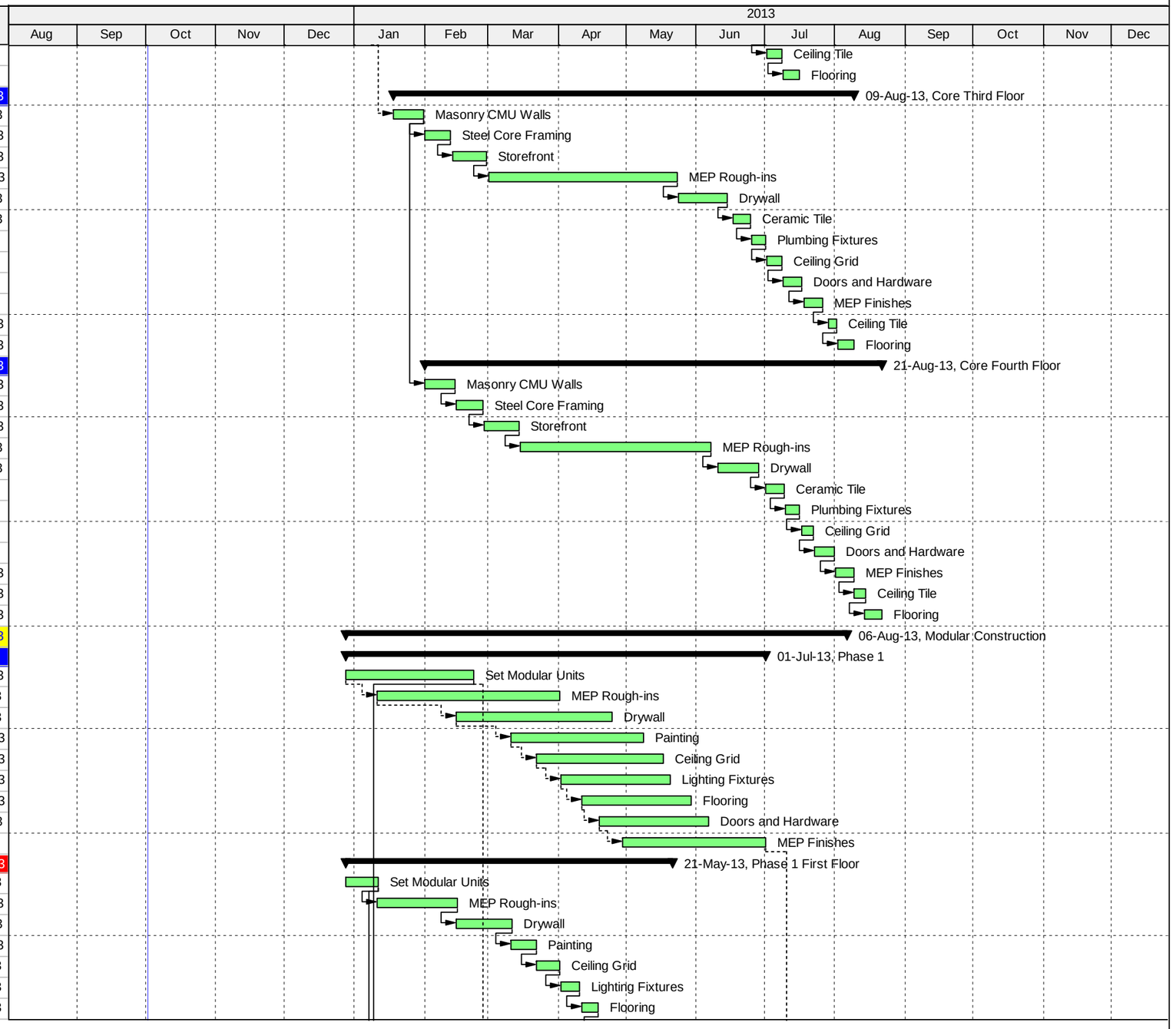


Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

TASK filter: All Activities

Mansfield University Building C and D

Activity ID	Activity Name	Original Duration	Start	Finish
C2-011	Ceiling Tile	4	02-Jul-13*	08-Jul-13
C2-012	Flooring	6	09-Jul-13*	16-Jul-13
Core Third Floor		144	18-Jan-13	09-Aug-13
C3-001	Masonry CMU Walls	10	18-Jan-1	31-Jan-13
C3-002	Steel Core Framing	8	01-Feb-1	12-Feb-13
C3-003	Storefront	12	13-Feb-1	28-Feb-13
C3-004	MEP Rough-ins	60	01-Mar-1	23-May-13
C3-005	Drywall	15	24-May-1	14-Jun-13
C3-006	Ceramic Tile	6	17-Jun-1	24-Jun-13
C3-007	Plumbing Fixtures	5	25-Jun-1	01-Jul-13
C3-008	Ceiling Grid	4	02-Jul-13*	08-Jul-13
C3-009	Doors and Hardware	7	09-Jul-13*	17-Jul-13
C3-010	MEP Finishes	7	18-Jul-13*	26-Jul-13
C3-011	Ceiling Tile	4	29-Jul-13*	01-Aug-13
C3-012	Flooring	6	02-Aug-1	09-Aug-13
Core Fourth Floor		142	01-Feb-13	21-Aug-13
C4-001	Masonry CMU Walls	10	01-Feb-1	14-Feb-13
C4-002	Steel Core Framing	8	15-Feb-1	26-Feb-13
C4-003	Storefront	12	27-Feb-1	14-Mar-13
C4-004	MEP Rough-ins	60	15-Mar-1	07-Jun-13
C4-005	Drywall	15	10-Jun-1	28-Jun-13
