Senior Thesis Final Report

April 7th, 2011

Innovative Technologies for Delivering Healthcare Facilities

Butler Health System

New Inpatient Tower
Addition and Renovation
Butler, PA

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Penn State AE Senior Thesis

Butler Health System
New Inpatient Tower
Butler, PA

BUTLER HEALTH SYSTEM

Courtesy of Turner

Courtesy of Design Group

Turner

Architectural Features

- The new Inpatient Tower is separated by floor, in terms of functionality:
  - Ground, 1st Floor– Support Spaces
  - 2nd Floor– Offices, Education, Public Space
  - 3rd-7th Floor– Procedural Spaces
- Façade composed of brick veneer and glazing
- Construction ties into existing, functional hospital

Project Overview

Owner:	Butler Healthcare Providers
Gen. Contractor:	Turner Construction
Owner's Rep.:	Ritter CM
Architect:	Design Group
Total Height:	7 Stories
Cost:	$80 Million
Size:	209,678 Square Feet
Duration:	September 08'– July 10'

MEP Systems

- All HVAC needs serviced by eight air handling units.
- Variable Air Volume System utilized to control airflow into each space.
- Radiant ceiling panels installed at perimeter of building to reduce heat loss.
- Incoming electrical power provided from existing hospital.
  - Utilizes 480/277V, 3 Phase, 4 wire and 208/120V
  - UPS System employed to minimize power failure
- 85 different luminaires and motion sensor detection
- Wet pipe sprinkler system throughout

Structural System

- Foundation system made up of grade beams, drilled piers, and concrete walls
  - Piers embedded over 36" into bedrock
  - Diameter of piers ranges from 30"-78"
- Beams and columns are wide flange
  - Columns mainly W12 and W14
  - Beams mainly W16 and W18
- Beams support metal decking and composite concrete
- Braced frame design accounts for lateral loads

CHRISTOPHER M. DILORENZO

Architectural Engineering | Construction Option

http://www.engr.psu.edu/ae/thesis/portfolios/2011/cmd5123

Executive Summary

This final report discusses three separate analyses performed on the Butler Health System New Inpatient Tower project. This project includes a 210,000 Square Foot addition to the existing Butler Memorial Hospital. In addition to this, there is also minor renovation work of the existing hospital. This thesis is based on the application of three revolutionizing industry technologies into this state-of-the-art hospital. The analyses topics included the application of a photovoltaic array, prefabrication of overhead MEP systems, and the application of additional BIM uses.

Analysis #1: Feasibility Study and Design for Photovoltaic Array Application
With the rising cost of energy, the idea of sustainability is becoming a growing concern in the construction industry. Although this project is a high-tech facility, the concept of sustainability was not addressed to a significant extent. This study involves installing a photovoltaic solar array on two separate roofs of this building. The array was determined to have a payback period of 2-years and a 25-year value of nearly $750,000. With the incentives provided by the government, it has been determined that this would be a logical investment for the owner.

Analysis #2: Implementing the Use of Prefabricated MEP Spaces
Efficiency and productivity are two terms that are consistently touched upon in the industry. With smaller margins and less profit available, contractors and owners continually seek for ways to improve the timeliness of the project. Because healthcare projects are infamous for complex MEP systems, this analysis deals with the concept of prefabricating of the overhead corridor spaces. This analysis resulted in doubling the productivity of the MEP subcontractors and a total project savings of nearly $1 million. These results prove that this concept would greatly benefit the entire project team.

Analysis #3: Analysis for the Potential Addition of Building Information Modeling Uses
The use of Building Information Modeling (BIM) is becoming a staple in the construction industry. With the idea of improving the project for the entire lifecycle of the building, BIM is seen as a staple. For this construction project, BIM was only utilized for 3D coordination and 4D modeling. The BIM Execution Guide and multiple case studies have been used to determine more optimal ways that BIM can be applied to the project. Through this analysis, several more BIM uses are determined to be beneficial. In particular, the idea of virtual mock-ups appears to be the most advantageous application. This analysis included the production of a virtual mock-up by using the game engine, Unity.

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Butler Health System

PACE Industry Members

My Family and Friends

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Project Overview

Butler Health System (BHS) is a community health system that provides healthcare services in locations throughout Western Pennsylvania. The hospital has locations throughout the area, with Butler Memorial Hospital being the main location. The original hospital was built in 1898, with several renovations and additions taking place throughout the past century. This most recent project, completed in 2010, is headlined with the addition of a new 7-story patient care tower.

The new inpatient tower includes spaces which encompass a wide variety of functions. The ground and first floors of the building are based around the support functions of the building. This includes both medical support functions as well as mechanical spaces. The second floor of the building is devoted entirely to offices and public spaces. The main lobby, pharmacy, and auditorium are located on this floor. Also, all medical offices are situated throughout this level. The third through seventh floors are the patient rooms and procedural spaces. This includes operating rooms, recovery rooms, and typical patient areas.

Turner Construction was the General Contractor for this project, and is also the sponsor for this thesis.

Project Name	Butler Health System- Inpatient Tower Addition and Renovation
Location	Butler, PA (911 East Brady Street)
Building Occupant Name	Butler Healthcare
Occupancy Type	R-2, I-2 overlay
Size	Addition- 208,076 SF Renovation- 1,602 SF
Number of Stories	Above Grade Throughout: 5 Partially Below Grade: 2

General Building Information

Site Plan of Existing Conditions

The original site at Butler Memorial Hospital included the Nixon Sarver Building. This building is located at the North Side of the Hospital, and was demolished prior to construction. The location of this building became the site of the new Inpatient Tower. The aerial photograph below, provided by *Bing Maps*, shows the site prior to the demolition. The Nixon Sarver Building is outlined in ORANGE.

Aerial Photograph Prior to Construction

With the demolition of the Nixon Sarver Building, the new tower is constructed in its place and connected with the existing hospital. All other sections of the hospital, shown in the photograph, will remain after construction. The existing parking areas were partially used for construction staging. Also, Turner Construction occupied one of the neighboring homes as an on-site office. The Existing Conditions site plan is included in Appendix A.

Local Conditions

Butler Memorial Hospital is located in Butler, PA at 911 East Brady Street. The complex is set on a 23-acre location in the city of Butler. Butler Health System owns not only the hospital structure, but also several residences around the perimeter of the hospital. The reason that these homes are owned is due to possible expansion. BHS did not need to tap into these land resources for this expansion project. The demolition of the existing Nixon Sarver Building gave the proper space for the addition of the new Inpatient Tower.

Due to the fact that the project was based in the center of a city, parking was limited for construction personnel. Due to this, additional parking was available in a parking lot about ½ miles from the jobsite. In order to limit the inconvenience for construction employees, a bus service was provided, which ran from the lot to the jobsite. Also, due to the limited site space and large Turner staff, more provisions were made. Among the local residences, Turner was able to use a house (owned by the hospital) to perform some of its operations. A site trailer was used for on-site work, and the house provided Turner an engineering office. The following picture shows the site during the excavation process:

RED: Turner's Engineering Office
BLUE: Turner's Field Office
YELLOW: Limited Construction Parking
ORANGE: Route to Additional Construction Parking

Overhead Site Layout

In Butler, as in many areas, it is typical for steel construction to be used for larger buildings of this sort. Butler Memorial Hospital followed suit, and a steel structural system was utilized. Due to the fact that it was a renovation, masonry was used for a majority of the exterior, to tie into the existing building. The new Inpatient Tower uses a brick color that is very close to the masonry used on the existing hospital.

According to the geotechnical report, provided by Pennsylvania Soil and Rock Incorporated, the subsurface exploration showed a variety of substances. The excavation encountered fill, decomposed rock and readily excavatable bedrock. This bedrock included shale, claystone, and weathered sandstone. As stated in the geotechnical report, the decomposed rock and overburdened materials could be removed with conventional earthwork practices.

Client Information

BUTLER HEALTH SYSTEM

Butler Health System (BHS) is a community health system that serves Western Pennsylvania. The system includes doctors, nurses, and other healthcare professionals. These healthcare professionals provide individualized care to all patients. Because Butler Health System is considered a community health system, it conducts Community Health Assessment Surveys. In order to better the healthcare provided to the community, new services and education programs are constantly introduced. The cornerstone of BHS is Butler Memorial Hospital, which is the focus of this thesis project. Butler Memorial Hospital came to existence in 1898. Overall, there are currently about 1,700 employees employed by BHS.

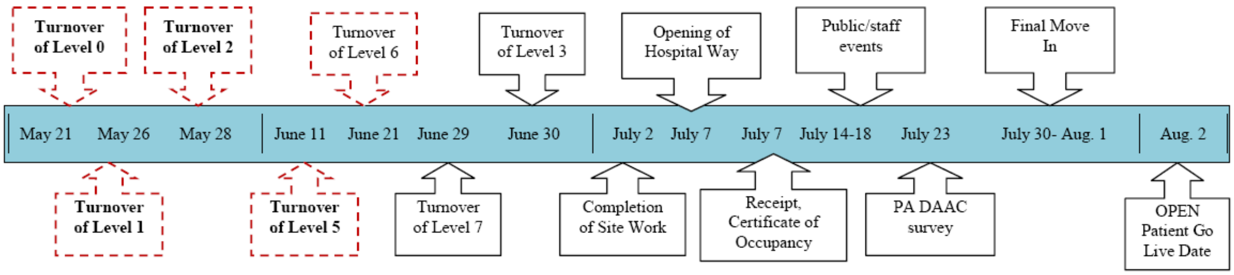
The Addition and Renovation Project at Butler Memorial Hospital is a project that will help to serve the 189,000 residents of Butler County and several surrounding counties. The existing hospital includes a 259-bed acute-care hospital on a 23-acre campus in the city of Butler. The facility was aged and included a strained emergency department. Also, the size of the facility was not able to effectively serve the growing demand for healthcare services in this area.

Because of the growing demand, the new Inpatient Tower was constructed, along with a renovation of some of the existing facilities. The new tower includes:

- New nurses' stations outside each new patient room
- 10 state-of-the-art Operating Rooms
- Two floors of Medical Surgical Units with 26 rooms each
- A new Intensive Care Unit with 24 beds and support area
- Individual rooms for each patient with spaces for families to stay the night
- Austin's Play Area (Mario Lemieux Foundation) for children
- Patient-tracking monitors for families located throughout
- 43,000-square-foot lobby with a chapel, coffee shop, training classrooms, and auditorium

Cost is not a driving factor for this project, but a detailed budget is necessary in order to ensure that the project meets the needs of Butler Health System. Because of this, budget meetings were continually monitored in order to verify that the cost was on track. **Schedule** was the driving factor because it is crucial that all spaces were turned over to the owner, due to patient scheduling. For example, the Operating Rooms had a set date that surgery was to begin. Because of this, Turner was pressed to complete all work in the Operating Room area prior to this date. There was no way to modify this date because surgeries had been scheduled. The need for precise scheduling is shown by Butler Health System's Expansion Updates provided on its website. In each update, a turnover schedule was shown:

PROJECT TIMELINE, MAY-AUGUST



Butlerhealthsystem.org

Sequencing was a major issue in the turnover of the project. This was due to the fact that the Hospital had set dates to move patients into each floor. If the spaces were not turned over at the proper time, there would be no space for these scheduled patients. The importance of scheduling can also be seen from the above figure.

The new Inpatient Tower at Butler Memorial Hospital was always determined to be a state-of-art facility for healthcare. During its design and construction, quality was something that was focused on in extraordinary amounts. This quality is demonstrated in the new Operating Rooms, Patient Rooms, and support areas among others.

New Operating Room

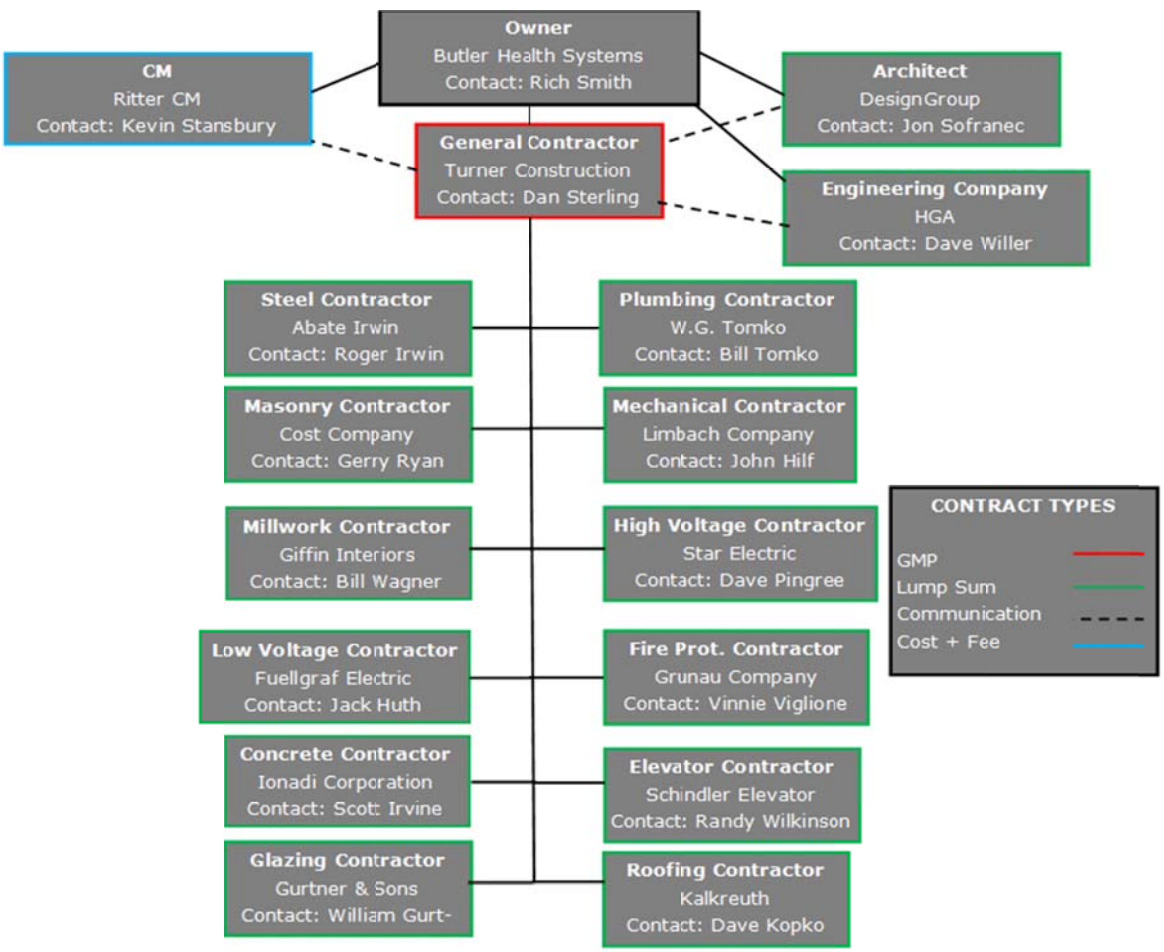
New Private Patient Room

It is evident that schedule and quality were the most important factors in satisfying the owner. Because of this, these two factors were the ones seen as most critical for the project team.

Project Delivery System

The addition of the new Inpatient Tower at Butler Memorial Hospital was completed using a Design-Bid-Build delivery system. Turner was selected as the General Contractor by utilizing a negotiated GMP. Turner was added to a short list of contractors devised by Butler Health System. When it came to determining the appropriate General Contractor, Turner was awarded the contract for several key reasons. Butler Health System decided that Turner should receive the contract due to the ability of using BIM, the General Conditions, proposed fee, and the competency of the interviewed Turner personnel. The interviewed personnel included the Project Executive, Project Manager, and Project Engineer.

Once awarded the project, Turner developed a list of qualified subcontractors for each of the composed bid packages. From this point, bids were requested, and the lowest qualified bidder was awarded the subcontract. Each of these awarded subcontracts are lump sum contracts.



Project Organization Chart

Turner maintains All-Risk Builder's Risk Insurance for these subcontracts. Turner's CCIP Program requires that several documents be submitted by each subcontractor. Turner requires that all subcontractors hold the following insurances from the start of work until final completion:

- Workers' Compensation and Employers' Liability Insurance
- Commercial General Liability Insurance
- Commercial Automobile Liability Insurance

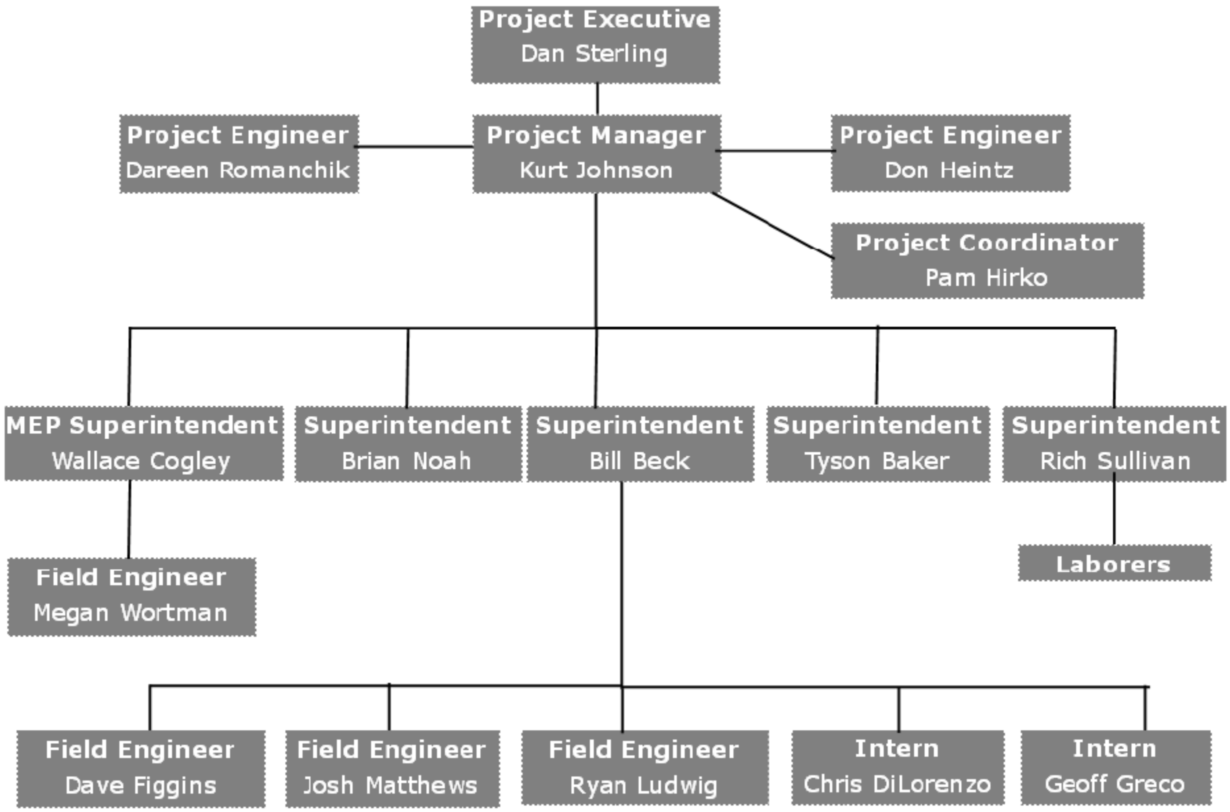
If the subcontractor fails to hold the specified insurances, Turner reserves the right to procure and maintain those insurances. The subcontractor would then be responsible for paying the cost of this service.

The subcontractor is also responsible for furnishing Turner a performance and payment bond. The subcontractor and its surety agree to promptly pay all lawful claims during the project. Turner is therefore relieved of fault for any liability loss, damage and expense, including interests, costs, and attorney fees.

The contract types and delivery system appears to be appropriate for the project at hand. Because it is a large-scale project involving complexities typical of a hospital, it is necessary to have a competent General Contractor. Due to Turner's exceptional record on healthcare projects, it gave BHS a great opportunity to produce a quality project. Also, because of Turner's experience, it was possible to devise a list of qualified subcontractors. With Turner's decision on subcontractors, it would be evident to the owner that the project team is a competent one.

Staffing Plan

Prior to the project, Turner looked into the most efficient way to staff this project. Because of the size and complexity of the project, the on-site team is relatively large. Also, there was significant support being provided by personnel in Turner's Pittsburgh Office. The diagram below shows the staffing plan for Turner on-site:



Turner Staffing Chart

For this project, Dan Sterling was the Project Executive. His main contact was Kurt Johnson, the on-site Project Manager. Everyone on site indirectly reported to Kurt Johnson, as shown above. This structure worked efficiently for this project due to its intricacies and size. While this staff made minor changes through the duration of the 2-year project, the layout of the chart only varied slightly throughout. Not included in this chart, is the office personnel. This includes departments such as estimating, purchasing, and IT.

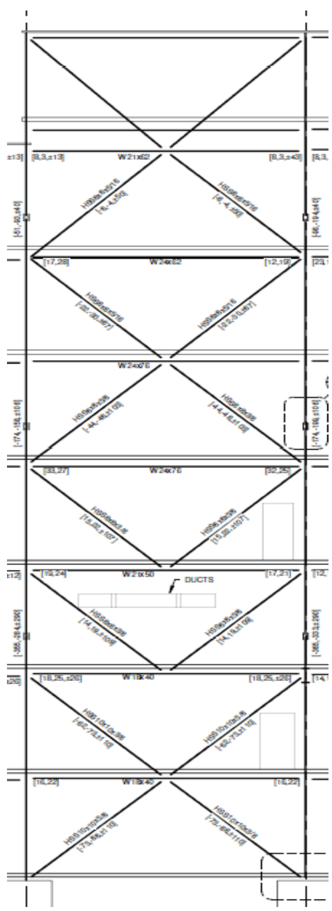
Building Systems Summary

Demolition

The new tower is constructed where the original Nixon Sarver Building was located. This building was demolished prior to construction. In the contract, there was some selective demolition that was performed prior to foundation work. Where the new tower meets the existing hospital, some demolition was necessary in order to properly construct the caissons. In this demolition, there was no lead or asbestos encountered.

Structural Steel Frame

The majority of the structure of the new Inpatient Tower is composed of structural steel. The structural columns are mainly W12's and W14's. The steel beams in this building are mainly W16's and W18's. The W shaped beams and columns are ASTM A992, with a yield strength of 50ksi. For the lateral loads on the tower, K-frame braces are utilized. This bracing system is made up of HSS sections. The HSS sections vary based on the floor level. The lower floors are mainly HSS 10x10 and the upper floors are mainly HSS 8x8. These HSS sections are ASTM A500, Grade B, with a yield strength of 36ksi. The lateral bracing for the building is shown below:



Drawing S300: Lateral Bracing

The structural steel frame supports a load that is distributed over composite metal decking, which supports composite concrete slabs. The slabs are a total thickness of 6 ½", with a total topping of 3 ½". The structural drawings indicate that the floor slabs shall have a strength of 3500 PSI at 28 days. The structural steel was erected using a crawler crane, which navigated throughout the site depending on the location of the pick. The crane was a Manitowoc Model 777. The specifications include the following:

- 200 Ton Capacity
- 4,830 ft-kips Maximum Load Moment
- 300' Boom Length
- 29,500 lb. Clamshell Capacity
- 20,000 lb. Dragline Capacity
- 340 HP Engine Standard

Manitowoc Setting Steel

Cast-in-Place Concrete

Cast-in-place concrete was used on several parts of the project. It was used for the drilled piers in the foundation system. It was also used for the lightweight concrete on metal decking. All concrete on this project was cast-in-place. All formwork is designed, constructed, and maintained to insure completed work within tolerance limits specified in ACI 301 and ACI 347. The formwork varies depending on if the concrete is exposed or unexposed. For exposed concrete surfaces, panels must be used that will provide continuous, true, and smooth surfaces. For unexposed surfaces, plywood, lumber, or metal can be used. For all cast-in-place concrete, it must be shored until 75% of the required compressive strength is reached. The cast-in-place concrete was all placed using a concrete truck and pump.

