Final Report

April7, 2010

Emily Couric Clinical Cancer Center
Charlottesville, VA

http://www.engr.psu.edu/ae/thesis/portfolios/2010/bnm5016/index.html

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Emily Couric Clinical Cancer Center
Charlottesville, VA
University of Virginia

Project Team:

OWNER: University of Virginia
CM: Gilbane Building Co.
ARCHITECT: Zimmer-Gunsul-Frasca Architects, LLC
MEP ENGINEERS: AEI
SURVEYING ENGINEERS: Hurt & Profitt
STRUCTURAL ENGINEERS: Robert Silman Associates, PLLC
CONSULTANTS: Shirmer
TESTING AGENCY: Schnabel

Building Statistics:

FUNCTION: Out Patient Diagnostic and Treatment Center
SIZE: 153,104 SF
STORIES: 6
CONSTRUCTION: Apr. 2008 – Dec. 2010
COST: $74 Million
DELIVERY METHOD: Design-Bid-Build

Architecture:

DESIGN: Consolidate existing services into one building
ROOM TYPES: Exam, 3 Linear Accelerator, Offices, Radiation/Oncology, Café, Access HUB, Phlebotomy
LOBBY: Large entry lobby 2 stories
EXPANSION: Entire fourth floor

Building Envelope:

WALLS: Mostly Brick Veneer with a large Curtain Wall
ROOF: Main roof, EPDM single-ply roof membrane system with a white acrylic coating. Roof garden exists with similar materials

Lighting/Electrical:

480/277 Volts distributed throughout the building
23 Local transformers step from 480 to 208/120 V
83 panel boards located throughout the building
65 different light fixtures
Lighting uses 277 Volts
Recessed and suspended mounted fixtures with mostly fluorescent lights

Structural:

FOUNDATION: Spread footings for support columns
FRAMING: Structural Steel, Columns varying from W10x33 to W14x159
CONCRETE SLAB: 3" GA composite deck with 3.5" L.W. concrete and WWF 6x6 W2.9xW2.9
LIVE LOAD: Average is 100 PSF to include partitions

Mechanical:

SYSTEM: All-air with a local reheat unit in each room
4 MAIN AHUS: each supply 45,000 CFM, 529 MBH heating capacity, 2,390 MBH cooling capacity located in the penthouse
288 AIR TERMINAL UNITS: Varying from 70-1790 CFM, 1994-92108 Btuh Heating Coil Capacity

Brittany Muth

2010 Construction Option

<http://www.engr.psu.edu/ae/thesis/portfolios/2010/bnm5016/index.html>

EXECUTIVE SUMMARY

The Emily Couric Clinical Cancer Center in Charlottesville, VA is a 154,000 SF building owned by the University of Virginia. It is being constructed to combine existing cancer services into one building. It is scheduled for 2 years and to end within the budget of $74 million. There were a few topics that were of interest to be studied and analyzed in this thesis.

The first analysis will be of the topic of using BIM technologies for façade construction. BIM was not implemented on this project at all. Not many people have been using BIM for the façade and it would be interesting to see how BIM can be used for façade construction. If people are using it for façade construction, in what ways is it being used and how do people wish it could be used?

The second analysis is of incorporating solar panels into the façade. Typically, solar panels are put on the roof and out of sight or they are put in fields away from the building. What kind of solar panels exist that can be designed into the façade? The Emily Couric Clinical Cancer Center has a large curtain wall on the South side of the building and it would be interesting if solar panels could be incorporated into the curtain wall without blocking the view. If there are technologies that can be incorporated into the curtain wall, are they economical? What would the payback period be and is it actually beneficial to be incorporated into the façade? All of these questions will be answered and discussed in great detail later in this paper.

The final analysis will be analyzed in the most detail. It is an analysis of the option of prefabricating the brick façade on the cancer center. It seems like a logical analysis because the majority of the façade is either brick or curtain wall so why not look into the possibilities? The prefabrication of the brick façade is not only a construction management depth but also a mechanical breadth. The impact on the budget, schedule, site logistic, and mechanical system will be analyzed. Also being discussed is the decision as to whether or not the prefabricated façade is actually beneficial or just a waste of money to decrease the schedule.

All of these analyses are discussed in more detail with a conclusion as to whether the results are worth implementing on the project or if it was a good idea not to implement them. Some of the are beneficial and others are not as beneficial. Nonetheless, all of the analysis were beneficial to my education and have taught me a lot about these topics that I can use in the industry.

CREDITS AND ACKNOWLEDGMENTS

University of Virginia:
Fred Dunn
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Dee Eadie

Gilbane Building Company
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Wayne Martin

Clark Nexson
Jonathan Walker

Davis Construction

Balfour Beatty

Jacobs Engineering

United States Army Corps Engineers:

The Pennsylvania State University:
Faculty

Friends and family

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INTRODUCTION

The Emily Couric Clinical Cancer Center is being constructed on the University of Virginia to consolidate their cancer services into one building. The University of Virginia (UVA) is located in Charlottesville, Virginia and it was founded by Thomas Jefferson in 1819. UVA currently has over 20,000 students attending the university. They have many degree programs in ten different schools including engineering, law, and medicine.

The cancer center has been in the planning stages since 2005 and under a budget of **$74 million**. The building is a design-bid-build project with the construction managers being Gilbane Building Company. The building is a 6 story building containing **153,104 SF**. The UVA broke ground on April 12, 2008 and is expecting the project to be completed December 29, 2010 to allow 3 months to move in furniture and prepare for opening day.

UVA chose to build this building because they have a lot of services for cancer patients already but they are spread out in different buildings throughout campus. They thought it would be a good idea to consolidate the services into one building making it easier on the patients. Dee Eadie explained it as a “one stop shopping experience in a holistic healing environment that provides hope, solace, and cutting edge cancer treatment.”There are two reasons why the building was chosen to be constructed. One of the reasons was the death of the Virginia State Senator Emily Couric that was related to cancer. The other reason was there is an expected growth in cancer patients in the next fifteen years due to the aging baby boomers. The project is on its way to becoming a LEED Silver project with the newest technologies.

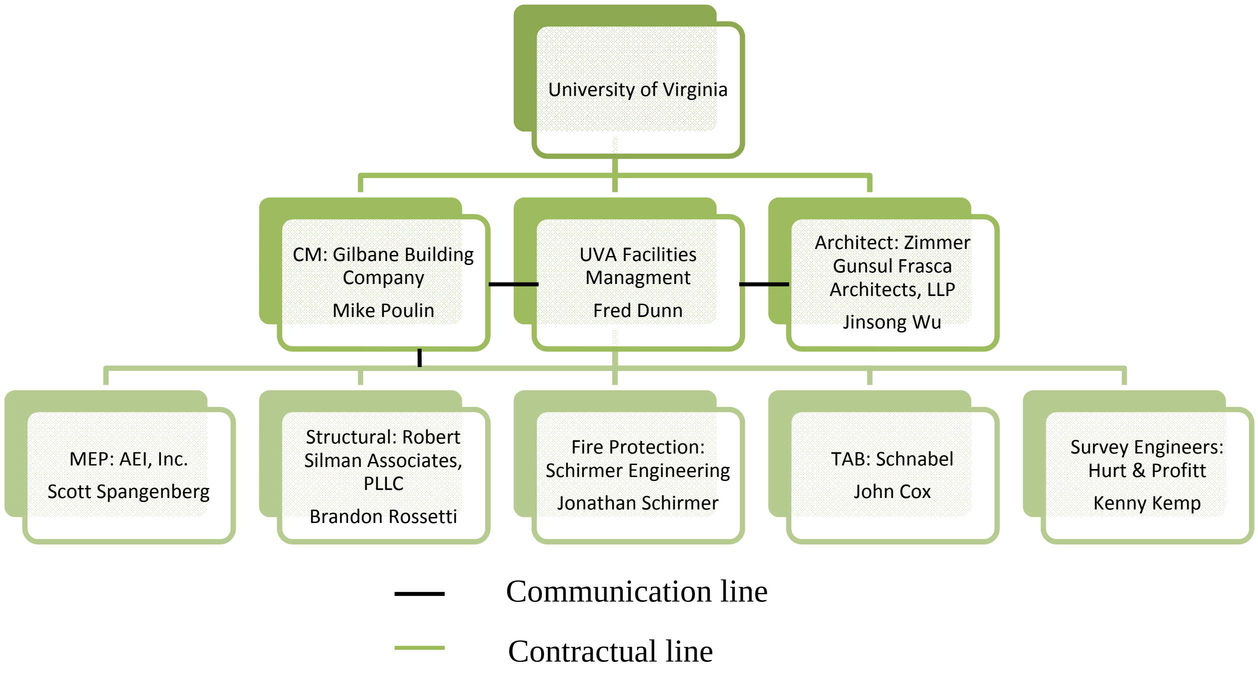
PROJECT BACKGROUND

PROJECT DELIVERY SYSTEM

The Emily Couric Clinical Cancer Center is being delivered as a design-bid-build project. There was not a big push to get it done as fast as possible therefore the design-bid-build process seemed to be logical to use.The contractors are responsible to obtain and maintain “all-risk” builder’s risk insurance in both the owner’s and contractor’s name. The contractor is required to have worker’s compensation, employer’s liability insurance, commercial general liability insurance, automobile liability insurance and occurrence-based liability insurance throughout the entire duration of the project. The contractor is required to provide a standard performance bond and a standard labor and material payment bond. Each of the subcontractors were chosen by first being pre-qualified and then by competitive bid. Having the contractors prequalify helps to guarantee the quality of the project and then you can find the contractor who will provide the quality for the best price by making it a competitive bid.

The owner holds all of the contracts of the trades and the CM helps to monitor the work and assure the work is being completed and to the owner’s expectations. The contractors have agreed to report to both the owner and the CM with any questions or concerns. This was chosen because it allows the owner to be involved more because they have experience in construction. One issue could arise because the CM has no contractual agreement with the subcontractors and could have little influence on them if they are falling behind. Below, in **Figure 1**, is an organizational chart representing communication lines and contractual lines.

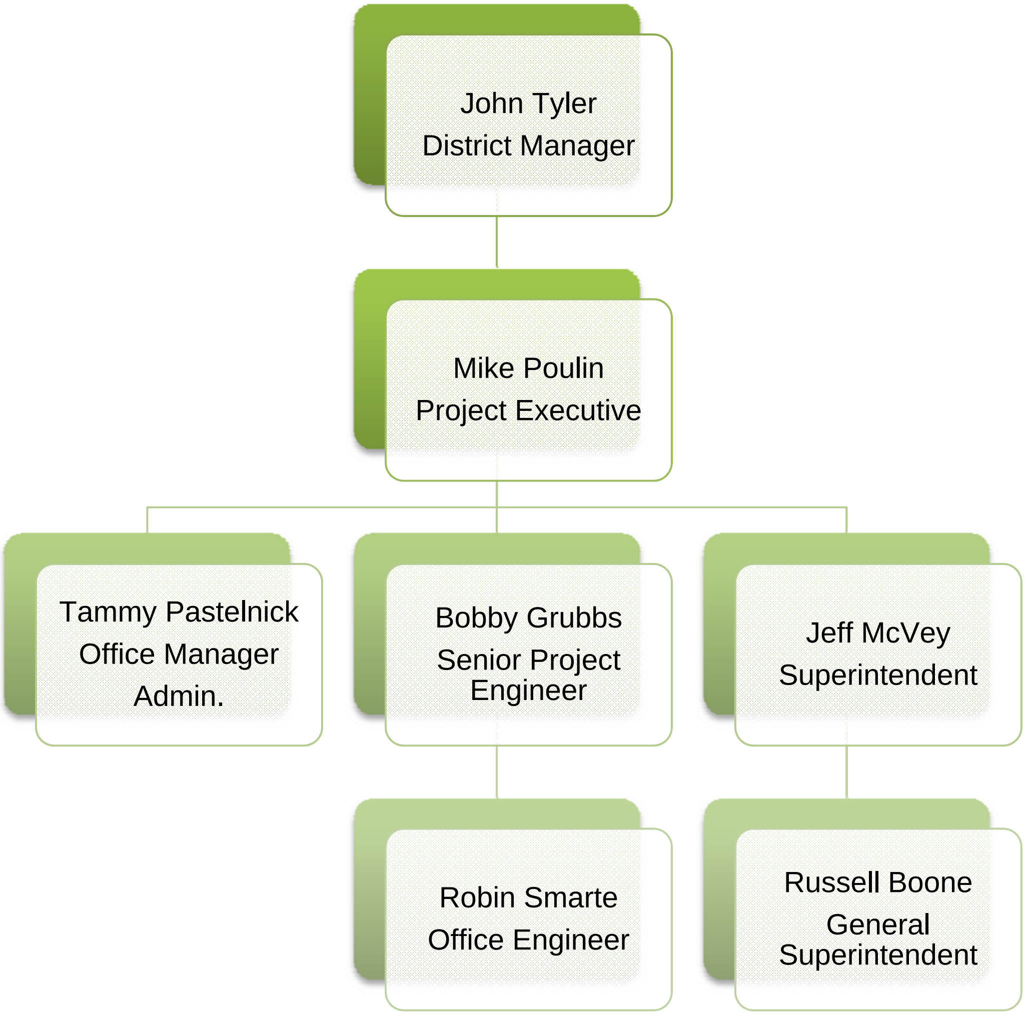
Figure 1: Project Level Organizational Chart



CONSTRUCTION MANAGER ORGANIZATIONAL CHART

Gilbane Building Company put together a staffing plan for their company as shown in **Figure 2** below. It includes a district manager, project executive, office manager, senior project engineer, office engineer, superintendent and a general superintendent. The lines on the figure show the relationship and who reports to whom. The office manager takes care of the administrative items. The senior project engineer is in charge of the typical engineering functions and the office engineer is in charge of RFI's and submittals. The superintendents are responsible for different field duties.

Figure 2: Construction Manager (Gilbane Building Co.) Organizational Chart



SITE CONDITIONS

The existing site conditions consisted of a parking garage that the University of Virginia has decided to demolish. The site does not contain a lot of extra space for trailers, storage of materials, and easy mobilization around the site. Therefore, the office trailers will be located near the site but not on the site. Existing utilities are also located on the site and need to be taken into consideration during construction.

The parking is very limited near the site and the employees have to try and find public parking if they drive to work. Most of the construction workers park in the nearby parking garage and the rest try to find other parking downtown as close to the site as possible. There will be temporary lighting located throughout the building after the floors start to be constructed. The working hours will be during daylight and it will not be necessary to light the sight during the night hours. Therefore, I did not locate any temporary lighting. The site outline is also the symbol for the fence surrounding the site during construction.

DEMOLITION

Since the parking garage was on the existing site, it needed to be demolished before construction could begin on the cancer center. Existing sidewalks and underground utilities also needed to be demolished before the construction could begin. The types of materials that were demolished were concrete, asphalt and other yard structures on the site. The method of demolition used for the parking garage was to take it down little by little from top to bottom. Each piece of the structure had to be carefully removed from the site. The use of explosives was not permitted because of the surrounding buildings and other issues caused by explosives. Not using explosives helps to reduce the dust irritation that would be created with explosives. A picture of the demolition stage, provided by the UVA, is shown in **Figure 3**.

Figure 3: Demolition of the existing parking garage.

ARCHITECTURE

Figure 4: Rendering of entrance lobby.

The general architecture of the cancer center includes a number of different spaces because the purpose was to bring together different services into one building. A few examples include 3 linear accelerator rooms, offices, radiation and oncology, a café, phlebotomy and an access hub. One of the grander spaces is the two story entry lobby which is encased with a curtain wall system to allow for optimal day lighting and bright space. The University of Virginia has decided to build a building that is larger than their needs to allow for expansion on the fourth floor. A rendering, provided by the UVA, of the entrance lobby is shown to the right in **Figure 4**. Below in **Figure 5**, is an image provided by the UVA of what the building will look like when it is completed.

Figure 5: Rendering of the facade of the cancer center.

BUILDING ENVELOPE

The building envelope includes many different materials and can be seen in the previous **Figure 5**, provided by the UVA. The main façade consists of a curtain wall system, brick veneer and stone. The building includes a large amount of masonry. The masonry on this project consists of eight inch concrete masonry units (CMU) as the exterior load bearing wall covered with brick veneer. The brick veneer is connected to the CMU block wall by galvanized bent steel plates. There was scaffolding placed around the building as they moved up the building to place the brick. At the floor levels the brick veneer changes and puts two rows of soldier bricks. The CMU blocks are covered with a transition membrane and insulation. There is a row of continuous stainless steel flashing around the building is used to direct water away from the building. Recycled content was used for this part of the building to help achieve LEED points for the project.

The curtain wall system is an aluminum frame system by Kawneer that is a sustainable product also attributing to the LEED credits. This all contributes to two different LEED credits including optimizing energy performance and on-site renewable energy. Together, these credits can total up to twenty six points which is a significant piece of the LEED Silver rating the University of Virginia is trying to obtain.

The LEED Silver rating, trying to be obtained, has affected the construction of the building envelope in a couple ways. They have designed a roof garden into their building to assist with the LEED points and it also creates a pleasant environment for the patients and employees to spend time at. The roofing materials they have chosen is an EPDM (ethylene propylene dieneterpolymer) single-ply roof membrane system with a white acrylic coating. This gives the building a white roof which helps to reduce the heat island effect and the cooling load of the building by reflecting the heat from the sun away from the building. In **Figure 6**, the components that make up an EPDM roofing system are shown (found atwww.roofwise-se.com).

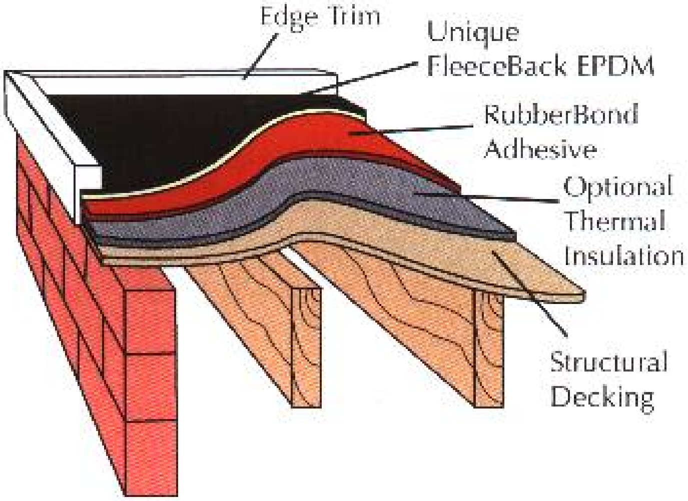


Figure 6: Example of EPDM Roofing components.

STRUCTURAL SYSTEM

Figure 7: Drilling and placing caissons.

The average live load calculated for the building is a 100 psf including partition. Using the loads the following system was designed and used for the Emily Couric Clinical Cancer Center. The foundation of the building consists of seventy seven caissons to support columns of the building. A picture of this part is shown in **Figure 7**, which was provided by the UVA. The main structural support in the building is a steel frame with metal deck and concrete slabs. The steel columns include a wide variety of sizes from W10x33 to W14x159. Temporary bracing was be used to provide for the loads subjected to the structure while being constructed. A crane was used to construct this system and also used for the cast in place concrete slab that was constructed on top of the steel frame. The concrete slab is a three inch galvanized composite deck with three and a half inches of lightweight concrete. It is reinforced with a welded wire fabric size of 6x6 W 2.9xW 2.9. The picture below, in **Figure 8**, is of the steel frame system and was provided by the UVA.

Figure 8: Structural system.

MECHANICAL SYSTEM

The designed mechanical system for the building is an all-air system with a local reheat unit in each room. There are four main air handling units (AHU), each supplying the building with 45,000 CFM of air. Each of the AHU's have a 2,390 MBH cooling capacity and a 529 MBH heating capacity. All of these units are located in the penthouse. The system also includes 288 air terminal units supplying varying amounts of air from 70-1790 CFM. These units have anywhere from 1,994 to 92,108 Btuh heating coil capacity. The necessary fire dampers and fire-stopping procedures will be installed on this project complying with ASTM E-814. There is also a wet-pipe fire-suppression sprinkler system going to be installed to protect the occupants in the case of a fire.

LIGHTING AND ELECTRICAL SYSTEMS

The electrical system is a 480/277 volt system distributed throughout the building. Twenty three local transformers are used to step the 480 to 208/120 volt system, which is what is used to power our buildings equipment and lights. There are eighty three panel boards located throughout the building to locally distribute the electric to the building.

The lighting system in the building is powered with 277 volts of electricity. There are sixty five different types of fixtures being installed in the building. The majority of the fixtures are recessed and suspended mounted fixtures. The typical bulbs used in the building are fluorescent lights, which typically use less energy to create the same amount of light as an incandescent bulb.

EXISTING CONDITIONS

LOCAL CONDITIONS

Typically in the Charlottesville, Virginia area, buildings are constructed using steel framing with composite metal decking for the structure of the project. Downtown Charlottesville is a little crowded and hard to store materials and move around the buildings being constructed. The construction workers have a difficult time finding parking near the site because they have to park in public parking areas. There is a garage near the site but it gets full quickly and they have to find other parking spots downtown. The University of Virginia owns most of the property in Charlottesville and is constructing a few projects in the area. They are very interested in becoming more sustainable and achieving LEED certification.

Along with the LEED certification, recycling is available and is being used on this project. They recycle over 90 percent of their waste materials and it is very common in the area. The tipping fees are not known for this project and are being researched.

The soils on the site in Charlottesville, VA consist of dense sand and hard consistency silts and hard consistency disintegrated rock. Due to there already being a structure on the site there was existing fill detected in their analysis that is above the natural materials. The soil is suitable for new compacted structural fill except it is not recommended for direct support for slaps and pavements due to its high swell values.

The water levels were observed between 29 and 40 feet in a few borings and the others remained dry up to 26.5 feet. A water observation well was drilled and measured at 4 days and 38 days. The depths of the water level were measured to be 35.5 and 31.5 feet in the water observation well.

One thing that needs to be identified under local conditions is the zoning regulations for the location of the building. The Emily Couric Clinical Cancer Center is located in the B-3 Commercial zoning section of Charlottesville, VA according to the Code of Ordinances of Charlottesville, VA. Under chapter 34, Article IV, Division 2, the height of a building is limited to 70 feet. Hospitals and health clinics in the B-3 zoning areas are required to have a by-right use permit. The green box on the map below, in Figure, shows the location and zoning area of the Emily Couric Clinical Cancer Center. (www.charlottesville.org, Zoning Map, 2009)

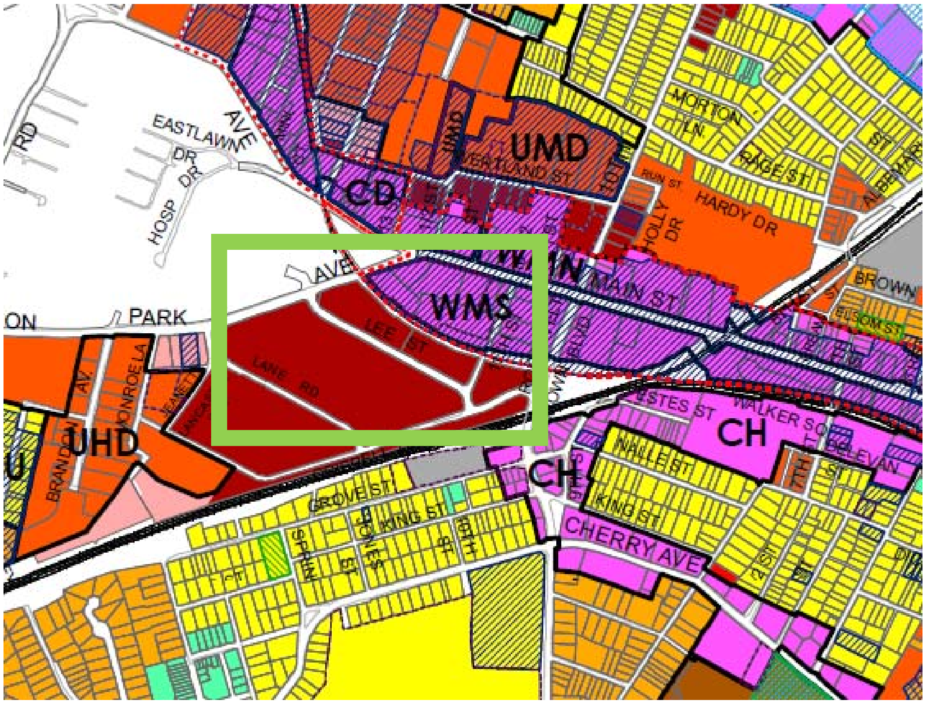


Figure 9: Zoning Map 2009
(0Hwww.charlottesville.org, Zoning Map, 2009)

PROJECT SCHEDULE

A detailed project schedule, derived from a much more detailed schedule last updated in February 2009, can be found in **Appendix A**. This schedule expands upon the project schedule summary in the previous technical assignment. This project has been in the planning stages since 2005 and finally broke ground on April 12, 2008. They mobilized the site in June of 2008 as the garage demolition was finishing. They had to demolish an existing parking garage before they could start building the cancer center. The building is separated into three different sections by column lines F-K, C-F, and Z-C for the construction of the exterior walls. The steel is split into 17 sequences and will top out on May 28, 2009. It is being constructed from the east to the west, floor by floor and will be substantially complete on December 29, 2010.