C4-006	Ceramic Tile	6	01-Jul-13*	09-Jul-13
C4-007	Plumbing Fixtures	5	10-Jul-13*	16-Jul-13
C4-008	Ceiling Grid	4	17-Jul-13*	22-Jul-13
C4-009	Doors and Hardware	7	23-Jul-13*	31-Jul-13
C4-010	MEP Finishes	7	01-Aug-1	09-Aug-13
C4-011	Ceiling Tile	4	09-Aug-1	14-Aug-13
C4-012	Flooring	6	14-Aug-1	21-Aug-13
Modular Construction		155	28-Dec-12	06-Aug-13
Phase 1		130	28-Dec-12	01-Jul-13
M-1001	Set Modular Units	40	28-Dec-1	22-Feb-13
M-1002	MEP Rough-ins	57	11-Jan-1	01-Apr-13
M-1003	Drywall	49	15-Feb-1	24-Apr-13
M-1004	Painting	43	11-Mar-1	08-May-13
M-1005	Ceiling Grid	41	22-Mar-1	17-May-13
M-1006	Lighting Fixtures	35	02-Apr-1	20-May-13
M-1007	Flooring	34	11-Apr-1	29-May-13
M-1008	Doors and Hardware	34	19-Apr-1	06-Jun-13
M-1009	MEP Finishes	45	29-Apr-1	01-Jul-13
Phase 1 First Floor		102	28-Dec-12	21-May-13
M1-001	Set Modular Units	10	28-Dec-1	11-Jan-13
M1-002	MEP Rough-ins	26	11-Jan-1	15-Feb-13
M1-003	Drywall	17	15-Feb-1	11-Mar-13
M1-004	Painting	10	11-Mar-1	22-Mar-13
M1-005	Ceiling Grid	7	22-Mar-1	01-Apr-13
M1-006	Lighting Fixtures	7	02-Apr-1	10-Apr-13
M1-007	Flooring	6	11-Apr-1	18-Apr-13