Concrete Slabs being Pumped

Mechanical System

The majority of the new tower is served by three air handling units on the highest roof. These three units (AHU-1,2,3) are served by two water-cooled chillers on the first floor. Each of these rooftop units supplies 62,000 CFM, which serve every floor of the building. The Operating Rooms are controlled by two separate air handling units (AHU-4,5), which reside on the 5th floor penthouse. Each of these units supply 18,500 CFM to the Operating Rooms. All five of these units are variable air volume units. There are also three other air handling units in the building. AHU-6 supplies the first floor chiller room with 4,700 CFM. AHU-7 supplies the first floor electrical room with 4,000 CFM. The elevator penthouse is supplied with 4,700 CFM from AHU-8. The last three air handling units are constant volume units.

The heating for the building is controlled through two boilers, located on the first floor. These 215 HP Boilers supply the hot water to each of the air handling units in the tower. The new tower utilizes a Variable Air Volume (VAV) system throughout. The air from the air handling units is supplied to the VAV boxes. These boxes adjust the volume of the air that passes into each space in order to keep the space at the desired temperature. In addition to these aspects of the mechanical system, radiant ceiling panels are also employed. These panels exist at the perimeter of the building, on the upper three floors.

The building also is completely covered by a wet pipe sprinkler system, with a fire pump room being located on the first floor of the building. Additionally, the building contains fire rated walls (1-3 hours) and smoke barrier walls. Along with these systems, smoke and fire dampers are installed in the ductwork in order to control the spread of a fire.

Electrical System

Due to the fact that the inpatient tower is an addition to the existing hospital, the power for the addition comes from the existing facility. The power enters into the electrical room on the west side of the tower. It is here that the power encounters the 2500 kVa transformer, which then supplies the power to the upper floors. This main electrical room is located on the first floor of the building. Power is also then to electrical rooms throughout the upper floors. Each of the upper floors has at least two additional electrical rooms. Inside of these electrical rooms, both 120/208 and 277/480 volt panels are utilized for the distribution to the respective floors.

On the ground floor, two emergency generators are installed in order to combat any power failure. A UPS system is employed to minimize problems in the event of a failure. In the OR and IT rooms, a flywheel system is used. With this system, there is no blip when switching over to emergency power. This system is used due to the critical activities in these spaces that cannot afford to be affected by power loss.

Masonry

Masonry is used for both the building enclosure and also as some wall construction on the ground and 1st floors. The mechanical and electrical rooms on the bottom floors are enclosed by 8" CMU walls. These walls are used as fire rated walls, due to the nature of the equipment in these spaces. The CMU walls are a standard 8"x16". The load bearing type complies with ASTM C 90 and an average compressive strength of 2,000 psi. Also, all reinforcing steel for grouted concrete masonry walls, bond beams, concrete masonry lintels, and other similar work shall conform to ASTM A 615 or A616, Grade 60.

The masonry used for the building enclosure is a face brick veneer. This assembly includes an air cavity and rigid 2" polyisocyanurate rigid insulation. This is attached to 6" structural steel stud framing. The face brick on this project must comply with ASTM C 216 and have a compressive strength of 3,000 psi. The framing is concealed by sheathing and gypsum wall board.

For the construction of the masonry, free-standing scaffolding and hydraulic scaffolding were used. The scaffolding was assembled based on efficiency in order to reduce wasting any valuable construction time. The anchoring for the masonry depends on the use. For brick veneer over concrete, dovetail anchors are used. Veneer anchors are used over metal stud and gypsum sheathing.

Curtain Wall

The glazing system used is an aluminum curtain wall system. There are several different glass types used throughout the project. This includes 1" tinted insulating glass, 1" spandrel glass, 1" insulating glass, and ¼" clear float glass. These different glass types have a low "E" coating and a ½" air space for insulation purposes. All glass and glazing has been fabricated and installed to withstand normal thermal movement, wind loading, and sometimes impact loading.

Masonry and Curtain Wall

Support of Excavation

When the excavation took place for the new tower, benching was used as support of the excavation. This benching was sloped at adequate levels to meet OSHA requirements. Once the foundations were constructed, these excavated areas were backfilled. The slope between excavations was not to exceed one vertical for every two horizontal.

Project Cost Evaluation

Construction Cost

To report the actual building construction cost, the following line items have been excluded:

- Fringes/Taxes/Insurance
- Site Work
- Contingency
- General Conditions
- Fee

All cost per square foot information is based on a total addition project size of 208,076 square feet. These costs are based on the final estimated values produced by Turner Construction's GMP.

Total Building Construction Cost = **$67,173,679**
Building Cost per Square Foot= **$323**

Total Project Cost

All line items have been included for the total project cost.

Total Project Cost = **$79,750,974**
Project Cost per Square Foot = **$383**

Building Systems Costs

System	Total Cost	Cost per Square Foot
Mechanical System	$9,949,569	$48
Electrical System	$12,296,394	$59
Structural System	$5,844,805	$28
Plumbing System	$5,152,886	$25

General Conditions Estimate

The General Conditions estimate for the new Inpatient Tower is composed of several different elements. The elements included in the General Conditions estimate, provided by Turner Construction, are the following:

- Temporary Facilities
- Temporary Utilities
- Protection and Safety
- General Expenses
- Project Staff
- Fringes/Taxes/Insurance

The total General Conditions cost for the project is estimated at **$5,395,896.** This cost is in comparison with a direct construction cost of **$69,339,103.**

Along with the General Conditions, there are also contingencies allocated into the project. The contingencies include:

- Design/Development
- Construction

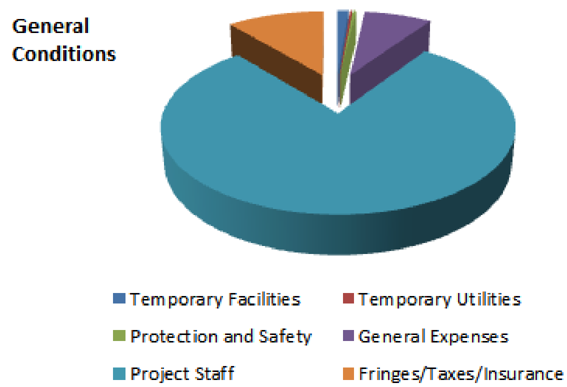
The total contingency costs for the projects comes out to be **$2,083,437.00**

All information on the General Conditions and Contingencies are included in Appendix B: General Conditions Estimate. The following tables are included in Appendix B:

- Table 1: General Conditions Estimate
- Table 2: Contingency Costs
- Table 3: Onsite Staff Rates

In the figure below, it is obvious that the Project Staff makes up a majority of the General Conditions Cost. Also in Appendix B, a table is included to show the base monthly and hourly billing rates of on-site employees. All home office employees are not included in this cost breakdown. Home office employees would include:

- Operations Manager
- Purchasing Department
- Estimating Department
- Project Executive
- Administration
- IT
- Accounting
- Cost Engineering Department



It is quite evident that a construction delay would drastically increase the cost of a construction project. By analyzing the tables in Appendix B, the following calculations depict the approximated monthly fees of the project:

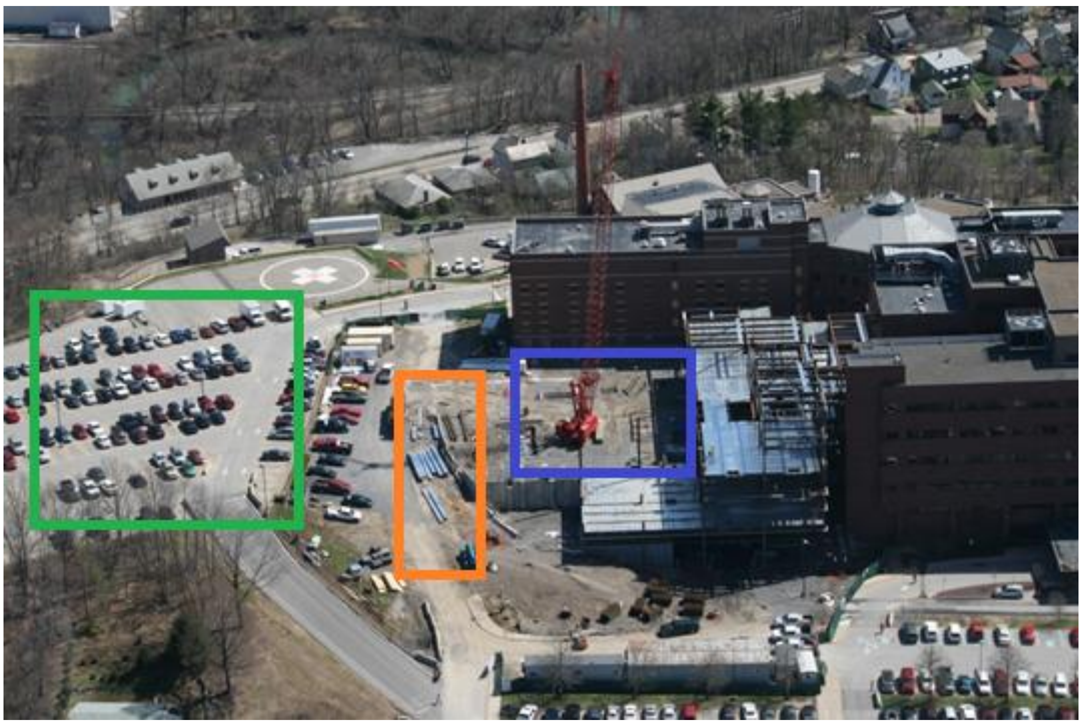
- Temporary Utilities: **$560.00/month**
- Protection and Safety: **$840.00/month**
- General Expenses: **$16,300.00/month**
- Project Staff: **$169,150.00/month**
- Total Monthly Rate: **$186,850/month**

With a total monthly General Conditions rate in this cost range, it is obviously critical that the schedule must be closely monitored. Any delays in the project will lead to a major cost increase to some party in the construction process. The monthly cost for the project staff is the most critical factor in this cost.

Site Layout Planning

For the steel erection phase of the New Inpatient Tower, one crane was used for the setting of all structural steel. The Manitowoc Model 777 is a lattice boom crawler crane. This crane was able to navigate within a small area in order to assemble the entire structure of the building. This limited site logistic complexities because only one area was needed for crane use. The steel beams and columns were also staged in nearby areas in order to minimize construction interference.

The site plan of the steel erection phase is included in Appendix D: Site Layout Planning. This site plan is referenced from the included photographs, taken during the steel erection phase:



View from Northwest: Manitowoc setting steel

It is seen in the above photograph that the site logistics did not change much for this phase. The on-site parking is still shown on the left side of the photograph. Also, the site trailers are shown in the foreground of the construction. This limited change to the site logistics minimized difficulties on the job site.

ORANGE: Steel Staging Area
BLUE: Area for Crane Use
GREEN: North Parking Lot

Image from Northwest: Manitowoc setting steel

The above photograph again shows the minimal disturbances to the site during steel erection. The staged steel is shown just to the right of the crawler crane. With the staging space so close to the erection, it again minimizes interference with the rest of the construction sites. As the steel erection progressed, the crane never had to move from the same general location.

The layout of the site, devised by Turner, seems to be the most effective way to utilize the site. As seen in the photographs, a confined space is designated as the space for crane movement. With minimal movement required by the crane, it also reduces potential safety hazards.

Refer to Appendix D: Site Layout Planning for the site plans. The site layout plans included in this appendix include an overall site plan, as well as an enlarged plan of the crane access area.

Detailed Project Schedule

The design process of the Butler Health System New Inpatient Tower began on February 4th, 2008. The design process continued throughout the majority of the construction. During this time period, several design releases were developed at specific times. The release dates of these portions of the projects were based on the planned dates of construction activities.

Before the design was completed, the GMP was developed by Turner Construction. Along with the actual construction activity, BIM Coordination and Procurement also began early on in the process. Construction of the New Inpatient Tower began on August 18th, 2008. Below are some of the critical dates of the construction process:

Structural Steel Erection:	2/17/2009 – 6/8/2009
Concrete Pouring:	1/26/2009 – 7/30/2009
Masonry Work:	6/23/2009 – 3/22/2009
Windows and Curtain Wall:	10/12/2009 – 3/1/2010
Vertical Work:	5/15/2009 – 5/27/2010
Ground Floor Work:	6/2/2009 – 1/7/2010
First Floor Work:	6/1/2009 – 1/20/2010
Second Floor Work:	6/16/2009 – 7/6/2010
Third Floor Work:	6/16/2009 – 6/9/2010
Fifth Floor Work:	7/24/2009 – 5/18/2010
Sixth Floor Work:	8/5/2009 – 6/10/2010
Seventh Floor Work:	8/20/2009 – 5/5/2010
Roofing:	6/9/2009 – 4/1/2010
Final Sitework:	12/18/2009 – 7/7/2010
Turnover/Commissioning:	1/8/2010 – 7/9/2010

All of these summary activities along with detailed activities are included in Appendix C: Detailed Project Schedule.

The procurement process of the project continued from the onset to the near completion of construction. The actual construction of the tower ran from May 29th, 2008 through July 7th, 2010. With a duration of this extent, it is necessary to break down the construction into activities by floor. It can be seen from the dates above that the work on each floor overlapped significantly. This was necessary because of the strict turnover dates. Butler Health Systems had already committed dates that patients were to be serviced in the new tower. With immovable deadlines such as these, serious attention to detail was needed for the project schedule.

The entire hospital was completely in the hand of the owner's by the end of June 2010. While the tower was already turned over the owner, commissioning and sitework continued throughout July.

Feasibility Study and Design for Photovoltaic Array Application

Problem Identification

The New Inpatient Tower at Butler Memorial Hospital is a state-of-the-art facility, which employs new technologies throughout. Although this project is considered a high-tech building, one issue was not addressed. The idea of sustainability was never seen as a high priority for the construction of this new tower. Because medical facilities of this magnitude use an extraordinary amount of energy, sustainable options could produce enormous benefits to the owner of the facility. In particular, the idea of installing a photovoltaic (PV) array to the building could greatly reduce the energy costs.

Because of the potential benefits that can be reaped by properly applying photovoltaic systems to high-energy buildings, it is an idea that should be addressed. In order to determine if the idea is a valuable suggestion, a feasibility study needs to be performed based on a produced design. This study will include the following:

- Background Information
- Initial Site and Building Analysis
- Potential Energy Reductions: Studies with Lighting
- Array Design
- Structural System Impact
- Energy Impact
- Electrical Tie-In
- Financial Feasibility

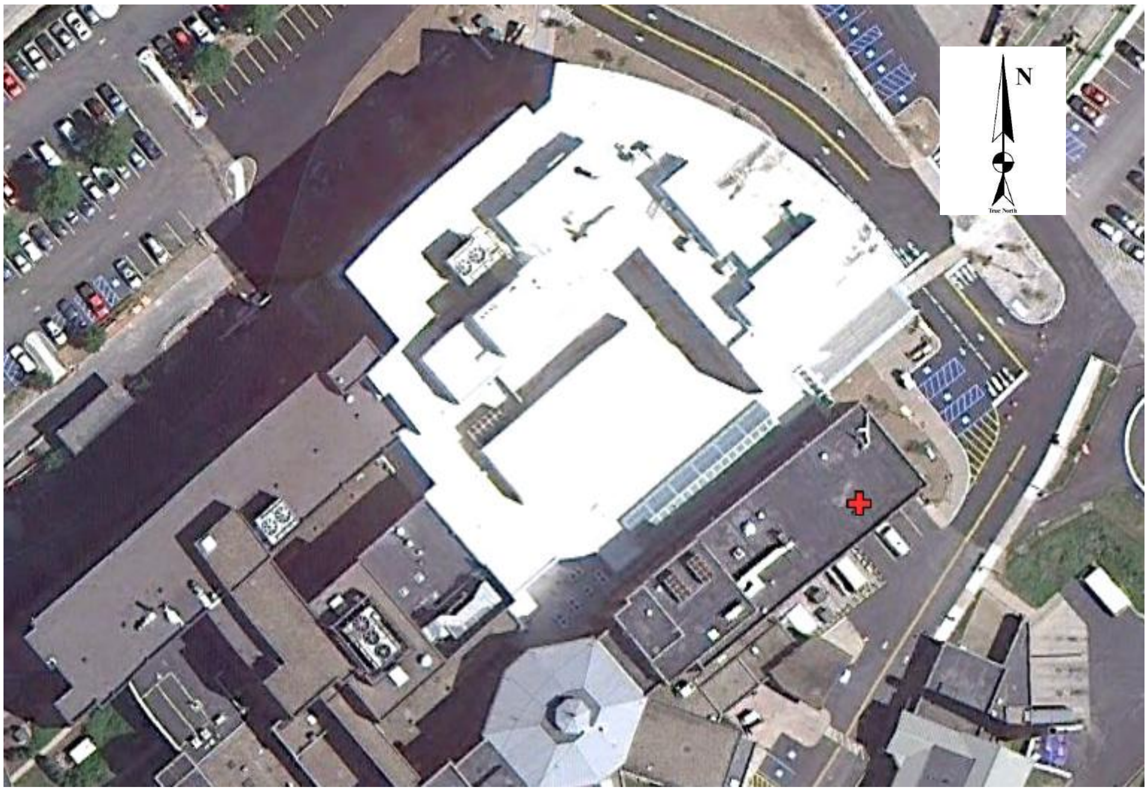
Background Information

With the continuing rising cost of energy throughout the world, several ideas have been explored as ways to combat this problem. One of these main ideas is the application of photovoltaic panels to buildings. Photovoltaic cells are put together to form these photovoltaic panels, which absorb solar radiation. The panels then work, as semiconductors, to convert this solar energy into usable electricity. The electricity that is generated from these panels are able to be stored in a battery or used to power equipment. Both of these techniques have been utilized to reduce the energy cost of buildings.

In terms of applying photovoltaic panels into buildings, there are two main ways to do this. PV panels can be used for buildings by either integrating them into the building or mounting the panels. These panels can be mounted either on the building, or at a nearby location. One main location of these panels would be the roof of the facility. While photovoltaic panels can be used to create electricity for buildings that exist at an extreme distance from the power grid, they can also be used on buildings that are already tied into the electrical grid. This is the case at Butler Memorial Hospital, as the existing building and new inpatient tower are already tied into the existing grid. The installation and application of a photovoltaic array can be used to reduce the overall energy consumption of the building. This is particularly important for healthcare facilities, in which the energy consumption is particularly significant.

Initial Site and Building Analysis

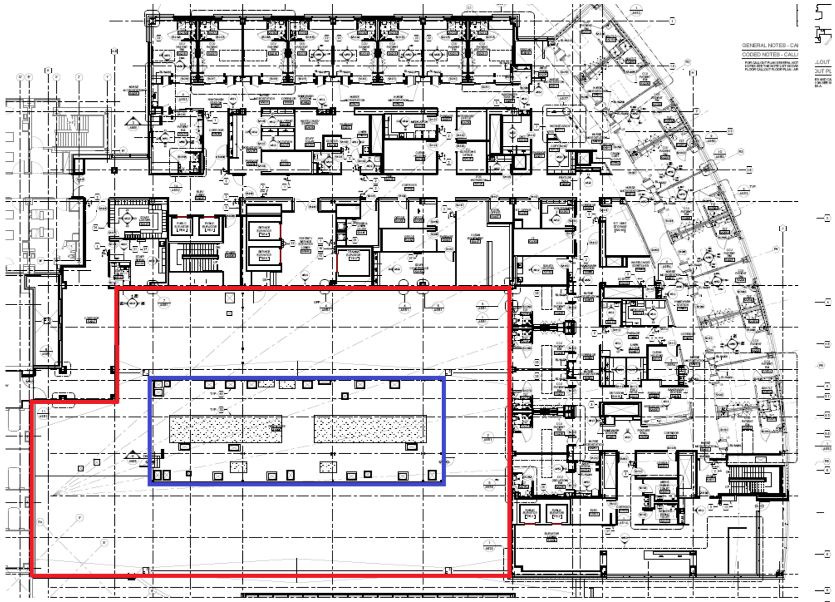
The first step to determine the feasibility of employing a system of this nature is to look into the specifics of the existing site. The below picture shows the site, courtesy of Google Earth, post-construction:



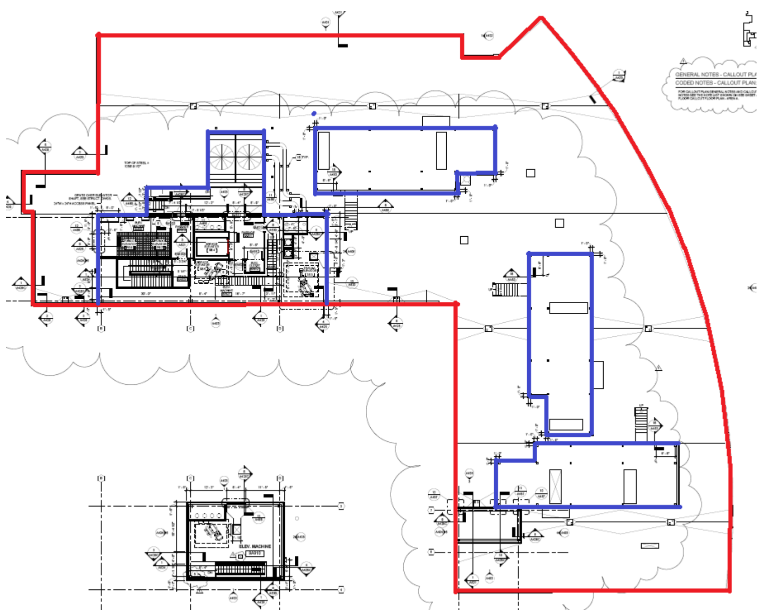
Google Earth Overhead View of Site

The new is indicated by the white roofing. The existing hospital, identified by the black roofing, is located southwest of the addition.

As noticed by the shadow produced in the Google Earth image, it is apparent that sunlight is highly prevalent on the roof of the new tower. It is also clear that there are a significant amount of potential obstructions on the roof of the tower. The upper roof houses an elevator machine room, along with three air-handling units. The lower roof includes its own large air-handling unit. To thoroughly analyze the two roofs, with their obstructions, it is necessary to take a closer look at each roof. In the two images on the following page, the roof is outlined in **RED** while the roof obstructions, including air-handling units and machine rooms, are outlined in **BLUE.**



5th Floor Roof Diagram



8th Floor Roof Diagram

It is clear from the images that roof obstructions will certainly affect the areas of the roof that will be affected by sunlight. The following table includes information of area allocation on each of the roofs.

Roof	Total Area	AHU/Machine Room Area	Available Area
5th Floor	15,330 SF	4,150 SF	11,730 SF
8th Floor	23,550 SF	3,600 SF	19,400 SF

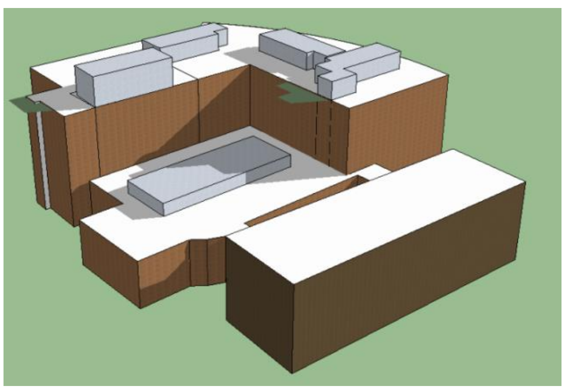
Roof Areas

Once the available areas have been determined, the next step for the initial layout of the PV system is to perform a shadow analysis. The shadow analysis for this study was conducted using Google Sketch-up. The following site information must be used to perform this analysis:

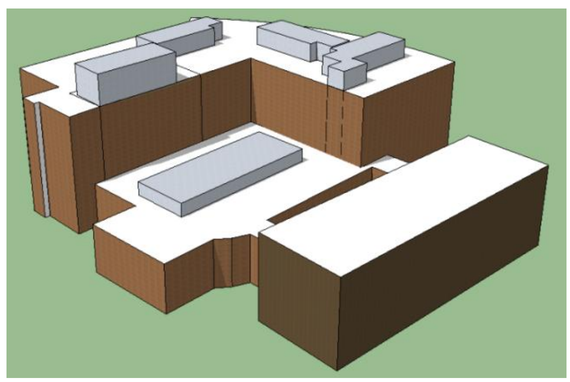
Site Location: Butler, PA
Latitude: 40.87°
Longitude: 79.88°
Summer Solstice: June 21st
Winter Solstice: December 22nd
Spring/Fall Equinox: March 20th, September 23rd

Each of these inputs is necessary in order to develop the solar shading analysis. The shadows cast by the air-handling units, machine room, and adjacent building are all shown in the Sketch-up model. For each of the above dates, the shadows cast at 9:00 AM and 4:00 PM are determined.