ANALYSIS 1: FAÇADE CONSTRUCTABILITY ANALYZED WITH BIM

BACKGROUND

The first analysis will deal with the use of Building Information Modeling (BIM) for at least the façade of the Emily Couric Clinical Cancer Center. BIM is becoming more and more popular in the construction industry and the technology is becoming more advanced and user friendly to make this tool more useful in actual construction. BIM is very helpful in coordination and clash detection on construction projects. There are many benefits to using BIM on a construction project; one of the main reasons is that building the building in a virtual environment helps to reduce the number of construction conflicts in the field. This analysis will provide an area for critical industry research and constructability analysis.

PROBLEM/OPPORTUNITY STATEMENT

The University of Virginia chose not to implement the use of Building Information Modeling on the Emily Couric Clinical Cancer Center. After discussing some of the time consuming issues on the project with the project team, it was determined that the façade of the building consumed a large amount of time on coordination on this project. Because the façade includes many different materials, the connections of these materials needed to be intensely coordinated. Because the use of BIM was not implemented on this project all of the analysis will be based on previous projects and what is expected of proper use of BIM technologies.

RESEARCH STEPS

1. Create survey questions to be sent to numerous industry members.
2. Create and easy to use, short survey in www.surveymonkey.com
3. Make contacts to send survey to and allow time for responses.
4. Send survey to the numerous contacts.
5. Collect data.
6. Review and analyze data.
7. Apply results to the Emily Couric Clinical Cancer Center.

INTERVIEW AND SURVEY QUESTIONS

The responses to these questions are provided in Appendix B.

1. Have you worked on projects that both used traditional detailing/coordination of the façade and projects that have used BIM technologies for the façade construction?
2. Rate your experience with using BIM for the façade construction.
    a. No experience
    b. Little experience
    c. Some experience
    d. Moderate Experience
    e. Expert
    f. Please list size of project and other comments.
3. Using BIM has increased the constructability of a complex façade.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
    f. Please explain in what ways.
4. Using BIM has increased the productivity of façade construction.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
    f. Please explain in what ways.
5. BIM is beneficial for façade analysis and coordination.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
    f. Please explain in what ways.
6. The learning curve negatively affected the productivity of the use of BIM for the facade.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
    f. Please explain in what ways.

7. Using BIM for the façade construction helps to reduce the cost of the façade significantly.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
    f. Please explain in what ways.
8. Please explain what the most difficult part was about using BIM for facade construction.
9. Please explain what is most beneficial about using BIM for facade construction.

EXPECTED OUTCOME

The expected outcome of this analysis is to see how BIM could improve the process of the construction of the façade and hopefully add value to the project. The pros and cons to using BIM will be analyzed for the company and the project. A detailed cost analysis will not be conducted because the information from experienced companies is not public and it is difficult to calculate.

ANALYSIS

After receiving the results of the survey that was sent out to the industry members, it became apparent that using BIM (Building Information Modeling) for the façade construction is not a popular choice among project teams today. Only a few people responded to the survey and all of them had very similar answers to the questions. This leads me to believe that this is the most common thoughts in the industry.

The use of BIM for façade construction is not quite to the standards of items such as using it for mechanical, electrical, plumbing, etc. coordination and phasing. It is still very new and upcoming in the industry. Companies have looked at using BIM for mockups of the façade more than the entire façade construction. Companies are just now starting to implement BIM for the entire façade construction and find it more beneficial for facades that are very complex. It is more beneficial for the complex facades because, since there are multiple materials and scopes coming together, BIM helps to coordinate and organize the process.

BIM had definitely improved the coordination process and effectiveness of coordinating different trades and scopes on projects. One question in the survey was about increasing the constructability of the façade and if it was believed that BIM increased the constructability. The industry members feel that it is most beneficial for constructability by coordinating all the trades but sometimes the trades are not happy to model in three dimensions and continue to use two dimensions. BIM is also believed to reduce the schedule and assists in sequencing the trades properly. It does not necessarily make the project easier to construct but it helps to make the contractors more efficient. The industry members say that building an entire project with a very detailed façade is not a good use of BIM yet, but they do think that it is very beneficial to build very detailed mockups of how building facades tie into each other. Another problem with using BIM for the façade construction is that not many façade contractors are modeling yet which does not allow three dimensional fabrication drawings. Overall, it seems to be making a breakthrough in the industry right now but it is mostly used for mockups of how the different façade materials meet and join together. These connections can be very detailed and confusing in the fields which can allow for delays on the project or even change orders if the façade is not constructed properly. If these connections are not constructed properly, many problems can occur and can cost the project team a large amount of money.

Does BIM increase the productivity of the façade construction? All of the industry members that responded to the survey agreed that it definitely increases the productivity of the façade construction. Even though not many projects have used BIM for complete façade construction it is definitely believed to impact productivity because of a few different reasons. The model can be sent to the contractor and subs in a means of coordination which will help reduce the schedule because it can provide the most efficient sequencing of the trades. This maximizes the productivity of the contractors and reduces the schedule of the entire project. The façade is normally on the critical path; therefore, if its schedule is reduced, the overall project schedule is reduced. The main reason it increases the productivity is that is helps to plan the execution of the project. If you have the most effective plan of execution, your project should be constructed in the most efficient way.

There are mixed feelings about whether or not BIM is beneficial for façade analysis and coordination. It was pointed out that there are certain areas that it is beneficial such as quantifying materials in façade energy analyses. The BIM model software providers do not currently have the capabilities to import information to understand subjects such as the possibilities of water infiltration or energy loss due to air gaps. However, the BIM model can be imported into a third party software if needed. Once the software providers can include this kind of information the façade analysis will be more beneficial than what it is now. It is genuinely agreed upon that coordination and sequencing is definitely a benefit of using BIM for the façade construction.

When asked if the industry felt that the learning curve negatively affected the productivity of the use of BIM for façade, the industry did not feel that it was an issue that could not be overcome. It was stated though that experienced modelers definitely are beneficial to the project and help improve the productivity. Overall, the industry members feel that the BIM model is definitely beneficial for productivity in the field because they have a “visual tool and a centralized database” that helps to understand the complexities of the façade. The consensus was to find a detail modeler that can use the proper tools to create a sufficient model for the team to use.

In response to the question about using BIM to help reduce the cost of the façade, the responses were mixed. A few agree and others disagree. One person, stated that there is no way that it should cost less because facades have a clearer picture and do not require a lot of rework and the material costs do not change, therefore the cost would not change. The rest of the responses were more towards agreeing that it would save money. It would save money because it avoids expensive errors and mistakes during construction but you would not know how much money you actually would be saving because the mistakes would not happen. Another reason for it to save money is that it would increase productivity which helps decrease the cost because time and labor is not being wasted. Using BIM would also create an opportunity to do more prefabrication which "allows for less field waste and a higher quality product which reduces the chances of rework."

The survey included a question asking them to explain the most difficult part about using BIM for façade construction and there were many different responses. The majority of the responses referred to including the correct amount of detail in a model. There are setbacks in using BIM for façade construction because the software does not provide the ability to add the correct amount of detail to make the model beneficial. Once the software providers can include the ability to apply more detail to the models, the models will be more beneficial for the façade construction. Another difficult part about using BIM is to know when to stop drawing in BIM. This makes a good point because you need to know when you get to the point where the model will stop adding quality and benefits to the project and project team.

It was also asked what the most beneficial part about using BIM for façade construction. The responses were more diverse. Some people simply like the idea of having the ability to send the model to sub-contractors to develop shop drawings from it. This just makes the process simpler and easier to do. Others like that after the model is completed you have a better understanding of the design. There are thoughts that the model helps with window and door scheduling and material identifications. Fewer mistakes are made by the contractor when the BIM model is used through the entire process including design and construction documents. The model also helps to increase the productivity in the field which is beneficial to the project in a few different ways such as schedule and cost of the project. It was also stated that the model helps to avoid tolerance conflicts in slab edge as-built conditions, curtain wall and precast shop drawings.

CONCLUSION

After reviewing all of the survey results and analyzing all of the data, I have come to the conclusion that using BIM technology on the project would have been very beneficial to the project. Most of the projects that have used BIM for façade construction have been over 150,000 SF which the Emily Couric Clinical Cancer Center falls into that category. The extent that BIM should have been used on the project may not be to the detailed level that MEP systems are modeled in but it could be used in a less detailed model. Using BIM technologies for at least a mockup of the façade would be very beneficial because it would help to coordinate the more difficult connections of the façade materials.

The learning curve would not be a major problem because the detail would not be to the extent that you would need expert modelers. One thing that took a lot of time for the project team was to coordinate shop drawings for the many different façade material connections. Using BIM for mockups would help to create shop drawings and make the coordination process a quicker one, which could result in a possible schedule reduction. Reducing the schedule could also reduce the cost of the project because less time would be spent on coordination and reworking the mistakes.

It is agreed upon by the industry that using BIM helps to improve the constructability of the façade, reduces the schedule of the façade, and improves the coordination of the façade. All of these tasks are very important in façade construction and if they could all be improved by implementing the BIM process, then the project could be improved overall. Because Gilbane Building Company has used BIM on other projects, I believe that it should not be too difficult to train others or use an experienced modeler on the project.

ANALYSIS 2: INCORPORATING PHOTOVOLTAIC PANELS INTO THE FAÇADE

(Electrical Breadth Study)

BACKGROUND

The second analysis will deal with adding solar panels to the building. After looking into different façade materials, it was of interest to somehow incorporate photovoltaic panels into the façade. Photovoltaic panels are becoming more popular in the sustainable building market and they were not included in the design of the Emily Couric Clinical Cancer Center. Photovoltaic panels are beneficial for many different reasons including savings on the amount of energy purchased from the grid and also reducing the amount of fossil fuels being used to produce the energy. The analysis will be of installing photovoltaic panels into the curtain wall of the cancer center. Using photovoltaic panels could possibly contribute to the LEED points that the University of Virginia is trying to obtain for a LEED Silver rated building. This analysis will provide information in value engineering and also will be used for a mechanical breadth and electrical breadth.

PROBLEM/OPPORTUNITY STATEMENT

After looking into how the façade of the project could be changed to improve the value of the building, it was clear that photovoltaic panels could be incorporated into the project. One of the places the panels could be incorporated would be the curtain wall which is mainly closing in a lobby space. This change could definitely add value to the project and reduce the energy bills the cancer center will be receiving once the building is up and running. Initially the cost of the photovoltaic panels could be very expensive; therefore, a life cycle cost analysis will be calculated to determine the payback period to decide if the panels are actually beneficial to the project. Adding photovoltaic panels also would affect the electrical system by changing the size of feeders and transformers that would be needed. The new size of feeders and transformers will be calculated and compared to the existing feeders and transformers.

RESEARCH STEPS

1. Research different photovoltaic panels for curtain wall construction.
2. Choose a photovoltaic panel to incorporate into the façade.
3. Collect cost information of the photovoltaic panels.
4. Calculate impact on electrical system such as sizing transformers and feeders.
5. Compare the new size of the feeders and transformers to the existing ones.
6. Calculate impact on the heating and cooling loads of the lobby space the curtain wall surrounds.
7. Calculate the life cycle cost analysis and decide if the panels are beneficial to the project.

EXPECTED OUTCOME

The expected outcome of this analysis is that the panels will be beneficial to the project in multiple ways. The feeders and transformers should be less than what the building is currently designed for which could be cheaper and more efficient. It is expected that the panels will reduce the energy costs of the building and the payback period will be short enough to be more beneficial to the project. It is also expected to add LEED points to the project which would help to obtain the LEED Silver rating the University of Virginia is trying to obtain.

ANALYSIS

The first step of this analysis was to research the products and learn about the many different kinds of photovoltaic panels that are available. After using the internet to search the materials, it became apparent that putting solar panels into curtain walls is not a very common idea. There have been a few different technologies created that are transparent or semi-transparent solar panels. Not every manufacturing company makes these kinds of solar panels.

The transparent or semi-transparent can be of two different types. The most common type is to have the solar panels placed in glass and have space between small panels that is just clear so you can see through the window. This kind is represented below in **Figure 10**. The other type that exists is more of a window. It is just like looking through tinted glass, there are no panels blocking your view, it is simply just like a normal window. This type is shown in **Figure 11** below.

Figure 10: Solar Panel (www.diytrade.com)

Figure 11: Transparent Solar Panels. (Centennial Solar)

There is still another option that exists, which is to take a normal photovoltaic panel and just place it in the curtain wall. If this option is chosen, the structural integrity needs to be reevaluated for the curtain wall because the solar panels weigh more than the glass that the curtain wall was designed to support. This option is the one I chose but due to time constraints, I will not be analyzing the structural aspects of the curtain wall.

The solar panels I chose to use are manufactured by Trina Solar. I chose these panels because after analyzing my curtain wall façade, I noticed that the majority of the façade is on the South side of the building which is the most beneficial location for the placement of solar panels because the South side is the side that receives the most sunlight throughout the day. The solar panels will only be replacing the 5’ x 9’ windows on the South side of the curtain wall. This gives a total of 1,710 SF of solar panels on the south façade. Each 5’ x 9’ window will be replaced with three 3’ x 5’ solar panels of the Trina Solar model TSM-DA05. The specification sheet is shown in **Appendix E** and looks like the solar panel to the right in **Figure 12**.

Figure 12: TSM-DA05 Solar Panel (Trina Solar)

After talking with Jonathon Walker with Clark Nexson, also a Penn State Architectural Engineering alumnus, he introduced me to the program RETScreen. This program assists in calculating the energy savings of using solar panels and also the lifecycle costs of the solar panels. I originally thought it could be possible to select solar panels that would have a payback period between five to ten years. It was interesting to see the results of the actual calculations.

There was a lot of information to enter into the RETScreen program and all of the results are posted in Appendix F. I needed to research the electricity costs in Charlottesville, Virginia. I found on the internet that the average for Virginia is 8.1 cents per kilowatt hour. The program wanted the cost in megawatt hour so the cost used in the program was $81.00. Because this was the average, I used the same value for every month of the year.

I assumed the inverter properties to be 96% efficient, a capacity of 100, and miscellaneous losses of 5%. After entering all of the values for the solar panels, the program calculated the total electricity exported to the grid would be 75.534 MWh. The next step was to calculate the cost and analyze it. I assumed approximately $2,000.00 per panel because I could not reach a sales representative in time to get a more exact price. Using $2,000.00 for each panel gives you a total of **$228,000.00** because there will be 114 panels that would be installed. The green strips in **Figure 13** below represent where the solar panels will be located on the curtain wall. The engineering costs are also assumed to be $20,000.00 for the whole system which may be conservative. The cost of the power system is approximately $7.00 per Watt and $7,000 per KW provided by Les Aseere and Randy Sansbury of Johns Manville Roofing. These two men specialize in integrating PV technology on roofs.

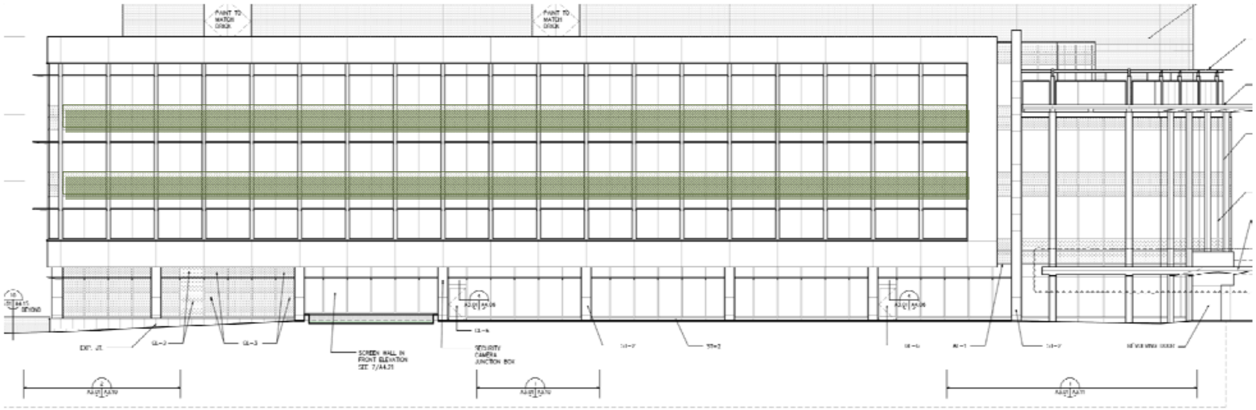


Figure 13: South Elevation (A3.01 elevation 1) provided by the Drawings by Zimmer Gunsul Frasca Architects.

After calculating all of that information, the inflation rates and incentives needed to be entered. I did not find a value for incentives for Virginia buildings to use solar power but there are incentive programs after researching online. I assumed a fuel cost escalation rate of 2% and inflation rate to be 3%. I used a project life of 50 years to see the payback period of the solar panels. I used an electricity export escalation rate of 5% due to the cap coming off of electricity rates. After entering all of this information, the payback period was calculated to be **41 years**, shown in **Figure 14**. This is a very long time for a payback period and does not give a good reason to install solar panels. The money could be spent elsewhere. It is common for solar panels to have a payback period longer than the expected life of the solar panels.

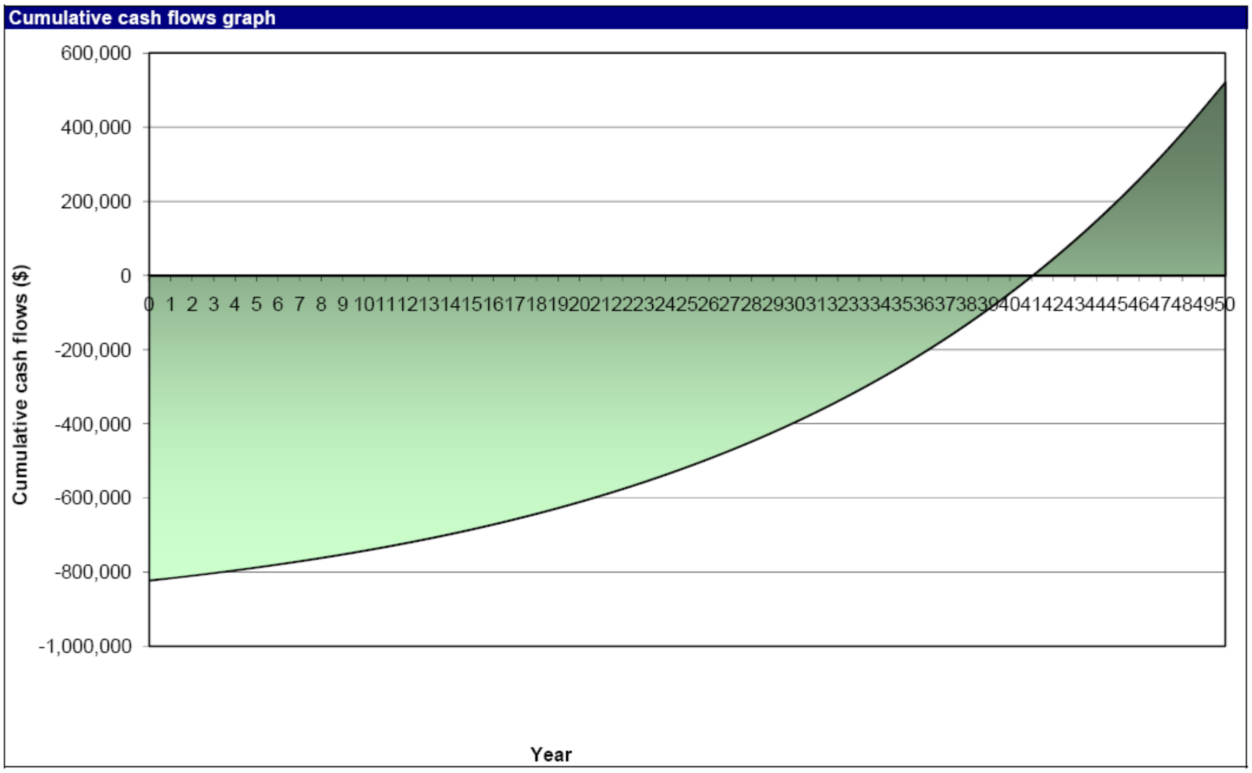


Figure 14: RETScreen graph of the payback period.

Overall, the system would not be a good choice for the value of the dollar. It takes too long to get the money back that was spent on the system. Even though it is good for the environment and adds to LEED points, it is not that beneficial to the building owners, the University of Virginia.

ANALYSIS 3: USING PREFABRICATION FOR THE FAÇADE

(CONSTRUCTION MANAGEMENT DEPTH)
(Mechanical Breadth)

BACKGROUND

The third analysis will deal with the use of prefabrication of the façade. The façade of the Emily Couric Clinical Cancer Center is so complex with so many different materials including a curtain wall, brick veneer, stone and others. Since there are so many different materials, it is very difficult to coordinate how these materials will connect to each other. Prefabrication allows for difficult connections to be constructed in a controlled environment and reduces the amount of coordination needed to construct this in the field. Prefabrication is beneficial for different reasons. It is capable of increasing the quality of the project because the items being prefabricated are constructed in a controlled environment and can be inspected more closely and in a timelier manner. Another reason to use prefabrication is to reduce the schedule of a project. Projects that are on very tight time schedules often prefabricate more items because they can be built ahead of time and be installed more quickly on site. Prefabrication is more often used in mechanical and electrical systems or systems that are highly repetitive. Sometimes the use of prefabrication can also reduce the cost of the project due to less labor used in the field and the higher level of quality reduces the chances of having to rebuild areas of the building. This analysis will allow for area of critical industry research, schedule reduction, and constructability to be analyzed.

PROBLEM/OPPORTUNITY STATEMENT

The Emily Couric Clinical Cancer Center includes a very complex façade and the façade is on the critical path of the project. This means that the façade needs to be completed on time and the coordination of the complex façade could result in a delayed start on the construction delaying the entire project. Therefore, the use of prefabrication will be analyzed to reduce the schedule of the façade and keep the project on time. Another aspect of changing to a prefabricated brick façade is that it changes the properties of the wall. Therefore, the R-values and heat losses need to be calculated to contribute to the analysis of whether or not the prefabricated façade is beneficial in that aspect.

RESEARCH STEPS

1. Contact a prefabrication company that is willing to aid in the understanding of the prefabrication process and provide detailed steps of analyzing the value of prefabricating.
2. Make list of all materials used in the façade of the building and find prices of materials to analyze the cost of the project.
3. Take off all materials in the façade.
4. Gather prices and labor hours for all façade materials.

5. Compare and analyze the results.

ANALYSIS

Prefabrication is not often a common suggestion for façade construction. The façade construction is on the critical path of almost every building and can take a very long time depending on how complex the façade is. Because the Emily Couric Clinical Cancer Center has a very complex façade with many different materials, it takes a very long time to construct. Prefabrication of the façade was chosen to analyze how much quicker the façade could be installed and if it would have been beneficial to the project by shortening the schedule.

The scheduled duration of the façade construction is from May 18, 2009 to January 6, 2010 for a total of 244 days. This is about six and a half months of façade construction. Originally, I thought that prefabrication would result in a cost reduction, schedule reduction and quality improvement. If this turned out to be the case, why do people not choose this option more often?

After making a few phone calls to prefabrication companies to get some contacts to assist me with my research and studies, I reached a man named Wayne Martin who works for Eastern Exterior Wall Systems Inc. He was already familiar with the thesis program at The University of Pennsylvania's Architectural Engineering program. He has actually judged the finalist competitions before and knew a lot about the program. Mr. Martin was very willing to help and allowed me to contact him with many questions about the process.

After talking with Mr. Martin, he pointed out that the prefabrication of the façade for the Emily Couric Clinical Cancer Center may actually be more expensive. He stressed the fact that prefabrication would definitely decrease the schedule and improve the quality of the project. Mr. Martin helped me to get on the right track by teaching me how the process works and how to get information.

First, a list of all materials would need to be made to estimate how many materials are needed. Once the materials are taken off, prices of the materials need to be gathered. There are a couple ways that these prices can be obtained which are to call local companies and get the actual local prices and the other is to use RS Means. RS Means is what I chose to use, due to time constraints, and it is recognized throughout the industry. After compiling the list of materials, we picked a prefab system that would be suitable for the Emily Couric Clinical Cancer Center's façade. The system we picked was a thin brick system.