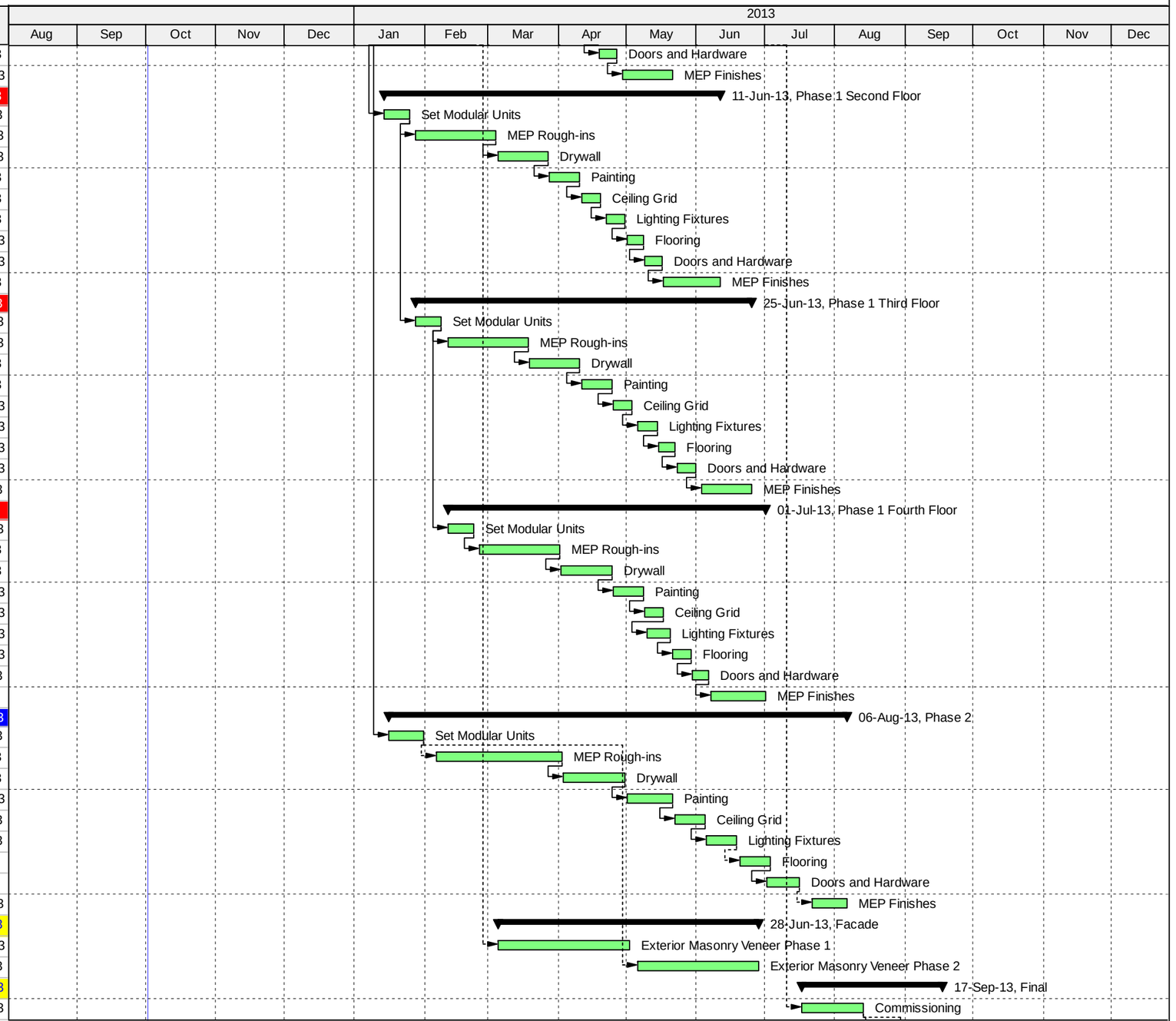


Actual Work | Remaining Work | Critical Remaining Work | Milestone | Summary

TASK filter: All Activities

Mansfield University Building C and D

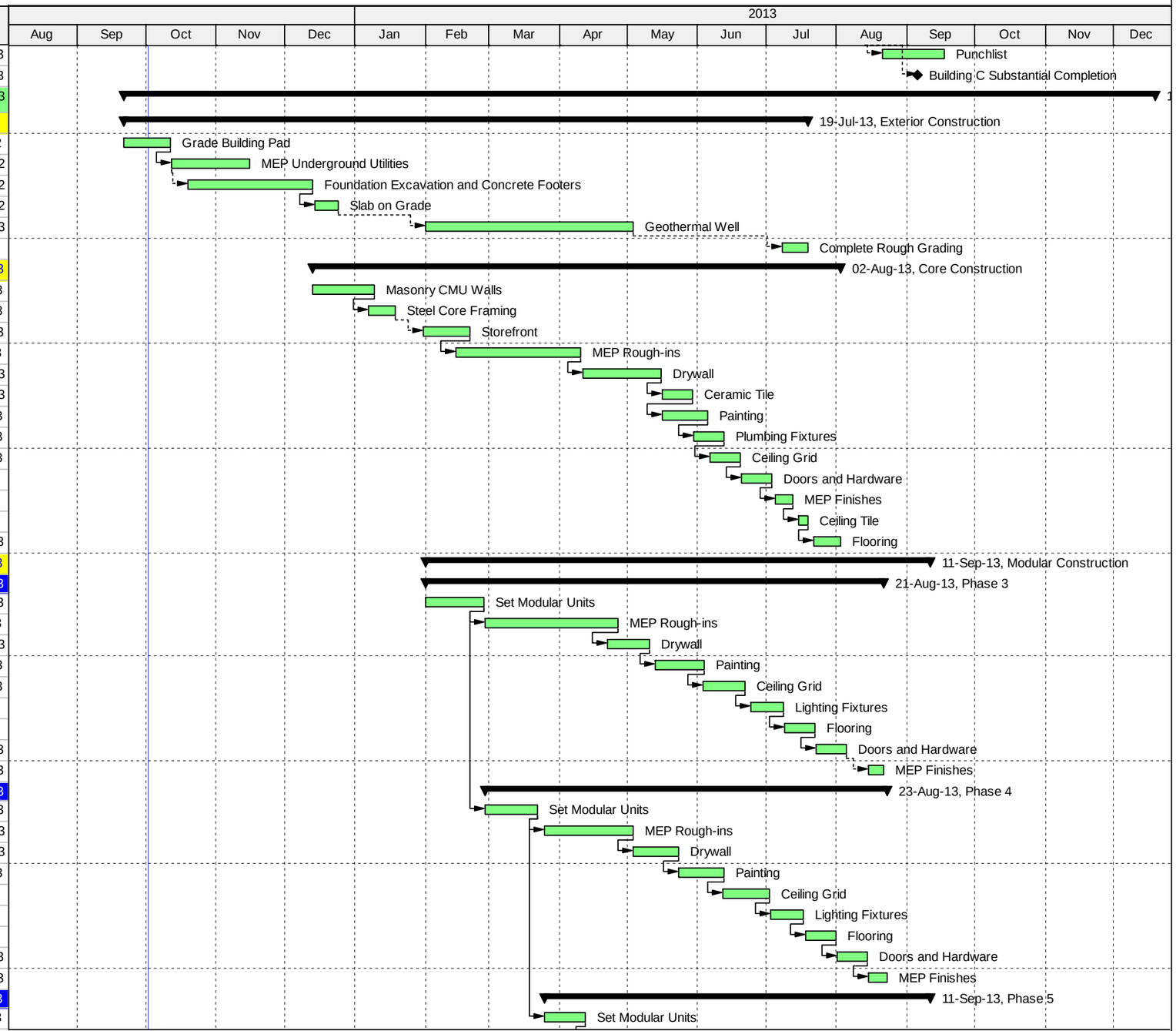
Activity ID	Activity Name	Original Duration	Start	Finish
M1-008	Doors and Hardware	6	19-Apr-1	26-Apr-13
M1-009	MEP Finishes	17	29-Apr-1	21-May-13
Phase 1 Second Floor		106	14-Jan-13	11-Jun-13
M2-001	Set Modular Units	10	14-Jan-1	25-Jan-13
M2-002	MEP Rough-ins	26	28-Jan-1	04-Mar-13
M2-003	Drywall	17	05-Mar-1	27-Mar-13
M2-004	Painting	10	28-Mar-1	10-Apr-13
M2-005	Ceiling Grid	7	11-Apr-1:	19-Apr-13
M2-006	Lighting Fixtures	7	22-Apr-1	30-Apr-13
M2-007	Flooring	6	01-May-1	08-May-13
M2-008	Doors and Hardware	6	09-May-1	16-May-13