Summer Solstice

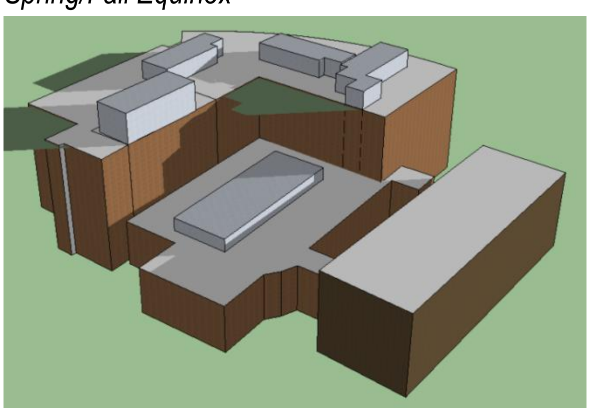


9:00 AM

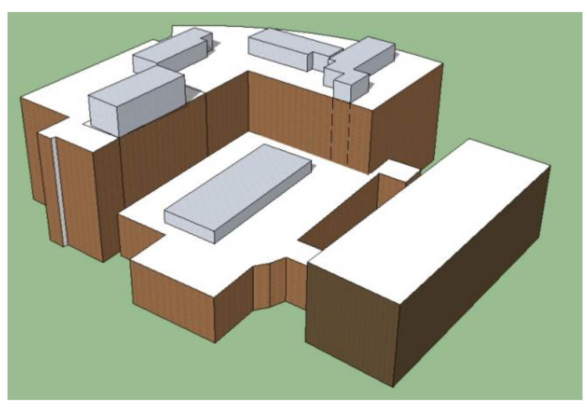


4:00 PM

Spring/Fall Equinox

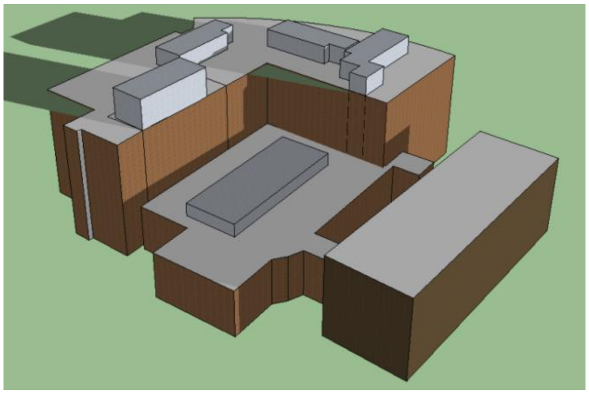


9:00 AM

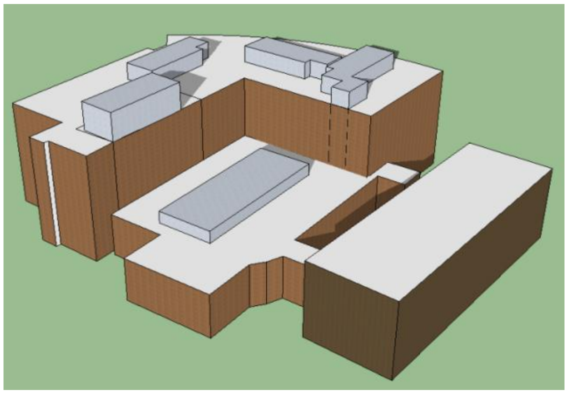


4:00 PM

Winter Solstice

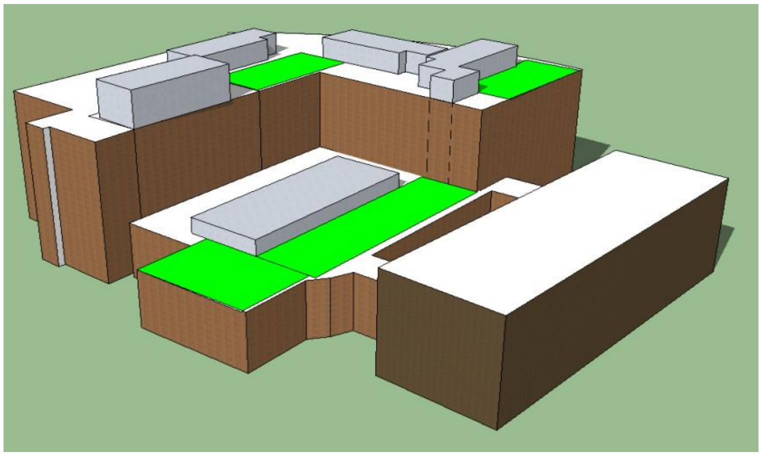


9:00 AM



4:00 PM

In order to determine the areas that would provide the most benefit for PV placement, it is necessary to analyze each of the above diagrams. After performing this analysis, it is possible to highlight these areas. The image below represents the areas that have been determined to be the most suitable for PV implementation. These areas are highlighted in **GREEN.**



Layout of potential PV Locations

The area of best potential location, which is shown on the previous page, totals to approximately 9,600 square feet.

Potential Energy Reductions

Photovoltaic panels can be effective in providing all of the electricity for a building. In this instance, as with most medical facilities, the energy consumption is too high to be completely serviced by the PV array. After the completion of the new inpatient tower, the electric billing information for Butler Memorial Hospital, for one month, is included below:

Energy Used: 1,696,531 kwh
Demand: 3,011 kw
Monthly Cost: $98,428.30
It is quite apparent that the energy usage by the hospital is a subject that can be targeted in terms of reducing the overall utility costs. The monthly energy use approximates to over 56,000 kwh per day. Because of this high energy usage, it is not feasible for a photovoltaic array to provide all of the power for the facility. Because of this, it is more reasonable to limit the target of energy reduction. In this instance, it has been determined that the available roof space would be utilized to provide solely the energy necessary for lighting the new inpatient tower.

In order to determine if the lighting load can be eliminated or significantly reduced, the amount of energy used by the lights must be closely analyzed. The following table illustrates the types of lights, the quantity, and the wattage. Each of these numbers are used to determine the total kwh consumption by the lighting system.

Column1	Column2	Column3	Column4	Column5
Light Type	Description	Wattage	# of Lamps	Total Watts
AF1	4' Cylinder Custom Stair Pendant	58	2	116
AF2	2' Cylinder Custom Stair Pendant	36	2	72
AF3	2' Drum Custom Stair Pendant	85	3	255
AM1	Reception Desk Pendant	6	34	204
AM2	Pharmacy Pendant	7	3	21
BF4	Wall Sconce	19	72	1368
CF1	4' Staggered Strip-Corridors	58	351	20358
CF2	4' Staggered Strip- Board Room	58	16	928
CF3	4' Cove Light	32	4	128
CF4	2' Cove Light	18	3	54
CF7	2' Curvable Strip- Board Room	84	30	2520
CM1	LED Cove in Chapel	6	16	96
DF1	Fluorescent Downlight 7" Aperture	52	332	17264
DF2	Fluorescent Downlight 7" Aperture	52	7	364
DF3	IC Rated Downlight	28	12	336
DF4	Fluorescent Downlight 4" Aperture	14	130	1820
DF5	Fluorescent Downlight 6" Aperture	28	306	8568
DF6	Fluorescent Downlight-Board Room	28	14	392

DF7	Black Housing 7" Auditorium	52	25	1300
DF9	Black Housing 7" Auditorium	52	20	1040
DF10	Shower Downlight	26	59	1534
DF11	Fluorescent Downlight-Training	56	55	3080
DG2	Adj. Incandescent Downlight 4"	50	162	8100
DG3	Incandescent Downlight 6"	150	30	4500
DG4	Incandescent Downlight 6"	150	16	2400
DG5	Incandescent Downlight-Chapel	50	12	600
DG6	Incandescent Downlight-Chapel	50	4	200
DH2	Exterior Metal Halide 6"	48	14	672
DH3	Lobby Downlight- 7"	93	8	744
EG1	Recessed Gimbal	14	8	112
JF3	4' Wall Bracket	58	8	464
JF5	4' Indirect/Direct- Conference	58	18	1044
JF8	4' Wall Wash	28	3	84
LF1	2x4 Gasketed Surgical Troffer	174	96	16704
LF2	2x4 Lens Troffer	58	335	19430
LF3	3 Lamp Lens Troffer	85	20	1700
LF5	1x4 Gasketed Surgical Troffer	85	24	2040
LF6	2x2 Lensed Troffer	45	34	1530
LF7	3 Lamp 2x4 Troffer	85	8	680
LF9	2x4 Gasketed Surgical Troffer	174	10	1740
MF1	2x2 Sealed Acrylic	76	114	8664
MF3	2x4 Basket Style	58	256	14848
MF4	2x2 Basket Style	31	176	5456
MF5	2x2 Basket Style	74	55	4070
MF6	2x4 Basket Style	58	93	5394
NF1	6"x4' Industrial Wrap Around	58	189	10962
NF2	Industrial Pit Light	26	42	1092
TH1	Lobby Track Lighting	48	12	576
TH2	Single Circuit Track-Gift Shop	75	38	2850
TH3	Lobby Track Lighting	48	12	576
UF1	4' Solid Front Undercabinet	32	71	2272
UF3	2' Solid Front Undercabinet	18	22	396
		Total Energy Usage per Hour (kw)		181.718

Calculated Lighting Loads- Entire Addition

The table on the previous pages determines that the total energy use per hour is approximately 182 kW. In order to size the necessary PV array, the energy usage must be converted to kilowatt-hours. While a majority of the lights will be used throughout the day, such as in hallways, lobbies, and some patient rooms, several rooms will not be occupied for the duration of a typical day. For example, storage spaces, conference rooms, exterior spaces, and empty patient rooms will not require lighting at all times of the day. Because of this, an assumption must be made for the total energy use. The assumption made for this calculation will be that the lighting system will need to provide the total energy usage for 18 hours per day.

Total Energy Usage per Day = 182 kW * 18 hours = **3,276 kWh**

After performing this calculation, it was apparent that it would definitely not be possible to power the lighting system for the entire building. In order to confirm this, a solar panel calculator, provided by BDBatteries, indicated that even with 300W solar panels (highest wattage available), almost 4,000 panels would be needed to suit this load. This value was determined by utilizing the following information:

Number of kWh used per month: 3,276 * 30 = 98,280 kWh
Average sun-hours per day: Butler, PA = 3.28
Wattage of panels: 300W

Because this was immediately deemed as impossible, the ultimate goal of the system was altered. In order to reduce the energy costs for the hospital, the PV array would be sized to meet the energy needs of all corridors and lobby spaces. Because these lights are operating on a continuous basis, this could lead to significant energy savings. The lighting load produced by the corridors is included in the below table.

Light Type	Description	Wattage	# of Lamps	Total Watts
CF1	4' Staggered Strip-Corridors	58	351	20358
DF1	Fluorescent Downlight 7" Aperture	52	316	16432
DF3	IC Rated Downlight	28	8	224
JF3	4' Wall Bracket	58	10	580
LF2	2x4 Lens Troffer	58	20	1160
MF4	2x2 Basket Style	31	208	6448
MF6	2x4 Basket Style	58	81	4698
NF1	6"x4' Industrial Wrap Around	58	8	464
TH3	Lobby Track Lighting	48	12	576
		Total Energy Usage per Hour (kw)		50.94

Calculated Lighting Loads- Corridors & Lobbies

By using the information provided in the previous table, the total energy usage per day can be computed:
Total Energy Usage per Day = 51 kW * 24 hours = **1,224 kWh**

As with the previous analysis of the complete lighting load of the new addition, the energy needed to account for all corridor lighting is much greater than anticipated. Similar calculations were performed on the corridor lighting load. With the highest possible wattage for the PV panels, over 1500 panels will still be needed to power all corridor lighting. The calculations are provided below.

Number of kWh used per month: 1,224 * 30 = 36,720 kWh
Average sun-hours per day: Butler, PA = 3.28
Wattage of panels: 300W

Because the lighting uses much more energy than anticipated, a new approach will be taken to reduce the total energy cost. It is clear that the photovoltaic array will not be able to provide enough power to completely energize the corridor lighting. The analysis will now first consider the total number of panels that can be installed on the roof space that was explained earlier in the analysis. The number of panels will be based on the total area of the roof as well as the tilt of the array. The tilt is crucial because this will determine spacing, based on shadows.

Array Design

To determine the layout of the array, the shading produced by the panels must be analyzed. As each row of panels casts a shadow, the spacing will be determined to minimize shadow interference. According to "Photovoltaic Systems-2nd Edition," by James Dunlop, the tilt of fixed panels should be equal to the latitude of the site location. Because the latitude in Butler is 41°, this will be established as the tilt of each row of the array.

This tilt angle and the general site location will be used to determine the spacing between the rows of PV panels. Using a calculator, provided by *Sustainable by Design,* the following inputs were required:

Panel Height: 59"
Panel Thickness: 1.4"
Panel Spacing: Varying
Panel Tilt: 41°
Latitude: 41°
Orientation: South (Optimal for energy production)

The following page depicts the studies based on spacing.

Various numbers for panel spacing have been used to determine the optimal distance between panels. By changing the spacing between rows, the calculator compares the percentage of sun that actually hits the panels at different times of the day throughout the year. For example, with a spacing of 2' between rows, the following chart has been calculated.

	MORNING									AFTERNOON								
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
Jan					10%	16%	18%	20%	20%	20%	18%	16%	10%					Jan
Feb				7%	18%	22%	23%	24%	24%	24%	23%	22%	18%	7%				Feb
Mar				26%	28%	29%	29%	29%	29%	29%	29%	29%	28%	26%				Mar
Apr			0%	46%	38%	36%	35%	35%	34%	35%	35%	36%	39%	46%				Apr
May			100%	65%	47%	42%	40%	39%	38%	39%	40%	42%	47%	65%				May
Jun			100%	75%	51%	45%	42%	41%	41%	41%	42%	45%	51%	75%				Jun
Jul			100%	71%	49%	44%	41%	40%	40%	40%	41%	44%	49%	71%				Jul
Aug			0%	56%	42%	39%	37%	37%	36%	37%	37%	39%	42%	56%				Aug
Sep			0%	35%	33%	32%	32%	32%	32%	32%	32%	32%	33%	35%				Sep
Oct				15%	22%	25%	26%	26%	26%	26%	26%	25%	22%	15%				Oct
Nov					12%	18%	20%	21%	21%	21%	20%	18%	12%					Nov
Dec					7%	14%	17%	18%	19%	18%	17%	14%	7%					Dec
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
	MORNING									AFTERNOON								

Percentages of Sun Striking Panels with 2' Spacing

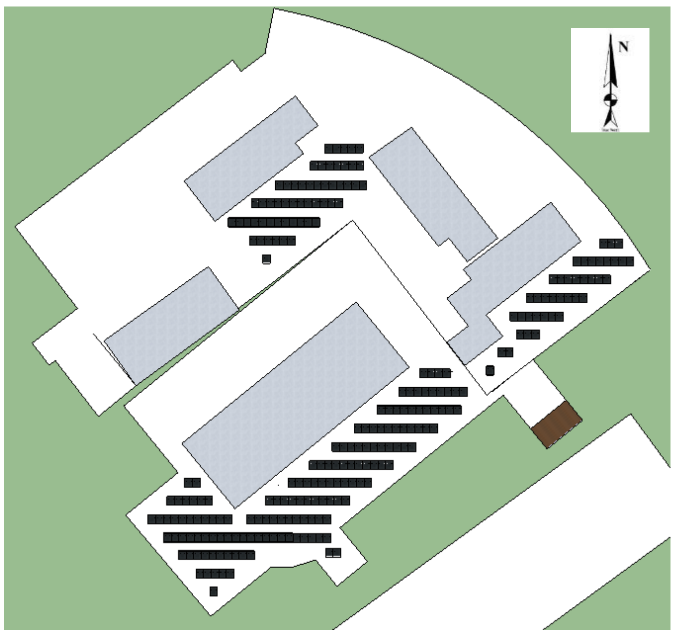
The chart above displays the fact that a small percentage of sunlight is actually in contact with the panels during a large portion of the day. By comparing multiple spacing variations, it was determined to be optimal if the rows of panels were spaced four feet apart. The panels will also be offset five feet from the roof edge for clearance purposes.

	MORNING									AFTERNOON								
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
Jan					20%	32%	37%	40%	40%	40%	37%	32%	20%					Jan
Feb				14%	37%	44%	47%	48%	49%	48%	47%	44%	37%	15%				Feb
Mar				53%	57%	58%	59%	59%	59%	59%	59%	58%	57%	53%				Mar
Apr			0%	94%	78%	73%	71%	70%	70%	70%	71%	73%	79%	95%				Apr
May			100%	100%	96%	85%	81%	79%	78%	79%	81%	86%	96%	100%				May
Jun			100%	100%	100%	92%	86%	84%	83%	84%	86%	92%	100%	100%				Jun
Jul			100%	100%	100%	89%	84%	82%	81%	82%	84%	89%	100%	100%				Jul
Aug			0%	100%	87%	79%	76%	74%	74%	74%	76%	79%	86%	100%				Aug
Sep			0%	72%	66%	65%	64%	64%	64%	64%	64%	65%	66%	71%				Sep
Oct				30%	45%	50%	52%	53%	53%	53%	52%	50%	45%	30%				Oct
Nov					25%	36%	40%	42%	43%	42%	40%	36%	25%					Nov
Dec					15%	28%	34%	37%	38%	37%	34%	28%	15%					Dec
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
	MORNING									AFTERNOON								

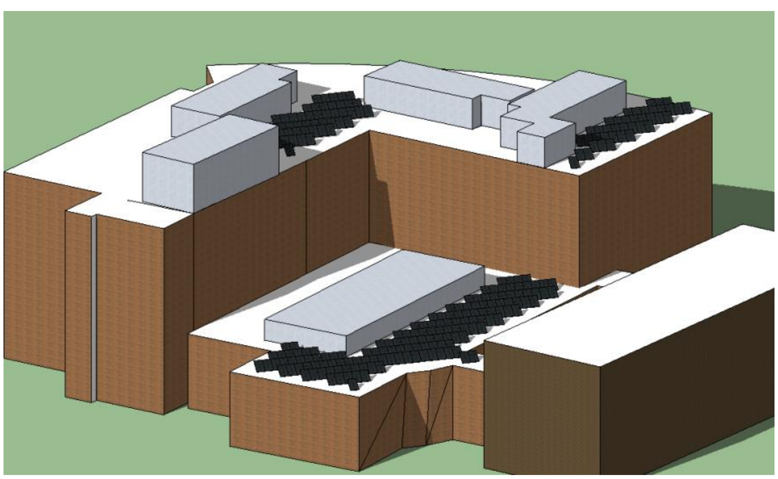
Percentages of Sun Striking Panels with 4' Spacing

For this project, it was decided that Kyocera's 210 Watt KD210GX-LP will be the panels installed. These panels are idea for large commercial grid tie systems. Because the hospital is already tied into the electrical grid, this would be an ideal product. The specifications sheet for this panel is included in Appendix E. The panels will be mounted using an adjustable roof ground mount, provided by RapidRac.

The optimal spacing was then utilized to layout the photovoltaic array on the three prime roofing positions, indicated earlier in this section. The panels were directed to face directly south, maximizing the solar gain. Using Google Sketchup, the array layout can be visualized by referencing the following figures.



Plan View of PV Array

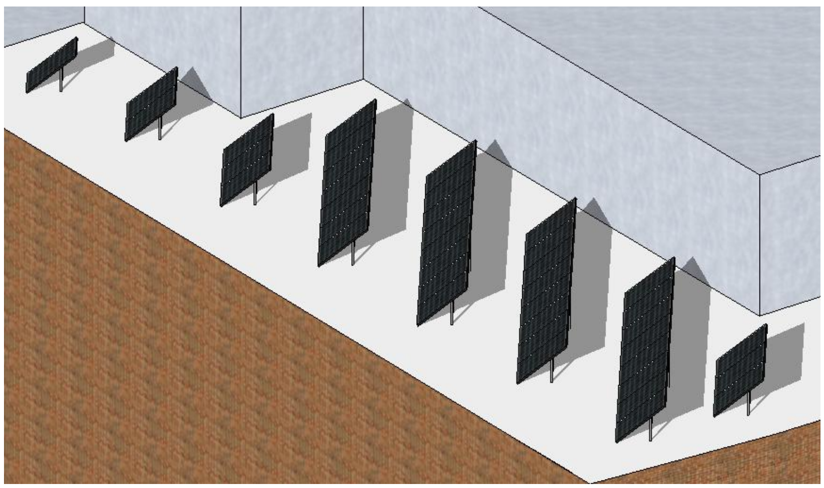


Isometric View of Panel Placement

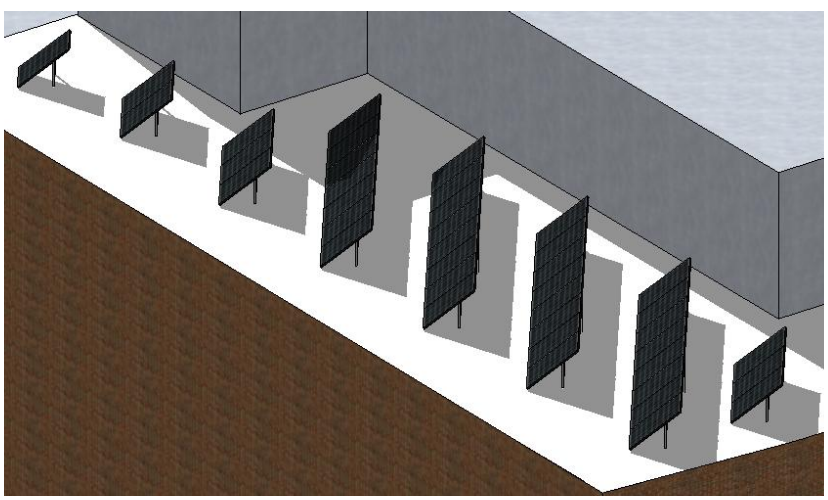
The array has been placed in the planned sections, which have the potential for the highest solar gain throughout the year. With four feet separating the rows of panels, and a five foot clearance from the edges of the roof, the following numbers of panels were placed:

Lower Roof: 149 Panels
Upper Roof: 95 Panels
Total: 244 Panels

The calculated spacing between the rows also was confirmed to be successful. The following images illustrate the shadows that will be cast from each row of panels.



Shadows Cast at 10:00 AM: Fall Equinox



Shadows Cast at 5:00 PM: Fall Equinox

Throughout the day, the angle of shading produced by the panels changes. The images on the previous page show exactly how the shadows will be cast in the morning and evening, when the largest shadows will be present. In both cases, it is clear that panels are not shaded by another row.

Structural Breadth- Structural Impact

With the installation of this system, it is clear that the photovoltaic array will possibly present structural problems that would need to be addressed with modifying the types of beams used for the roof support. For this analysis, the lower roof array will be structurally analyzed. The first step would be to look into the existing roof design. The following information pertains to the structural design of the roof members:

- Fifth Floor Roof Live Load: 115 PSF
- Minimum Roof Design Load: 30 PSF

The below image shows the designed structure of one bay for the fifth floor roof. For this drawing, the W18x40 beams are 30' long, spaced at 7'. These beams connected to W24x62 girders, which span 28' and are spaced at 30'.