There are a couple reasons to choose this system rather than just build the planned system. First, using this system allows the façade to weigh up to seventy five percent less than the designed system. (http://www.eews.com/solution.html) Another reason is that it eliminates the use of a weep system. (http://www.eews.com/solution.html) There is no place in this system to collect water and cause leaking and other problems like typical cavity walls. This system is collected in the brick and mortar and is ex-filtrated through the materials with the weather patterns. It is evenly distributed and released from the building and does not collect in the building because there is no air cavity. One of the reasons that this system may cost more is because in the original plan, there is supposed to be eight inch concrete masonry units sitting on top of the concrete slabs as represented in **Figure 15**below.

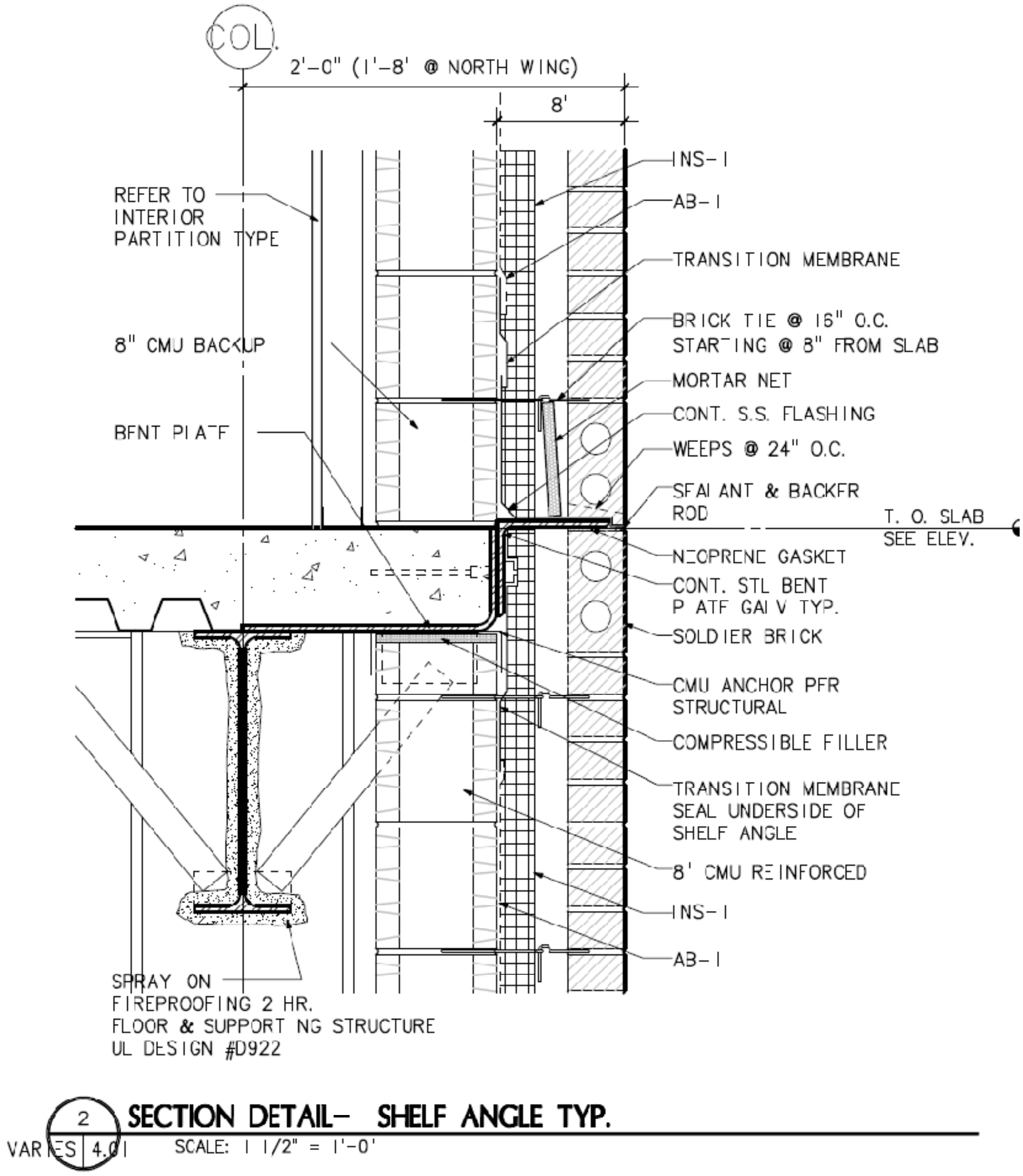


Figure 15: Detail 2 on Drawing A4.01 of the Emily Couric Clinical Cancer Center Drawings by Architects Zimmer-Gunsul-Frasca

The materials selected for this system are as follows in the following order:

- Cold formed structural stud: 6" 16 ga. 1-5/8" @ 16" o.c.

- 5/8" sheathing
- WP membrane
- Z
- 5/8" sheathing
- Lath
- Scratch coat
- Laticrete
- Thin brick

These materials are specific to Eastern Exterior Wall Systems, Inc. and the Emily Couric Clinical Cancer Center project. The following picture, **Figure 16**, is a general representation of how thin brick facades are constructed.

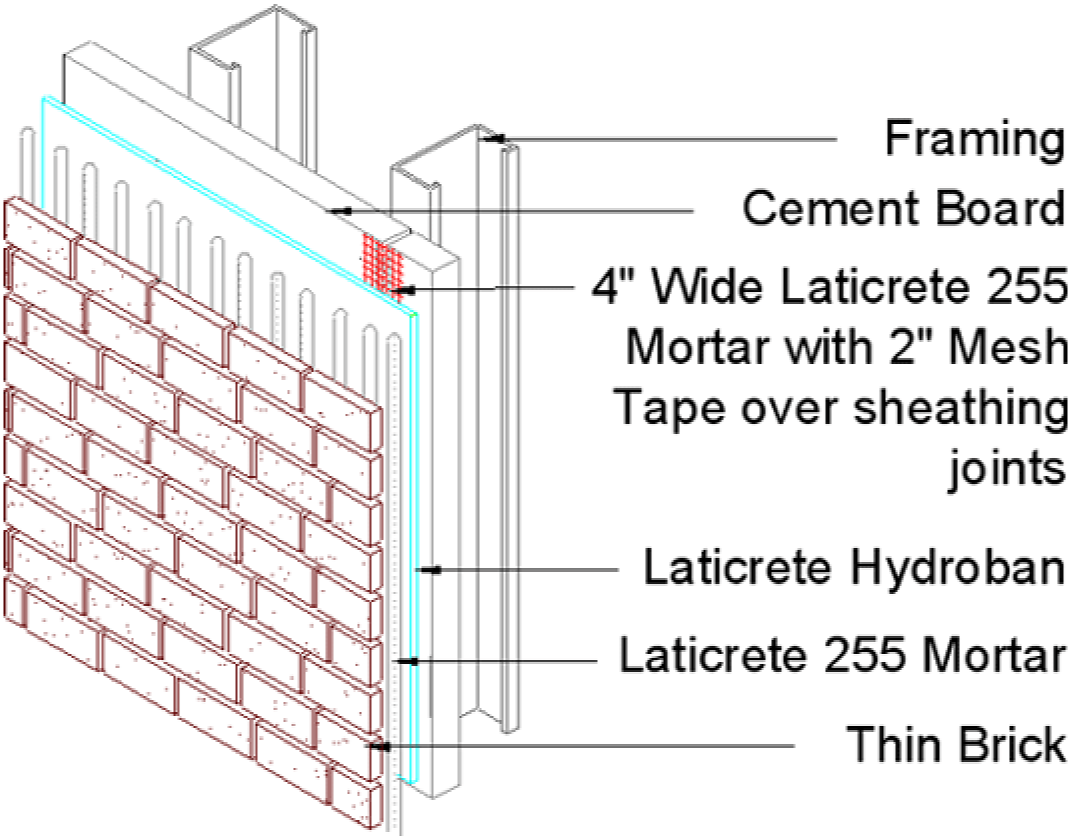


Figure 16: Thin brick construction. (http://www.specifiedproductsinc.com/products_brick.htm)

After fully understanding the systems and its pros and cons, it was time to calculate the cost and duration of constructing this prefabricated system. I first calculated the entire brick façade area, which is 33,472 square feet, to know how many materials are going to be needed. I then went to RS Means CostWorks and found all of the materials needed in the façade. I entered the quantities into the spreadsheet to come up with a total of **$3,328,558.00**. The duration of the construction of the prefabricated façade was **213 days**. This was shorter than the traditional stick built façade that was used on the Emily Couric Clinical Cancer Center. In **Table 1** below, the comparisons of the original façade and the prefabricated façade are shown.

	Original	Prefab
Schedule	244	178
Cost	$1,836,375.00	$3,234,414.00

Table 1: Original vs. Prefabrication

The original schedule duration came from the schedule I received from Gilbane Building Company and the cost came from numbers also provided by Gilbane Building Company. The estimate I calculated for the prefab is included in **Appendix C**. I only priced the brick portion of the façade because that is what my study focused on. The stick built cost, including overhead and profit, of the brick façade is **$1,836,375.00**. The prefab estimate including overhead and profit is **$3,234,414.00**. The difference of these two is $1,398,039.00 in which the prefabrication process costs significantly more than the original.

Although this price difference is significant, it still needs to be considered that the prefabricated façade can be installed much faster. The construction days are quite shorter for the prefab and this is still a bit misleading because the prefabricated façade can be built and stored in the factory and delivered to the site when ready. This could reduce the schedule even more.

I calculated the size of a typical panel of prefabricated façade to be the distance from column to column and between windows. This calculation is as follows:

Panel area: columns X dist between windows = 30’ X 7’ = 210 SF
Façade area / panel area = 33472 SF X 210 SF = 159 panels

Wayne Martin, with Eastern Exterior Wall Systems, Inc., informed me that typically a crew can install eight panels a day in an eight hour day. Therefore, the amount of time needed to install these panels is calculated as follows:

159 panels / 8 panels per day = 20 days

It would take 20 days to install all of the brick façade if it was prefabricated and delivered to the job site when it was needed. This is a very significant difference from 244 days to install the façade. This takes over a month off of the schedule. Having this section of the building can allow for other tasks to get started earlier even though the curtain wall will still take 159 days to be constructed. Overall, this process allows for the substantial completion date to be moved up two months. A detailed schedule can be found in **Appendix D**.

After all of the analyses conducted on this study, the benefits of doing prefabrication definitely outweigh the negative aspects of choosing this method. Although the prefabricated system costs nearly double the traditional method costs, the prefabricated system provides a much higher quality of building because it does not allow for the leaks and mistakes like the traditional stick built process. It is constructed in a factory where it can be inspected more frequently and mistakes can be caught easier and quicker. It also does not allow for water to collect in the wall because there is no air cavity for it to collect in. There is no need for sealants at the slab edge and any weep systems. This allows the building to be more tightly enclosed and this would be of value to the University of Virginia because this building is going to be used for cancer patients who cannot be exposed to a lot of mold and germs.

Another benefit of using the prefabricated system is that it will reduce the schedule by two months and will allow the owner to take over the building and use it two months earlier. This will allow the university to start making money from the building faster. Other benefits could be that the new system provides a better R-value and has less heat loss than the planned system. This will be discussed in the next section to cover my mechanical breadth. It also improves the site logistics plan because the site is so small there is not much room for the contractors to store materials and move around the building. Prefabricating the façade reduces the amount of materials that need to be stored on the site and helps to improve the amount of space available to other contractors and keeping the site clean. Also, the amount of scaffolding will be reduced which also cuts down on the cost and site logistics.

PREFABRICATION (CONTINUED): MECHANICAL BREADTH STUDY

Background

While analyzing the options of prefabricating the brick veneer façade, it is a possibility that the façade materials could change. Changing the façade materials, changes the properties of the wall which also changes the walls ability to either hold or lose heat. With a majority of the façade being brick veneer, changing the properties of the wall would have a significant impact on the mechanical system if the R-values change too much.

Research Steps

1. Calculate the R-value of the designed wall.
2. Decide to change the materials of the façade.
3. Calculate the R-value of the new façade materials
4. Compare the R-values and heat losses of the walls.
5. Analyze and decide which is better and if it contributes to the pros or cons of prefabricating the brick veneer façade.

Expected Outcome

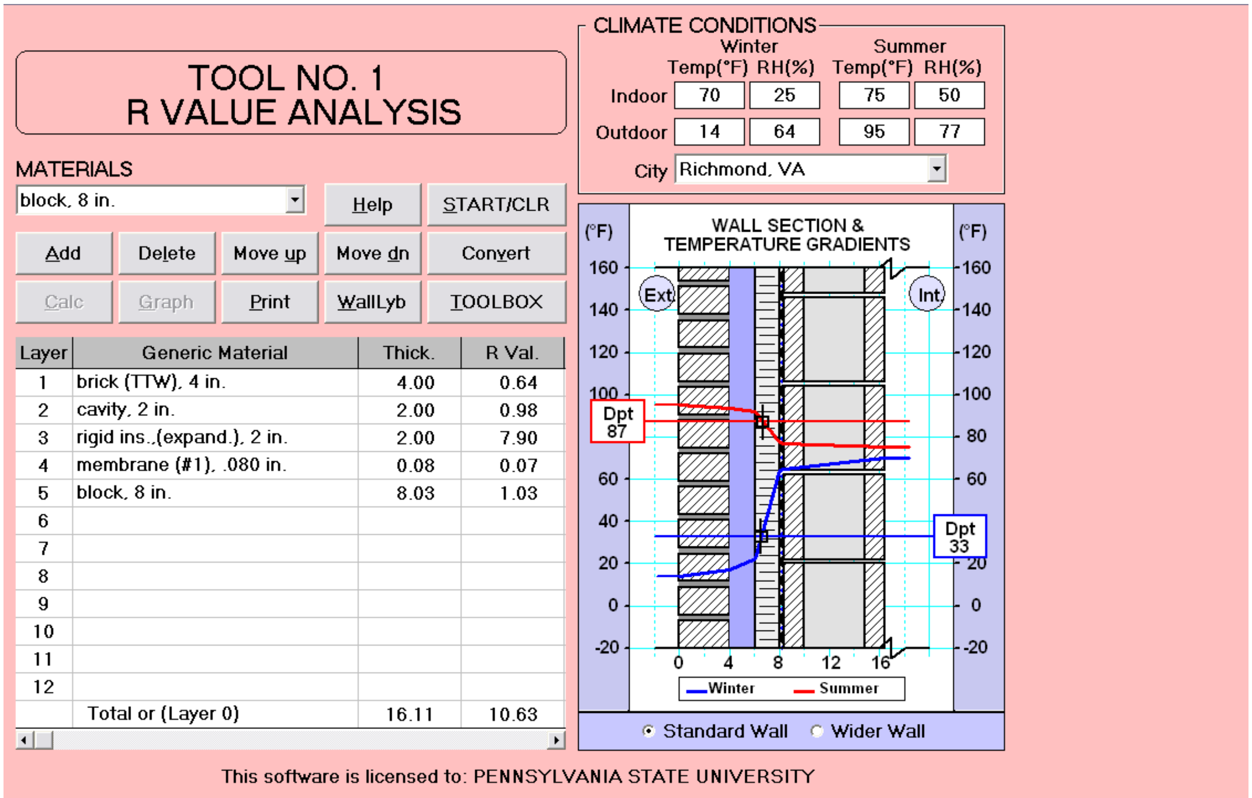
It is expected that changing the brick façade to a thin brick prefabricated system will improve the R-value of the wall from the traditional stick built brick façade. The heat losses are expected to be reduced by the new system, which could impact the mechanical system.

Analysis

Changing from the designed brick façade to the prefabricated brick façade changes the properties of the wall which could either decrease or increase the amount of heat loss for these walls. This could be detrimental to the mechanical system and could cause more issues than benefits. To fully understand how the walls function thermally, the R-values and U-values need to be calculated.

To calculate the R-values the program H.A.M. Toolbox will be used. This program has R-values of materials already programmed into the system and will calculate the total R-value of the assembly once it is imported.

The first step in using H.A.M. Toolbox is to select the location of the building. The closest location to Charlottesville, VA is Richmond, VA so that is what I selected to get the design parameters. This gave me the design temperatures of indoor 70 degrees Fahrenheit and 75 degrees Fahrenheit for winter and summer temperatures respectively. The outdoor temperatures are 14 degrees Fahrenheit and 95 degrees Fahrenheit for winter and summer respectively. These temperatures and the rest of the calculations for R-values can be found in **Figure 17** below. These temperatures will not change because the location does not change.



CLIMATE CONDITIONS

	Winter Temp(°F)	Winter RH(%)	Summer Temp(°F)	Summer RH(%)
Indoor	70	25	75	50
Outdoor	14	64	95	77

City: Richmond, VA

MATERIALS: block, 8 in.

Layer	Generic Material	Thick.	R Val.
1	brick (TTW), 4 in.	4.00	0.64
2	cavity, 2 in.	2.00	0.98
3	rigid ins.,(expand.), 2 in.	2.00	7.90
4	membrane (#1), .080 in.	0.08	0.07
5	block, 8 in.	8.03	1.03
6			
7			
8			
9			
10			
11			
12			
	Total or (Layer 0)	16.11	10.63

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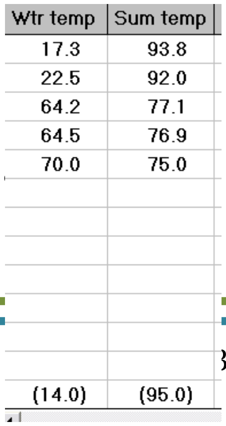
The items that do change are the wall properties. In the pictures of the program results you can see the different make ups of the materials. They are represented both graphically and in a list. The two can be compared in **Figure 17** and **Figure 18**. The originally designed façade consists of the following items:

- Brick
- Air Cavity
- Rigid Insulation
- A Transition Membrane
- And 8” CMU Block

These items are much different than the prefabricated façade materials which

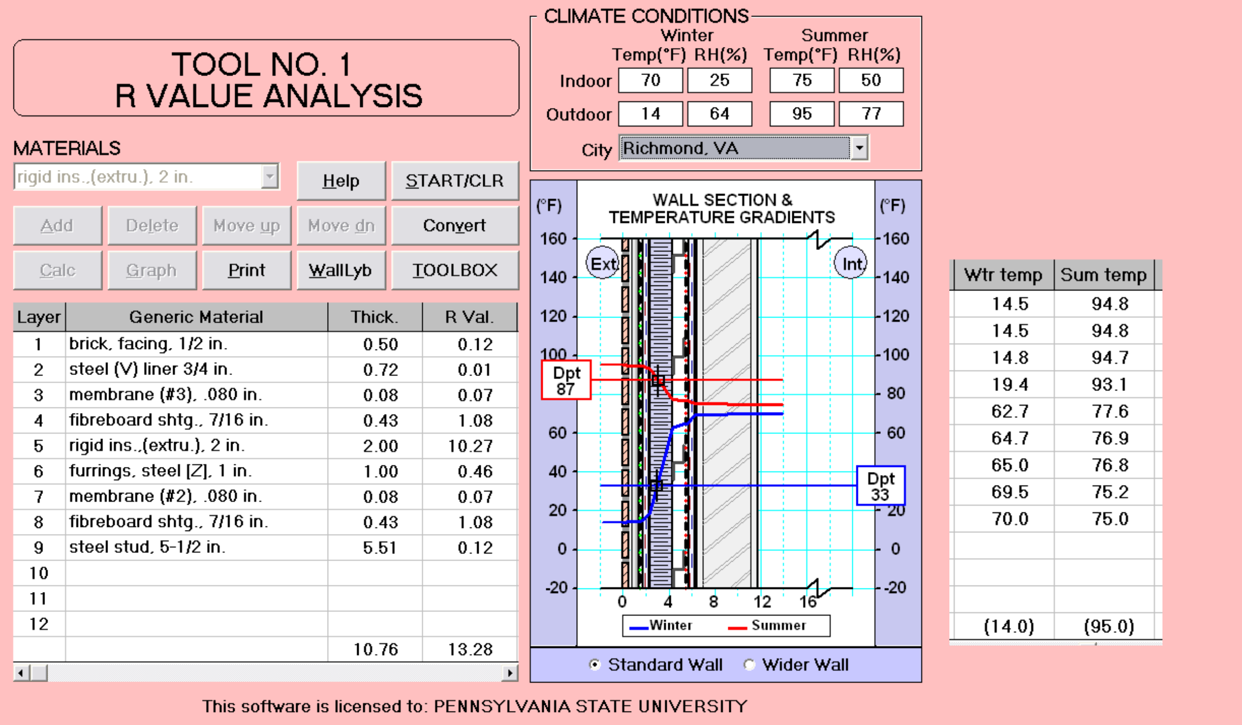
- Cold formed structural stud: 6" 16 ga. 1-5/8" @ 16" o.c.



Wtr temp	Sum temp
17.3	93.8
22.5	92.0
64.2	77.1
64.5	76.9
70.0	75.0
(14.0)	(95.0)

- 5/8" sheathing
- WP membrane
- Z
- 5/8" sheathing
- Lath
- Scratch coat
- Laticrete
- Thin brick

The R-values calculated for each of these assemblies are **10.63** for the originally designed brick façade and **13.28** for the prefabricated façade. These values can be seen in **Figure 17** and **Figure 18** which are shown above and below.



TOOL NO. 1
R VALUE ANALYSIS

CLIMATE CONDITIONS

	Winter Temp(°F)	Winter RH(%)	Summer Temp(°F)	Summer RH(%)
Indoor	70	25	75	50
Outdoor	14	64	95	77

City: Richmond, VA

MATERIALS: rigid ins.,(extru.), 2 in.

Layer	Generic Material	Thick.	R Val.
1	brick, facing, 1/2 in.	0.50	0.12
2	steel (V) liner 3/4 in.	0.72	0.01
3	membrane (#3), .080 in.	0.08	0.07
4	fibreboard shtg., 7/16 in.	0.43	1.08
5	rigid ins.,(extru.), 2 in.	2.00	10.27
6	furrings, steel [Z], 1 in.	1.00	0.46
7	membrane (#2), .080 in.	0.08	0.07
8	fibreboard shtg., 7/16 in.	0.43	1.08
9	steel stud, 5-1/2 in.	5.51	0.12
10			
11			
12			
		10.76	13.28

Wtr temp	Sum temp
14.5	94.8
14.5	94.8
14.8	94.7
19.4	93.1
62.7	77.6
64.7	76.9
65.0	76.8
69.5	75.2
70.0	75.0
(14.0)	(95.0)

● Standard Wall ○ Wider Wall

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Figure 18: Prefabricated Facade (H.A.M. Toolbox)

Now that the R-values are calculated, the U-values can be calculated by taking the reciprocal of R-value. The U-value is more valuable because you can calculate the heat loss with this value. The R-value simply helps get the U-value. The following equation is used to calculate heat loss for a flat surface: The area used will be 33,472 SF for the brick façade and the temperature difference will be 56 degrees and -20 degrees for winter and summer respectively.

Q = UAT

U = Conductance

A = Surface Area
T = Temperature Difference

Table 2, on the next page, is a chart of the U-values and the heat loss of each of the two different facades.

	U-Value Equation	U-Value	Winter Heat Loss	Summer Heat Loss
Originally Designed Façade	1/10.63	0.0941	176,384 BTU/HR	-62,994 BTU/HR
Prefabricated Façade	1/13.28	0.0753	141,145 BTU/HR	-50,409 BTU/HR

Table 2: U-Values and Heat Loss Calculations

These values show that the prefabricated façade has a much better insulation factor that results in less heat loss than the originally designed brick façade. This could be another pro to choosing the prefabricated façade. Overall, the prefabricated is definitely a better choice than the other design even though it is more costly, there are many benefits and having less heat loss is one of them since it will cost less to heat the building because of the reduced heat loss. \

CONCLUSIONS

This thesis has covered many different topics but each one involving the façade in some way. Critical industry research has been conducted, value engineering ideas have been introduced and analyzed, there was constructability reviews completed and a schedule reduction analysis completed.

The first analysis discussed was the use of BIM technologies for façade construction. This topic consisted of a survey given to industry members to complete and provide insight as to how BIM was currently being used in the industry for façade construction. It also gave them the opportunity to express how they feel about the technology and what they would like to see happen in the future with the technology. It was determined that using BIM on the Emily Couric Clinical Cancer Center would have been beneficial, at least to use on mockups, because it reduces the conflicts in the field and shop drawings can be created and coordinated from this process. Using BIM would have made the coordination process go a lot smoother and probably take less time than the traditional methods of coordination.