M2-009	MEP Finishes	17	17-May-1	11-Jun-13
Phase 1 Third Floor		106	28-Jan-13	25-Jun-13
M3-001	Set Modular Units	10	28-Jan-1	08-Feb-13
M3-002	MEP Rough-ins	26	11-Feb-1	18-Mar-13
M3-003	Drywall	17	19-Mar-1	10-Apr-13
M3-004	Painting	10	11-Apr-1:	24-Apr-13
M3-005	Ceiling Grid	7	25-Apr-1	03-May-13
M3-006	Lighting Fixtures	7	06-May-1	14-May-13
M3-007	Flooring	6	15-May-1	22-May-13
M3-008	Doors and Hardware	6	23-May-1	31-May-13
M3-009	MEP Finishes	17	03-Jun-1	25-Jun-13
Phase 1 Fourth Floor		100	11-Feb-13	01-Jul-13
M4-001	Set Modular Units	10	11-Feb-1	22-Feb-13
M4-002	MEP Rough-ins	26	25-Feb-1	01-Apr-13
M4-003	Drywall	17	02-Apr-1	24-Apr-13
M4-004	Painting	10	25-Apr-1	08-May-13
M4-005	Ceiling Grid	7	09-May-1	17-May-13
M4-006	Lighting Fixtures	7	10-May-1	20-May-13