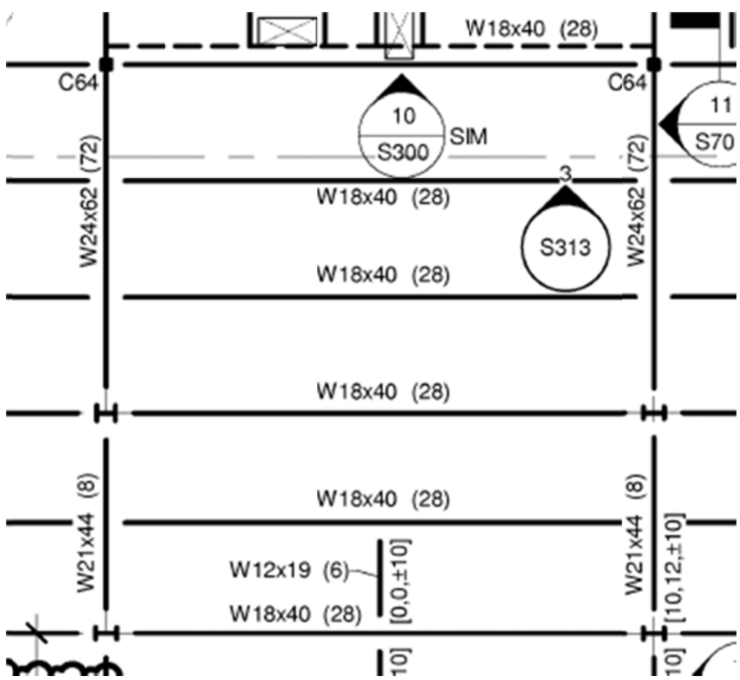
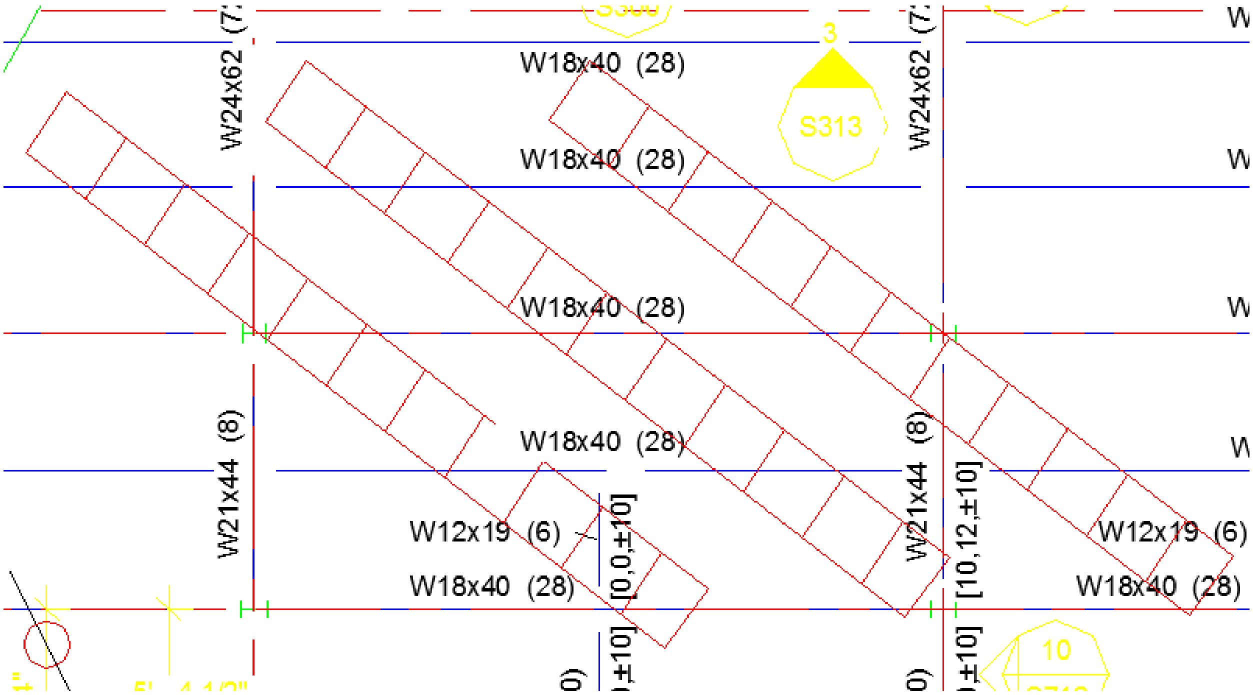


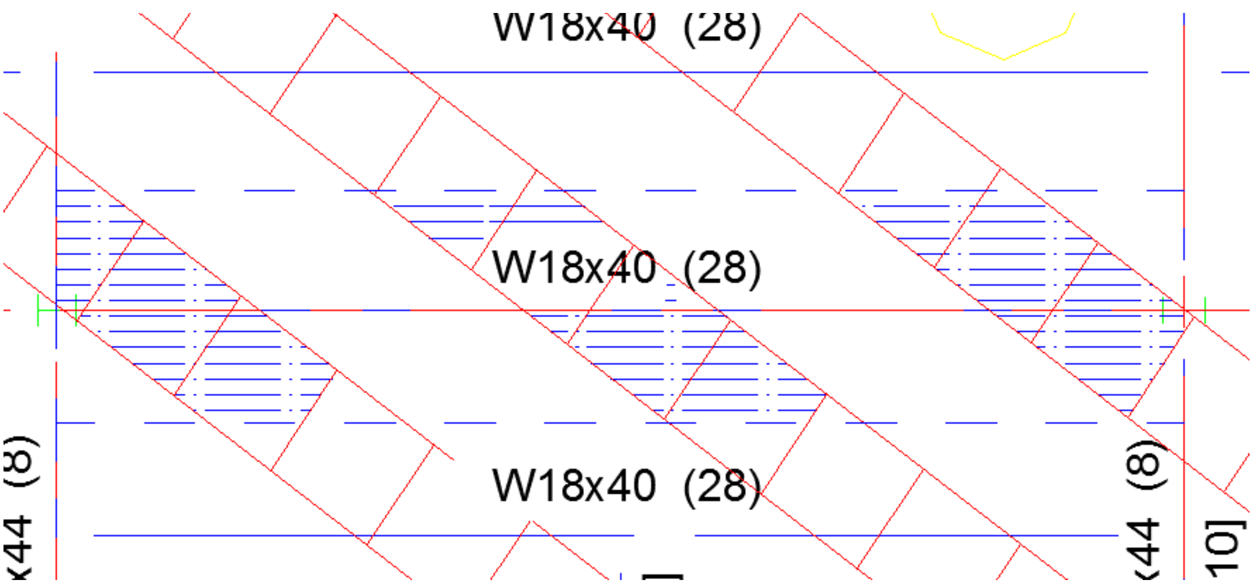
Image of a Typical Bay- 5th Floor Roof

The following image shows one section of the PV array overlain onto the same bay of the structural system.



Typical Bay with PV Array

Each row of the array consists of 11 panels. For structural analysis, the W18x40 will be analyzed first. The tributary area of the W18x40 is equal to 7', due to the spacing. The image below shows the tributary area.



Tributary Area of W18x40 Beams

From the previous image, it is seen that the total number of panels per tributary area is just over 9 panels. Because of this, the number of panels will be set at 10 for the calculations. The added load to the roofing system is calculated starting with the following table. The weight of the panels is 40.8 lbs., shown the specifications of the solar panel. The weight per square foot is based off of 210 SF (30'x7' tributary area).

Weight of PV Panels	# of Panels/Beam Trib. Area	Total Load Added to Area	Total PV PSF
40.8 lbs.	10	408 lbs.	2.0

Calculated Loads due to PV Array

RapidRac states that an additional 12 pounds must be included for each rack. This will add an additional 0.60 PSF, which comes to a total of 2.6 PSF added to the roof load.

Beam Loading Calculations (W18x40)

Factored Load: 1.2 (30 PSF +2.6 PSF) + 1.6 (115 PSF) = 223.12 PSF

Load (PLF) = (223.12 PSF) x (7' Tributary Area) = 1561.9 plf = 1.56 klf

Load per Support: (1.56 klf) x (30') / 2 Supports = 23.4 k

Bending Moment = $w_u l^2/8$ = (1.56 klf) (30')^2/8 = 175.5 kip-ft

W18x40: Max Bending Moment = 294 > 175.5, OK (AISC Steel Construction Manual)

Deflection Calculations:RGIR

Load: 32.6 PSF + 115 PSF = 147.6 PSF, 147.6 PSF x 7'Trib. Width = 1033.2 PLF

Deflection Max: L/240 = (30'x12"/1') / 240 = 1.5"

Deflection = $(5wl^2) / (384EI)$ = $\frac{5\ (1033.2\ PLF)\ (30')^4\ (1728\ Conversion)}{(384)(29{,}000{,}000\ psi)\ (612\ in^4)}$ = 1.06"<1.5", OK

Because the beam is acceptable for both bending and deflection, the existing W18x40 beam will be acceptable with the addition of the PV array. With the beams still being feasible after the addition of the array, the loading on the girders must be calculated to ensure no change is needed in the design. These calculations are included below:

Girder Loading Calculations (W24x62)

Factored Load: 1.2 (30 PSF +2.6 PSF) + 1.6 (115 PSF) = 223.12 PSF

Adding in Self Weight of Attached Beams: 223.12 PSF + 5 PSF = 228.12 PSF

Load (PLF) = (228.12 PSF) x (30' Tributary Area) = 6843.6 plf = 6.84 klf

Bending Moment = $w_u l^2/8$ = (6.84 klf) (28')^2/8 = 670.32 kip-ft

W24x62: Max Bending Moment = 574 k-ft < 670.32 k-ft, Not OK

Most Economical Beam: W24x76, Max Moment = 750 k-ft

Deflection Calculations:

Load: 32.6 PSF + 115 PSF = 147.6 PSF, 147.6 PSF x 30'Trib. Width = 4428.0 PLF

Deflection Max: L/240 = (28'x12"/1') / 240 = 1.4"

Deflection = $(5wl^2) / (384EI)$ = $\frac{5\ (4428.0)\ (28')^4\ (1728\ Conversion)}{(384)(29{,}000{,}000\ psi)\ (2100\ in^4)}$ = 1.00"<1.4", OK

With the deflection test passing after the beam size was changed to a W24x76, this new beam design will satisfy both bending and deflection requirements. Therefore, the beam must be resized to a W24x76.

Structural Summary:

- The beam size will remain as W18x40s.
- The girder size will be increased to W24x76s.

Renewable Energy/ Electrical Breadth - Energy Impact

Prior to determining the feasibility of the array installation, the energy produced by the panels must be calculated. The overall size of the system, which includes 244 panels with a power production of 210 watts, is 51,240 watts. This number, along with PV system parameters and energy costs, will all be combined using a calculator at pvwatts.org. The numbers needed for this analysis are shown below. Pittsburgh was referenced as the closest location to Butler.

Station Identification	
City:	Pittsburgh
State:	Pennsylvania
Latitude:	40.50° N
Longitude:	80.22° W
Elevation:	373 m
PV System Specifications	
DC Rating:	51.2 kW
DC to AC Derate Factor:	0.77
AC Rating:	39.5 kW
Array Type:	Fixed Tilt
Array Tilt:	41.0°
Array Azimuth:	180.0°

Results			
Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	2.66	3344	267.52
2	3.51	3983	318.64
3	4.24	5043	403.44
4	4.90	5618	449.44
5	5.16	5818	465.44
6	5.38	5688	455.04
7	5.24	5720	457.60
8	5.40	5913	473.04
9	4.64	5033	402.64
10	4.15	4827	386.16
11	2.64	3042	243.36
12	1.89	2205	176.40
Year	4.15	56235	4498.80

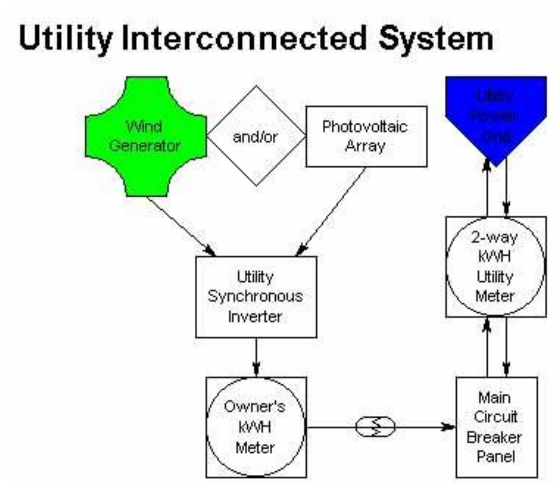
PVWatts Calculated Values

The total energy value was calculated to be $4,498.80 per year. For financial feasibility purposes, the PVWatts factor is calculated by dividing the total AC Energy produced per year, 56,235 by the size of the system, 51.2 kW. The factor obtained is calculated to be 1098.

Electrical Tie-In

As stated earlier in the report, the hospital is already connected to the electrical grid. Because of the large number of panels, the system will have to tie-in toe the existing system by using a supply-side interconnection. The National Electric Code (NEC) requires that the power produced by the PV array must tie-in with the existing grid prior to reaching the main distribution panel for the building. The tie-in would take place at a meter box before the panel.

In "Photovoltaic Systems- Second Edition," it is explained that for an interactive-only system, it is connected to the DC input for an interactive-only inverter. This is typically done at a site distribution panel. For this project, it is obvious that power will continue to constantly be pulled from the electrical grid. The PV array will produce only a small amount of the needed electricity. These interactive inverters are used to produce AC power, which then powers the building's various functions. Allstar Electric provides a diagram on its website, allstarelec.com, which can explain the process of supply-side interconnection. This diagram shows the power that would come from the array entering the inverter and then the meter, prior to reaching the main distribution panel. The grid would also tie into the meter before entering the building.



All Star Electric- Supply Side Interconnection

Financial Feasibility

The final decision on whether or not to install the designed system is based entirely on the economic feasibility. To determine if the system is a good choice economically, a complete payback analysis must be performed. The first step is to look into the immediate cost of the system. Engineering News-Record has released cost information for system installation in an article titled "Photovoltaic System Prices Drop as US Market Grows." In this article, it is stated that systems over 1,000 kW, which would be the case in this study, average $7 per watt. The initial cost of this system is calculated on the following page.

Initial Cost of PV System		
Size (kW)	**Price/Watt**	**Cost**
51.2	$7.00	$358,400.00

Initial Cost of PV Array

In an effort to promote sustainability, the government has instituted rebates and incentives to those who install these types of systems. These are listed below:

- Federal Tax Credit: 30% of gross installation cost
- Pennsylvania Sunshine Solar Rebate Program: 35% of cost up to $5,000
- PA Alternative Energy Production Tax Credit: 15% after all other incentives

The following table shows the calculations for the initial cost of the system after all rebates and incentives have been issued.

Initial Cost of PV System After Incentives			
Incentive Name	**Description**	**Cost Reduction**	**Adjusted Cost**
-	Initial Cost	-	$358,400.00
Federal Tax Credit	30% of Gross Installation	$107,520.00	$250,880.00
PA Sunshine Solar	35% of Cost (up to $5,000)	$5,000.00	$245,880.00
PA Alternative Energy Production	15% After All Other Incentives	$36,882.00	$208,998.00
		Final Cost	$208,998.00

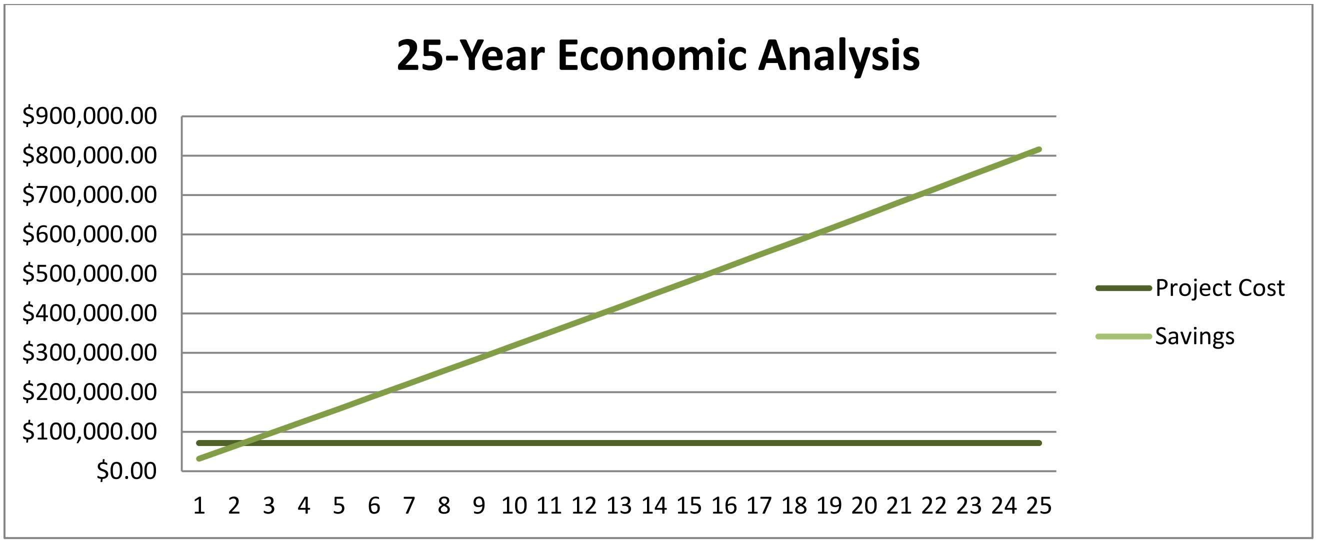
Cost of System After Incentives

Based off of the cost of the system and the available incentives, the payback of the system was calculated using a rebate and loan calculator. This calculator was created by Andrew Mackey, M.S. Construction Management student. This calculator provides the 25 year value of the system. For this situation, it was assumed that the cost is tied into the GMP, indicating that a bank loan would pay for the installation. The results of the loan and rebate calculator are shown on the following page.

Market			
Retail Cost of Electricity	0.16	$/kWh	
Elec. Rate increase	1.00%		
AECs Value	400	$/MWh	Rate paid by utility company
Loan			
Percentage Borrowed	100.00%		
Loan Value	$208,998.00		
Interest rate	2.50%	APY	Based off of current Interest Rates
Period	25	Years	
CRF	0.004486167		CRF = Capital-Recovery Factor = r(1+r)^n/[(1+r)^n-1]
Rebates / Incentives			
PA Solar Sunshine	16.15%		
PA Tax Rebate	15.00%		
Federal Tax Credit	30.00%		
DCED Grant	$90,000.00		
PEDA Grant	$90,000.00		All incentives discussed above
System			
Size	51.2	kW DC	
Cost / W	$7.00	$/W	
Total Cost	$358,400.00		
PVWatts Factor	1098		
Annual AC production	56218	kWh	
Roof Area Needed	5120	sq.ft.	
Value			
Up Front Expense	-$210,189.55		
Loan Cost	$281,280.00		
Total Expense	$71,090.45		
25 yr Value	**$745,127.93**		

PV Rebate and Loan 25-Year Value Calculator

From the above table, it is seen that the 25-year value of the system will result in a savings of $745,127.93 for the owner. All values above show the current trends in the market. This includes utility rates, loan rates, and incentives. This calculator also provides a graph, which shows exactly when the savings will meet the system cost; in other terms, the payback is reached. This graph is shown on the following page.



PV Array Calculated Payback

The chart indicates that the system will pay for itself at approximately two years after installation. With this short payback time, it is clearly economically beneficial for the owner to install the photovoltaic system.

Summary

After thoroughly analyzing the implementation of a Photovoltaic Array for Butler Health System, the following results have been produced:

- The shadow analysis and study of areas produced room for 244 panels, with 4' spacing.
- Additional roof space does exist if the owner would desire to add more panels, either to the existing hospital, or to the new addition.
- The initial cost of the system would be $208,998.00 after rebates and incentives.
- The structural system would have to be modified slightly. All W24x68 girders must be changed to W24x76 to support the added load.
- The system will provide an economic payback at the second year. This short payback time proves that it would be a beneficial investment.

Implementing the Use of Prefabricated MEP Spaces

Problem Identification

As with all construction projects, schedule was one of the driving factors for the Butler Hospital New Inpatient Tower. For this project in particular, it was actually the most critical issue. While cost was obviously important, the owner was more concerned with the schedule of the project. This is due to the fact that hospitals lose significant business and capital for every day that it is not in operation.

Early in the project, the hospital issued strict requirements for the schedule. The project team was aware of the fact that events as serious as surgeries were scheduled and there was no float time available. Due to this, the construction team frequently performed schedule updates to assess the performance of subcontractors and also direct information to the owner. One idea that was not explored to its greatest potential was prefabrication of mechanical, electrical, and plumbing(MEP) systems.

This study will include the following:

- Background Information
- Case Studies
- Initial Prefabrication Planning
- Reduction of Activity Cost and Duration
- Schedule Compression
- Module Concepts and Assembly
- Summary

Background Information

Hospitals are well known for possessing some of the most complex MEP systems in the construction industry. With a small ceiling space to work with, the plenum includes ductwork, piping, electrical work, fire suppression piping, and medical gas systems. With these systems, extensive coordination must take place throughout the duration of the project. Field clashes can lead to significant problems with both cost and schedule. To address these potential problems, Building Information Modeling was used for 3D clash detection and 4D modeling. This was discussed in more detail in the prior technical analysis.

Each system above the ceiling was modeled by the respective contractors. The systematic approach used to create the model allowed the systems to be analyzed to the smallest details. Some contractors used the additional detail to perform some prefabrication. By doing this, waste could be reduced on site because pieces could be shipped to site with exact dimensions. While this was beneficial, only two of the contractors performed some of this prefabrication. The mechanical contractor used the model to cut sheet metal for ductwork to eliminate some problems in the field. The fire protection contractor followed suit by prefabricating the pipe runs for above ceiling spaces. This produced a benefit similar to that of the mechanical contractor. This provided an advantage to these contractors, but there is reason to believe that additional prefabrication could produce more collaboration and benefit.

Case Studies

To completely understand the benefits of prefabrication, the first step will be looking into several case studies in which MEP prefabrication has benefited projects. In particular, healthcare projects are closely analyzed. The experiences in these case studies can be used to see how prefabrication of these systems has been used in each project. The work that went into this process is evident by looking into each of these individual articles. The results of using prefabrication will then be compared to potential uses for the New Inpatient Tower.

Miami Valley Hospital

In one project, the use of prefabrication is analyzed for a hospital construction project relatively close to this project. In Dayton, Ohio, the Miami Valley Hospital used prefabrication in several different ways. While overhead ceiling plenum space was combated with prefabricated systems, the project team used prefabrication for other facets of construction. The off-site assembled components include:

- Patient room toilets, casework, and headwalls
- Modular workstations for staff
- Utilized curtain wall sections
- Temporary pedestrian footbridge

Each of these components helped to shorten the construction timeframe. For the purpose of this thesis, the benefits of integrated MEP racks in corridors will be explored. With corridors containing very similar MEP systems throughout the building, it was determined that these spaces could be modularized and prefabricated. This same procedure could not be followed for medical rooms due to the complex systems. The team felt that prefabrication of medical room systems would not produce nearly as many benefits as the corridor spaces.

The Miami Valley Hospital is a 500,000 SF, 12-story addition to an existing hospital. While the addition aspect is similar to the new Butler Inpatient Tower, the Miami Valley Hospital project is significantly larger. Through the use of the prefabrication technique, the project experienced higher quality construction, a faster schedule, and a safer environment to work. Each of these benefits are key construction issues.

Another similarity to the New Inpatient Tower is the fact that a large construction manager led the project. While Turner headed up all operations in Butler, Skanska USA was in authority for this project. This similarity shows that the delivery system for Butler Memorial Hospital could follow suit with the hospital in

Dayton. By looking back at this project, the construction team was able to determine some of the key principles for successfully applying prefabrication to a project. Some of the rules for setting up prefabrication in construction include:

- Make sure that prefabrication serves the design and not vice versa.
- Engage the critical subcontractors and suppliers at an early stage of design.
- Use Building Information Modeling- if not, it is almost impossible to do.
- Make use of just-in-time delivery to keep the job site open and organized.
- Be sure that modules can be delivered on conventional flatbread trucks.

These rules are seen as vital for the successful implementation of prefabrication. By reviewing these guidelines, it is clear that Butler Hospital has the potential of bringing prefab to the forefront. Because BIM was used extensively to coordinate clash detection and scheduling, significant detail already exists for each of the above-ceiling systems. This available detail is what is necessary for the process of prefabrication to be effective. If the contractors have already closely resolved all clashes with construction, the potential is evident.

Although BIM was used as a major assistance for the project, one key difference is present between this project and the Miami Valley Hospital. As discussed in the Building Information Modeling analysis, critical subcontractors were not brought on board during the design phase. For prefabrication to actually work for a project, the early involvement is a necessity. If all details are not complete early, the prefabrication process will not be able to begin at a reasonable time. If it is started at the optimal time, the prefabricated units can be built for just-in-time delivery to line up with on-site installation. With cooperation needed from all project parties, this would not be possible without early design participation.