The second analysis was the analysis that focused on incorporating solar panels into curtain wall of the building. This served an electrical breadth and was determined not beneficial to the project. The energy savings was not significant enough to have an impact on payback period. To be implemented into the project, the payback would need to be around five to ten years, not the 41 years that it was calculated to be.

The third and final analysis was the prefabrication of the brick façade. This analysis served as a construction management depth and mechanical breadth. It discussed the advantages and the disadvantages of using the prefabricated system. The biggest disadvantage is the cost of the prefabricated façade is much more expensive. There are many advantages though include it can reduce the schedule significantly and also increases the insulation which has an impact on the mechanical system. It loses less heat and helps to save on energy bills in the winter. The quality of the prefabricated façade is also a large benefit because it does not have space for water to collect and damage the building by leaks and mold.

All of these analyses have been very educational and I will use all of the information learned here in everyday life as a construction manager. The lessons learned have been very valuable from how important time management is to the very tiny details of how the prefabrication process is used and implemented.

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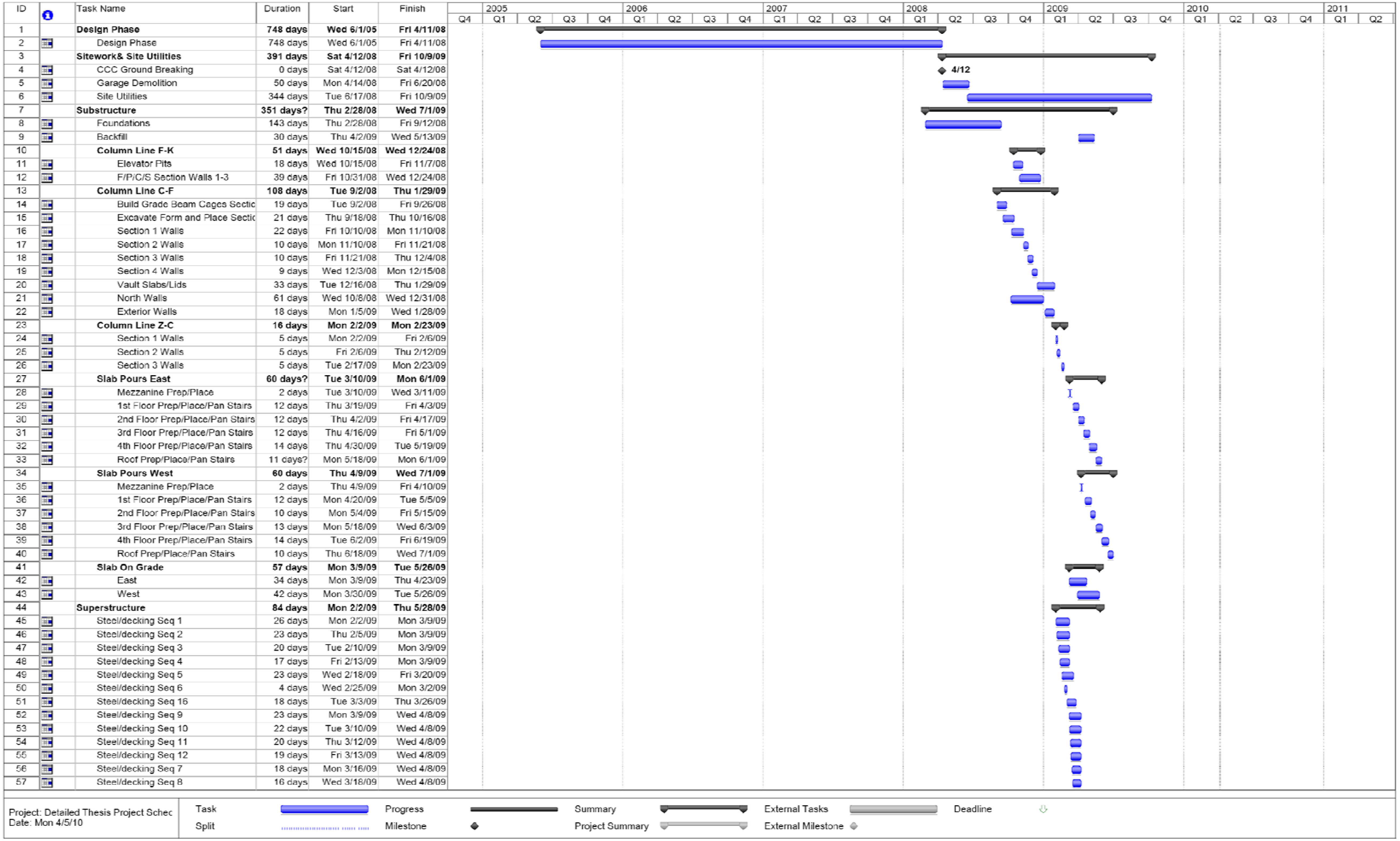
APPENDIX A: DETAILED PROJECT SCHEDULE



ID	ℹ	Task Name	Duration	Start	Finish
1		**Design Phase**	**748 days**	**Wed 6/1/05**	**Fri 4/11/08**
2	▦	Design Phase	748 days	Wed 6/1/05	Fri 4/11/08
3		**Sitework& Site Utilities**	**391 days**	**Sat 4/12/08**	**Fri 10/9/09**
4	▦	CCC Ground Breaking	0 days	Sat 4/12/08	Sat 4/12/08
5	▦	Garage Demolition	50 days	Mon 4/14/08	Fri 6/20/08
6	▦	Site Utilities	344 days	Tue 6/17/08	Fri 10/9/09
7		**Substructure**	**351 days?**	**Thu 2/28/08**	**Wed 7/1/09**
8	▦	Foundations	143 days	Thu 2/28/08	Fri 9/12/08
9	▦	Backfill	30 days	Thu 4/2/09	Wed 5/13/09
10		**Column Line F-K**	**51 days**	**Wed 10/15/08**	**Wed 12/24/08**
11	▦	Elevator Pits	18 days	Wed 10/15/08	Fri 11/7/08
12	▦	F/P/C/S Section Walls 1-3	39 days	Fri 10/31/08	Wed 12/24/08
13		**Column Line C-F**	**108 days**	**Tue 9/2/08**	**Thu 1/29/09**
14	▦	Build Grade Beam Cages Sectic	19 days	Tue 9/2/08	Fri 9/26/08
15	▦	Excavate Form and Place Sectic	21 days	Thu 9/18/08	Thu 10/16/08
16	▦	Section 1 Walls	22 days	Fri 10/10/08	Mon 11/10/08
17	▦	Section 2 Walls	10 days	Mon 11/10/08	Fri 11/21/08
18	▦	Section 3 Walls	10 days	Fri 11/21/08	Thu 12/4/08
19	▦	Section 4 Walls	9 days	Wed 12/3/08	Mon 12/15/08
20	▦	Vault Slabs/Lids	33 days	Tue 12/16/08	Thu 1/29/09
21	▦	North Walls	61 days	Wed 10/8/08	Wed 12/31/08
22	▦	Exterior Walls	18 days	Mon 1/5/09	Wed 1/28/09
23		**Column Line Z-C**	**16 days**	**Mon 2/2/09**	**Mon 2/23/09**
24	▦	Section 1 Walls	5 days	Mon 2/2/09	Fri 2/6/09
25	▦	Section 2 Walls	5 days	Fri 2/6/09	Thu 2/12/09
26	▦	Section 3 Walls	5 days	Tue 2/17/09	Mon 2/23/09
27		**Slab Pours East**	**60 days?**	**Tue 3/10/09**	**Mon 6/1/09**
28	▦	Mezzanine Prep/Place	2 days	Tue 3/10/09	Wed 3/11/09
29	▦	1st Floor Prep/Place/Pan Stairs	12 days	Thu 3/19/09	Fri 4/3/09
30	▦	2nd Floor Prep/Place/Pan Stairs	12 days	Thu 4/2/09	Fri 4/17/09
31	▦	3rd Floor Prep/Place/Pan Stairs	12 days	Thu 4/16/09	Fri 5/1/09
32	▦	4th Floor Prep/Place/Pan Stairs	14 days	Thu 4/30/09	Tue 5/19/09
33	▦	Roof Prep/Place/Pan Stairs	11 days?	Mon 5/18/09	Mon 6/1/09
34		**Slab Pours West**	**60 days**	**Thu 4/9/09**	**Wed 7/1/09**
35	▦	Mezzanine Prep/Place	2 days	Thu 4/9/09	Fri 4/10/09
36	▦	1st Floor Prep/Place/Pan Stairs	12 days	Mon 4/20/09	Tue 5/5/09
37	▦	2nd Floor Prep/Place/Pan Stairs	10 days	Mon 5/4/09	Fri 5/15/09
38	▦	3rd Floor Prep/Place/Pan Stairs	13 days	Mon 5/18/09	Wed 6/3/09
39	▦	4th Floor Prep/Place/Pan Stairs	14 days	Tue 6/2/09	Fri 6/19/09
40	▦	Roof Prep/Place/Pan Stairs	10 days	Thu 6/18/09	Wed 7/1/09
41		**Slab On Grade**	**57 days**	**Mon 3/9/09**	**Tue 5/26/09**
42	▦	East	34 days	Mon 3/9/09	Thu 4/23/09
43	▦	West	42 days	Mon 3/30/09	Tue 5/26/09
44		**Superstructure**	**84 days**	**Mon 2/2/09**	**Thu 5/28/09**
45	▦	Steel/decking Seq 1	26 days	Mon 2/2/09	Mon 3/9/09
46	▦	Steel/decking Seq 2	23 days	Thu 2/5/09	Mon 3/9/09
47	▦	Steel/decking Seq 3	20 days	Tue 2/10/09	Mon 3/9/09
48	▦	Steel/decking Seq 4	17 days	Fri 2/13/09	Mon 3/9/09
49	▦	Steel/decking Seq 5	23 days	Wed 2/18/09	Fri 3/20/09
50	▦	Steel/decking Seq 6	4 days	Wed 2/25/09	Mon 3/2/09
51	▦	Steel/decking Seq 16	18 days	Tue 3/3/09	Thu 3/26/09
52	▦	Steel/decking Seq 9	23 days	Mon 3/9/09	Wed 4/8/09
53	▦	Steel/decking Seq 10	22 days	Tue 3/10/09	Wed 4/8/09
54	▦	Steel/decking Seq 11	20 days	Thu 3/12/09	Wed 4/8/09
55	▦	Steel/decking Seq 12	19 days	Fri 3/13/09	Wed 4/8/09
56	▦	Steel/decking Seq 7	18 days	Mon 3/16/09	Wed 4/8/09
57	▦	Steel/decking Seq 8	16 days	Wed 3/18/09	Wed 4/8/09

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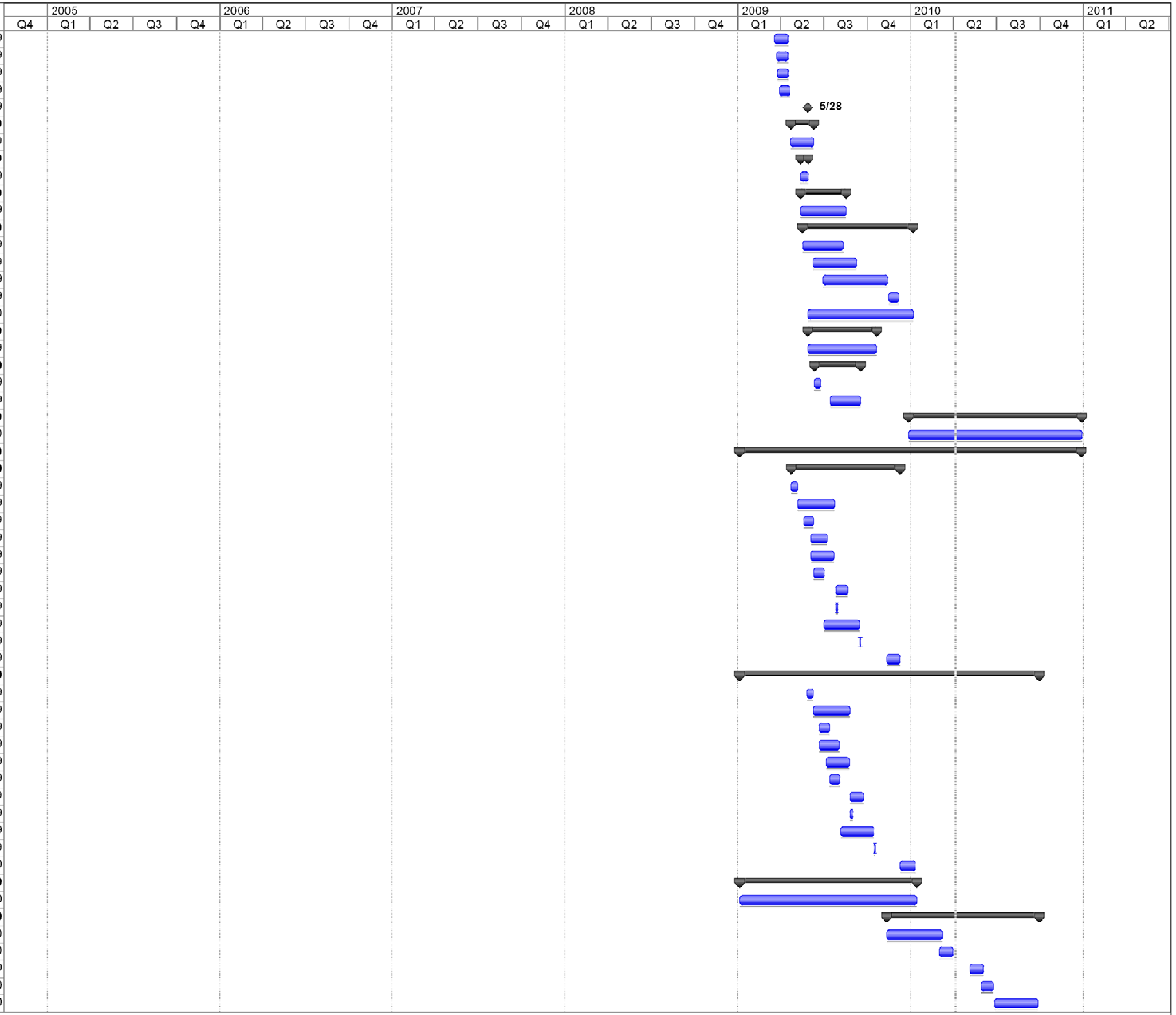
ID	ℹ	Task Name	Duration	Start	Finish
58	▦	Steel/decking Seq 14	20 days	Fri 3/20/09	Thu 4/16/09
59	▦	Steel/decking Seq 15	18 days	Tue 3/24/09	Thu 4/16/09
60	▦	Steel/decking Seq 13	16 days	Thu 3/26/09	Thu 4/16/09
61	▦	Steel/decking Seq 17	16 days	Mon 3/30/09	Mon 4/20/09
62	▦	Structure Top out	0 days	Thu 5/28/09	Thu 5/28/09
63		**Fire Proofing**	**35 days**	**Thu 4/23/09**	**Wed 6/10/09**
64	▦	Fire Proofing	35 days	Thu 4/23/09	Wed 6/10/09
65		**West Terrace Structure**	**12 days?**	**Thu 5/14/09**	**Fri 5/29/09**
66	▦	West Terrace	12 days?	Thu 5/14/09	Fri 5/29/09
67		**Loading Dock Structure**	**68 days**	**Thu 5/14/09**	**Mon 8/17/09**
68	▦	Loading Dock Structure	68 days	Thu 5/14/09	Mon 8/17/09
69		**Façade**	**168 days**	**Mon 5/18/09**	**Wed 1/6/10**
70	▦	East/North Column F	62 days	Mon 5/18/09	Tue 8/11/09
71	▦	North/West Elevations	67 days	Tue 6/9/09	Wed 9/9/09
72	▦	Penthouse	99 days	Tue 6/30/09	Fri 11/13/09
73	▦	South Elevation	16 days	Mon 11/16/09	Mon 12/7/09
74	▦	Curtain Wall All Elevations	159 days	Fri 5/29/09	Wed 1/6/10
75		**Roof**	**104 days**	**Fri 5/29/09**	**Wed 10/21/09**
76	▦	Roof	104 days	Fri 5/29/09	Wed 10/21/09
77		**MEP**	**70 days**	**Fri 6/12/09**	**Thu 9/17/09**
78	▦	MEP Rough-in East Risers	10 days	Fri 6/12/09	Thu 6/25/09
79	▦	MEP Rough-in West Risers	47 days	Wed 7/15/09	Thu 9/17/09
80		**Finishes**	**263 days**	**Mon 12/28/09**	**Wed 12/29/10**
81	▦	Finishes	263 days	Mon 12/28/09	Wed 12/29/10
82		**Interiors**	**517 days?**	**Mon 1/5/09**	**Wed 12/29/10**
83		**Ground East**	**165 days**	**Fri 4/24/09**	**Thu 12/10/09**
84	▦	Fire Proofing	10 days	Fri 4/24/09	Thu 5/7/09
85	▦	Frame Walls	56 days	Fri 5/8/09	Fri 7/24/09
86	▦	Duct Rough-in	16 days	Wed 5/20/09	Wed 6/10/09
87	▦	Electrical Rooms/Equipment	26 days	Thu 6/4/09	Thu 7/9/09
88	▦	HVAC/Plumbing Piping	36 days	Thu 6/4/09	Thu 7/23/09
89	▦	Duct Branches/Sprinkler Main	16 days	Thu 6/11/09	Thu 7/2/09
90	▦	Plumbing Rough-in	20 days	Mon 7/27/09	Fri 8/21/09
91	▦	Medical Gas Rough-in	5 days	Mon 7/27/09	Fri 7/31/09
92	▦	Electrical Rough-in	54 days	Thu 7/2/09	Tue 9/15/09
93	▦	Inspections	2 days	Wed 9/16/09	Thu 9/17/09
94	▦	Pull Wire	21 days	Thu 11/12/09	Thu 12/10/09
95		**Ground West**	**454 days**	**Mon 1/5/09**	**Thu 9/30/10**
96	▦	Fire Proofing	10 days	Wed 5/27/09	Tue 6/9/09
97	▦	Frame Walls	55 days	Wed 6/10/09	Tue 8/25/09
98	▦	Duct Rough-in	16 days	Mon 6/22/09	Mon 7/13/09
99	▦	Electrical Rooms/Equipment	31 days	Mon 6/22/09	Mon 8/3/09
100	▦	HVAC/Plumbing Piping	35 days	Tue 7/7/09	Mon 8/24/09
101	▦	Duct Branches/Sprinkler Main	16 days	Tue 7/14/09	Tue 8/4/09
102	▦	Plumbing Rough-in	21 days	Wed 8/26/09	Wed 9/23/09
103	▦	Medical Gas Rough-in	5 days	Wed 8/26/09	Tue 9/1/09
104	▦	Electrical Rough-in	50 days	Fri 8/7/09	Thu 10/15/09
105	▦	Inspections	2 days	Fri 10/16/09	Mon 10/19/09
106	▦	Pull Wire	22 days	Fri 12/11/09	Mon 1/11/10
107		**Main Electrical Room**	**269 days**	**Mon 1/5/09**	**Thu 1/14/10**
108	▦	Main Electrical Room	269 days	Mon 1/5/09	Thu 1/14/10
109		**Finishes**	**231 days**	**Thu 11/12/09**	**Thu 9/30/10**
110	▦	Partitions/Ceilings/Soffits/Fi	85 days	Thu 11/12/09	Wed 3/10/10
111	▦	Light Fixtures	20 days	Thu 3/4/10	Wed 3/31/10
112	▦	Casework	21 days	Fri 5/7/10	Fri 6/4/10
113	▦	Plumbing Fixtures	20 days	Mon 5/31/10	Fri 6/25/10
114	▦	Misc. Finishes	66 days	Mon 6/28/10	Mon 9/27/10



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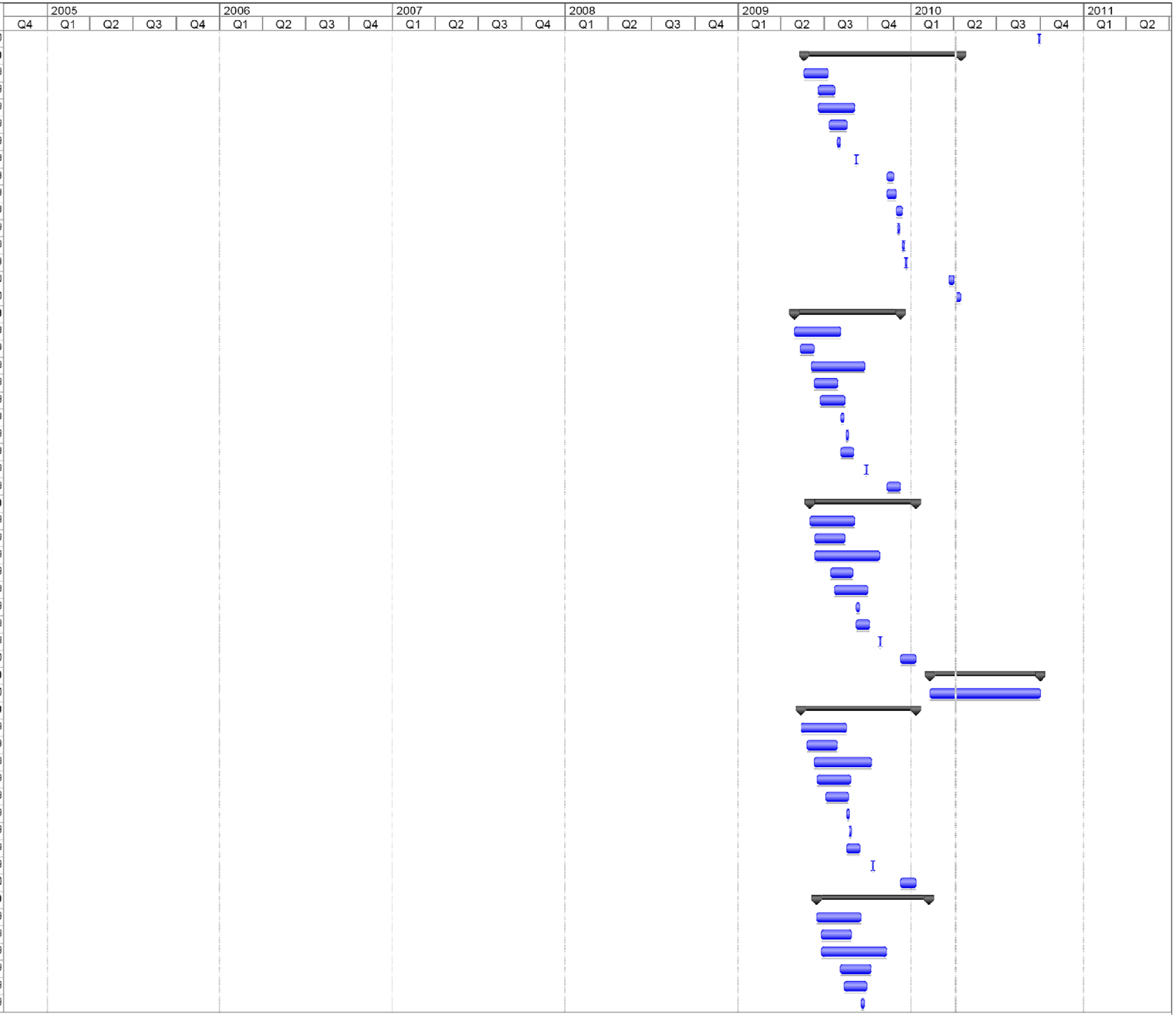
Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◇		