M4-007	Flooring	6	21-May-1	29-May-13
M4-008	Doors and Hardware	6	30-May-1	06-Jun-13
M4-009	MEP Finishes	17	07-Jun-1	01-Jul-13
Phase 2		143	16-Jan-13	06-Aug-13
M-2001	Set Modular Units	12	16-Jan-1	31-Jan-13
M-2002	MEP Rough-ins	40	06-Feb-1	02-Apr-13
M-2003	Drywall	20	03-Apr-1	30-Apr-13
M-2004	Painting	15	01-May-1	21-May-13
M-2005	Ceiling Grid	9	22-May-1	04-Jun-13
M-2006	Lighting Fixtures	10	05-Jun-1	18-Jun-13
M-2007	Flooring	10	20-Jun-1	03-Jul-13
M-2008	Doors and Hardware	10	02-Jul-13*	16-Jul-13
M-2009	MEP Finishes	12	22-Jul-13*	06-Aug-13
Facade		83	05-Mar-13	28-Jun-13
F-0001	Exterior Masonry Veneer Phase 1	43	05-Mar-1	02-May-13
F-0002	Exterior Masonry Veneer Phase 2	39	06-May-1	28-Jun-13
Final		44	17-Jul-13	17-Sep-13
F-1001	Commissioning	20	17-Jul-13*	13-Aug-13