Early in the project, Skanska realized that the only way to produce the modularized MEP racks was to bring all of the subcontractors together. To make this possible, a warehouse was rented within three miles of the job site. Using conventional building materials, tradespersons came together to assemble modules to be shipped to the jobsite. These overhead racks measured 8x22-foot and were put together to complete corridors, which were 16-feet wide. These prefabricated modules were installed on five of the patient-room floors. By closely coordinating all of the details in the model, the racks were able to be built exactly how they were modeled.

Due to the prefabrication process, the productivity of workers well exceeded that of traditional construction. Because these modules were assembled at bench-level as opposed to overhead, the building of these modules was much easier for the craftsmen. The plumbing contractor was able to triple the productivity by working in this manner. The article states that a typical plumber is able to install 200 feet of pipe per day. With the easier installation environment, this output was tripled to 600 feet per day. In addition to the improvement in productivity, the wages were also lower in this environment. The craftsmen assembling these modules were paid 80% of their on-site rate. It is clear that this approach to construction saves in two ways. Not only is productivity increased, but the wage is also significantly lower.

The most important benefit of this new type of installation is the increased safety. With the bench-height installation, workers were not at as much risk in comparison to on-site, overhead installation. For this project, no shop injuries took place. The final benefit of the prefabrication process again involves productivity. In a typical construction project, the MEP rough-in work takes place after the structure is completed. By constructing the overhead systems in the shop, the rough-in phase can take place as foundation and superstructure work is progressing.

In summary, the prefabrication of systems at the Miami Valley Hospital created benefits in quality, schedule, and safety. By the end of the project, the process did not create enormous cost benefit. Although this is the case, the team believes that all of the benefits ultimately made the project more successful. Because of its success, Skanska plans on emphasizing the use of prefabrication in other projects. In reality, the plan is to increase the use of prefabrication to more complex aspects. Skanska executives have mentioned that because the MEP racks were only used for straight sections of corridors, it is possible to address more complicated areas.

Walsgrave (Coventry) Hospital

Another relevant case study involves a hospital project in Coventry, West Midlands, in England. For this project, as with the Miami Valley Hospital, used prefabricated MEP modules for above ceiling space. MEP Solutions, a European MEP prefabricator, produced each of these modules with the assistance of the specialty contractors. The components for the ceiling were completely based off of data converted from a 3-dimensional model. This is particularly important because the same model existed for Butler Memorial Hospital's New Inpatient Tower. The success in Ashington could be related to potential ideas for improvement for Butler's Hospital.

The modules for this project, when converted to US units, are sized at approximately 20' long x 6.5' wide x 2' deep. The modules arrived on site complete with pre-insulated, pre-tested heating and chilled water pipes, electrical work, trunking, racking, and ductwork. The ductwork was also protected from debris, eliminating any need for cleaning of the equipment after arrival to the job site. The first 20 modules were completed and delivered to the site in just two weeks.

The project team has estimated that the prefabrication operations resulted in a 15% savings in installation cost as well as a 10-week reduction in schedule. This is due to the fact that the modules were able to be installed as the structure of the building was being built. This ruled out additional delays as contractors were never forced to wait for others to complete work. Also, the modules built to much tighter tolerances and higher precision due to the coordination of the work.

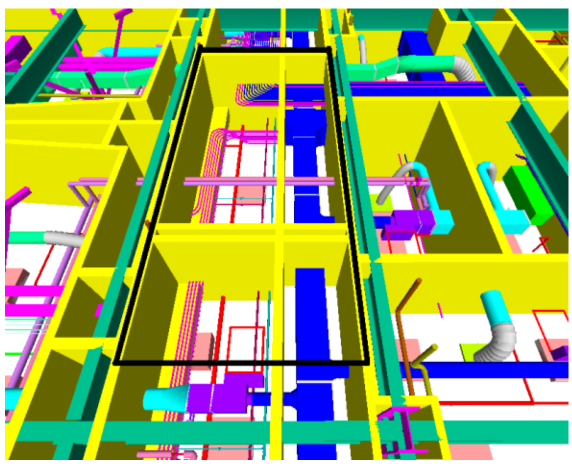
Prefabrication of MEP systems proved highly beneficial for both of the case studies. With the similarities between the work done and the proposed idea for implementing these same principles for Butler Memorial

Hospital, it is feasible to believe that this could be advantageous. In order to explain the plan and benefits of using prefabrication, a detailed analysis follows.

Initial Prefabrication Planning

For the Butler Hospital New Inpatient Tower, it is feasible that similar methods of prefabrication implementation could be beneficial to the project. As with these projects, which were both healthcare buildings, the idea of prefabricated MEP overhead systems will be confined to the corridors of the building, especially the patient hallways. With the limited overhead space in these areas, it is appropriate to believe that the modular principles could save significant time in the field. Although it could be possible to use this mentality for the entire building, the complexity of overhead systems in the actual patient rooms may be too difficult to modularize, especially being a new concept.

The corridors, although complex, seem to be the most appropriate to consider prefabrication.



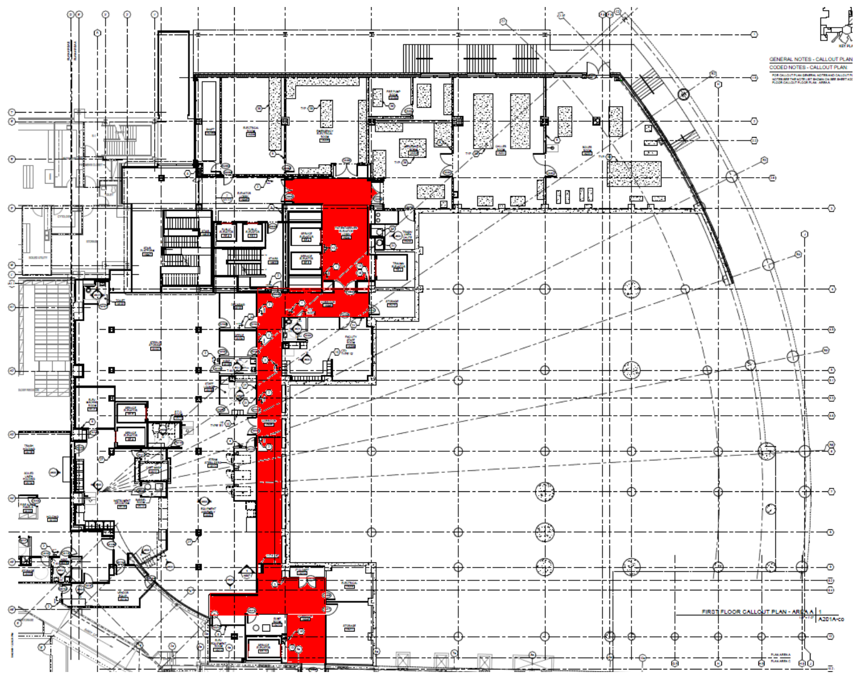
BIM Image of Overhead MEP Work- Butler Hospital

In the above image, the corridor is called out with a black outline. The patient rooms surround the hallway on both sides. As evident in the image, the corridor systems are relatively simple compared to the MEP systems overhead in the patient rooms. Although it may be possible to prefabricate the patient room systems, this appears to be the best solution to reduce schedule and cost.

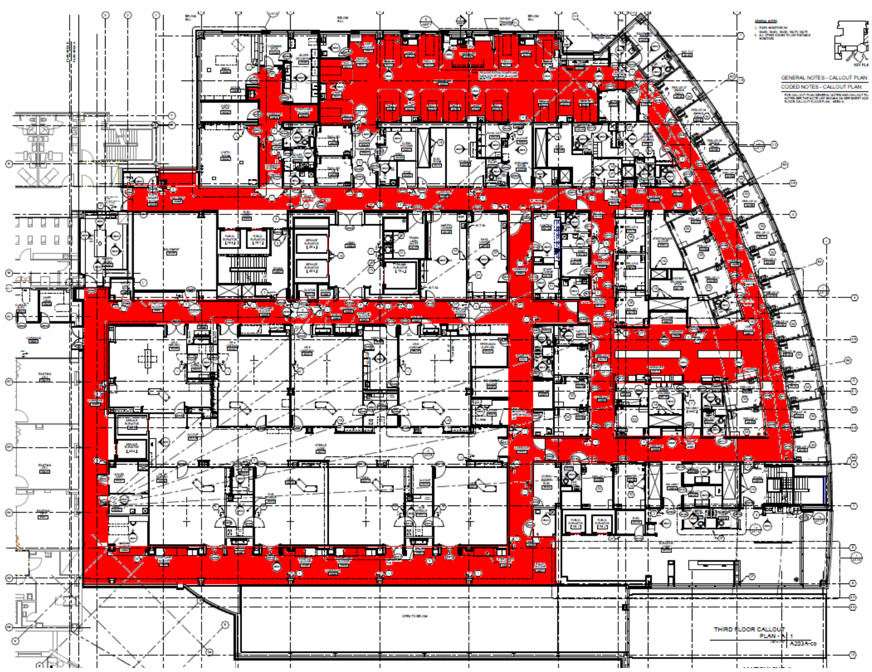
The plan of using the prefabricated corridor modules will be used for the following areas:

- Ground Floor: N/A
- First Floor: Main Corridor Stretching From East to West
- Second Floor: N/A
- 3rd Floor: Main Corridors in OR Suite, Central Corridors, PACU Area
- 5th Floor-7th Floor: Central Corridors for Patient Hallways

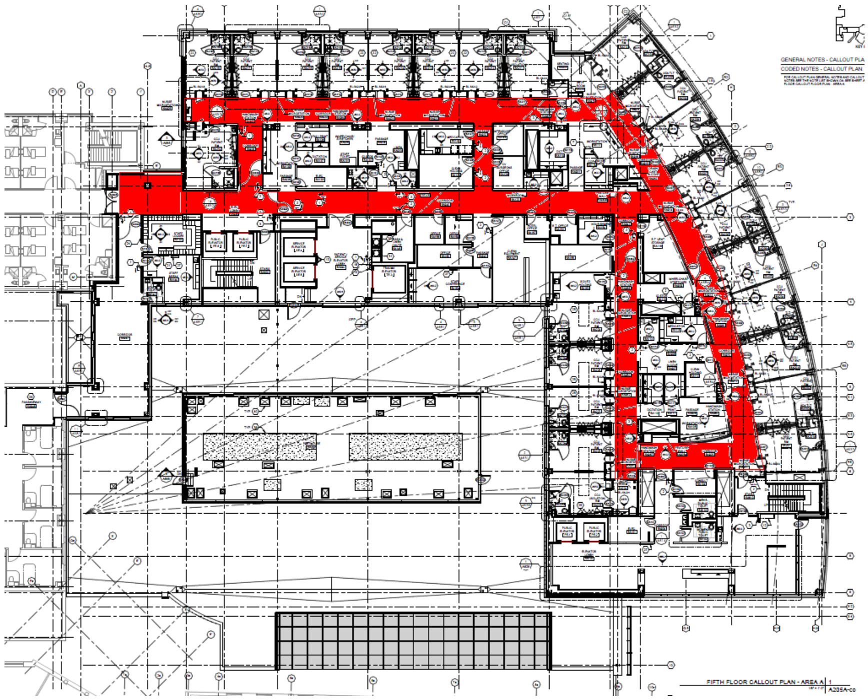
Three diagrams follow for the multiple floors being prefabricated.



First Floor Prefabricated Areas



Third Floor Prefabricated Areas



Fifth Floor-Seventh Floor Prefabricated Areas

Because the corridors will be the only areas with modularized systems, only the main systems will be analyzed on a scheduling basis. All main MEP work will be modified based on the productivity of prefabrication. Any branch MEP work will remain the same because this equipment is not considered in the distribution networks throughout the corridors.

Reduction of Activity Duration and Cost

The Miami Valley Hospital yielded results of tripling the efficiency of the overhead MEP work. This success will be used as the basis for the schedule reduction of activities on this project. As discussed above, the only modularized components will be the corridors of several of the floors. To calculate the reduction in days spent installing main MEP systems in the corridors, it has been determined that the efficiency will double, instead of triple. This was done to show a lesser case scenario. Although the crew on Miami Valley Hospital had cut the duration into a third of the original schedule, it will be assumed that Butler Hospital's prefabrication will reduce the overhead corridor work in half.

The spreadsheet showing the new durations of prefabricated MEP systems is included in Appendix F. The final numbers for the main MEP systems are shown below:

	Original Duration	Prefabricated Duration	Reduction in Duration
Time	918 Days	483 Days	435 Days

Duration Comparison (Original vs. Prefabricated)

This reduction in days does not mean that the construction will take place in 435 less days. This verifies that the MEP contractors will be able to perform the main MEP work in a much smaller timeframe. The saved time will allow the craftsmen to continue work in other sections of the building. To determine the cost savings by using prefabrication, it is necessary to compare the time saved by each of the MEP contractors. The following table shows the reduction in duration for each of these contractors.

Contractor	Original Duration	Prefabricated Duration	Reduction in Duration
Mechanical	221 Days	120 Days	101 Days
Electrical	228 Days	119 Days	109 Days
Plumbing	339 Days	175 Days	164 Days
Fire Protection	130 Days	69 Days	61 Days

Duration Comparison by Contractor

These duration reductions can then be used to determine the total cost savings for the prefabrication operation. First, the cost of each type of tradesman on site must be referenced. The data below shows the hourly labor rate for each of the MEP contractors.

Contractor	Hourly Rate
Mechanical	$31.38/Hour
Electrical	$38/Hour
Plumbing	$34.75/Hour
Fire Protection	$30.84/Hour

Hourly Contractor Rates

The final value needed to compute the cost savings is the actual number of tradesmen installing the corridor equipment. After speaking with the project team, the estimated number of installers is included in the following spreadsheet. By using this number, with an 8-hour work day, the total field cost savings for prefabrication can be estimated. These calculations are provided below.

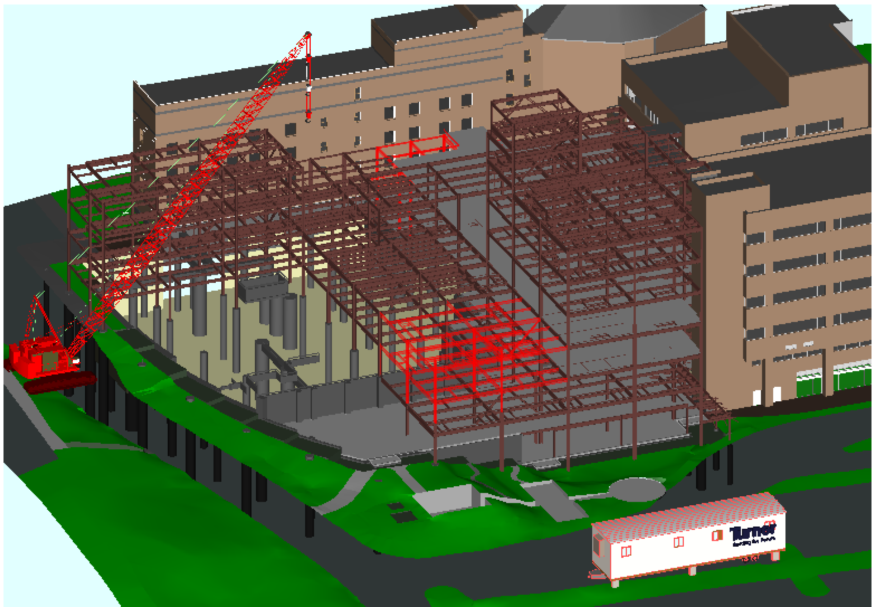
Contractor	Hourly Rate	Number of Workers	Number of Days	Total Cost Savings
Mechanical	$31.38/Hr.	9	101 Days	$228,195
Electrical	$38/Hr.	12	109 Days	$397,632
Plumbing	$34.75/Hr.	7	164 Days	$319,144
Fire Protection	$30.84/Hr.	2	61 Days	$30,100
Total				**$975,071**

Total Cost Savings by Trade

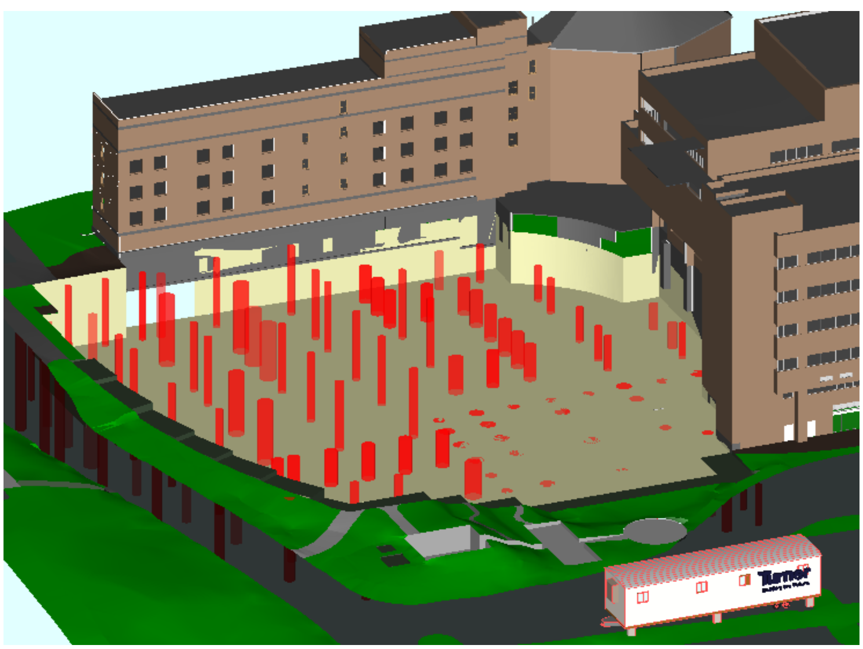
The calculated total cost savings for the prefabrication of the corridor MEP work comes in at just under $1 Million. With an original MEP cost of approximately $33 Million, this provides the owner with 3% savings in MEP work. Also, this will allow for more collaboration between trades and less conflicts in the field. With the MEP 3D model already existing, this appears to be a feasible operation.

Schedule Compression

One of the top advantages for prefabrication is the time that construction can begin for the prefabricated systems. Because the units can be built off-site, there is no need to wait until work space is available to begin installing the equipment. The MEP work can therefore begin while the structure is being erected, as opposed to when the space has already been built. The following two images compares exactly when the MEP systems can begin assembly.



Original Schedule Start of MEP Installation – June 2nd, 2009

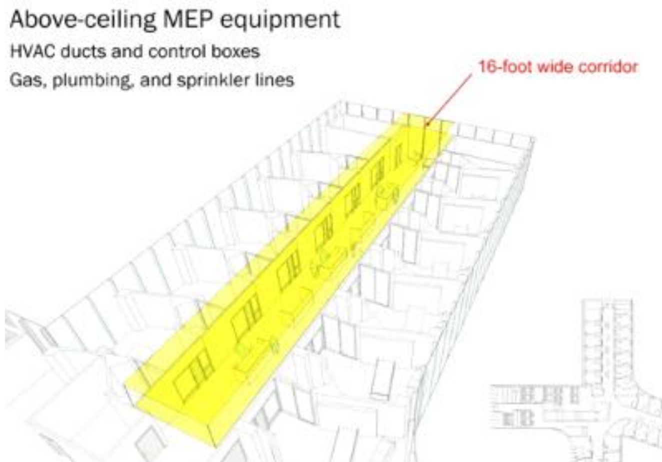


Prefabricated Schedule Start of MEP Installation- October, 2008

Module Concepts and Assembly

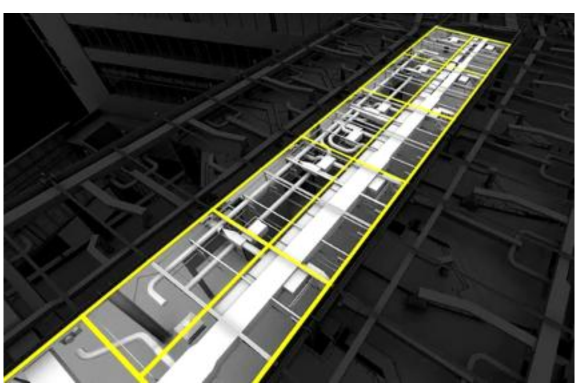
Now that it has been determined a financial benefit to utilize MEP prefabrication, it is necessary to look more into the details of the actual modules. Referencing both of the case studies and the layout of the MEP systems for the New Inpatient Tower, the 8' modules seem to be the best case scenario. The majority of the hallways are exactly 8' wide for the patient care areas of the hospital.

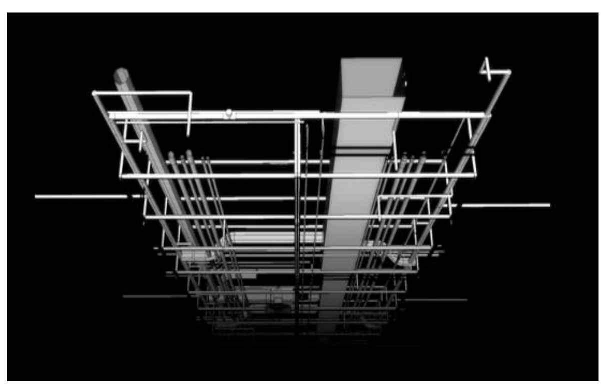
For the Miami Valley Hospital, the corridors were much wider than those present at Butler Memorial Hospital. The corridors for this project were 16' wide, and therefore required two 8' modules to be connected to cover the width of the hallway. This same methodology would be used for any of the corridors for this project that were over 8' wide. The planning for the Miami Valley Hospital prefabrication is evident in the images below. These images are presented in a video explaining the case study. This video is titled "A Prefabrication Study," by Ryan Hullinger.



Miami Valley Hospital Case Study

With the space shown above, the project team broke up the corridor into 8' wide sections, which is shown below.





Modular Concept for Miami Valley Hospital *Image of Installed Module*

All of the systems would be installed inside of the steel framing. The modules would be assembled separately in the shop, and shipped to the job site. Once arriving at the jobsite, they would be simply attached to one another. The same video shows several images of the modules arriving to the job site and being installed. This would be identical for Butler implementation.

Modules Arriving to the Job Site

Modules Hoisted to the Appropriate Floor

Modules Connected in the Corridor

By using modules with a size of 8' wide x 20' long, the total number of modules can be calculated based on the total square footage of prefabricated overhead systems. For the entire building, the area of prefabricated MEP systems is approximately 27,500 SF. This area can be referenced by the earlier images showing the areas to be prefabricated. With this amount of space being prefabricated, a total of approximately 175 modules will be constructed. These modules will be shipped to the site on flatbed trucks. Due to the fact that equipment would need to be delivered to the site despite prefabrication, no additional cost is assumed for this operation.

Summary

After thoroughly analyzing the concept of utilizing prefabricated MEP spaces, the following conclusions have been made:

- With BIM already being utilized for the project, proper 3D coordination already exists to allow for the possibility of prefabrication of MEP systems.
- For efficiency purposes, the corridors have been deemed the most feasible components to prefabricate.
- The prefabricated systems include mechanical, electrical, plumbing, and fire protection systems.
- A total of 435 days have been saved for all contractors combined. This is a conservative number when compared to the Miami Valley Hospital case study.
- This allows for just-in-time delivery of modules as well as module construction beginning at the start of the project, as opposed to when certain areas are available.
- An increase in contractor coordination occurs due to working in the same shop.
- A total cost savings of nearly $1 Million can be achieved due to an increase in productivity. This does not include savings due to the lower cost of labor (80% of on-site tradesmen).
- Much less waste would be produced with cut-to-length MEP systems.
- Most importantly, the safety of workers is drastically improved due to bench-height construction as opposed to overhead work.

Analysis for the Potential Addition of Building Information Modeling Uses

Problem Identification

Due to the complexities of the mechanical, electrical, and plumbing (MEP) systems in healthcare facilities, the project team at Butler Memorial Hospital immediately addressed the idea of applying Building Information Modeling (BIM) to the construction of the facility. BIM was utilized for a few crucial reasons in this project. Clash detection was determined to be the top priority of the process. With extensive and detailed work going into all of the aforementioned systems, a computerized model can be used to combat clashes between the systems. In addition the pursuing the benefits of clash detection, the project team also used the model to create a 4D schedule of both the MEP systems and the structural system. This was used to improve site logistics and allow the processes to become more efficient.