ID	ℹ	Task Name	Duration	Start	Finish
115	▦	TAB	3 days	Tue 9/28/10	Thu 9/30/10
116		**Mezzanine/Sub Basement Mechani**	**237 days**	**Thu 5/21/09**	**Fri 4/16/10**
117	▦	Mechanical Equipment/Sprinkler	37 days	Thu 5/21/09	Fri 7/10/09
118	▦	HVAC Piping	26 days	Fri 6/19/09	Fri 7/24/09
119	▦	Electrical Rough-in	56 days	Fri 6/19/09	Fri 9/4/09
120	▦	Electrical Conduit Feeder/Equipr	27 days	Mon 7/13/09	Tue 8/18/09
121	▦	Frame Walls	4 days	Thu 7/30/09	Tue 8/4/09
122	▦	Inspections	1 day	Tue 9/8/09	Tue 9/8/09
123	▦	Pull Wire	10 days	Thu 11/12/09	Wed 11/25/09
124	▦	Hang/Finish Drywall	13 days	Thu 11/12/09	Mon 11/30/09
125	▦	Pneumatic Tube Equipment	10 days	Tue 12/1/09	Mon 12/14/09
126	▦	Test Electrical Equipment	3 days	Fri 12/4/09	Tue 12/8/09
127	▦	Paint	4 days	Tue 12/15/09	Fri 12/18/09
128	▦	Install Fixtures	3 days	Mon 12/21/09	Wed 12/23/09
129	▦	Misc. Finishes	9 days	Tue 3/23/10	Fri 4/2/10
130	▦	TAB	10 days	Mon 4/5/10	Fri 4/16/10
131		**1st Floor East**	**161 days**	**Thu 4/30/09**	**Thu 12/10/09**
132	▦	Frame Walls	70 days	Thu 4/30/09	Wed 8/5/09
133	▦	HVAC/Plumbing Piping	22 days	Tue 5/12/09	Wed 6/10/09
134	▦	Electrical Rough-in	81 days	Fri 6/5/09	Fri 9/25/09
135	▦	Electrical Conduit Feeder/Equipr	36 days	Thu 6/11/09	Thu 7/30/09
136	▦	Duct Branches/Mech. Equip. Sh	39 days	Tue 6/23/09	Fri 8/14/09
137	▦	Medical Gas Rough-in	5 days	Thu 8/6/09	Wed 8/12/09
138	▦	Elevator Shafts	5 days	Mon 8/17/09	Fri 8/21/09
139	▦	Plumbing Rough-in	20 days	Thu 8/6/09	Wed 9/2/09
140	▦	Inspections	2 days	Mon 9/28/09	Tue 9/29/09
141	▦	Pull Wire	21 days	Thu 11/12/09	Thu 12/10/09
142		**1st Floor West**	**160 days**	**Tue 6/2/09**	**Mon 1/11/10**
143	▦	Frame Walls	69 days	Tue 6/2/09	Fri 9/4/09
144	▦	HVAC/Plumbing Piping	46 days	Fri 6/12/09	Fri 8/14/09
145	▦	Electrical Rough-in	98 days	Fri 6/12/09	Tue 10/27/09
146	▦	Electrical Conduit Feeder/Equipr	33 days	Thu 7/16/09	Mon 8/31/09
147	▦	Duct Branches/Mech. Equip. Sh	50 days	Fri 7/24/09	Thu 10/1/09
148	▦	Medical Gas Rough-in	5 days	Tue 9/8/09	Mon 9/14/09
149	▦	Plumbing Rough-in	20 days	Tue 9/8/09	Mon 10/5/09
150	▦	Inspections	2 days	Wed 10/28/09	Thu 10/29/09
151	▦	Pull Wire	22 days	Fri 12/11/09	Mon 1/11/10
152		**Lobby**	**167 days**	**Thu 2/11/10**	**Fri 10/1/10**
153	▦	Lobby	167 days	Thu 2/11/10	Fri 10/1/10
154		**2nd Floor East**	**173 days?**	**Thu 5/14/09**	**Mon 1/11/10**
155	▦	Frame Walls	68 days?	Thu 5/14/09	Mon 8/17/09
156	▦	HVAC/Plumbing Piping	46 days?	Wed 5/27/09	Wed 7/29/09
157	▦	Electrical Rough-in	87 days?	Thu 6/11/09	Fri 10/9/09
158	▦	Electrical Conduit Feeder/Equipr	52 days?	Wed 6/17/09	Thu 8/27/09
159	▦	Duct Branches/Mech. Equip. Sh	35 days?	Mon 7/6/09	Fri 8/21/09
160	▦	Medical Gas Rough-in	5 days?	Tue 8/18/09	Mon 8/24/09
161	▦	Elevator Shafts	5 days?	Mon 8/24/09	Fri 8/28/09
162	▦	Plumbing Rough-in	21 days?	Tue 8/18/09	Tue 9/15/09
163	▦	Inspections	2 days?	Mon 10/12/09	Tue 10/13/09
164	▦	Pull Wire	22 days?	Fri 12/11/09	Mon 1/11/10
165		**2nd Floor West**	**170 days?**	**Tue 6/16/09**	**Mon 2/8/10**
166	▦	Frame Walls	68 days?	Tue 6/16/09	Thu 9/17/09
167	▦	HVAC/Plumbing Piping	46 days?	Fri 6/26/09	Fri 8/28/09
168	▦	Electrical Rough-in	98 days?	Fri 6/26/09	Tue 11/10/09
169	▦	Duct Branches/Mech. Equip. Sh	47 days?	Wed 8/5/09	Thu 10/8/09
170	▦	Electrical Conduit Feeder/Equipr	34 days?	Thu 8/13/09	Tue 9/29/09
171	▦	Medical Gas Rough-in	5 days?	Fri 9/18/09	Thu 9/24/09



Project: Detailed Thesis Project Schec
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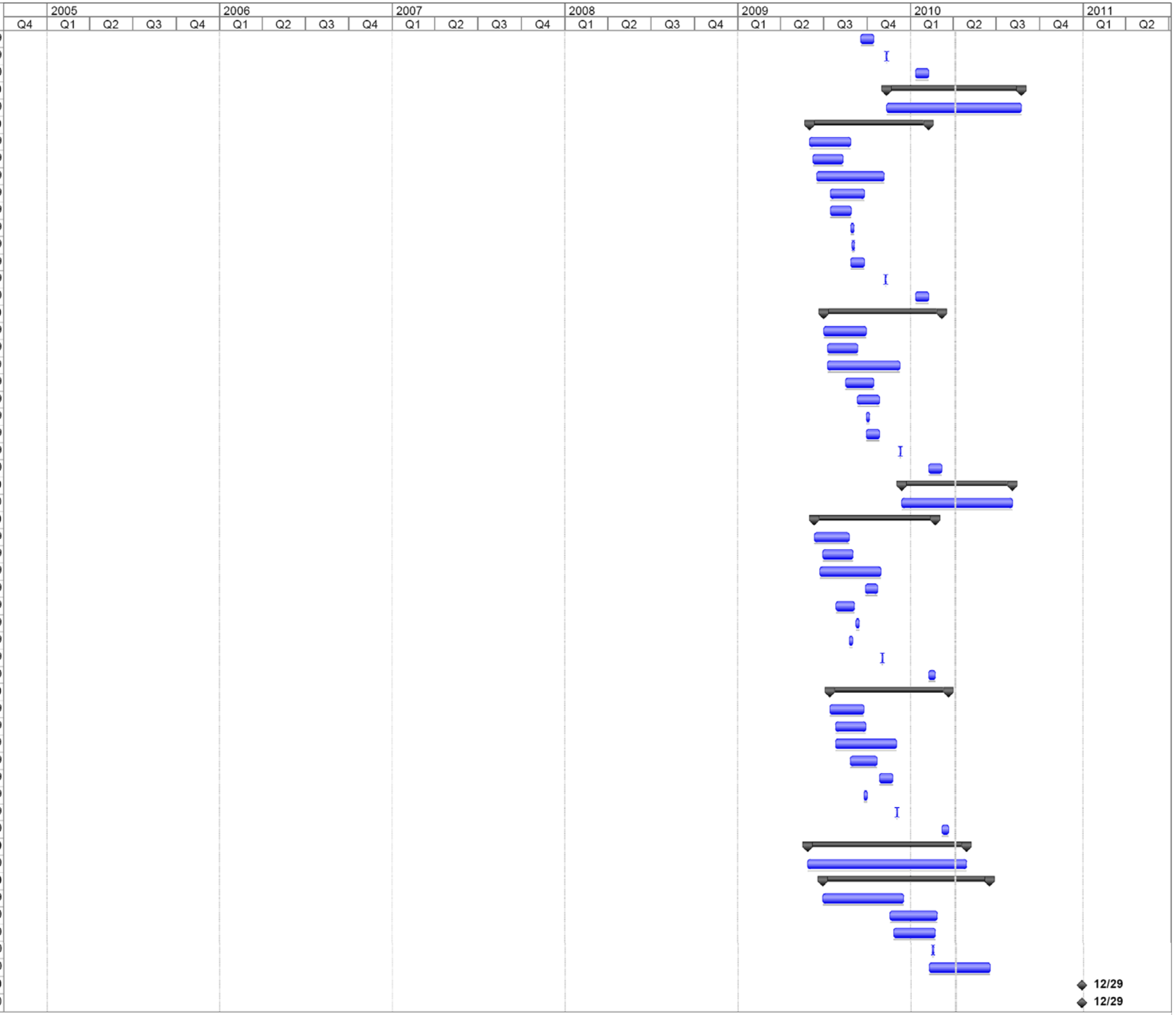
Task
Split
Progress
Milestone ◆
Summary
Project Summary
External Tasks
External Milestone ◆
Deadline ⇩

ID	ℹ	Task Name	Duration	Start	Finish
172	▦	Plumbing Rough-in	20 days?	Fri 9/18/09	Thu 10/15/09
173	▦	Inspections	2 days?	Wed 11/11/09	Thu 11/12/09
174	▦	Pull Wire	20 days?	Tue 1/12/10	Mon 2/8/10
175		**Lobby**	**203 days**	**Thu 11/12/09**	**Mon 8/23/10**
176	▦	Lobby	203 days	Thu 11/12/09	Mon 8/23/10
177		**3rd Floor East**	**180 days?**	**Tue 6/2/09**	**Mon 2/8/10**
178	▦	Frame Walls	63 days?	Tue 6/2/09	Thu 8/27/09
179	▦	HVAC/Plumbing Piping	46 days?	Tue 6/9/09	Tue 8/11/09
180	▦	Electrical Rough-in	103 days?	Wed 6/17/09	Fri 11/6/09
181	▦	Electrical Conduit Feeder/Equipı	52 days?	Thu 7/16/09	Fri 9/25/09
182	▦	Duct Branches/Mech. Equip. Sh	32 days?	Thu 7/16/09	Fri 8/28/09
183	▦	Medical Gas Rough-in	5 days?	Fri 8/28/09	Thu 9/3/09
184	▦	Elevator Shafts	5 days?	Mon 8/31/09	Fri 9/4/09
185	▦	Plumbing Rough-in	21 days?	Fri 8/28/09	Fri 9/25/09
186	▦	Inspections	2 days?	Mon 11/9/09	Tue 11/10/09
187	▦	Pull Wire	20 days?	Tue 1/12/10	Mon 2/8/10
188		**3rd Floor West**	**178 days?**	**Thu 7/2/09**	**Mon 3/8/10**
189	▦	Frame Walls	64 days?	Thu 7/2/09	Tue 9/29/09
190	▦	HVAC/Plumbing Piping	46 days?	Fri 7/10/09	Fri 9/11/09
191	▦	Electrical Rough-in	109 days?	Fri 7/10/09	Wed 12/9/09
192	▦	Duct Branches/Mech. Equip. Sh	44 days?	Mon 8/17/09	Thu 10/15/09
193	▦	Electrical Conduit Feeder/Equipı	33 days?	Fri 9/11/09	Tue 10/27/09
194	▦	Medical Gas Rough-in	5 days?	Wed 9/30/09	Tue 10/6/09
195	▦	Plumbing Rough-in	20 days?	Wed 9/30/09	Tue 10/27/09
196	▦	Inspections	2 days?	Thu 12/10/09	Fri 12/11/09
197	▦	Pull Wire	20 days?	Tue 2/9/10	Mon 3/8/10
198		**Lobby**	**168 days**	**Mon 12/14/09**	**Wed 8/4/10**
199	▦	Lobby	168 days	Mon 12/14/09	Wed 8/4/10
200		**4th Floor East**	**182 days?**	**Fri 6/12/09**	**Mon 2/22/10**
201	▦	Frame Walls	52 days?	Fri 6/12/09	Mon 8/24/09
202	▦	HVAC/Plumbing Piping	46 days?	Tue 6/30/09	Tue 9/1/09
203	▦	Electrical Rough-in	93 days?	Wed 6/24/09	Fri 10/30/09
204	▦	Electrical Conduit Feeder/Equipı	20 days?	Mon 9/28/09	Fri 10/23/09
205	▦	Duct Branches/Mech. Equip. Sh	29 days?	Tue 7/28/09	Fri 9/4/09
206	▦	Elevator Shafts	5 days?	Tue 9/8/09	Mon 9/14/09
207	▦	Plumbing Rough-in	5 days?	Tue 8/25/09	Mon 8/31/09
208	▦	Inspections	2 days?	Mon 11/2/09	Tue 11/3/09
209	▦	Pull Wire	10 days?	Tue 2/9/10	Mon 2/22/10
210		**4th Floor West**	**179 days?**	**Wed 7/15/09**	**Mon 3/22/10**
211	▦	Frame Walls	52 days?	Wed 7/15/09	Thu 9/24/09
212	▦	HVAC/Plumbing Piping	46 days?	Mon 7/27/09	Mon 9/28/09
213	▦	Electrical Rough-in	93 days?	Mon 7/27/09	Wed 12/2/09
214	▦	Duct Branches/Mech. Equip. Sh	41 days?	Thu 8/27/09	Thu 10/22/09
215	▦	Electrical Conduit Feeder/Equipı	20 days?	Wed 10/28/09	Tue 11/24/09
216	▦	Plumbing Rough-in	5 days?	Fri 9/25/09	Thu 10/1/09
217	▦	Inspections	2 days?	Thu 12/3/09	Fri 12/4/09
218	▦	Pull Wire	10 days?	Tue 3/9/10	Mon 3/22/10
219		**Roof Garden**	**240 days**	**Fri 5/29/09**	**Thu 4/29/10**
220	▦	Roof Garden	240 days	Fri 5/29/09	Thu 4/29/10
221		**Penthouse**	**253 days?**	**Tue 6/30/09**	**Thu 6/17/10**
222	▦	AHU's/Mechanical Equipment	123 days?	Tue 6/30/09	Thu 12/17/09
223	▦	Rough-in Electrical/Pull Wire	72 days?	Thu 11/19/09	Fri 2/26/10
224	▦	Duct/piping/sprinkler	62 days?	Fri 11/27/09	Mon 2/22/10
225	▦	Plumbing Rough-in	4 days?	Mon 2/15/10	Thu 2/18/10
226	▦	Frame/finish walls	93 days?	Tue 2/9/10	Thu 6/17/10
227		**Substantial Completion**	**0 days**	**Wed 12/29/10**	**Wed 12/29/10**
228	▦	Substantial Completion	0 days	Wed 12/29/10	Wed 12/29/10



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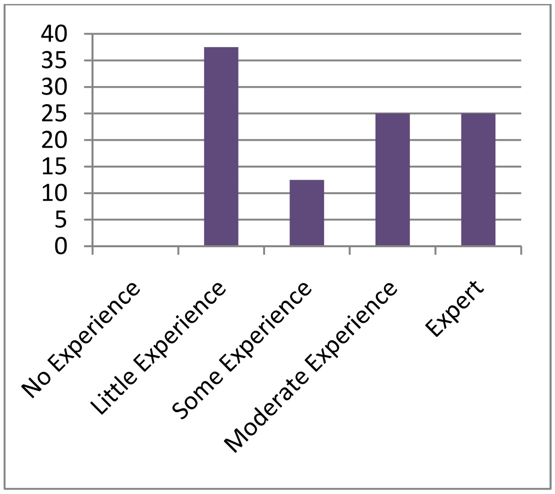
Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆		

APPENDIX B: SURVEY RESULTS

1. Have you worked on projects that both used traditional detailing/coordination of the façade and projects that have used BIM technologies for the façade construction?
    i. 75% Yes
    ii. 25% No
2. Rate your experience with using BIM for the façade construction.



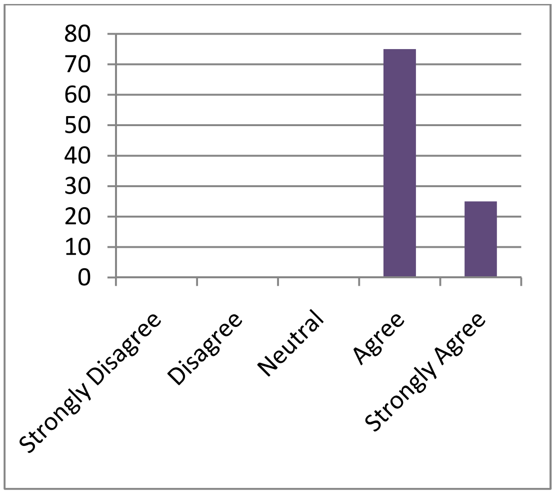
Comments:

a. Approximately 150,000 sf.
b. 150,000 sf glazed facade on Pharma building in Wuxi, China sticks out
c. Most of the projects we work on here are certainly over 100,000 sq ft. But as a range we work on projects from 75,000 sqft to 450,000 sq ft.
d. The current software applications that allow facade (curtain wall and metal panels) modeling to not have the level of detail required to produce shop drawings and actually utilize to construct the building in the field.

   We have been successful tracking exterior facade materials utilizing BIM and integrating our schedule.

   Higher education jobs usually have more complex skins where there are multiple materials and scopes coming together. This is where the real benefits of BIM can be unlocked.
e. We've done some work looking at mock-up of facade, but nothing formal. We are just starting a project that will require detailed facade construction modeling that is a good case example, but we won't have any good models until June. The project in question is a complex replacement of an existing curtain wall.

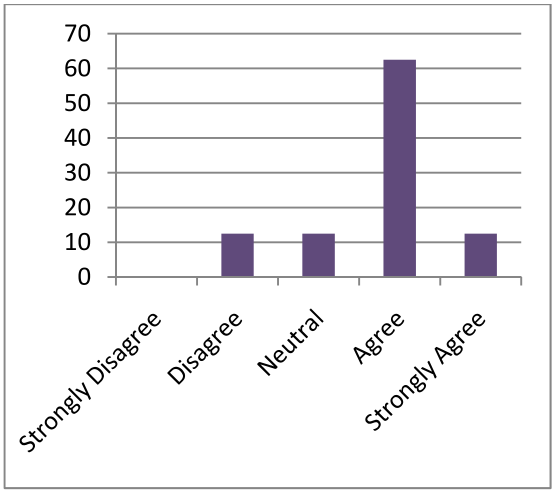
3. Using BIM has increased the constructability of a complex façade.



Comments:

a. Structural analysis and details
b. Mostly in the coordination of the project between all disciplines, Architectural, Structural, mechanical, and electrical. It can help with civil engineering especially if the civil engineer is working in BIM. Often times we find that they are reluctant, and stick with 2d methods.
c. I think it helps decrease the schedule and properly sequence trades and required equipment such as scaffolding. It may not be easier to construct but contractors can be more efficient.
d. While I don't see modeling a whole project in the required level of detail yet, I can see where performing a detailed virtual mock-up of how building facades tie-into each other will be beneficial on many of our projects. Unfortunately, only a few skin subs do any modeling, so being able to use 3D modeling for fabrication drawings is a minimal use that I would like to see expanded in the industry.

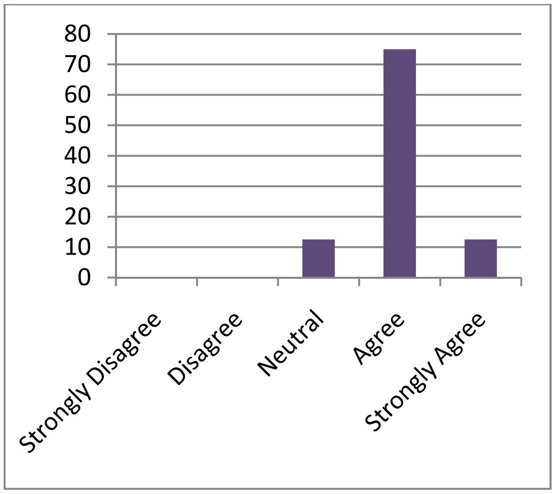
4. Using BIM has increased the productivity of façade construction.



Comments:

a. I'm an ae so not sure if those filthy construction workers get er done quicker
b. The BIM model can be sent to the contractor as well as any of the subs involved. It can be sent to the curtain wall manufacturer as a means of coordination. It is often used as a means of verifying the design intent and a communicative link between architect and contractors.
c. The sequencing and scheduling of multiple trades and equipment is much easier to visualize and therefore communicate with the entire project team.
d. It will definitely be useful to plan execution, which will prevent conflicts, increasing productivity. Hopefully once we start to do more of this we'll see data where projects that do this level of mock-up have less leaks.

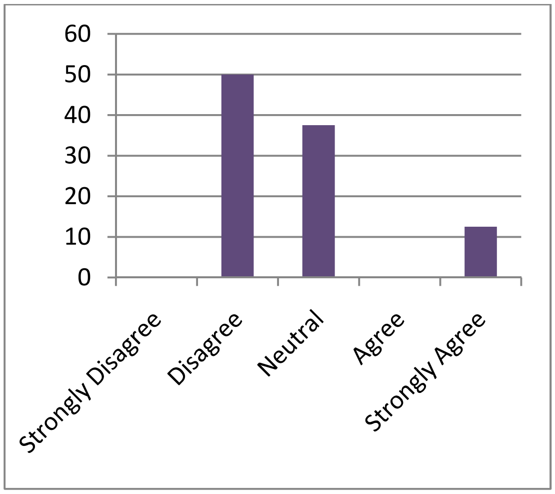
5. BIM is beneficial for façade analysis and coordination.



Comments:

a. passive lighting, coordinating with structural components
b. It is a beneficial to be able to quantify different materials in the facade for energy analysis. However, we are not inputting the raw data into the different materials in a facade at this point. For instance, glass has many properties; shading coefficients, percentage of transparencies and so on that our mechanical and electrical engineers rely on to meet energy codes. So far that information has not made it into the BIM model. We do, however, import that information from the BIM to a third party software at times.
c. At this point the analysis of facade systems to better understand possibilities for water infiltration or energy loss due to air gaps is not possible with the current software providers. Tekla is making huge strides in making this a reality. Once that is the case facade analysis will be extremely beneficial and contractors will gain a significant amount of benefits with the ability to add intelligence to these objects. Coordination and sequencing will always be a benefit!

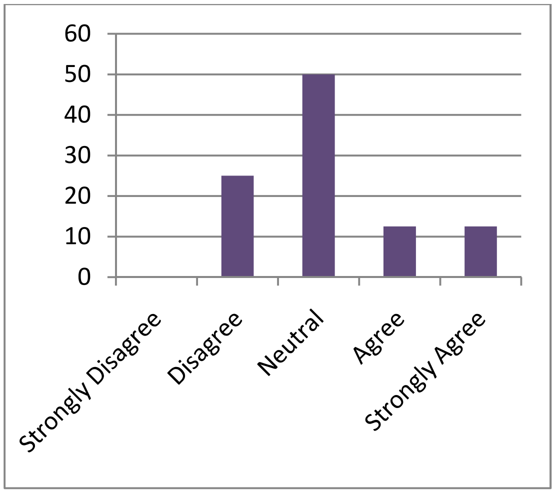
6. The learning curve negatively affected the productivity of the use of BIM for the facade.



Comments:

   a. I'm a little confused by the question but I'll try to answer. Absolutely, a staff fresh out of the gate will struggle with anything related to change/new process. In my experience I was already working with experienced staff though.
   b. You do need someone who is more experienced in BIM for modeling the exterior. As a student, this is the one area where BIM should be used, and learned.
   c. If you can find the right people to detail the productivity in the field will always benefit from having this as a visual tool and centralized database.
   d. We would supplement the skills of our team with modelers who can use tools like Revit or sketch-up to model these complex conditions and present a model for the team to use.

7. Using BIM for the façade construction helps to reduce the cost of the façade significantly.



Comments:

   a. Tolerances can be adhered to that are cost driven, i.e. the radius of a curved wall must stay outside a certain dimension otherwise the manufacturer and/or installer will charge more.

   b. I think BIM again helps save on expensive errors and mistakes during construction.
   c. The increase in productivity helps to reduce cost. The ability to do more in shop pre-fabrication allows for less field waste and a higher quality product which reduces the chances for re-work.
   d. I can't see this happening. It's not like MEP work where you avoid uninstalling and reinstalling. Facades usually have a clearer picture of who installs first. The material costs won't really change, but perhaps could be some efficiency in labor with less re-work.