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
F-1002	Punchlist	19	21-Aug-1	17-Sep-13
F-1003	Building C Substantial Completion	0		05-Sep-13
Building D		318	21-Sep-12	19-Dec-13
Exterior Construction		211	21-Sep-12	19-Jul-13
E-1001	Grade Building Pad	15	21-Sep-12	11-Oct-12
E-1002	MEP Underground Utilities	25	12-Oct-1	15-Nov-12
E-1003	Foundation Excavation and Concrete Foote	39	19-Oct-1	13-Dec-12
E-1004	Slab on Grade	7	14-Dec-1	24-Dec-12
E-1005	Geothermal Well	66	01-Feb-1	03-May-13
E-1006	Complete Rough Grading	10	08-Jul-13*	19-Jul-13
Core Construction		163	13-Dec-12	02-Aug-13
C-1001	Masonry CMU Walls	18	13-Dec-1	09-Jan-13
C-1002	Steel Core Framing	10	07-Jan-1	18-Jan-13
C-1003	Storefront	15	31-Jan-1	20-Feb-13
C-1004	MEP Rough-ins	40	14-Feb-1	10-Apr-13
C-1005	Drywall	25	11-Apr-1	15-May-13
C-1006	Ceramic Tile	9	16-May-1	29-May-13
C-1007	Painting	14	16-May-1	05-Jun-13
C-1008	Plumbing Fixtures	10	30-May-1	12-Jun-13
C-1009	Ceiling Grid	10	06-Jun-1	19-Jun-13
C-1010	Doors and Hardware	10	20-Jun-1	03-Jul-13
C-1011	MEP Finishes	6	05-Jul-13*	12-Jul-13
C-1012	Ceiling Tile	5	15-Jul-13*	19-Jul-13
C-1013	Flooring	10	22-Jul-13*	02-Aug-13
Modular Construction		156	01-Feb-13	11-Sep-13
Phase 3		142	01-Feb-13	21-Aug-13
M-3001	Set Modular Units	18	01-Feb-1	26-Feb-13
M-3002	MEP Rough-ins	43	27-Feb-1	26-Apr-13
M-3003	Drywall	15	22-Apr-1	10-May-13
M-3004	Painting	15	13-May-1	03-Jun-13
M-3005	Ceiling Grid	15	03-Jun-1	21-Jun-13
M-3006	Lighting Fixtures	10	24-Jun-1	08-Jul-13
M-3007	Flooring	10	09-Jul-13*	22-Jul-13
M-3008	Doors and Hardware	10	23-Jul-13*	05-Aug-13
M-3009	MEP Finishes	5	15-Aug-1	21-Aug-13
Phase 4		126	27-Feb-13	23-Aug-13
M-4001	Set Modular Units	18	27-Feb-1	22-Mar-13
M-4002	MEP Rough-ins	30	25-Mar-1	03-May-13
M-4003	Drywall	15	03-May-1	23-May-13
M-4004	Painting	14	23-May-1	12-Jun-13
M-4005	Ceiling Grid	15	12-Jun-1	02-Jul-13
M-4006	Lighting Fixtures	10	03-Jul-13*	17-Jul-13
M-4007	Flooring	10	18-Jul-13*	31-Jul-13
M-4008	Doors and Hardware	10	01-Aug-1	14-Aug-13
M-4009	MEP Finishes	7	15-Aug-1	23-Aug-13
Phase 5		120	25-Mar-13	11-Sep-13
M-5001	Set Modular Units	15	25-Mar-1	12-Apr-13