While these uses clearly benefited the project and the flow of work, it is also possible that the application of additional BIM uses could have provided even more benefits to the entire project team. By thoroughly investigating the Building Information Modeling plan used on this project along with other potential uses, the impending additional benefits can be utilized. In addition to looking into the uses explained in the BIM Execution Guide, several other healthcare case studies will be addressed. By clearly seeing the benefits that other projects experienced due to BIM, it could be possible to apply these principles to the New Inpatient Tower at Butler Memorial Hospital.

Background Information

Early in the project, Butler Health System informed Turner Construction that it would like to utilize BIM on the addition of the new tower. With this go-ahead from the owner, Turner proceeded with this request and was able to significantly benefit from its inception. The hospital was not particular in any way with this request, but knew the benefits that could ensue from using the technology. Because of this, the construction team had the ability to apply the needs of the software as it deemed necessary.

The coordination plans, using BIM, began in April of 2009. At this time, the structural steel erection had already begun. The process continued throughout the remainder of the work on the superstructure and during the installation of all MEP systems. The following systems were all added to the architectural model:

- Mechanical (Ductwork and Piping)
- Electrical
- Plumbing
- Fire Protection
- Structural
- Medical Gases

Revisions were frequently made and weekly meetings were used to address any issues in the field. Because the process had started after the project had begun, no prequalification was performed for any of the subcontractors. Although some contractors, including the mechanical and plumbing trades, had significant experience with BIM, others did not. Both the high-voltage electrical contractor and the fire protection contractor had no previous experience with the process of Building Information Modeling. This did create a learning curve, but it did benefit the subcontractors by allowing them to learn the process.

BIM Execution Guide

Penn State has put together a BIM Execution Guide, which documents the variety of ways BIM can be used. While it is clearly not feasible to bring every use into the project, it may be beneficial to specifically address a few. These different uses of Building Information Modeling have been discussed in depth in AE 597G: BIM Execution Planning. The various uses of BIM are shown below:

Building Maintenance Scheduling	Design Authoring
Building Systems Analysis	Engineering Analysis
Asset Management	Sustainability Evaluation (LEED)
Space Management and Tracking	Code Validation
Disaster Planning	Design Reviews
Record Modeling	Programming
Site Utilization Planning	Site Analysis
Construction System Design (Virtual Mock-up)	Phase Planning (4D Modeling)
Digital Fabrication	Cost Estimation
3D Control and Planning (Digital Layout)	Existing Conditions Modeling
3D Coordination	

While it is clearly not feasible to apply each of the above BIM uses for a project, it is necessary to evaluate the importance and necessity of each. The BIM Execution Guide states “Teams should not focus on whether or not to use BIM in general, but instead they need to define the specific implementation areas and uses.” BIM needs to be applied in a way to maximize the value to the entire project team but also minimize the cost of its application.

Although BIM was a highly productive process at Butler Memorial Hospital, a BIM Project Execution Plan was never developed. The benefits of this plan can be maximized if it is developed early in the project. It also must be continually developed throughout the lifetime of the project. The BIM Execution Guide states that the plan must do the following:

- Define the scope of BIM implementation on the project
- Identify the process flow for BIM tasks
- Define the information exchanges between parties
- Describe the required project and company infrastructure that would be necessary to support the implementation

In order to develop this execution plan, several steps must take place. To effectively devise this plan, which is to be implemented in the project, the first decision that must be made includes the actual uses that will be employed. The goals of using BIM, as well as the defined uses, must be clearly identified. The project team is the group that must decide and develop the plan, based off of the potential values of each individual BIM application. Commonly, the main project goals include reducing the schedule duration, higher productivity in the field, a higher quality project, and less cost associated with change orders.

Along with the uses explained in the BIM Execution Guide, additional research must be performed in order to determine the finest way to deliver Building Information Modeling to the New Inpatient Tower.

Case Studies

One of the optimal ways to decide on the application of the most effective BIM uses is to perform research on methods used in similar projects. Due to the complexity of healthcare projects, Building Information Modeling has readily been used. The decisions and details that go into BIM implementation have been thoroughly researched and analyzed by some of the Penn State faculty.

One part of this research will deal with a publication that was developed involving three Penn State Faculty members. These researchers put together *A Unified Process Approach to Healthcare Project Delivery: Synergies between Greening Strategies, Lean Principles, and BIM.* In this paper, BIM is defined as "the process of generating and managing building data during its life cycle." The National Building Information Modeling Standards (NBIMS) also discusses the lifecycle idea in its definition of Building Information Modeling. In their definition, it is supposed to include everything from the early design considerations to the demolition of the building.

This paper links the usage of BIM with lean principles, which focuses on eliminating waste for a project due to collaboration and planning. By putting both of these into practice, the writers believe that it can lead to a better project in terms of cost, schedule, and satisfaction of all team members. An explanation is provided that explains that if these ideas are incorporated together, especially at the early design stages of a project, it will greatly impact the project. This is due to the idea that the early part of a project delivery can produce the highest effect and value for a project.

Lean principles, which can be strengthened through the use of BIM, are discussed in the next analysis. The idea of prefabrication is one concept that is prevalent in lean construction due to an elimination of waste. This publication includes the point that BIM can be used as an aid for sharing information regarding repetitive functions. The repetitive functions are also discussed in the prefabrication analysis.

As discussed earlier, BIM was applied to the New Inpatient Tower to deal with the intricacies associated with the detailed systems of a hospital. This article also addresses this concept of using BIM because of the precision required to meet the needs of a healthcare facility. Two other places where BIM can aid the project, which is included in this article, include simulating processes and facility operations. The idea of modeling processes is one that has been mentioned by the project team, post construction. Because of problems that came to fruition involving functionality problems, several spaces dealt with significant changes during construction. If these problems have been discovered prior to construction, the cost of these changes would have been greatly minimized.

This publication goes into depth on this subject by providing an example. The study illustrates the fact that the typical nurse walks between four and six miles on any given work day. If this time, which is a process, is reduced, the nurse will be able to spend significantly more time with the patient. Because the main goal of a healthcare facility is to provide the patients with the best possible care, this is a crucial issue. By using BIM to provide scenario simulations and layout design, the ideas could be displayed to the owner to produce a higher quality facility.

The idea of facility management is another use that is introduced in this publication as well as in the BIM Execution Guide. By transferring the use of BIM to facility maintenance personnel, problems could be anticipated prior to the actual occurrence. This provides benefits to both the staff that will be correcting the problem and the patients that could suffer from these problems.

Prior to the abovementioned article was published, another paper was written by Penn State researchers. This paper, *Case Studies in BIM Implementation for Programming of Healthcare Facilities,* written by Dr. John Messner and Russel Manning, discusses BIM on two separate healthcare projects. This paper also touches on the fact that BIM can provide the most beneficial results by being applied during the early design stages of the project. Some of the main reasons that BIM can be particularly beneficial in healthcare include:

- Facility layout, minimizing disease transference
- Complex MEP Coordination
- Engineering Simulation Models
- Accurate as-built information for future renovations

This paper compared the use of Building Information Modeling on two separate healthcare projects. In the first example project, an expeditionary hospital was designed and constructed in a developing nation, in conflict. For this project, the original plan did not incorporate BIM into its plan for development. This plan was eventually cancelled due to a functional disconnect because of communication problems between the US designed plan and other project parties located in the Middle East, US, and Germany. Because of the late cancellation of the project, the team was pressed for time and the redesign efforts needed to be completed in a short two and a half month timeframe.

At this point, the project team realized that the use BIM could help combat this reduced schedule. At this point, only one person on the project team had BIM experience, and to a limited extent. By utilizing this software, the design work was completed in only 44 days. This was in comparison to the 24 months that was needed for the original design, using a CAD architect. The BIM model, despite the reduction in time spent designing, included significantly more detail than the original plans. For example, the model was easily able to produce sectional and isometric details. The ability to produce these details was much more trivial than with the original CAD designed model. Because of the parametric qualities of the model, which did not exist for the original design, the project team could continually update quantities and working cost estimates.

The second example project involved a Medical Research Lab in the United States. This studied project was a renovation, as compared to new construction. This project encountered very similar time constraints as the conceptually designed project had to be used to develop a phasing plan, scope of work, and a Request for Proposals in less than seven months. The team immediately embraced BIM as a way to develop space utilization plans. This space utilization concept allowed the team to plan the layout of the facility, by department and function, and present the ideas to the owner. By using simple color schemes, participants that had no experience in design were able to clearly understand the layout of the new research lab. Statistically, projects typically use at least one week of excess time looking into space utilization. With this approach, the spaces were continually updated and saved approximately 100+ man hours for the project. Because the AE was not spending as much time to determine layout, more time was able to be spent focusing on the specifics of the design. The time savings on this project led to a cost savings of 62%.

As with the expeditionary hospital, the user group had not been exposed to BIM prior to this project. The owner members also had a limited exposure to BIM prior to this project. The ability to quickly understand the model shows that the learning curve for the modeling software is not a major problem. In the end, the owner believed that the scope of work was much more understandable by utilizing the model.

By looking at both case studies, the authors sought to find the benefits of BIM that both cases had seen. The instant 3D visualization of spaces was able to be understood and evaluated by technical and non-technical staff. This ability gave anyone the chance to give input to the project team regarding design of the spaces. The convenience of quickly developing sections, perspectives, plan views, and quantity take-offs was vital for both projects. Because changes are able to be immediately inputted into the model, the man-hours needed to make these changes was significantly reduced. The parametric attributes associated with the model also produced enormous benefits. Information was able to be programmed into the model and comparison of documents and records was able to be done with a high confidence in accuracy. All of these benefits allowed the concept update time to be reduced from typically weeks and months to just days. In summary, if the proper BIM uses are applied to the projects at the proper time, success is evident. The proper time appears to be during the programming and conceptual design stages of a project. The modeling process can give the entire team the chance to collaborate and communicate on a new level.

The final case study involves the use of BIM and Virtual Design and Construction (VDC) on a healthcare project in Northern California. Because MEP systems for a healthcare project can exceed 50% of the total project cost, the importance of the systems is evident. As the coordination of MEP systems has moved drastically past the light-table technology of the past, the usage of BIM and VDC are prevalent throughout construction. As with the previously discussed case studies, it was decided early on that BIM/VDC must be applied to the early stages of the project. MEP contractors were also pre-qualified for this project.

For this project, the general contractor worked as the facilitator for coordination of the model. The modeled systems were each inputted by their respective installers. The systems that were modeled, as with Butler Hospital, include the architectural, structural, MEP, fire protection, and medical gas systems. The model was continually updated by the general contractor and all clashes were remedied. Because of the constant interaction between the project team and the model, only 2 of the 333 RFIs on the project dealt with field conflict. This number is down from the typical 200-300 field conflict RFIs.

Also, due to this collaboration, there were zero change orders related to field conflicts. Typically, the cost of MEP change orders due to field issues ranges from 1-2% of the total cost of the MEP systems. Due to exact locations of systems and extensive prefabrication, only one injury occurred due to MEP overhead work. The mechanical contractor estimated that the field productivity was improved between 5 and 25%. All plumbing and low pressure ductwork was prefabricated for this project. Commonly, no plumbing prefabrication takes place, and only 50% of ductwork. The benefits of prefabrication will be explained in more detail in the next analysis.

After the project was completed, the advantages of using BIM and VDC were clearly unmistakable to the project team. The owner and team have only requested that some changes be made to future projects. By modeling all of the architectural finishes, including furniture, the team may be more able to observe the way the space will finally appear. Also, a virtual mock-up of all the rooms would help to explain potential issues that could be faced by the owner after occupation.

After analysis of the case studies and the BIM Execution Guide, the next step would be to determine the uses that would most benefit the New Inpatient Tower at Butler Memorial Hospital. In order to establish the top BIM uses, the list of uses explained in the BIM Execution Guide must again be referenced.

Building Maintenance Scheduling	Design Authoring
Building Systems Analysis	Engineering Analysis
Asset Management	Sustainability Evaluation (LEED)
Space Management and Tracking	Code Validation
Disaster Planning	Design Reviews
Record Modeling	Programming
Site Utilization Planning	Site Analysis
Construction System Design (Virtual Mock-up)	Phase Planning (4D Modeling)
Digital Fabrication	Cost Estimation
3D Control and Planning (Digital Layout)	Existing Conditions Modeling
3D Coordination	

The uses that would most benefit the project are highlighted above. Currently, 3D coordination is the only use that was applied to the project.

For the purpose of this report, each of the highlighted uses will be briefly summarized as how, and why, they should be applied to the New Inpatient Tower. In addition, one of the uses will be analyzed in significant depth. By speaking with project team members and comparing the discussion with the aforementioned case studies, the most significant use that could have been applied is the use of virtual mock-ups. Due to this discovery, a virtual mock-up will be created for this report.

Building Maintenance Scheduling

As BIM begins to be commonplace in the AEC industry, one of the most important benefits includes the possibility of using the model to coordinate maintenance and upkeep of the facility. The majority of this maintenance scheduling involves the mechanical, electrical, and plumbing systems. Because these systems are typically above the ceiling, it can be difficult for the maintenance staff to keep track of where each piece of equipment is located. The BIM Execution Guide states that "A successful program will improve building performance, reduce repairs, and reduce overall maintenance costs.

Although most may believe that it is too technical to turn all of this information over to the maintenance staff, this is not necessarily true. With proper training of the staff, the model can be turned over without an issue. Because the MEP system is already modeled for the New Inpatient Tower, the owner would already be able to see where each piece of equipment is exactly located. From there, intelligence could always potentially be added to the model to include the information necessary for maintenance. This added intelligence would include an additional cost, so it would be up to the decisions made by the owner.

Record Modeling

The BIM Execution Guide defines Record Modeling as "a process to depict an accurate representation of the physical condition, environment, and assets of a facility." The record model provides information on any aspect of the building. This added intelligence allows the team and owner to view information on warranties, serial codes, maintenance issues, etc. This process links directly with Building Maintenance Scheduling.

The construction team has already put together a detailed BIM for the coordination process. This existing model can easily be used to serve as a record model, simply by adding information to each of the elements of the systems. If the owner ultimately decides to use the model in the future, after construction, this record model will serve as the basis. This model will also aid the owner if additional construction or renovation will be necessary. Another critical impact of record modeling is that it can be used for permitting inspections. The Department of Health inspection was a highly detailed and complicated process. With the use of record modeling, any changes could be displayed to the inspection authority.

Digital Fabrication

The next analysis deals strictly with the concept of MEP prefabrication. Complex MEP systems are prevalent in all healthcare projects. With the large amount of overhead utility work, the working BIM helps to coordinate the installation of the equipment. The detailed model could potentially be utilized to prefabricate different parts of the project. For this project in particular, it would make sense to use digital fabrication for the purpose of prefabricating the overhead MEP spaces, which are analyzed in further detail in the next analysis.

For this process, information is extracted from a 3D model, which already exists for this project. The model is then spooled into multiple sections, and the equipment can be fabricated off-site. This reduces installation time and field conflicts. If the team decides that MEP prefabrication would be a beneficial process, digital fabrication could aid this operation.

Code Validation

Although this BIM use is not widely applied, and is still developing, it is possible that this concept could be tied into the modeling process. As mentioned earlier, code officials play a large role in the overall schedule of the project. The Department of Health and local officials' inspections are the final events that must take place prior to opening the facility. The complexities and importance of systems in a healthcare project comes with stringent requirements.

The BIM Execution Guide explains that the model can be used to determine if code has been validated. If this process is begun early in the process, there is potential to eliminate code problems in the future. Changes to the design can be immediately incorporated into the model and code issues can be checked. By doing this, it can save time because the project will not to be reviewed multiple times for code compliance.

Programming

The case studies discussed earlier mentioned the concept of space allocation. This is done during the programming stage of a project. As a new building is being designed and constructed, the entire project team must be able to see how space will be divided for the building. For the New Inpatient Tower, some of the divisions include office space, treatment space, and support. To properly design and construct the building, the design and construction team must be able to communicate the space allocation with the owner.

The case studies indicate that the use of BIM for space allocation can save over 100 man hours for a project. This saved time can then be used to finalize specific design details. By simply using color coding, the project team will be able to display the layout of the facility to the owner. Even though the owner has minimal construction experience, this method of explaining the layout allows the experience to be trivial. This model can also be used by the owner in the future. As changes are made to the personnel and procedures of the hospital, the space management and tracking can be utilized.

Cost Estimation

For this project, a Revit Model and Navisworks Model were used for design and coordination purposes, respectively. Although these models existed, the team did not use the models to perform cost estimates. If established as a program early in the project, the design team and the construction team can keep a close eye on cost overruns and changes. By using different software programs, the model can be quantified and also estimated.

The owner could benefit from this BIM use because budget can be closely watched throughout the entire project. From the design to completion, any changes can be inputted into the model and cost information can be extracted. This process can save the team significant estimating time. In turn, the cost of the project could be lowered for the owner's sake.

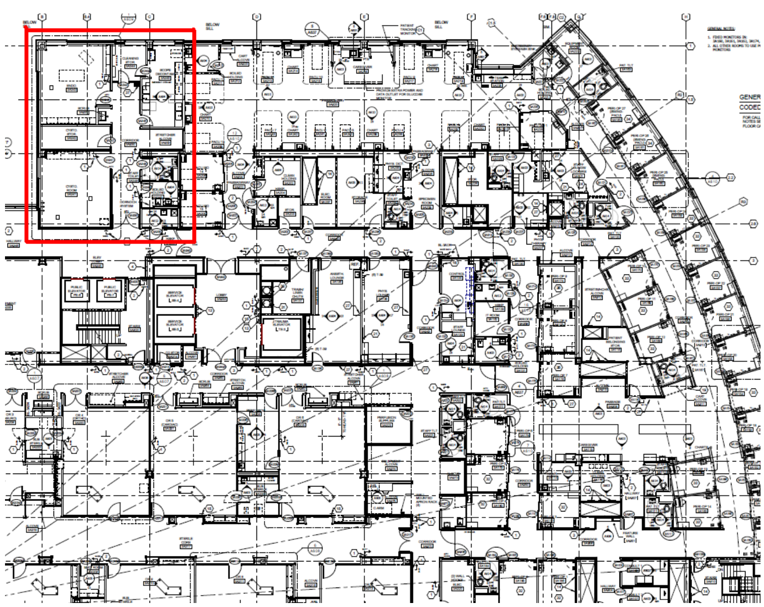
Virtual Mock-ups

The previously discussed BIM uses, along with Virtual Mock-ups have been determined as the most beneficial uses for this project. The project team feels that Virtual Mock-ups would be the best use for the New Inpatient Tower. In particular, mock-ups of the operating rooms could produce the most gain. This is due to several issues with the rooms, including but not limited to the following:

- Relocation of Operating Room TV monitors
- Interference between OR overhead booms and lights/diffusers
- Relocation of Operating Room power outlets

Although the design of the operating rooms was reviewed by the hospital, it is difficult to portray exactly what the space will look like through the use of 2D drawings. To clearly visualize the spaces, a virtual mock-up could be provided to the doctors and staff that will display exactly how the rooms will function.

For the purpose of this thesis, a virtual mock-up of a specific area has been created. One of the main areas that produced many changes to design is the Cystoscopy and Endoscopy areas. These operating rooms are confined to a small area on the third floor of the New Inpatient Tower.



3rd Floor: Cysto/Endo Area Highlighted

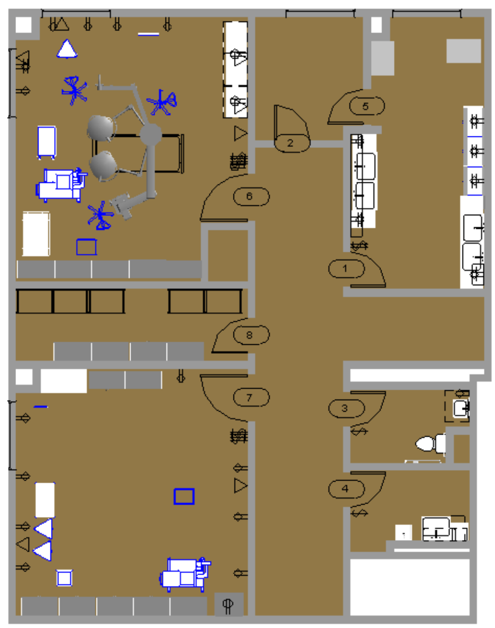
Although this represents only a small portion of the building, the same principle can be applied to the rest of the building. The operating rooms produced the most problems for the project team, so this visualization could be very beneficial for all of these areas.

To create the virtual mock-up of the space, several steps needed to take place. For the purpose of this thesis, a Revit model was created for the Cystoscopy/Endoscopy hallway. This model includes intricate detail to show the location of several important parts of these rooms. This close detail includes, but is not limited to, the following:

- Lighting Fixtures
- Diffusers and Registers
- Electrical Power Outlets
- Data Outlets
- Medical Boom in the Endoscopy Room
- Designed Location of Mobile Medical Equipment
- Plumbing Fixtures

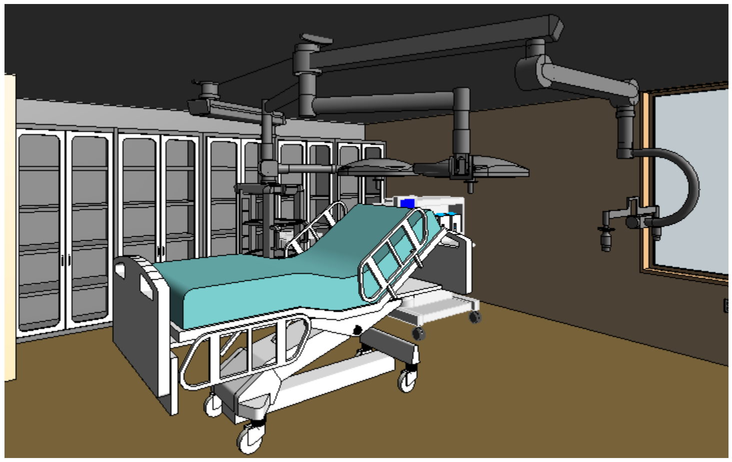
Each of these components is critical for the usage of these spaces. With the magnitude of operations taking place in these operating rooms, the functionality of the space is crucial. With the aforementioned problems discovered in these spaces, it is possible that these errors could have been discovered early.

Once this Revit model was created to the closest possible accuracy, the file was transferred to 3D Studio Max and then transferred to the game engine, Unity. Unity is a 3D authoring tool that is used to create video games or in this case, architectural visualizations. By importing this model from 3D Studio Max, it allows the user to interactively be involved in the space. This would be a beneficial tool for the users of the space in question. If doctors and medical staff were able to visualize this space prior to the construction, problems could be identified early on and corrected in a quicker and less expensive manner.



Revit Model Floor plan

Using the created Revit model, it is possible to obtain some interior views of the inside of the building. Although these images can be clear and detailed, the user does not have the ability to interact with the space. With the use of a virtual mock-up, created in Unity, the user will be able to move throughout the space and see it as it will look as a finished product. The following page shows several interior images, produced from the Revit model.



Interior View of Endoscopy Room

Interior View of Cystoscopy Room

Interior View of Scope Decontamination Room

Despite the detail provided from Revit, a true mock-up involves interaction. Within Unity, textures and lighting can be edited. The lighting allows the space to appear as it would post construction. As mentioned, textures can be changed to make the appearance of items look as they actually would. For the purpose of this virtual mock-up, this is not a critical aspect. While this can be beneficial for aesthetics purposes, the idea of this mock-up is to allow the medical staff to see exactly how a space will look and function. Also, the virtual mock-up allows the user to move within the model. For example, doors are able to swing and medical equipment can be displaced.

Below are some images from the Unity model:

Interior View of Endoscopy Room

Interior View of Cystoscopy Room

It is evident from the previous groups of pictures that Unity produces a much more realistic model for the owner to reference. For the purpose of this project, a walkthrough of the Cystoscopy/Endoscopy hallway has been produced. This walkthrough will be conducted during the presentation of this thesis.

Summary

After thoroughly analyzing the idea of increasing BIM usage on the project, the following conclusions have been made:

- The BIM Execution Guide provides several ways that BIM can be applied to a project.
- Case studies have determined that BIM is most beneficial when implemented early in the design stage. Because of this, more benefits could have been reaped if BIM had been instilled earlier in the Butler Hospital project.
- The BIM uses that would most benefit this project include Building Maintenance Scheduling, Record Modeling, Virtual Mock-ups, Digital Fabrication, 3D Coordination, Code Validation, Programming, and Cost Estimation.
- Per project team interviews and case study analysis, the use of Virtual Mock-Ups has been determined as potentially the use that could lead to the most benefits.
- A 3D model and Virtual Mock-up has been created for a small area of the building, which can be implemented throughout project.