8. Please explain what the most difficult part was about using BIM for facade construction.
   Comments:
   a. Learning curve in software, thinking out of the box to construct pieces as needed.
   b. Training people to do it correctly
   c. Editing the facade (archicad)
   d. Developing parts specific to the selected system...then reacting to a change in that system late in design development stage.
   e. Determining when to stop drawing in BIM
   f. There is not one difficult part, but I think it is taking BIM to the next level to be able to put more info in and get more analysis out. That is where the difficulties lie.
   g. Lack of much needed detail in the models - not everything shown on a shop drawing is present in most modeling software platforms for curtain wall and metal panels.
   h. Modeling efforts involved. Without many subcontractors modeling, it is hard to build a model with the right level of expertise to get the most benefit.
9. Please explain what is most beneficial about using BIM for facade construction.
   Comments:
   a. Coordination, identifying issues early.
   b. can create shop drawings from it
   c. managing costs
   d. Coordination between trades.
   e. The idea that I could sent the model off to a sub-contractor to develop shop drawings for the facade.
   f. After building a BIM model, you will have a very good sense of the design. BIM will definitely help with window and door scheduling, material identification via mapping of material textures in the elevations. There are less mistakes made by the contractor is the BIM model is used through the entire design and construction documents process.
   g. Increase of field productivity.
   h. Slab edge as-built conditions, curtain wall and precast shop drawings are where we can get some better information to avoid tolerance conflicts.
10. Please provide any additional comments you have on this topic.

a. All bim tools (revitarchicadbentlybim) do not create facades equally. archicad stinks revit is much better, not sure about bentley). knowing the tool used to create facades seems like it will be critical to quantify the data you gather in this survey

APPENDIX C: PREFABRICATION COST ANALYSIS (FROM COST WORKS)

ECCCC

Charlottes\ VA

Data Release : Year 2010 **Unit Cost Estimate**

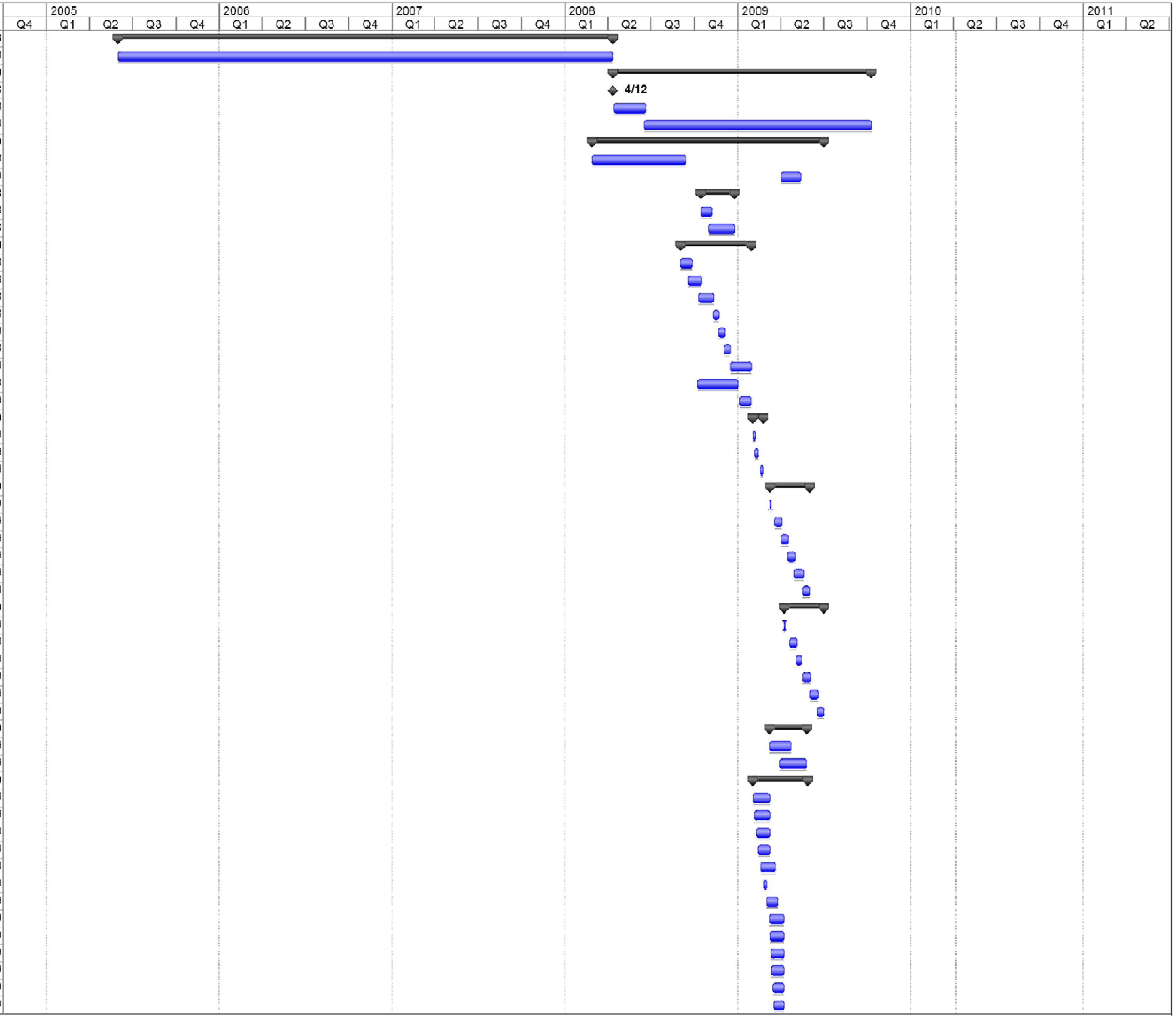
Quantity	LineNumber	Description	Crew	Daily Output	Days	Labor Hours	Unit	Material	Labor	Total	Ext. Mat.	Ext. Labor	Ext. Total
33472	071353102200	Elastomeric sheet waterproofing, polyethylene and rubberized asphalt sheets, 1/8" thick	3	550	20	0.029	S.F.	$ 0.85	$ 2.00	$ 2.85	$ 28,451.20	$ 66,944.00	$ 95,395.20
33472	072113101940	Extruded polystyrene insulation, rigid, for walls, 25 PSI compressive strength, 2" thick, R10	4	730	11	0.011	S.F.	$ 1.03	$ 1.80	$ 2.83	$ 34,476.16	$ 60,249.60	$ 94,725.76
33472	042113140020	Thin brick veneer, modular, 2-2/3" x 5/8" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding, grout and reinforcing	4	92	91	0.174	S.F.	$ 10.93	$ 10.00	$ 20.93	$ 365,848.96	$334,720.00	$ 700,568.96
33472	096616100500	Scratch Coat	4	75	112	0.107	S.F.	$ 0.72	$ 2.40	$ 3.12	$ 24,099.84	$ 80,332.80	$ 104,432.64
25167	054113304400	Partition, galv LB studs, 16 ga x 6" W studs 16" O.C. x 8' H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	4	64	197	0.25	L.F.	$ 10.84	$ 9.43	$ 20.27	$ 272,810.28	$237,324.81	$ 510,135.09
33472	092236230600	Metal Lath, for use with diamond lath, for 15 lb asphalt sheathing paper, add	4	100	84		S.F.	$ 0.54	$ 1.60	$ 2.14	$ 18,074.88	$ 53,555.20	$ 71,630.08
66944	061636103100	Sheathing, wood fiber, regular, no vapor barrier, 5/8" thick	3	1200	19	0.013	S.F.	$ 0.50	$ 1.00	$ 1.50	$ 33,472.00	$ 66,944.00	$ 100,416.00
Total					**178**						**$ 777,233.32**	**$900,070.41**	**$ 1,677,303.73**

Mat. O&P	Labor O&P	Total O&P	Ext. Labor O&P	Ext. Total O&P	Labor Type	Data Release
$ 0.94	$ 0.83	$ 1.77	$ 27,781.76	$ 59,245.44	STD	Year 2010
$ 1.13	$ 0.36	$ 1.49	$ 12,049.92	$ 49,873.28	STD	Year 2010
$ 12.05	$ 4.48	$ 16.53	$149,954.56	$ 553,292.16	STD	Year 2010
$ 0.79	$ 3.51	$ 4.30	$117,486.72	$ 143,929.60	STD	Year 2010
$ 11.93	$ 14.51	$ 26.44	$365,173.17	$ 665,415.48	STD	Year 2010
$ 0.59	$ -	$ 0.59	$ -	$ 19,748.48	STD	Year 2010
$ 0.55	$ 0.43	$ 0.98	$ 28,785.92	$ 65,605.12	STD	Year 2010
			$701,232.05	**$ 1,557,109.56**		

Final Total	$ 3,234,413.29

APPENDIX D: PREFAB REDUCED SCHEDULE

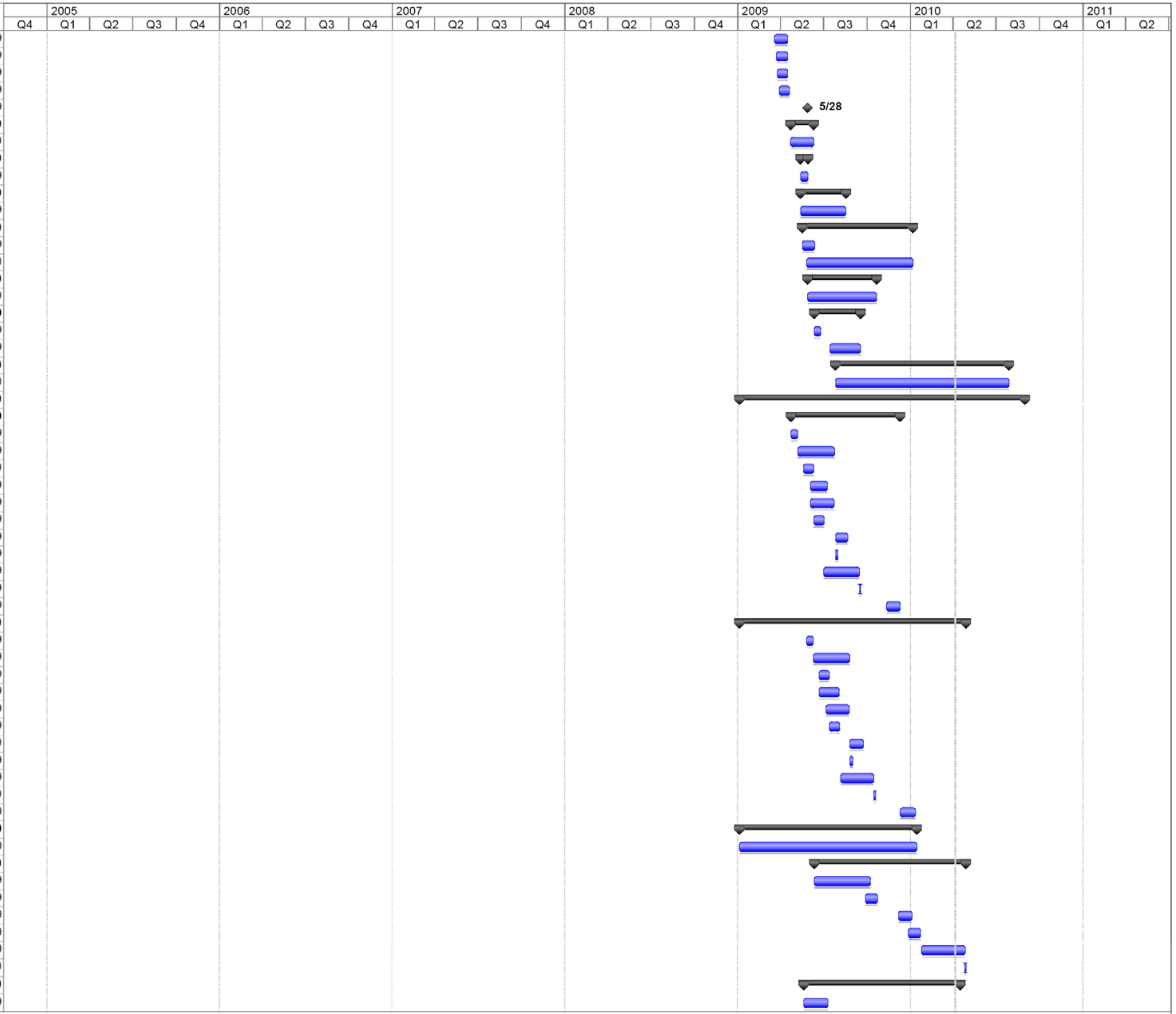
ID	ℹ	Task Name	Duration	Start	Finish
1		**Design Phase**	**748 days**	**Wed 6/1/05**	**Fri 4/11/08**
2	▦	Design Phase	748 days	Wed 6/1/05	Fri 4/11/08
3		**Sitework& Site Utilities**	**391 days**	**Sat 4/12/08**	**Fri 10/9/09**
4	▦	CCC Ground Breaking	0 days	Sat 4/12/08	Sat 4/12/08
5	▦	Garage Demolition	50 days	Mon 4/14/08	Fri 6/20/08
6	▦	Site Utilities	344 days	Tue 6/17/08	Fri 10/9/09
7		**Substructure**	**351 days?**	**Thu 2/28/08**	**Wed 7/1/09**
8	▦	Foundations	143 days	Thu 2/28/08	Fri 9/12/08
9	▦	Backfill	30 days	Thu 4/2/09	Wed 5/13/09
10		**Column Line F-K**	**51 days**	**Wed 10/15/08**	**Wed 12/24/08**
11	▦	Elevator Pits	18 days	Wed 10/15/08	Fri 11/7/08
12	▦	F/P/C/S Section Walls 1-3	39 days	Fri 10/31/08	Wed 12/24/08
13		**Column Line C-F**	**108 days**	**Tue 9/2/08**	**Thu 1/29/09**
14	▦	Build Grade Beam Cages Sectic	19 days	Tue 9/2/08	Fri 9/26/08
15	▦	Excavate Form and Place Sectic	21 days	Thu 9/18/08	Thu 10/16/08
16	▦	Section 1 Walls	22 days	Fri 10/10/08	Mon 11/10/08
17	▦	Section 2 Walls	10 days	Mon 11/10/08	Fri 11/21/08
18	▦	Section 3 Walls	10 days	Fri 11/21/08	Thu 12/4/08
19	▦	Section 4 Walls	9 days	Wed 12/3/08	Mon 12/15/08
20	▦	Vault Slabs/Lids	33 days	Tue 12/16/08	Thu 1/29/09
21	▦	North Walls	61 days	Wed 10/8/08	Wed 12/31/08
22	▦	Exterior Walls	18 days	Mon 1/5/09	Wed 1/28/09
23		**Column Line Z-C**	**16 days**	**Mon 2/2/09**	**Mon 2/23/09**
24	▦	Section 1 Walls	5 days	Mon 2/2/09	Fri 2/6/09
25	▦	Section 2 Walls	5 days	Fri 2/6/09	Thu 2/12/09
26	▦	Section 3 Walls	5 days	Tue 2/17/09	Mon 2/23/09
27		**Slab Pours East**	**60 days?**	**Tue 3/10/09**	**Mon 6/1/09**
28	▦	Mezzanine Prep/Place	2 days	Tue 3/10/09	Wed 3/11/09
29	▦	1st Floor Prep/Place/Pan Stairs	12 days	Thu 3/19/09	Fri 4/3/09
30	▦	2nd Floor Prep/Place/Pan Stairs	12 days	Thu 4/2/09	Fri 4/17/09
31	▦	3rd Floor Prep/Place/Pan Stairs	12 days	Thu 4/16/09	Fri 5/1/09
32	▦	4th Floor Prep/Place/Pan Stairs	14 days	Thu 4/30/09	Tue 5/19/09
33	▦	Roof Prep/Place/Pan Stairs	11 days?	Mon 5/18/09	Mon 6/1/09
34		**Slab Pours West**	**60 days**	**Thu 4/9/09**	**Wed 7/1/09**
35	▦	Mezzanine Prep/Place	2 days	Thu 4/9/09	Fri 4/10/09
36	▦	1st Floor Prep/Place/Pan Stairs	12 days	Mon 4/20/09	Tue 5/5/09
37	▦	2nd Floor Prep/Place/Pan Stairs	10 days	Mon 5/4/09	Fri 5/15/09
38	▦	3rd Floor Prep/Place/Pan Stairs	13 days	Mon 5/18/09	Wed 6/3/09
39	▦	4th Floor Prep/Place/Pan Stairs	14 days	Tue 6/2/09	Fri 6/19/09
40	▦	Roof Prep/Place/Pan Stairs	10 days	Thu 6/18/09	Wed 7/1/09
41		**Slab On Grade**	**57 days**	**Mon 3/9/09**	**Tue 5/26/09**
42	▦	East	34 days	Mon 3/9/09	Thu 4/23/09
43	▦	West	42 days	Mon 3/30/09	Tue 5/26/09
44		**Superstructure**	**84 days**	**Mon 2/2/09**	**Thu 5/28/09**
45	▦	Steel/decking Seq 1	26 days	Mon 2/2/09	Mon 3/9/09
46	▦	Steel/decking Seq 2	23 days	Thu 2/5/09	Mon 3/9/09
47	▦	Steel/decking Seq 3	20 days	Tue 2/10/09	Mon 3/9/09
48	▦	Steel/decking Seq 4	17 days	Fri 2/13/09	Mon 3/9/09
49	▦	Steel/decking Seq 5	23 days	Wed 2/18/09	Fri 3/20/09
50	▦	Steel/decking Seq 6	4 days	Wed 2/25/09	Mon 3/2/09
51	▦	Steel/decking Seq 16	18 days	Tue 3/3/09	Thu 3/26/09
52	▦	Steel/decking Seq 9	23 days	Mon 3/9/09	Wed 4/8/09
53	▦	Steel/decking Seq 10	22 days	Tue 3/10/09	Wed 4/8/09
54	▦	Steel/decking Seq 11	20 days	Thu 3/12/09	Wed 4/8/09
55	▦	Steel/decking Seq 12	19 days	Fri 3/13/09	Wed 4/8/09
56	▦	Steel/decking Seq 7	18 days	Mon 3/16/09	Wed 4/8/09
57	▦	Steel/decking Seq 8	16 days	Wed 3/18/09	Wed 4/8/09



Project: Proposed Prefab Schedule
Date: Mon 4/5/10

Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩
Split	┄	Milestone	◆	Project Summary	▬	External Milestone	◆		

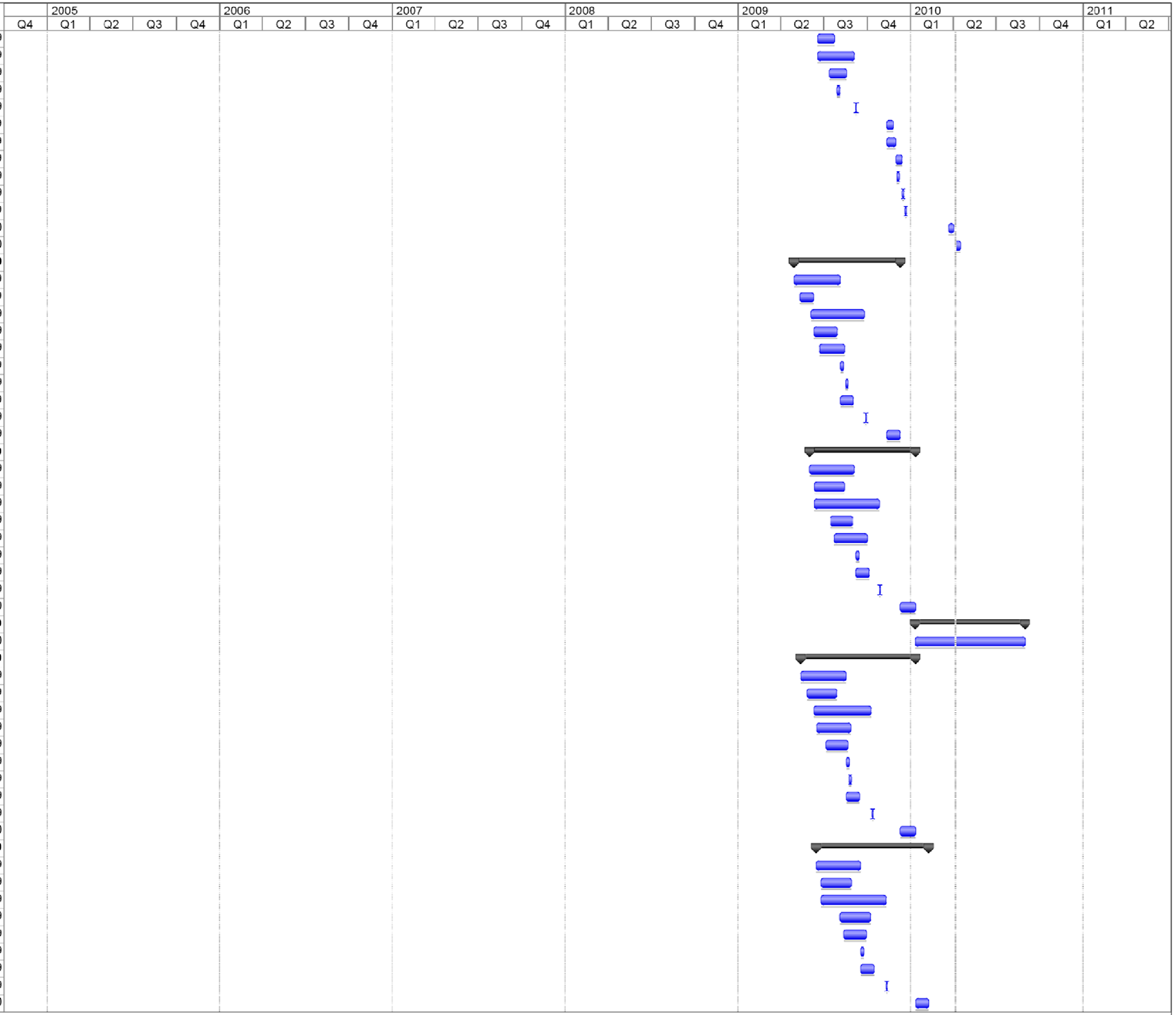
ID	ℹ	Task Name	Duration	Start	Finish
58	▦	Steel/decking Seq 14	20 days	Fri 3/20/09	Thu 4/16/09
59	▦	Steel/decking Seq 15	18 days	Tue 3/24/09	Thu 4/16/09
60	▦	Steel/decking Seq 13	16 days	Thu 3/26/09	Thu 4/16/09
61	▦	Steel/decking Seq 17	16 days	Mon 3/30/09	Mon 4/20/09
62	▦	Structure Top out	0 days	Thu 5/28/09	Thu 5/28/09
63		**Fire Proofing**	**35 days**	**Thu 4/23/09**	**Wed 6/10/09**
64	▦	Fire Proofing	35 days	Thu 4/23/09	Wed 6/10/09
65		**West Terrace Structure**	**12 days?**	**Thu 5/14/09**	**Fri 5/29/09**
66	▦	West Terrace	12 days?	Thu 5/14/09	Fri 5/29/09
67		**Loading Dock Structure**	**68 days**	**Thu 5/14/09**	**Mon 8/17/09**
68	▦	Loading Dock Structure	68 days	Thu 5/14/09	Mon 8/17/09
69		**Façade**	**168 days**	**Mon 5/18/09**	**Wed 1/6/10**
70	▦	Brick Façade	20 days	Mon 5/18/09	Fri 6/12/09
71	▦	Curtain Wall All Elevations	161 days	Wed 5/27/09	Wed 1/6/10
72		**Roof**	**104 days**	**Fri 5/29/09**	**Wed 10/21/09**
73	▦	Roof	104 days	Fri 5/29/09	Wed 10/21/09
74		**MEP**	**70 days**	**Fri 6/12/09**	**Thu 9/17/09**
75	▦	MEP Rough-in East Risers	10 days	Fri 6/12/09	Thu 6/25/09
76	▦	MEP Rough-in West Risers	47 days	Wed 7/15/09	Thu 9/17/09
77		**Finishes**	**263 days**	**Mon 7/27/09**	**Wed 7/28/10**
78	▦	Finishes	263 days	Mon 7/27/09	Wed 7/28/10
79		**Interiors**	**432 days?**	**Mon 1/5/09**	**Tue 8/31/10**
80		**Ground East**	**165 days**	**Fri 4/24/09**	**Thu 12/10/09**
81	▦	Fire Proofing	10 days	Fri 4/24/09	Thu 5/7/09
82	▦	Frame Walls	56 days	Fri 5/8/09	Fri 7/24/09
83	▦	Duct Rough-in	16 days	Wed 5/20/09	Wed 6/10/09
84	▦	Electrical Rooms/Equipment	26 days	Thu 6/4/09	Thu 7/9/09
85	▦	HVAC/Plumbing Piping	36 days	Thu 6/4/09	Thu 7/23/09
86	▦	Duct Branches/Sprinkler Main	16 days	Thu 6/11/09	Thu 7/2/09
87	▦	Plumbing Rough-in	20 days	Mon 7/27/09	Fri 8/21/09
88	▦	Medical Gas Rough-in	5 days	Mon 7/27/09	Fri 7/31/09
89	▦	Electrical Rough-in	54 days	Thu 7/2/09	Tue 9/15/09
90	▦	Inspections	2 days	Wed 9/16/09	Thu 9/17/09
91	▦	Pull Wire	21 days	Thu 11/12/09	Thu 12/10/09
92		**Ground West**	**343 days**	**Mon 1/5/09**	**Wed 4/28/10**
93	▦	Fire Proofing	10 days	Wed 5/27/09	Tue 6/9/09
94	▦	Frame Walls	55 days	Wed 6/10/09	Tue 8/25/09
95	▦	Duct Rough-in	16 days	Mon 6/22/09	Mon 7/13/09
96	▦	Electrical Rooms/Equipment	31 days	Mon 6/22/09	Mon 8/3/09
97	▦	HVAC/Plumbing Piping	35 days	Tue 7/7/09	Mon 8/24/09
98	▦	Duct Branches/Sprinkler Main	16 days	Tue 7/14/09	Tue 8/4/09
99	▦	Plumbing Rough-in	21 days	Wed 8/26/09	Wed 9/23/09
100	▦	Medical Gas Rough-in	5 days	Wed 8/26/09	Tue 9/1/09
101	▦	Electrical Rough-in	50 days	Fri 8/7/09	Thu 10/15/09
102	▦	Inspections	2 days	Fri 10/16/09	Mon 10/19/09
103	▦	Pull Wire	22 days	Fri 12/11/09	Mon 1/11/10
104		**Main Electrical Room**	**269 days**	**Mon 1/5/09**	**Thu 1/14/10**
105	▦	Main Electrical Room	269 days	Mon 1/5/09	Thu 1/14/10
106		**Finishes**	**229 days**	**Fri 6/12/09**	**Wed 4/28/10**
107	▦	Partitions/Ceilings/Soffits/Fi	85 days	Fri 6/12/09	Thu 10/8/09
108	▦	Light Fixtures	20 days	Mon 9/28/09	Fri 10/23/09
109	▦	Casework	21 days	Mon 12/7/09	Mon 1/4/10
110	▦	Plumbing Fixtures	20 days	Mon 12/28/09	Fri 1/22/10
111	▦	Misc. Finishes	66 days	Mon 1/25/10	Mon 4/26/10
112	▦	TAB	3 days	Mon 4/26/10	Wed 4/28/10
113		**Mezzanine/Sub Basement Mechani**	**237 days**	**Thu 5/21/09**	**Fri 4/16/10**
114	▦	Mechanical Equipment/Sprinkler	37 days	Thu 5/21/09	Fri 7/10/09