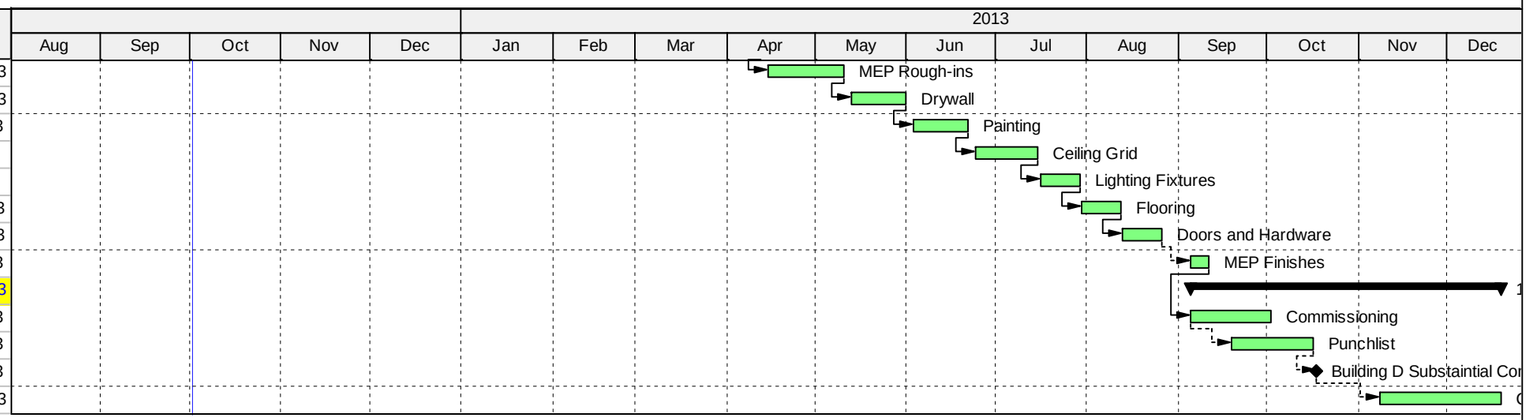


Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

TASK filter: All Activities

Mansfield University Building C and D

Activity ID	Activity Name	Original Duration	Start	Finish
M-5002	MEP Rough-ins	20	15-Apr-1	10-May-13
M-5003	Drywall	14	13-May-1	31-May-13
M-5004	Painting	15	03-Jun-1	21-Jun-13
M-5005	Ceiling Grid	15	24-Jun-1	15-Jul-13
M-5006	Lighting Fixtures	10	16-Jul-13*	29-Jul-13
M-5007	Flooring	10	30-Jul-13*	12-Aug-13
M-5008	Doors and Hardware	10	13-Aug-1	26-Aug-13
M-5009	MEP Finishes	5	05-Sep-1	11-Sep-13
Final		75	05-Sep-13	19-Dec-13
A1860	Commissioning	20	05-Sep-1	02-Oct-13
A1870	Punchlist	20	19-Sep-1	16-Oct-13
A1880	Building D Substaintial Completion	0		17-Oct-13
A1890	Close Out	29	08-Nov-1	19-Dec-13



Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

TASK filter: All Activities

APPENDIX C

PACE ROUNDTABLE NOTES

Student Name Michael Mahoney

Session #1

Topic: Operations and Maintenance Energy + BIM

Research Ideas:

(1) Value of combining BIM model with building automation system
- Industry members did not see a major benefit
- Research to develop program is not worth it.

(2) Recognition of energy usage.
- To decrease energy useage, show current energy usage of one building and compare to neighboring buildings.
- Energy efficiency to building users' comfort level.

Session #2

Topic: Supply Chain Modularization

Research Ideas:

(1) Preconstruction needed for modularization
- Planning and design needed for modularization
- Preconstruction time vs time in schedule saved.

(2) Break-even point stick built to modular
- Modular still provides increased quality and safety
- Less waste → more efficient use of materials
- Engineering out hazards.

Industry Panel: Differentiation in a Down Economy

Research Ideas:

(1)

(2)

Industry Member Discussion

Key Feedback:

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

Constructability of modular construction.
- Experience of labor force
- Quality increase
- Site logistics
- Pre-planning
- Lay down space

Life cycle cost of the building
- Expected life
- Expected energy usage
- LEED Points
- Owners goals

Suggested Resources:

What industry contacts are needed? Is the information available?