MAE Requirements

The Integrated BAE/MAE requirement for this thesis was fulfilled by incorporating a variety of topics from AE Graduate-Level courses. The topics were spread throughout the analyses topics.

AE 598C: Sustainable Construction Project Management
With sustainable construction practices revolutionizing the industry, the concept of using photovoltaic panels is one that must be addressed. Within this class, discussion took place regarding building orientation, panel tilt, spacing, and government incentives. Each of these principles are included in this report.

AE 597G: BIM Execution Planning
Penn State's CIC has created the BIM Execution Guide, which looks into the several potential uses that BIM can have for a project. In this course, this guide was referenced throughout, and basically served as the text. The process of learning about each of these uses, and producing process maps, provided an understanding of everything that goes into implementing the BIM uses. These uses are included in the BIM section of this report, and the final decisions were made based off of this guide.

AE 597F: Virtual Facility Prototyping
For this course, Unity was introduced as the main prototyping software. The knowledge gained in this class provided a base to build the virtual mock-up in the BIM analysis. The conversion of a Revit model to Unity, via 3D Studio Max, was presented in this course. Without this training, the mock-up would not have been possible.

Recommendations and Conclusions

Throughout the academic year, the Butler Memorial Hospital New Inpatient Tower was thoroughly analyzed. Once the building and the systems were understood, three analyses were performed in an attempt to better the overall project. These three analyses dealt with implementing some of the newer industry technologies. These topics included the following:

- Application of a Photovoltaic Array
- Prefabrication of Overhead MEP Spaces
- Increasing the BIM Usage

After performing the analyses, which are detailed throughout the report, the following conclusions have been reached:

Analysis #1: Photovoltaic Array

The designed photovoltaic array is composed of 244 panels, which are 210 Watt panels, spread throughout the 5th floor and 8th floor roofs. The system is a 51.5kwh system, with 4' spacing between rows. This array only requires small changes made to the structural system. The girder size would need to be increased from a W24x62 to a W24x76. The initial cost of the installation would be approximately $358,400. With government incentives and rebates, the final installation cost would be $208,998.00. Due to the energy savings, the final payback period for the system would be only two years. With this short payback timeframe, this would be a sensible investment to the owner.

Analysis #2: MEP Prefabrication

Healthcare facilities are known for having some of the most complex MEP systems in construction. With the large amount of services in the overhead ceiling spaces, coordination and installation can be a daunting task. With prefabricated MEP modules, this has been found to reduce the cost and schedule of the MEP installation. With BIM already being used for 3D clash detection, this concept is feasible to adopt. For this project, the corridor spaces will be prefabricated. This resulted in a doubling of productivity, and a reduction in cost of nearly $1 million. This would clearly be something that would benefit the entire project team.

Analysis #3: Increasing BIM Usage

The BIM Execution Guide addresses 21 different ways that BIM can be utilized. For this project, only two of these methods were implemented. For this analysis, case studies on similar projects have provided past examples in which other BIM uses greatly benefited the project. From these studies and problems addressed by Turner employees, the concept of virtual mock-ups appears to be the most beneficial application for this project. With several issues noticed after construction, a virtual mock-up of spaces could help reduce or eliminate these mishaps. A virtual model has been produced for one major area of concern. This same principle could eventually be adopted for the rest of the building.

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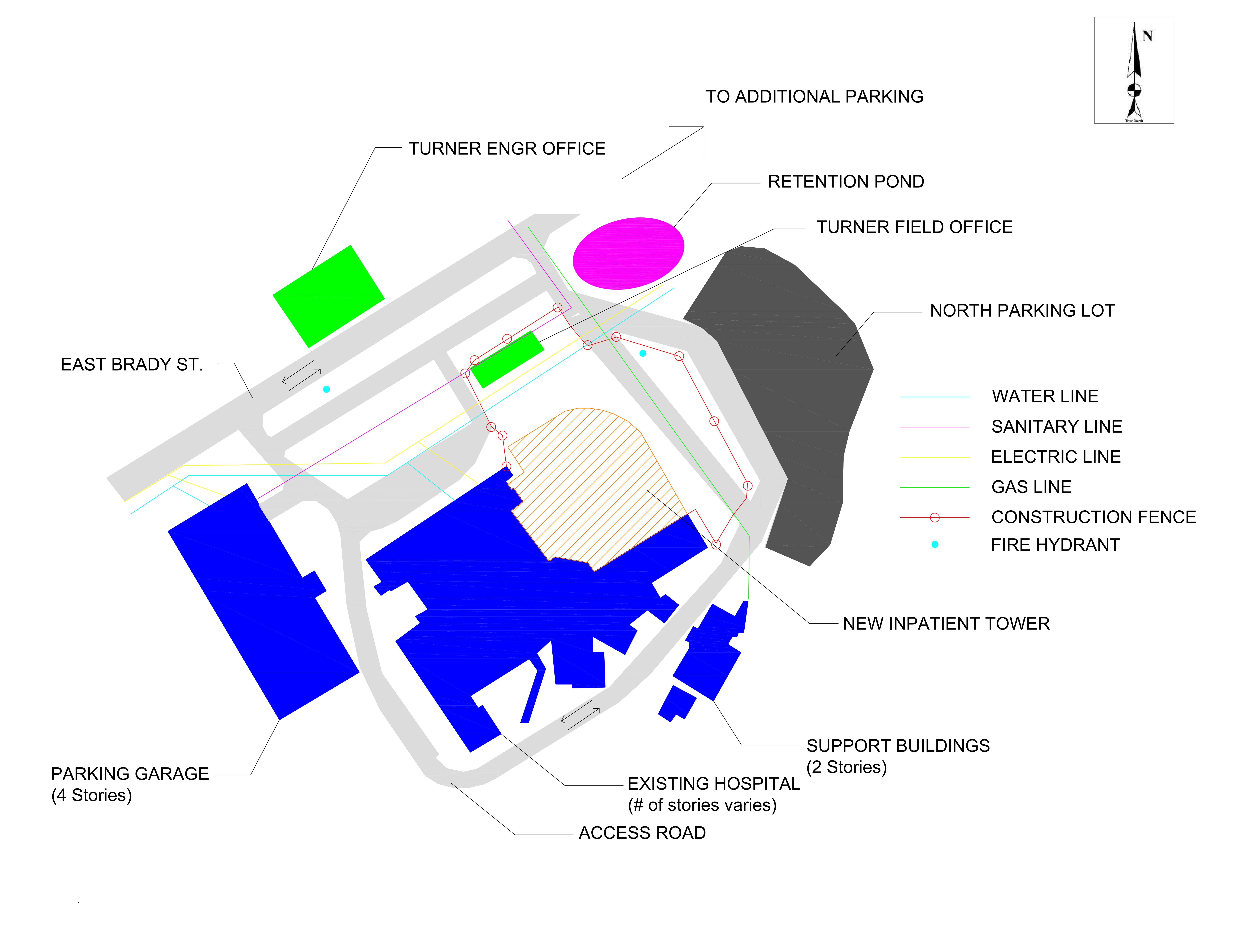
Appendix A: Existing Conditions Site Plan



General Notes

No.	Revision/Issue	Date

Firm Name and Address
CHRISTOPHER DILORENZO
PENN STATE AE-5TH YEAR
CONSTRUCTION

Project Name and Address
BUTLER INPATIENT TOWER
911 EAST BRADY STREET
BUTLER, PA

Project: SENIOR THESIS
Sheet:
Date: 10/5/2010
Scale: NTS

Appendix B: General Conditions Estimate

General Conditions Estimate

General Conditions Estimate				
Line Item	Unit Rate	Unit	Quantity	Total Cost
Temporary Facilities	$68,717.00	Each	1	$68,717.00
Temporary Utilities	$111.89	Weeks	114	$12,755.00
Protection and Safety	$168.15	Weeks	114	$19,169.00
General Expenses	$3,626.18	Weeks	114	$413,385.00
Project Staff	$37,590.80	Weeks	114	$4,285,351.00
Fringes/Taxes/Insurance	-	-	-	$596,519.00
			Total GC Cost	$5,395,896.00

Table 1: General Conditions Estimate

Contingency Costs	
Contingency	Cost
Design/Development	$416,865.00
Construction	$1,666,572.00
Total Contingency Cost	$2,083,437.00

Table 2: Contingency Costs

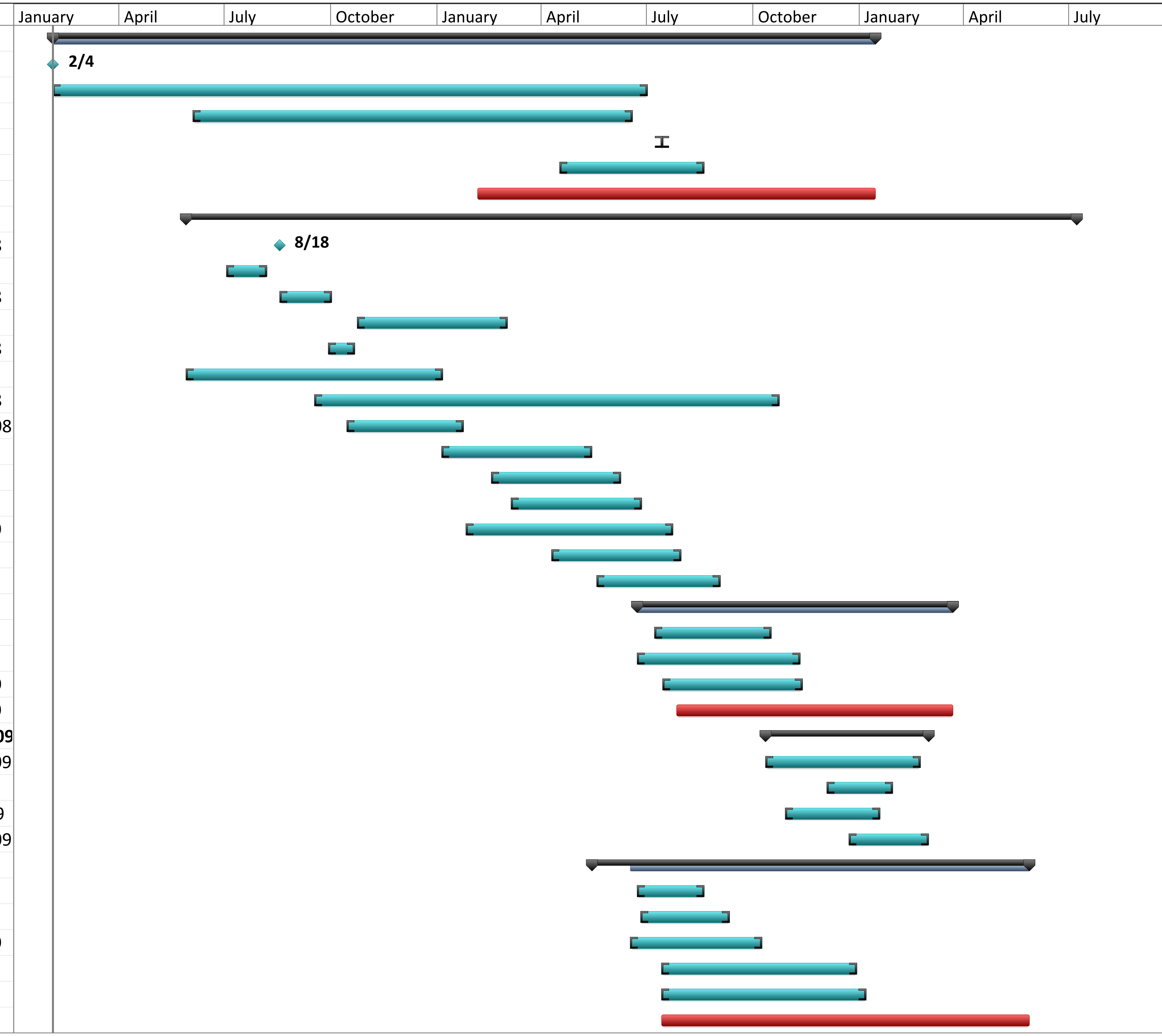
Onsite Staff Positions and Rates		
Staff Position	Base Monthly	Hourly Billing Rate
Project Manager	$9,448.00	$81.71
Project Engineer	$8,117.00	$70.20
MEP Superintendent	$5,800.00	$50.16
Senior Engineer	$8,494.00	$73.46
Assistant Engineer	$4,200.00	$36.32
Onsite Safety Engineer	$6,574.00	$56.85

Table 3: Onsite Staff Rates

Appendix C: Detailed Project Schedule

Butler Health System- New Inpatient Tower

ID	Task	Task Name	Duration	Start
1		**Preconstruction/Procurement**	**509 days**	**Mon 2/4/08**
2		Design Start	0 days	**Mon 2/4/08**
3		Schematic Design & Design Development	368 days	Mon 2/4/08
4		Construction Documents	272 days	Wed 6/4/08
5		GMP Development	1 day	Tue 7/14/09
6		BIM Coordination	89 days	Thu 4/16/09
7		Submittals and Procurement	246 days	Thu 2/5/09
8		**Construction**	**550 days**	**Thu 5/29/08**
9		Start Construction	0 days	Mon 8/18/08
10		Access Drive Design and Construction	25 days	Thu 7/3/08
11		Mass Excavation	33 days	Mon 8/18/08
12		Construct Foundations	92 days	Fri 10/24/08
13		Sanitary and Storm Line Installation	17 days	Mon 9/29/08
14		Site Electrical Relocation	158 days	Thu 5/29/08
15		Water/Gas/Oxygen Relocations	288 days	Wed 9/17/08
16		Install Caissons	73 days	Wed 10/15/08
17		Structural Steel Fabrication	94 days	Mon 1/5/09
18		Structural Steel Erection	80 days	Tue 2/17/09
19		Decking, Detailing, and Shear Stud Work	81 days	Fri 3/6/09
20		Concrete Slab on Grade	129 days	Mon 1/26/09
21		Concrete on Metal Deck	80 days	Fri 4/10/09
22		Spray on Fire Proofing	77 days	Tue 5/19/09
23		**Masonry Work**	**195 days**	**Tue 6/23/09**
24		Entire Floor Masonry	73 days	Wed 7/8/09
25		West Elevation Masonry	101 days	Tue 6/23/09
26		East and South Elevation Levels 5-8	87 days	Wed 7/15/09
27		North Elevation Masonry	171 days	Mon 7/27/09
28		**Windows and Curtain Wall Installation**	**101 days**	**Mon 10/12/09**
29		West Elevation	96 days	Mon 10/12/09
30		Northeast Elevation	41 days	Fri 12/4/09
31		North Elevation	58 days	Thu 10/29/09
32		South Elevation	49 days	Wed 12/23/09
33		**Vertical Work**	**270 days**	**Fri 5/15/09**
34		Service Elevators 8	42 days	Tue 6/23/09
35		Service Elevator 9	55 days	Fri 6/26/09
36		Service Elevator 10	82 days	Wed 6/17/09
37		Service Elevators 4&5	121 days	Tue 7/14/09
38		Trauma Elevator 3	127 days	Tue 7/14/09
39		Passenger Elevators 6 & 7	228 days	Tue 7/14/09

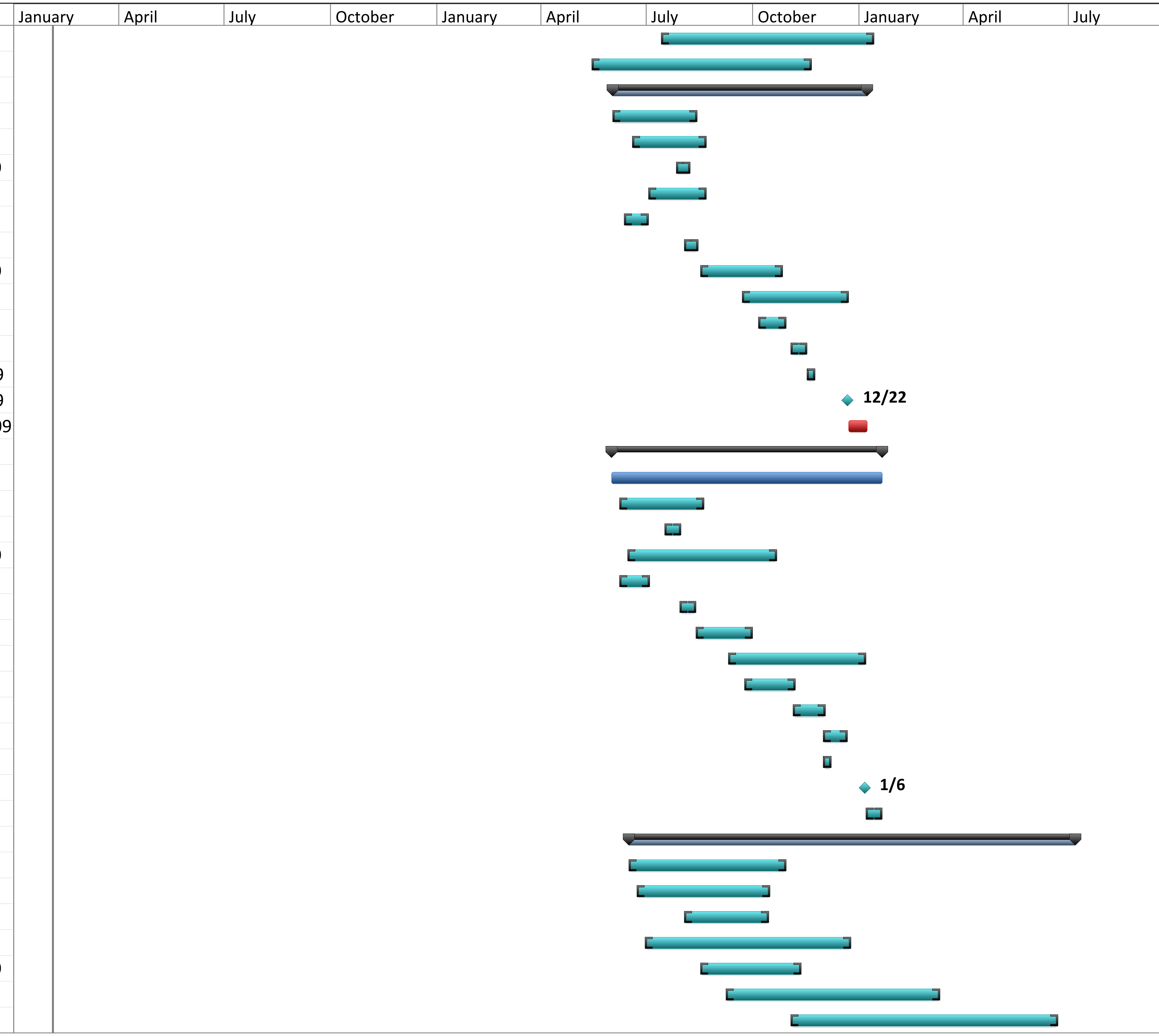


Project: Butler Hospital Inpatient
Date: October 27th, 2010

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Critical
Milestone	External Milestone	Manual Task	Start-only	Critical Split
Summary	Inactive Task	Duration-only	Finish-only	Progress

Butler Health System- New Inpatient Tower

ID	Task Name	Duration	Start
40	Passenger elevators 1 & 2	132 days	Tue 7/14/09
41	Stair Installation	136 days	Fri 5/15/09
42	**Ground Floor Work**	**158 days**	**Tue 6/2/09**
43	Mechanical Rough-In	53 days	Tue 6/2/09
44	Plumbing Rough-In	46 days	Fri 6/19/09
45	Fire Protection Rough-In	10 days	Mon 7/27/09
46	Electrical Rough-In	36 days	Fri 7/3/09
47	Construct Masonry Walls	15 days	Fri 6/12/09
48	Interior Studs and Door Frames	10 days	Mon 8/3/09
49	Ceilings and Drywall Installation	51 days	Mon 8/17/09
50	Prime and Paint Walls/Ceilings	66 days	Tue 9/22/09
51	Finish System Trim	18 days	Tue 10/6/09
52	Flooring Installation	10 days	Tue 11/3/09
53	Doors and Hardware	5 days	Tue 11/17/09
54	Substantial Completion Ground Floor	0 days	Tue 12/22/09
55	Balancing and Life Safety Testing	12 days	Wed 12/23/09
56	**First Floor Work**	**168 days**	**Mon 6/1/09**
57	Mechanical Rough-In and Mechanical Room	168 days	Mon 6/1/09
58	Plumbing Rough-In	53 days	Mon 6/8/09
59	Fire Protection Rough-In	10 days	Fri 7/17/09
60	Electrical Rough-In and Electrical Room	93 days	Mon 6/15/09
61	Construct Masonry Walls	20 days	Mon 6/8/09
62	Interior Studs and Door Frames	10 days	Thu 7/30/09
63	Ceilings and Drywall Installation	35 days	Thu 8/13/09
64	Prime and Paint Walls/Ceilings	85 days	Thu 9/10/09
65	Finish System Trim and Casework	32 days	Thu 9/24/09
66	Flooring Installation	20 days	Thu 11/5/09
67	Wall Protection and Misc. Specialties	15 days	Tue 12/1/09
68	Doors and Hardware	5 days	Tue 12/1/09
69	Substantial Completion Ground Floor	0 days	Wed 1/6/10
70	Balancing and Life Safety Testing	10 days	Thu 1/7/10
71	**Second Floor Work**	**276 days**	**Tue 6/16/09**
72	Mechanical Rough-In	98 days	Tue 6/16/09
73	Plumbing Rough-In	83 days	Tue 6/23/09
74	Fire Protection Rough-In	53 days	Mon 8/3/09
75	Electrical Rough-In	128 days	Tue 6/30/09
76	Interior Studs and Door Frames	63 days	Mon 8/17/09
77	Ceilings and Drywall Installation	133 days	Tue 9/8/09
78	Prime and Paint Walls/Ceilings	165 days	Tue 11/3/09

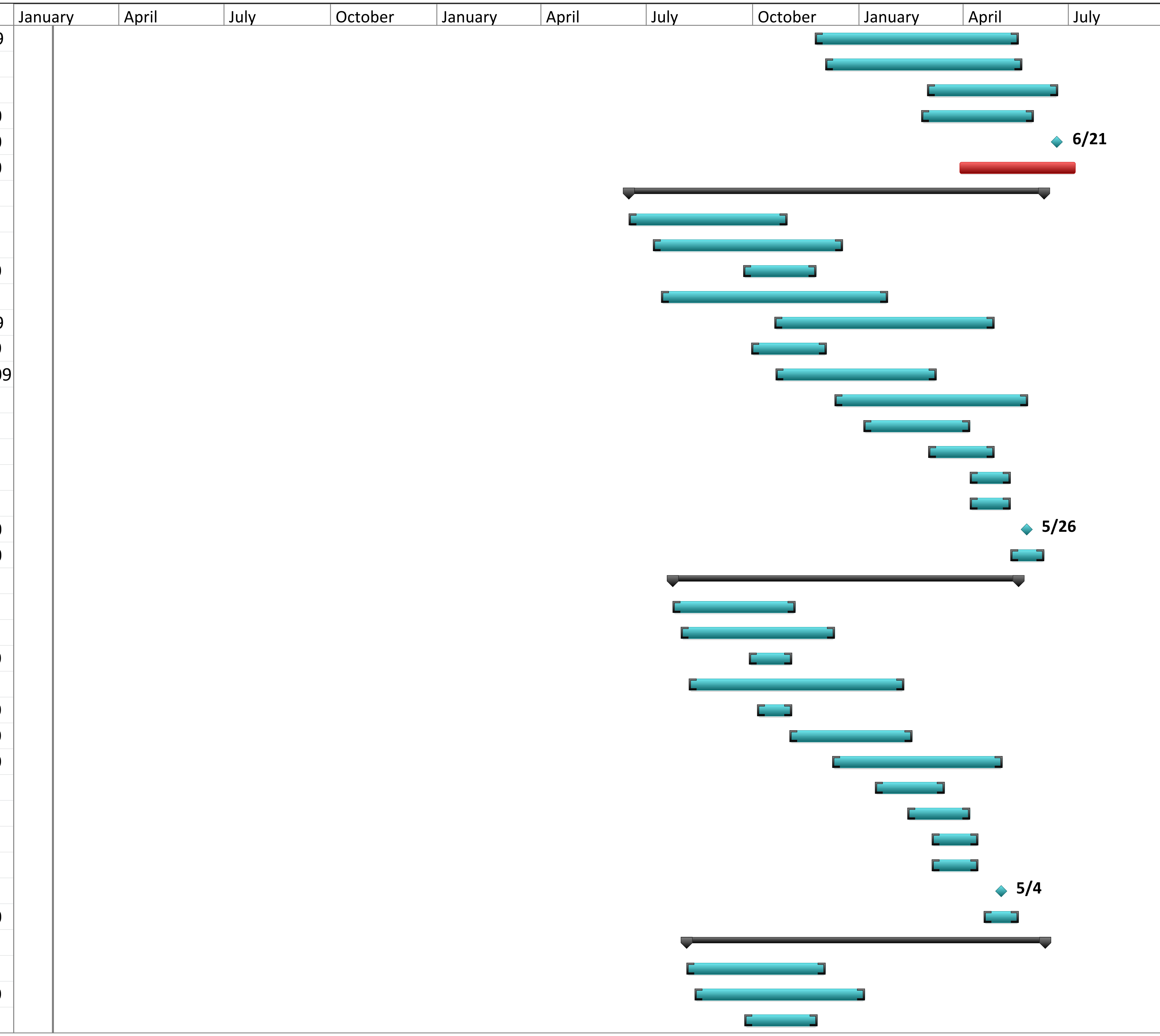


Project: Butler Hospital Inpatient
Date: October 27th, 2010

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Critical
Milestone	External Milestone	Manual Task	Start-only	Critical Split
Summary	Inactive Task	Duration-only	Finish-only	Progress