Project: Proposed Prefab Schedule
Date: Mon 4/5/10

Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline ⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone ◇		

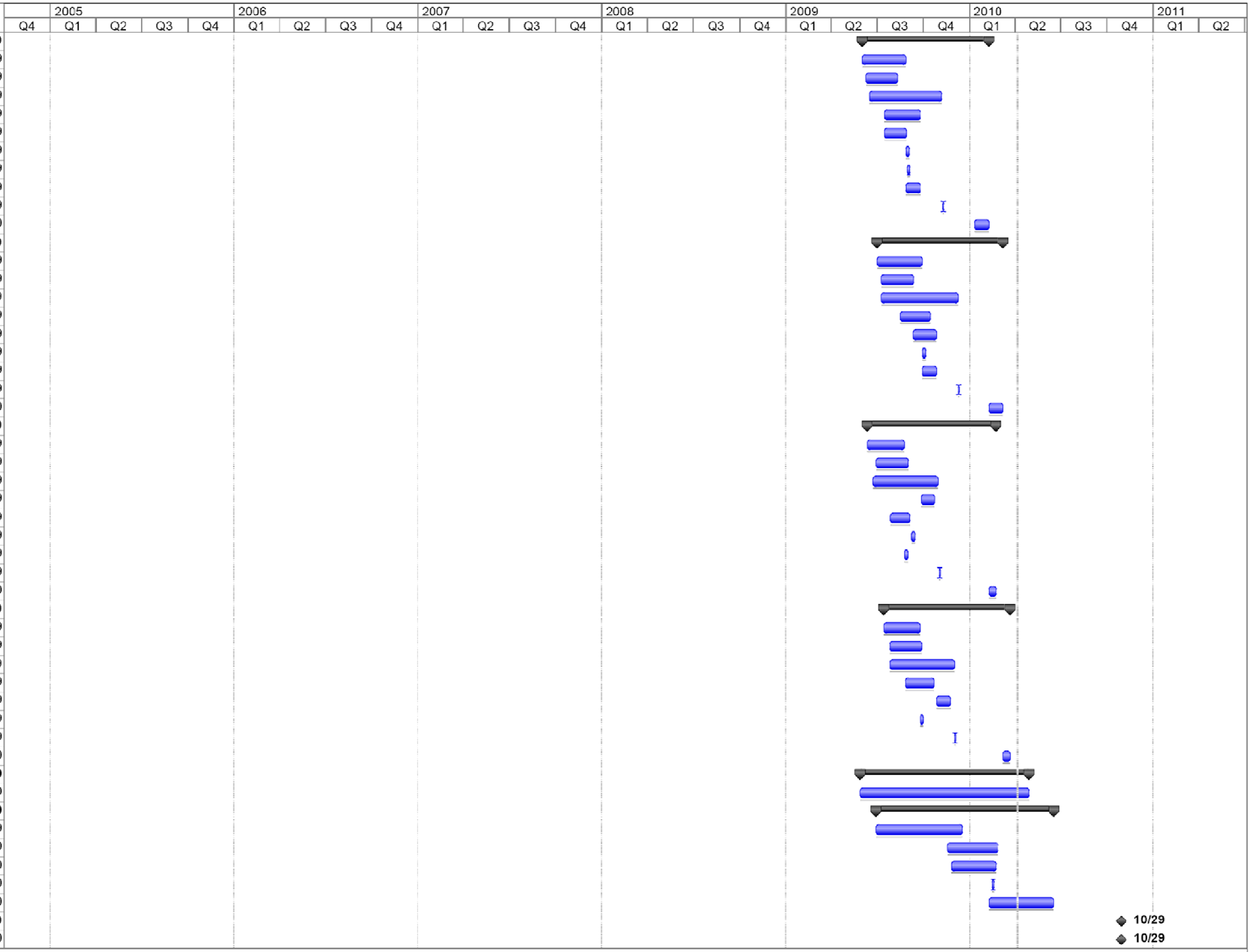
ID	ℹ	Task Name	Duration	Start	Finish
115	▦	HVAC Piping	26 days	Fri 6/19/09	Fri 7/24/09
116	▦	Electrical Rough-in	56 days	Fri 6/19/09	Fri 9/4/09
117	▦	Electrical Conduit Feeder/Equipı	27 days	Mon 7/13/09	Tue 8/18/09
118	▦	Frame Walls	4 days	Thu 7/30/09	Tue 8/4/09
119	▦	Inspections	1 day	Tue 9/8/09	Tue 9/8/09
120	▦	Pull Wire	10 days	Thu 11/12/09	Wed 11/25/09
121	▦	Hang/Finish Drywall	13 days	Thu 11/12/09	Mon 11/30/09
122	▦	Pneumatic Tube Equipment	10 days	Tue 12/1/09	Mon 12/14/09
123	▦	Test Electrical Equipment	3 days	Fri 12/4/09	Tue 12/8/09
124	▦	Paint	4 days	Tue 12/15/09	Fri 12/18/09
125	▦	Install Fixtures	3 days	Mon 12/21/09	Wed 12/23/09
126	▦	Misc. Finishes	9 days	Tue 3/23/10	Fri 4/2/10
127	▦	TAB	10 days	Mon 4/5/10	Fri 4/16/10
128		**1st Floor East**	**161 days**	**Thu 4/30/09**	**Thu 12/10/09**
129	▦	Frame Walls	70 days	Thu 4/30/09	Wed 8/5/09
130	▦	HVAC/Plumbing Piping	22 days	Tue 5/12/09	Wed 6/10/09
131	▦	Electrical Rough-in	81 days	Fri 6/5/09	Fri 9/25/09
132	▦	Electrical Conduit Feeder/Equipı	36 days	Thu 6/11/09	Thu 7/30/09
133	▦	Duct Branches/Mech. Equip. Sh	39 days	Tue 6/23/09	Fri 8/14/09
134	▦	Medical Gas Rough-in	5 days	Thu 8/6/09	Wed 8/12/09
135	▦	Elevator Shafts	5 days	Mon 8/17/09	Fri 8/21/09
136	▦	Plumbing Rough-in	20 days	Thu 8/6/09	Wed 9/2/09
137	▦	Inspections	2 days	Mon 9/28/09	Tue 9/29/09
138	▦	Pull Wire	21 days	Thu 11/12/09	Thu 12/10/09
139		**1st Floor West**	**160 days**	**Tue 6/2/09**	**Mon 1/11/10**
140	▦	Frame Walls	69 days	Tue 6/2/09	Fri 9/4/09
141	▦	HVAC/Plumbing Piping	46 days	Fri 6/12/09	Fri 8/14/09
142	▦	Electrical Rough-in	98 days	Fri 6/12/09	Tue 10/27/09
143	▦	Electrical Conduit Feeder/Equipı	33 days	Thu 7/16/09	Mon 8/31/09
144	▦	Duct Branches/Mech. Equip. Sh	50 days	Fri 7/24/09	Thu 10/1/09
145	▦	Medical Gas Rough-in	5 days	Tue 9/8/09	Mon 9/14/09
146	▦	Plumbing Rough-in	20 days	Tue 9/8/09	Mon 10/5/09
147	▦	Inspections	2 days	Wed 10/28/09	Thu 10/29/09
148	▦	Pull Wire	22 days	Fri 12/11/09	Mon 1/11/10
149		**Lobby**	**167 days**	**Mon 1/11/10**	**Tue 8/31/10**
150	▦	Lobby	167 days	Mon 1/11/10	Tue 8/31/10
151		**2nd Floor East**	**173 days?**	**Thu 5/14/09**	**Mon 1/11/10**
152	▦	Frame Walls	68 days?	Thu 5/14/09	Mon 8/17/09
153	▦	HVAC/Plumbing Piping	46 days?	Wed 5/27/09	Wed 7/29/09
154	▦	Electrical Rough-in	87 days?	Thu 6/11/09	Fri 10/9/09
155	▦	Electrical Conduit Feeder/Equipı	52 days?	Wed 6/17/09	Thu 8/27/09
156	▦	Duct Branches/Mech. Equip. Sh	35 days?	Mon 7/6/09	Fri 8/21/09
157	▦	Medical Gas Rough-in	5 days?	Tue 8/18/09	Mon 8/24/09
158	▦	Elevator Shafts	5 days?	Mon 8/24/09	Fri 8/28/09
159	▦	Plumbing Rough-in	21 days?	Tue 8/18/09	Tue 9/15/09
160	▦	Inspections	2 days?	Mon 10/12/09	Tue 10/13/09
161	▦	Pull Wire	22 days?	Fri 12/11/09	Mon 1/11/10
162		**2nd Floor West**	**170 days?**	**Tue 6/16/09**	**Mon 2/8/10**
163	▦	Frame Walls	68 days?	Tue 6/16/09	Thu 9/17/09
164	▦	HVAC/Plumbing Piping	46 days?	Fri 6/26/09	Fri 8/28/09
165	▦	Electrical Rough-in	98 days?	Fri 6/26/09	Tue 11/10/09
166	▦	Duct Branches/Mech. Equip. Sh	47 days?	Wed 8/5/09	Thu 10/8/09
167	▦	Electrical Conduit Feeder/Equipı	34 days?	Thu 8/13/09	Tue 9/29/09
168	▦	Medical Gas Rough-in	5 days?	Fri 9/18/09	Thu 9/24/09
169	▦	Plumbing Rough-in	20 days?	Fri 9/18/09	Thu 10/15/09
170	▦	Inspections	2 days?	Wed 11/11/09	Thu 11/12/09
171	▦	Pull Wire	20 days?	Tue 1/12/10	Mon 2/8/10



Project: Proposed Prefab Schedule
Date: Mon 4/5/10

Task
Split
Progress
Milestone ◆
Summary
Project Summary
External Tasks
External Milestone ◇
Deadline ⇩

ID	ℹ	Task Name	Duration	Start	Finish
172		**3rd Floor East**	**180 days?**	**Tue 6/2/09**	**Mon 2/8/10**
173	▦	Frame Walls	63 days?	Tue 6/2/09	Thu 8/27/09
174	▦	HVAC/Plumbing Piping	46 days?	Tue 6/9/09	Tue 8/11/09
175	▦	Electrical Rough-in	103 days?	Wed 6/17/09	Fri 11/6/09
176	▦	Electrical Conduit Feeder/Equipı	52 days?	Thu 7/16/09	Fri 9/25/09
177	▦	Duct Branches/Mech. Equip. Sh	32 days?	Thu 7/16/09	Fri 8/28/09
178	▦	Medical Gas Rough-in	5 days?	Fri 8/28/09	Thu 9/3/09
179	▦	Elevator Shafts	5 days?	Mon 8/31/09	Fri 9/4/09
180	▦	Plumbing Rough-in	21 days?	Fri 8/28/09	Fri 9/25/09
181	▦	Inspections	2 days?	Mon 11/9/09	Tue 11/10/09
182	▦	Pull Wire	20 days?	Tue 1/12/10	Mon 2/8/10
183		**3rd Floor West**	**178 days?**	**Thu 7/2/09**	**Mon 3/8/10**
184	▦	Frame Walls	64 days?	Thu 7/2/09	Tue 9/29/09
185	▦	HVAC/Plumbing Piping	46 days?	Fri 7/10/09	Fri 9/11/09
186	▦	Electrical Rough-in	109 days?	Fri 7/10/09	Wed 12/9/09
187	▦	Duct Branches/Mech. Equip. Sh	44 days?	Mon 8/17/09	Thu 10/15/09
188	▦	Electrical Conduit Feeder/Equipı	33 days?	Fri 9/11/09	Tue 10/27/09
189	▦	Medical Gas Rough-in	5 days?	Wed 9/30/09	Tue 10/6/09
190	▦	Plumbing Rough-in	20 days?	Wed 9/30/09	Tue 10/27/09
191	▦	Inspections	2 days?	Thu 12/10/09	Fri 12/11/09
192	▦	Pull Wire	20 days?	Tue 2/9/10	Mon 3/8/10
193		**4th Floor East**	**182 days?**	**Fri 6/12/09**	**Mon 2/22/10**
194	▦	Frame Walls	52 days?	Fri 6/12/09	Mon 8/24/09
195	▦	HVAC/Plumbing Piping	46 days?	Tue 6/30/09	Tue 9/1/09
196	▦	Electrical Rough-in	93 days?	Wed 6/24/09	Fri 10/30/09
197	▦	Electrical Conduit Feeder/Equipı	20 days?	Mon 9/28/09	Fri 10/23/09
198	▦	Duct Branches/Mech. Equip. Sh	29 days?	Tue 7/28/09	Fri 9/4/09
199	▦	Elevator Shafts	5 days?	Tue 9/8/09	Mon 9/14/09
200	▦	Plumbing Rough-in	5 days?	Tue 8/25/09	Mon 8/31/09
201	▦	Inspections	2 days?	Mon 11/2/09	Tue 11/3/09
202	▦	Pull Wire	10 days?	Tue 2/9/10	Mon 2/22/10
203		**4th Floor West**	**179 days?**	**Wed 7/15/09**	**Mon 3/22/10**
204	▦	Frame Walls	52 days?	Wed 7/15/09	Thu 9/24/09
205	▦	HVAC/Plumbing Piping	46 days?	Mon 7/27/09	Mon 9/28/09
206	▦	Electrical Rough-in	93 days?	Mon 7/27/09	Wed 12/2/09
207	▦	Duct Branches/Mech. Equip. Sh	41 days?	Thu 8/27/09	Thu 10/22/09
208	▦	Electrical Conduit Feeder/Equipı	20 days?	Wed 10/28/09	Tue 11/24/09
209	▦	Plumbing Rough-in	5 days?	Fri 9/25/09	Thu 10/1/09
210	▦	Inspections	2 days?	Thu 12/3/09	Fri 12/4/09
211	▦	Pull Wire	10 days?	Tue 3/9/10	Mon 3/22/10
212		**Roof Garden**	**240 days**	**Fri 5/29/09**	**Thu 4/29/10**
213	▦	Roof Garden	240 days	Fri 5/29/09	Thu 4/29/10
214		**Penthouse**	**253 days?**	**Tue 6/30/09**	**Thu 6/17/10**
215	▦	AHU's/Mechanical Equipment	123 days?	Tue 6/30/09	Thu 12/17/09
216	▦	Rough-in Electrical/Pull Wire	72 days?	Thu 11/19/09	Fri 2/26/10
217	▦	Duct/piping/sprinkler	62 days?	Fri 11/27/09	Mon 2/22/10
218	▦	Plumbing Rough-in	4 days?	Mon 2/15/10	Thu 2/18/10
219	▦	Frame/finish walls	93 days?	Tue 2/9/10	Thu 6/17/10
220		**Substantial Completion**	**0 days**	**Fri 10/29/10**	**Fri 10/29/10**
221	▦	Substantial Completion	0 days	Fri 10/29/10	Fri 10/29/10



Project: Proposed Prefab Schedule
Date: Mon 4/5/10

Task	▬	Progress	▬	Summary	▬	External Tasks	▬	Deadline	⇩
Split	┈	Milestone	◆	Project Summary	▬	External Milestone	◆		

APPENDIX E: TRINA SOLAR PANEL CUT SHEETS

Monocrystalline Solar Modules

Trinasolar

TRINA TSM-DA05, 220W to 240W

TYPICAL ELECTRICAL CHARACTERISTICS

Type	TSM-DA05	220	230	240
Max-Power	Pm(W)	220	230	240
Power Tolerance	(%)	±3	±3	±3
Max-Power Voltage	Vm(V)	29.8	30.0	30.6
Max-Power Current	Im(A)	7.39	7.66	7.84
Open-Circuit Voltage	Voc(V)	36.8	37.0	37.5
Short-Circuit Current	Isc(A)	8.00	8.18	8.38
Max-System Voltage	(VDC)		600	
Cell Efficiency	ηc (%)	15.5	16.2	16.9
Module Efficiency	ηm (%)	13.4	14.1	14.7
Number, type and arrangement of cells			60 pcs. Mono-Crystalline Silicon (6x10)	
Cell Size			6" x 6" | 156 mm x 156 mm	
No. of Bypass Diodes	(pcs.)		3	
Max. Series Fuse	(A)		14	
Pm Temperature Coefficient	(%/℃)		- 0.45	
Isc Temperature Coefficient	(%/℃)		0.05	
Voc Temperature Coefficient	(%/℃)		- 0.35	
NOCT- Nominal Operating Cell Temperature	(℃)		47±2	

MECHANICAL CHARACTERISTICS

Cable Type, Diameter and Length		3.31 mm^2 (12AWG), UL Certified
Type of Connector		Tyco
Dimension A*B*C		1650*992*46 (mm) | 64.96*39.05*1.81 (in.)
Weight		19.5 Kg | 43 lb
No. of Draining Holes In Frame		8
Glass, Type and Thickness		High Transmission, Low Iron, Tempered Glass 3.2 mm | 0.12" in.

PACKAGING CONFIGURATION

Packing Configuration		20 pcs./ box
Quantity/Pallet		1 box / pallet
Loading Capacity		520 pcs/40ft or 120 pcs/10ft

ABSOLUTE RATINGS

Dielectric Insulation Voltage	(VDC)	3000 max.
Operating Temperature	(℃)	-40~+85
Storage Temperature	(℃)	-40~+85

***STC Conditions**(1000W/m^2; 1.5 AM and 25℃ Cell temperature)*

High Efficiency
Monocrystalline Solar Modules

STRENGTHS

- Tolerance ± 3%
- 3 Bus Bar Configuration
- Plug & Play Connectors
- High Transmission, Low Iron Tempered Glass
- Can bear loads up to 5400 Pascals (IEC 61215 2nd)

WARRANTY

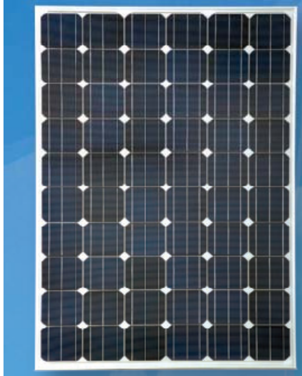
Manufacturing:	5 years
Power production:	90% : 10 years 80% : 25 years

CERTIFICATIONS

Monocrystalline Solar Modules

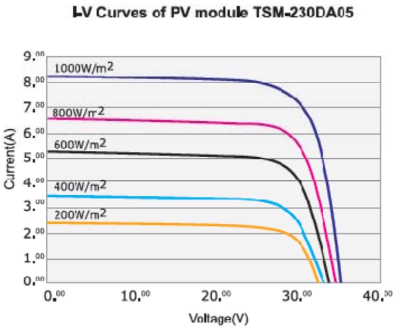
Trinasolar

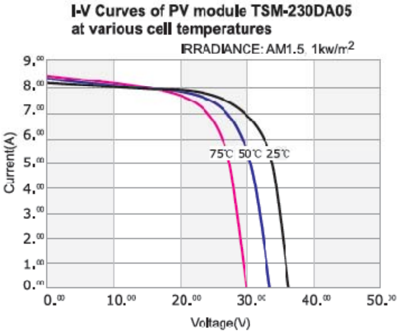
TRINA TSM-DA05, 220W to 240W



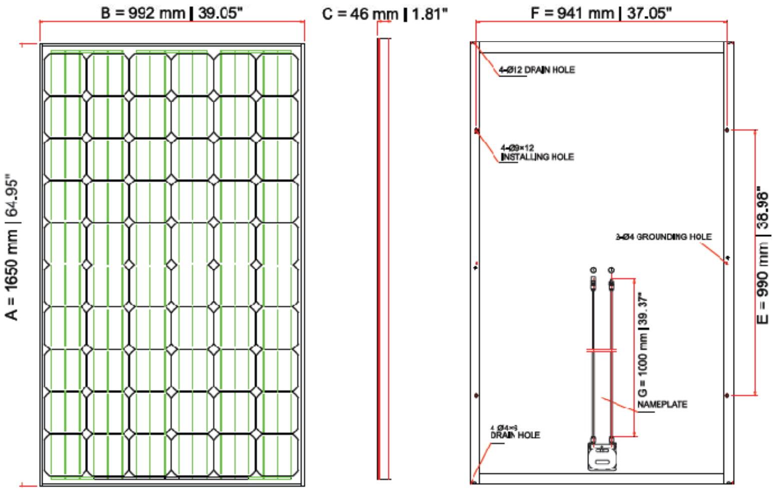
High Efficiency
Monocrystalline Solar Modules

I-V CURVES





DIMENSIONS

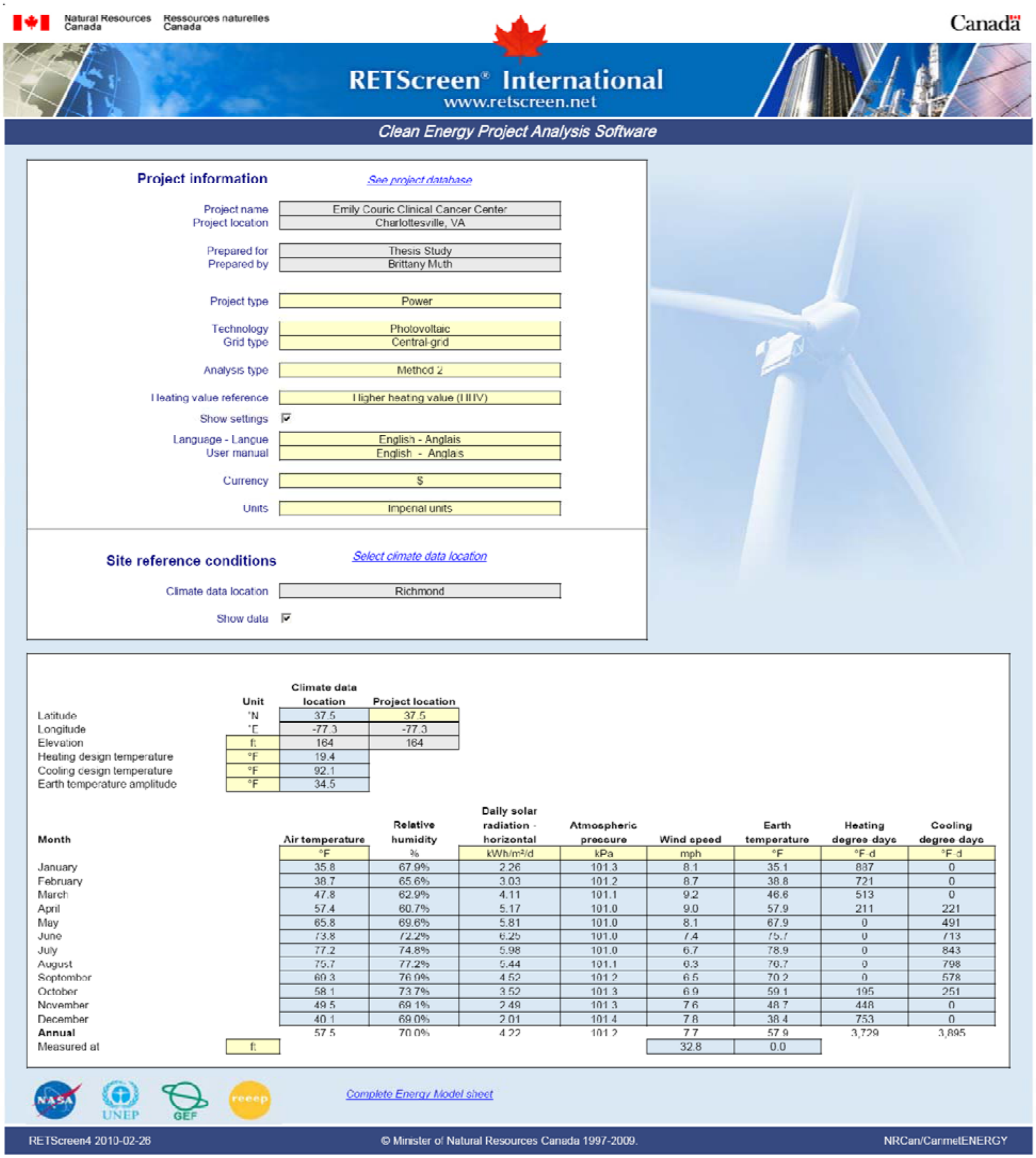


Dimensions A*B*C	1650*992*46 (mm) | 64.95*39.05*1.81 (in.)
Installation Hole E*F	990*941 (mm) | 38.98*37.05 (in.)
Cable Length G	1000 (mm) | 39.37 (in.)

*The company is not responsible for potential typing errors.

www.trinasolar.com

APPENDIX F: RETSCREEN RESULTS



Project information

Project name	Emily Couric Clinical Cancer Center
Project location	Charlottesville, VA
Prepared for	Thesis Study
Prepared by	Brittany Muth
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	☑
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	$
Units	Imperial units

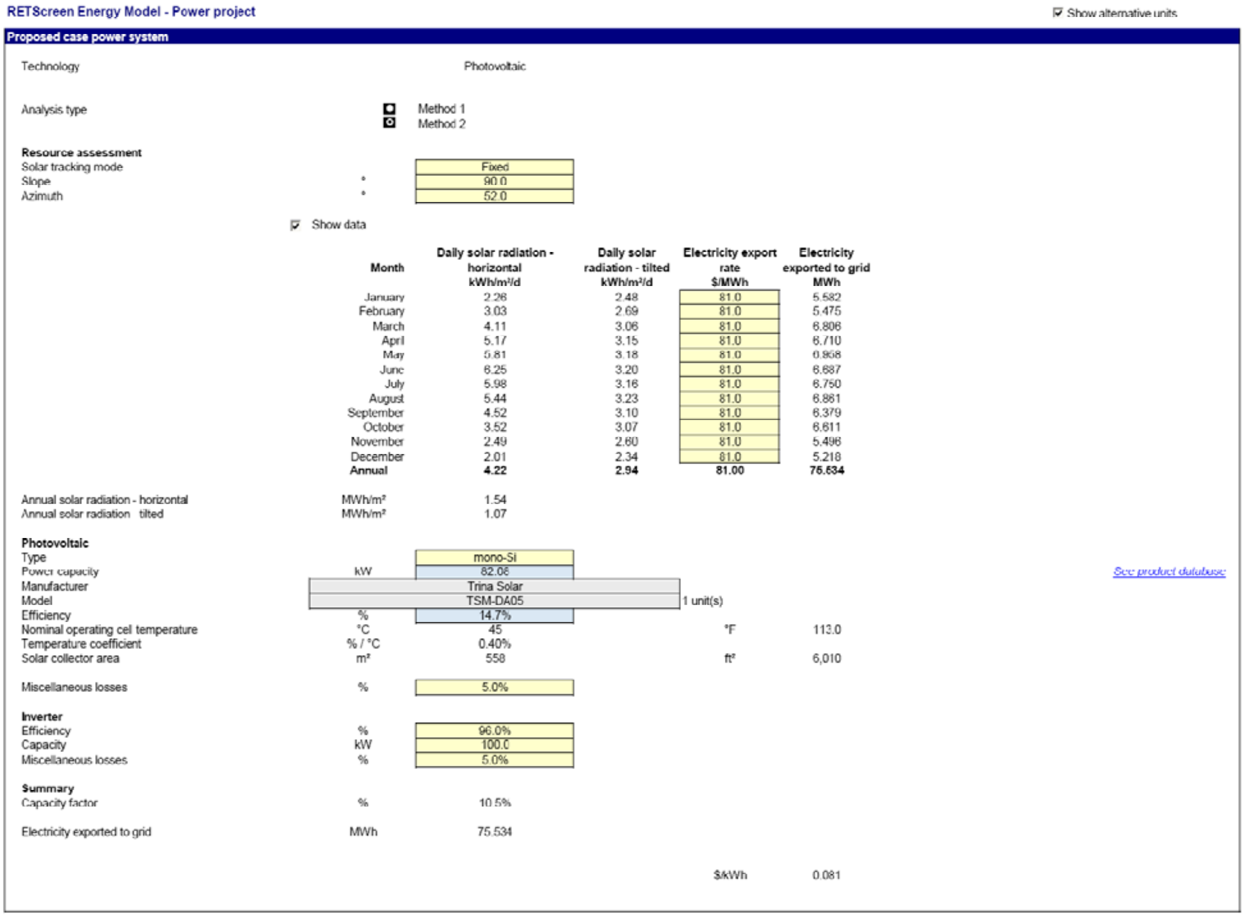
Site reference conditions

Climate data location	Richmond
Show data	☑

	Unit	Climate data location	Project location
Latitude	°N	37.5	37.5
Longitude	°E	-77.3	-77.3
Elevation	ft	164	164
Heating design temperature	°F	19.4	
Cooling design temperature	°F	92.1	
Earth temperature amplitude	°F	34.5	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°F	%	kWh/m²/d	kPa	mph	°F	°F-d	°F-d
January		35.8	67.9%	2.26	101.3	8.1	35.1	887	0
February		38.7	65.6%	3.03	101.2	8.7	38.8	721	0
March		47.8	62.9%	4.11	101.1	9.2	46.6	513	0
April		57.4	60.7%	5.17	101.0	9.0	57.9	211	221
May		65.8	69.6%	5.81	101.0	8.1	67.9	0	491
June		73.8	72.2%	6.25	101.0	7.4	75.7	0	713
July		77.2	74.8%	5.98	101.0	6.7	78.9	0	843
August		75.7	77.2%	5.44	101.1	6.3	76.7	0	798
September		69.3	76.0%	4.52	101.2	6.5	70.2	0	578
October		58.1	73.7%	3.52	101.3	6.9	59.1	195	251
November		49.5	69.1%	2.49	101.3	7.6	48.7	448	0
December		40.1	69.0%	2.01	101.4	7.8	38.4	753	0
Annual		57.5	70.0%	4.22	101.2	7.7	57.9	3,729	3,895
Measured at	ft					32.8	0.0		

RETScreen4 2010-02-26 © Minister of Natural Resources Canada 1997-2009. NRCan/CanmetENERGY



RETScreen Energy Model - Power project

☑ Show alternative units

Proposed case power system

Technology		Photovoltaic
Analysis type	○	Method 1
	●	Method 2

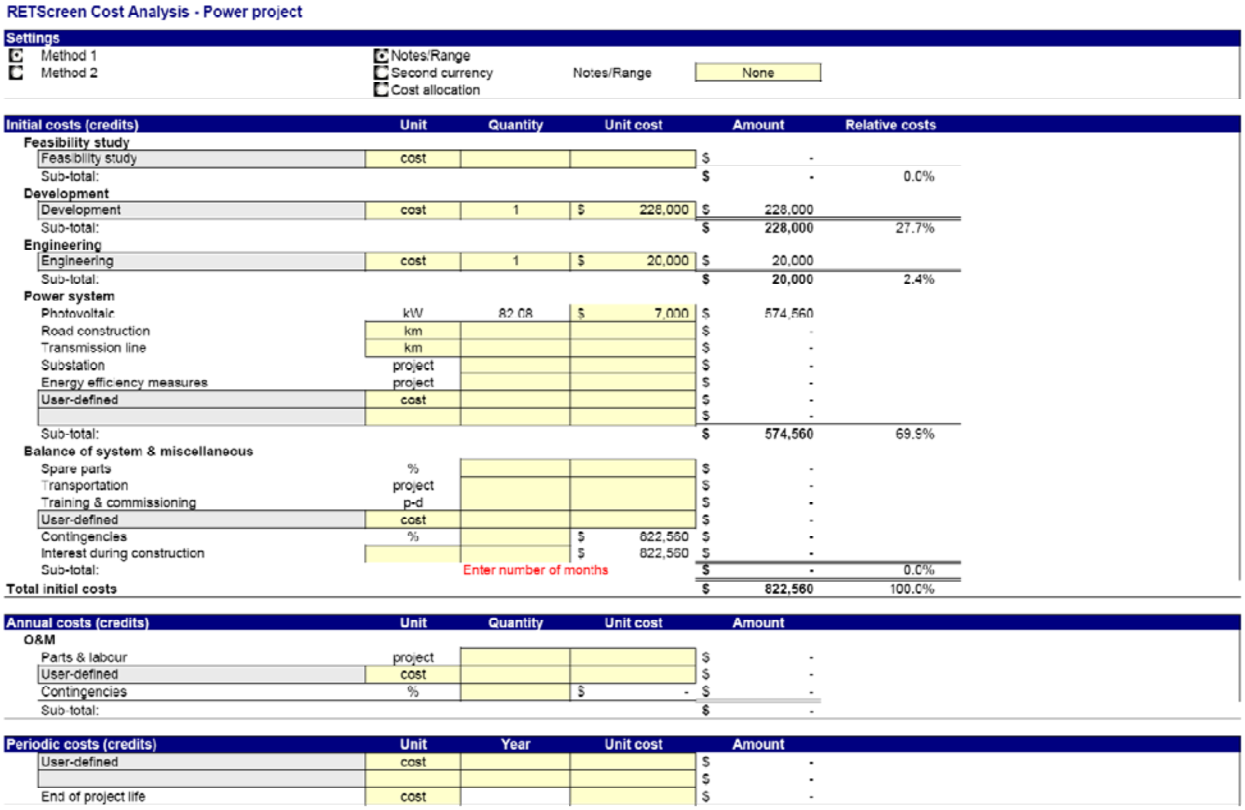
Resource assessment

Solar tracking mode		Fixed
Slope	°	90.0
Azimuth	°	52.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/MWh	Electricity exported to grid MWh
January	2.26	2.48	81.0	5.582
February	3.03	2.69	81.0	5.475
March	4.11	3.06	81.0	6.806
April	5.17	3.15	81.0	6.710
May	5.81	3.18	81.0	6.868
June	6.25	3.20	81.0	6.687
July	5.98	3.16	81.0	6.750
August	5.44	3.23	81.0	6.881
September	4.52	3.10	81.0	6.379
October	3.52	3.07	81.0	6.611
November	2.49	2.60	81.0	5.496
December	2.01	2.34	81.0	5.218
Annual	**4.22**	**2.94**	**81.00**	**75.634**

Annual solar radiation - horizontal	MWh/m²	1.54		
Annual solar radiation tilted	MWh/m²	1.07		
Photovoltaic				
Type		mono-Si		
Power capacity	kW	82.06		
Manufacturer		Trina Solar		
Model		TSM-DA05	1 unit(s)	
Efficiency	%	14.7%		
Nominal operating cel temperature	°C	45	°F	113.0
Temperature coefficient	% / °C	0.40%		
Solar collector area	m²	558	ft²	6,010
Miscellaneous losses	%	5.0%		
Inverter				
Efficiency	%	96.0%		
Capacity	kW	100.0		
Miscellaneous losses	%	5.0%		
Summary				
Capacity factor	%	10.5%		
Electricity exported to grid	MWh	75.534		
			$/kWh	0.081



RETScreen Cost Analysis - Power project

Settings

● Method 1
○ Method 2

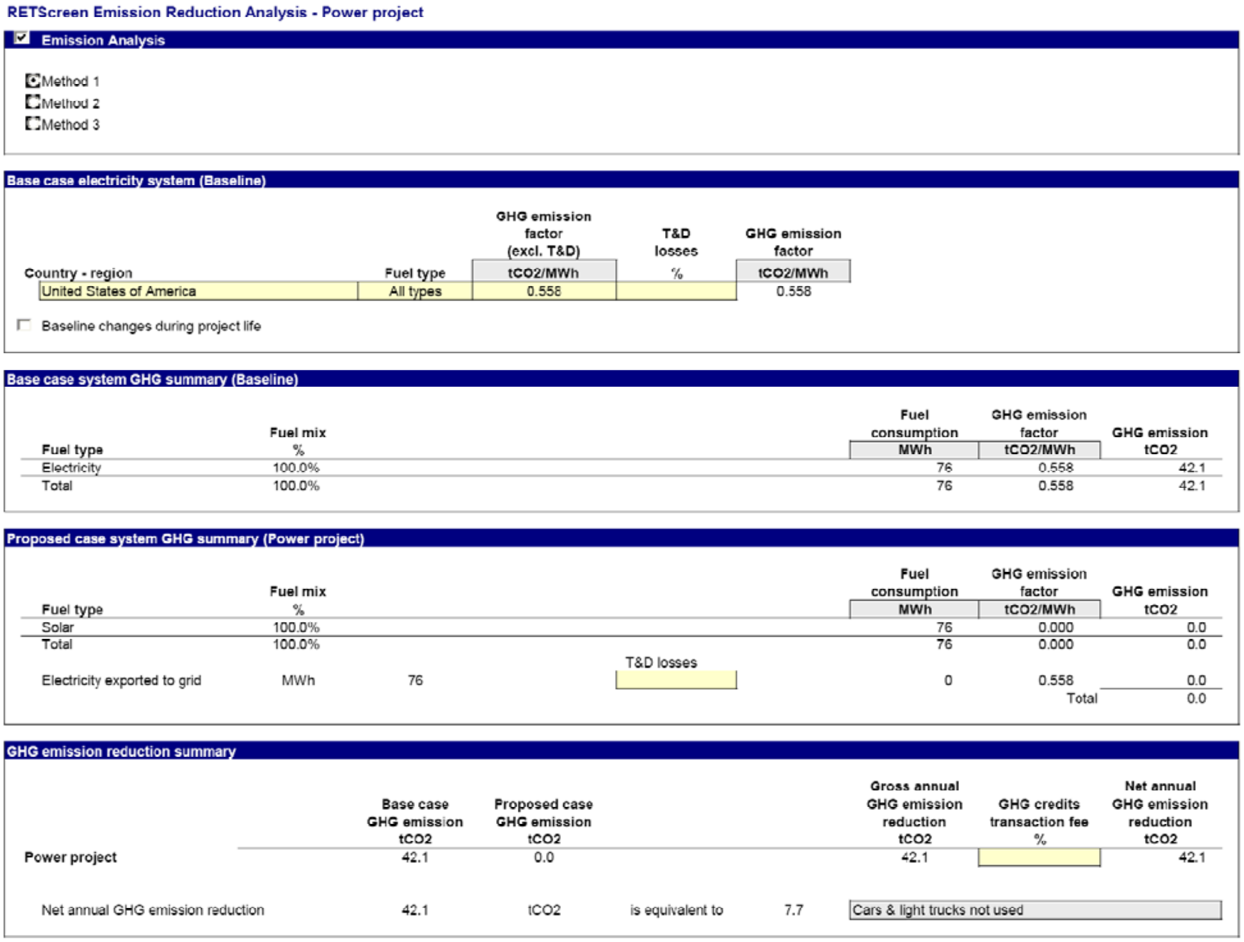
● Notes/Range
○ Second currency
○ Cost allocation

Notes/Range: None

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost			$ -	
Sub-total:				$ -	0.0%
Development					
Development	cost	1	$ 228,000	$ 228,000	
Sub-total:				$ 228,000	27.7%
Engineering					
Engineering	cost	1	$ 20,000	$ 20,000	
Sub-total:				$ 20,000	2.4%
Power system					
Photovoltaic	kW	82.08	$ 7,000	$ 574,560	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Sub-total:				$ 574,560	69.9%
Balance of system & miscellaneous					
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
User-defined	cost			$ -	
Contingencies	%		$ 822,560	$ -	
Interest during construction			$ 822,560	$ -	
Sub-total:		Enter number of months		$ -	0.0%
Total initial costs				$ 822,560	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project			$ -
User-defined	cost			$ -
Contingencies	%		$ -	$ -
Sub-total:				$ -

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost			$ -
				$ -
End of project life	cost			$ -



RETScreen Emission Reduction Analysis - Power project

☑ **Emission Analysis**

● Method 1
○ Method 2
○ Method 3

Base case electricity system (Baseline)

Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
United States of America	All types	0.558		0.558

☐ Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Electricity	100.0%	76	0.558	42.1
Total	100.0%	76	0.558	42.1

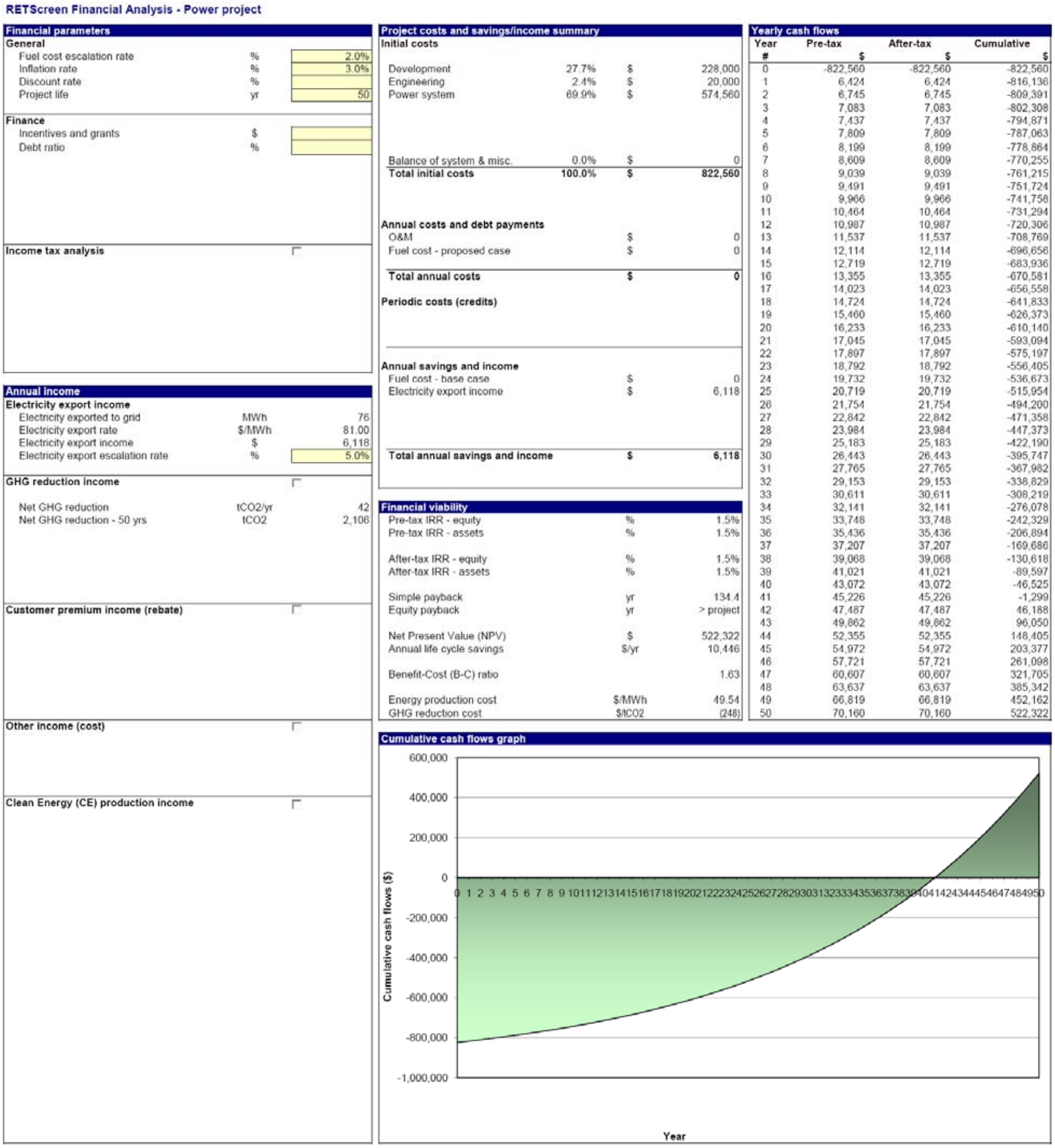
Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %		T&D losses	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Solar	100.0%			76	0.000	0.0
Total	100.0%			76	0.000	0.0
Electricity exported to grid	MWh	76		0	0.558	0.0
					Total	0.0

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	42.1	0.0	42.1		42.1

Net annual GHG emission reduction 42.1 tCO2 is equivalent to 7.7 Cars & light trucks not used



RETScreen Financial Analysis - Power project

Financial parameters

General		
Fuel cost escalation rate	%	2.0%
Inflation rate	%	3.0%
Discount rate	%	
Project life	yr	50
Finance		
Incentives and grants	$	
Debt ratio	%	

Income tax analysis ☐

Annual income

Electricity export income		
Electricity exported to grid	MWh	76
Electricity export rate	$/MWh	81.00
Electricity export income	$	6,118
Electricity export escalation rate	%	5.0%

GHG reduction income ☐

Net GHG reduction	tCO2/yr	42
Net GHG reduction - 50 yrs	tCO2	2,106

Customer premium income (rebate) ☐

Other income (cost) ☐

Clean Energy (CE) production income ☐

Project costs and savings/income summary

Initial costs			
Development	27.7%	$	228,000
Engineering	2.4%	$	20,000
Power system	69.9%	$	574,560
Balance of system & misc.	0.0%	$	0
Total initial costs	**100.0%**	**$**	**822,560**
Annual costs and debt payments			
O&M		$	0
Fuel cost - proposed case		$	0
Total annual costs		**$**	**0**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	6,118
Total annual savings and income		**$**	**6,118**

Financial viability

Pre-tax IRR - equity	%	1.5%
Pre-tax IRR - assets	%	1.5%
After-tax IRR - equity	%	1.5%
After-tax IRR - assets	%	1.5%
Simple payback	yr	134.4
Equity payback	yr	> project
Net Present Value (NPV)	$	522,322
Annual life cycle savings	$/yr	10,446
Benefit-Cost (B-C) ratio		1.63
Energy production cost	$/MWh	49.54
GHG reduction cost	$/tCO2	(248)

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-822,560	-822,560	-822,560
1	6,424	6,424	-816,136
2	6,745	6,745	-809,391
3	7,083	7,083	-802,308
4	7,437	7,437	-794,871
5	7,809	7,809	-787,063
6	8,199	8,199	-778,864
7	8,609	8,609	-770,255
8	9,039	9,039	-761,215
9	9,491	9,491	-751,724
10	9,966	9,966	-741,758
11	10,464	10,464	-731,294
12	10,987	10,987	-720,306
13	11,537	11,537	-708,769
14	12,114	12,114	-696,656
15	12,719	12,719	-683,936
16	13,355	13,355	-670,581
17	14,023	14,023	-656,558
18	14,724	14,724	-641,833
19	15,460	15,460	-626,373
20	16,233	16,233	-610,140
21	17,045	17,045	-593,094
22	17,897	17,897	-575,197
23	18,792	18,792	-556,405
24	19,732	19,732	-536,673
25	20,719	20,719	-515,954
26	21,754	21,754	-494,200
27	22,842	22,842	-471,358
28	23,984	23,984	-447,373
29	25,183	25,183	-422,190
30	26,443	26,443	-395,747
31	27,765	27,765	-367,982
32	29,153	29,153	-338,829
33	30,611	30,611	-308,219
34	32,141	32,141	-276,078
35	33,748	33,748	-242,329
36	35,436	35,436	-206,894
37	37,207	37,207	-169,686
38	39,068	39,068	-130,618
39	41,021	41,021	-89,597
40	43,072	43,072	-46,525
41	45,226	45,226	-1,299
42	47,487	47,487	46,188
43	49,862	49,862	96,050
44	52,355	52,355	148,405
45	54,972	54,972	203,377
46	57,721	57,721	261,098
47	60,607	60,607	321,705
48	63,637	63,637	385,342
49	66,819	66,819	452,162
50	70,160	70,160	522,322

Cumulative cash flows graph