Butler Health System- New Inpatient Tower

ID	Task	Task Name	Duration	Start
79		Finish System Trim and Casework	126 days	Tue 11/24/09
80		Flooring Installation	122 days	Thu 12/3/09
81		Wall Protection and Misc. Specialties	81 days	Mon 3/1/10
82		Doors and Hardware	69 days	Wed 2/24/10
83		Substantial Completion Ground Floor	0 days	Mon 6/21/10
84		Balancing and Life Safety Testing	72 days	Mon 3/29/10
85		**Third Floor Work**	**257 days**	**Tue 6/16/09**
86		Mechanical Rough-In	99 days	Tue 6/16/09
87		Plumbing Rough-In	118 days	Tue 7/7/09
88		Fire Protection Rough-In	45 days	Wed 9/23/09
89		Electrical Rough-In	140 days	Tue 7/14/09
90		Build Out Operating Rooms	136 days	Tue 10/20/09
91		Interior Studs and Door Frames	47 days	Wed 9/30/09
92		Ceilings and Drywall Installation	99 days	Wed 10/21/09
93		Prime and Paint Walls/Ceilings	119 days	Fri 12/11/09
94		Finish System Trim and Casework	66 days	Tue 1/5/10
95		Flooring Installation	41 days	Tue 3/2/10
96		Wall Protection and Misc. Specialties	25 days	Wed 4/7/10
97		Doors and Hardware	25 days	Wed 4/7/10
98		Substantial Completion Ground Floor	0 days	Wed 5/26/10
99		Balancing and Life Safety Testing	21 days	Wed 5/12/10
100		**Fifth Floor Work**	**213 days**	**Fri 7/24/09**
101		Mechanical Rough-In and Mechanical Room	76 days	Fri 7/24/09
102		Plumbing Rough-In	95 days	Fri 7/31/09
103		Fire Protection Rough-In	27 days	Mon 9/28/09
104		Electrical Rough-In	132 days	Fri 8/7/09
105		Interior Studs and Door Frames	22 days	Mon 10/5/09
106		Ceilings and Drywall Installation	76 days	Mon 11/2/09
107		Prime and Paint Walls/Ceilings	105 days	Wed 12/9/09
108		Finish System Trim and Casework	42 days	Fri 1/15/10
109		Flooring Installation	38 days	Fri 2/12/10
110		Wall Protection and Misc. Specialties	28 days	Fri 3/5/10
111		Doors and Hardware	28 days	Fri 3/5/10
112		Substantial Completion Ground Floor	0 days	Tue 5/4/10
113		Balancing and Life Safety Testing	22 days	Mon 4/19/10
114		**Sixth Floor Work**	**222 days**	**Wed 8/5/09**
115		Mechanical Rough-In	86 days	Wed 8/5/09
116		Plumbing Rough-In	105 days	Wed 8/12/09
117		Fire Protection Rough-In	45 days	Thu 9/24/09

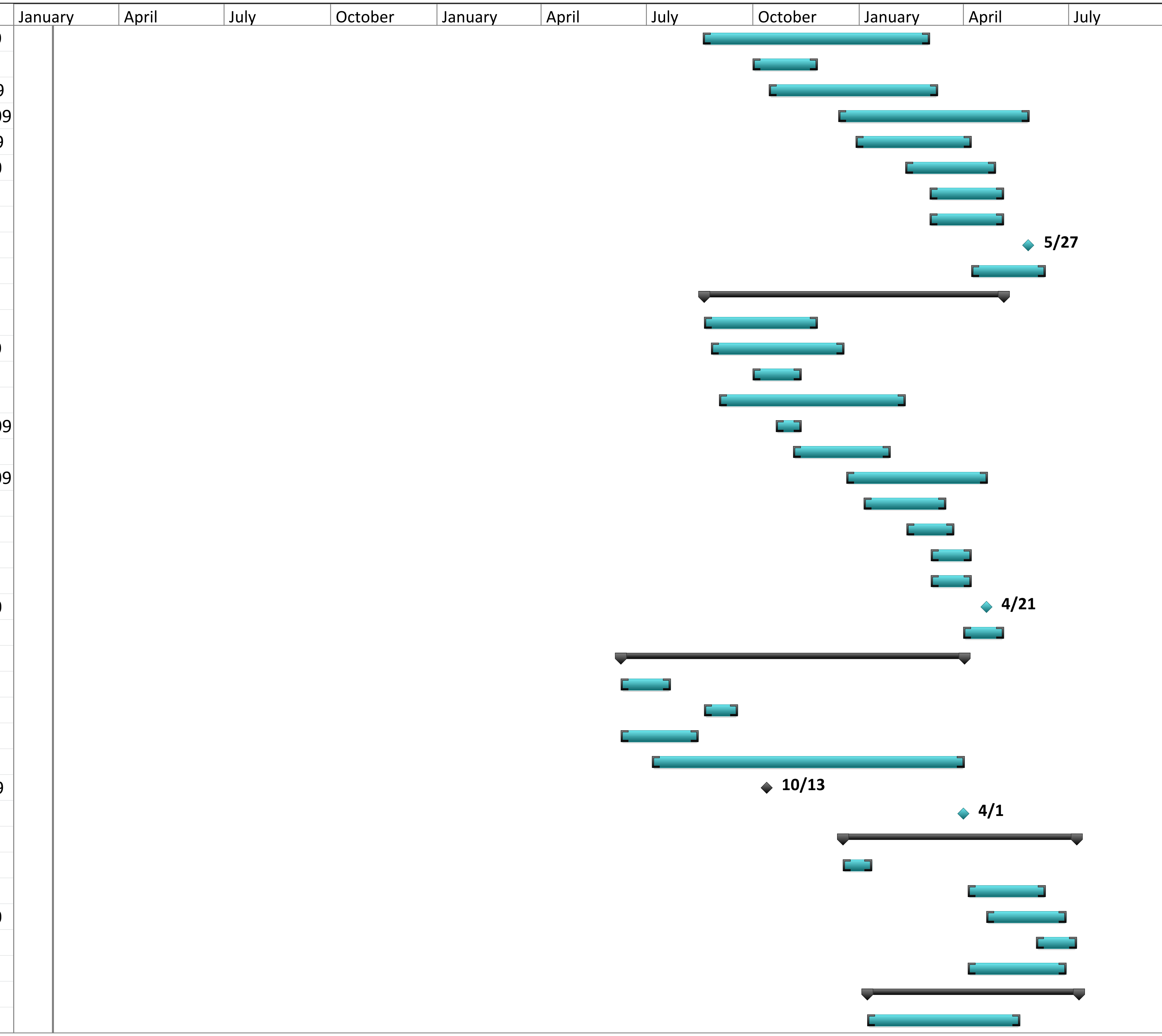


Project: Butler Hospital Inpatient
Date: October 27th, 2010

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Critical
Milestone	External Milestone	Manual Task	Start-only	Critical Split
Summary	Inactive Task	Duration-only	Finish-only	Progress

Butler Health System- New Inpatient Tower

ID	Task Name	Duration	Start
118	Electrical Rough-In	140 days	Wed 8/19/09
119	Interior Studs and Door Frames	40 days	Thu 10/1/09
120	Ceilings and Drywall Installation	104 days	Thu 10/15/09
121	Prime and Paint Walls/Ceilings	119 days	Mon 12/14/09
122	Finish System Trim and Casework	72 days	Tue 12/29/09
123	Flooring Installation	56 days	Wed 2/10/10
124	Wall Protection and Misc. Specialties	46 days	Wed 3/3/10
125	Doors and Hardware	46 days	Wed 3/3/10
126	Substantial Completion Ground Floor	0 days	Thu 5/27/10
127	Balancing and Life Safety Testing	46 days	Thu 4/8/10
128	**Seventh Floor Work**	**185 days**	**Thu 8/20/09**
129	Mechanical Rough-In and Penthouse Mains	70 days	Thu 8/20/09
130	Plumbing Rough-In	83 days	Wed 8/26/09
131	Fire Protection Rough-In	30 days	Thu 10/1/09
132	Electrical Rough-In	115 days	Wed 9/2/09
133	Interior Studs and Door Frames	16 days	Wed 10/21/09
134	Ceilings and Drywall Installation	60 days	Thu 11/5/09
135	Prime and Paint Walls/Ceilings	88 days	Mon 12/21/09
136	Finish System Trim and Casework	51 days	Tue 1/5/10
137	Flooring Installation	29 days	Thu 2/11/10
138	Wall Protection and Misc. Specialties	25 days	Thu 3/4/10
139	Doors and Hardware	25 days	Thu 3/4/10
140	Substantial Completion Ground Floor	0 days	Wed 4/21/10
141	Balancing and Life Safety Testing	25 days	Thu 4/1/10
142	**Roofing**	**213 days**	**Tue 6/9/09**
143	Studs and Sheathing	31 days	Tue 6/9/09
144	Metal Paneling	21 days	Thu 8/20/09
145	Complete Temporary Roofing	49 days	Tue 6/9/09
146	Complete Permanent Roofing	194 days	Mon 7/6/09
147	Building Dry-In	0 days	Tue 10/13/09
148	Building Watertight	0 days	Thu 4/1/10
149	**Final Sitework**	**144 days**	**Fri 12/18/09**
150	Exterior and Site Lighting	17 days	Fri 12/18/09
151	Seating Garden Area	49 days	Mon 4/5/10
152	North Parking Lot	49 days	Wed 4/21/10
153	ER Entry	25 days	Thu 6/3/10
154	Site Concrete and Paving	61 days	Mon 4/5/10
155	**Turnover/Commissioning**	**131 days**	**Fri 1/8/10**
156	Complete Punchlist	94 days	Fri 1/8/10

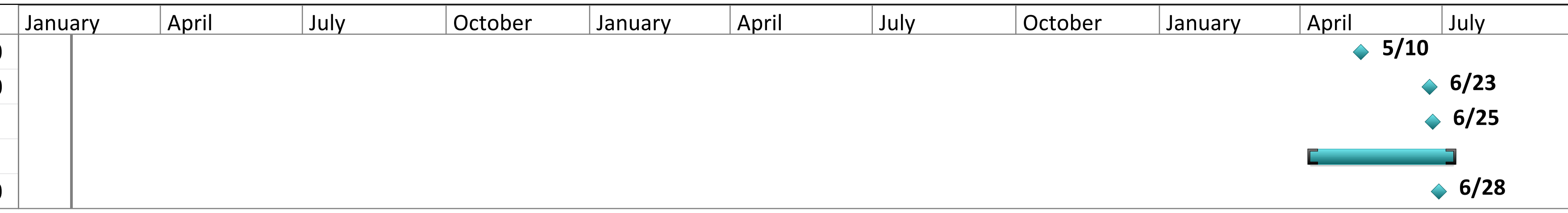


Project: Butler Hospital Inpatient
Date: October 27th, 2010

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Critical	
Milestone		External Milestone		Manual Task		Start-only		Critical Split	
Summary		Inactive Task		Duration-only		Finish-only		Progress	

Butler Health System- New Inpatient Tower

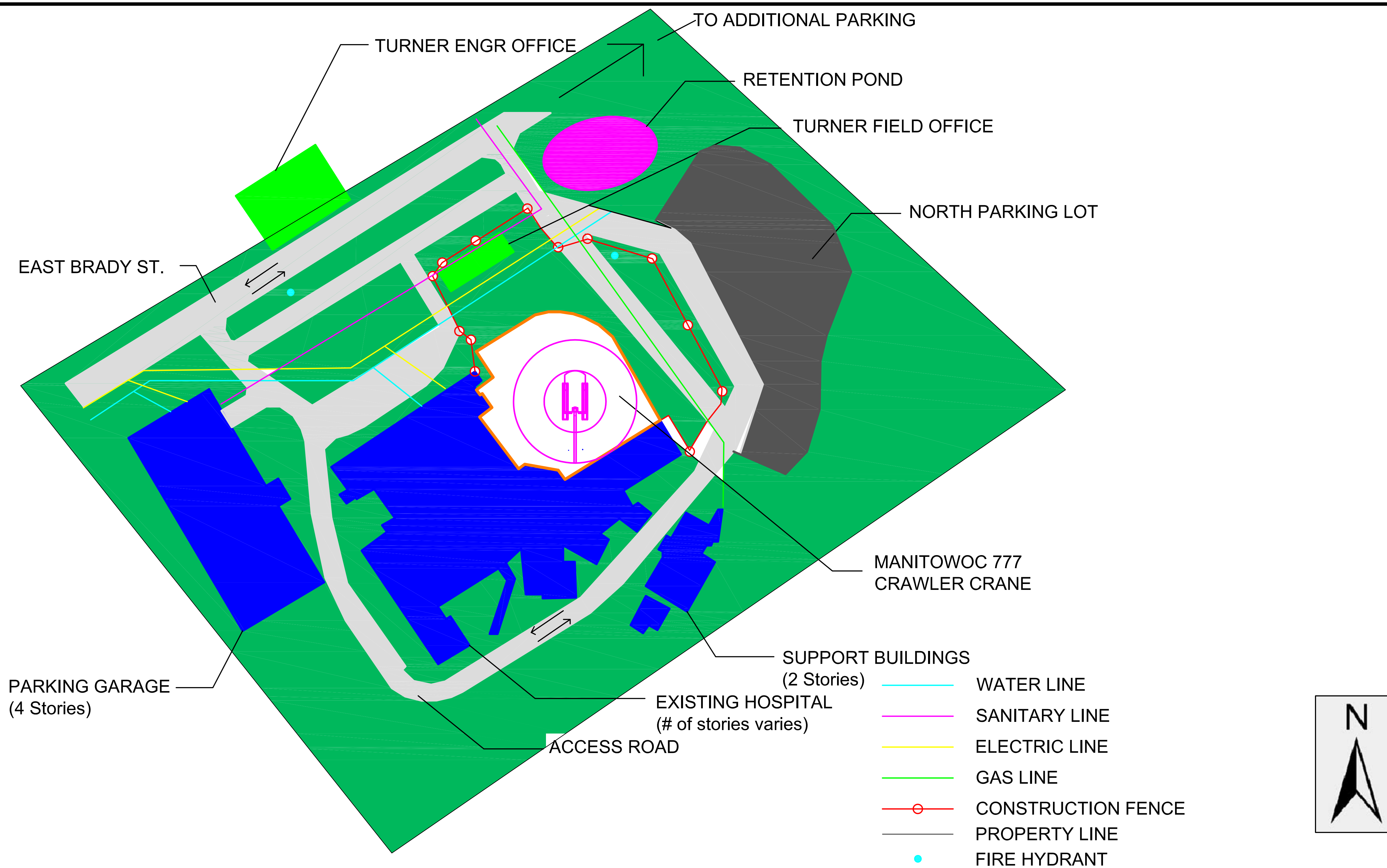
ID	Task Mode	Task Name	Duration	Start
157		Turnover Ground-2nd Floors	0 days	Mon 5/10/10
158		Turnover 3rd-5th Floors	0 days	Wed 6/23/10
159		Turnover 6th-7th Floors	0 days	Fri 6/25/10
160		Commissioning	69 days	Tue 4/6/10
161		Patient Go Live Date	0 days	Mon 6/28/10



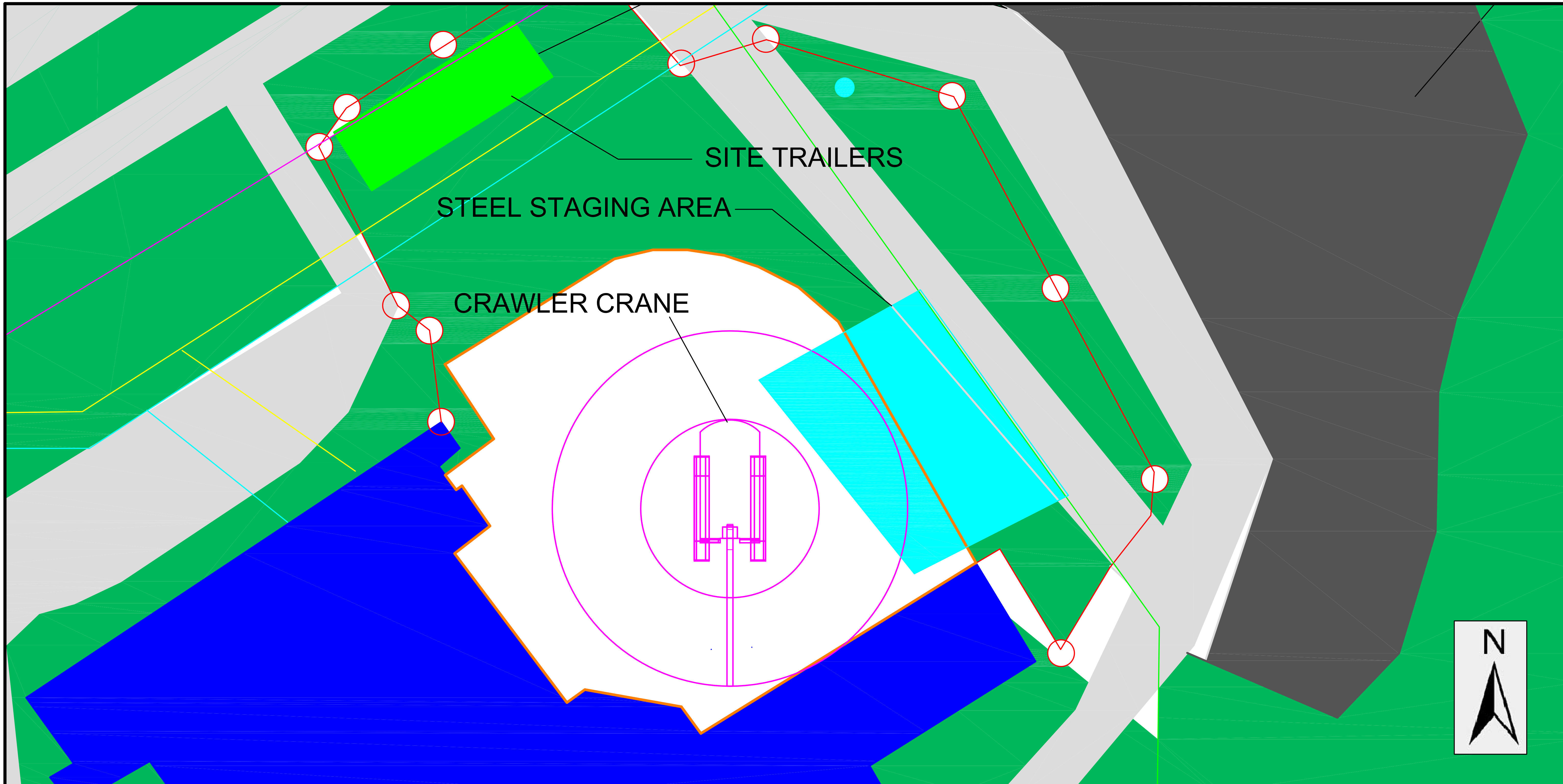
Project: Butler Hospital Inpatient
Date: October 27th, 2010

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Critical | Critical Split | Progress

Appendix D: Site Layout Planning

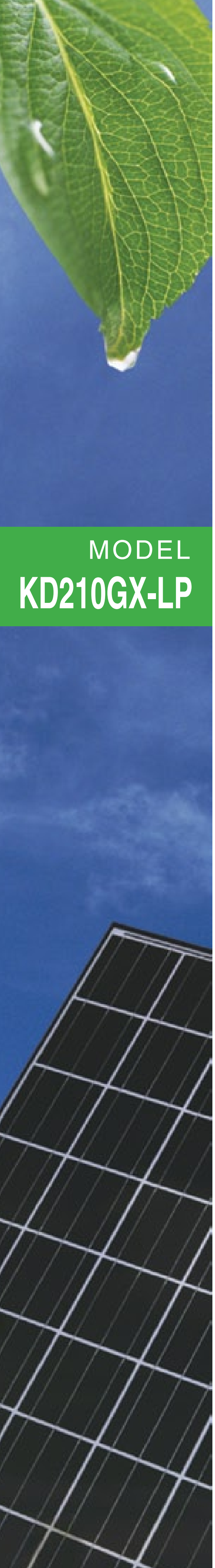


PROJECT: BUTLER HOSPITAL INPATIENT TOWER	TITLE: STEEL ERECTION SITEPLAN		SHEET: 1
LOCATION: BUTLER, PA	DATE: 10/27/2010	REVISIONS: 1 2 3	
YOUR NAME: CHRIS DILORENZO	SCALE: NTS		
AE SENIOR THESIS			



PROJECT: BUTLER HOSPITAL INPATIENT TOWER	TITLE: ENLARGED STEEL ERECTION PLAN		SHEET:
LOCATION: BUTLER, PA	DATE: 10/27/2010	REVISIONS: 1	1
YOUR NAME: CHRIS DILORENZO	SCALE: NTS	2	
AE SENIOR THESIS		3	

Appendix E: Photovoltaic Panel Specifications



MODEL
KD210GX-LP

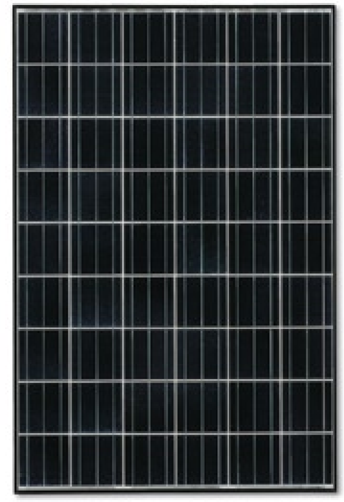
THE NEW VALUE FRONTIER

KYOCERA

KD210GX-LP

HIGH EFFICIENCY MULTICRYSTAL
PHOTOVOLTAIC MODULE

LISTED



HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES

Kyocera's advanced cell processing technology and automated production facilities produce a highly efficient multicrystal photovoltaic module.
The conversion efficiency of the Kyocera solar cell is over 16%.
These cells are encapsulated between a tempered glass cover and a pottant with back sheet to provide efficient protection from the severest environmental conditions.
The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.
Equipped with plug-in connectors.

APPLICATIONS

KD210GX-LP is ideal for grid tie system applications.

- Residential roof top systems
- Large commercial grid tie systems
- Water Pumping systems
- High Voltage stand alone systems
- etc.

QUALIFICATIONS

- **MODULE** : UL1703 listed
- **FACTORY** : ISO9001 and ISO 14001

QUALITY ASSURANCE

Kyocera multicrystal photovoltaic modules have passed the following tests.

● Thermal cycling test ● Thermal shock test ● Thermal / Freezing and high humidity cycling test ● Electrical isolation test
● Hail impact test ● Mechanical, wind and twist loading test ● Salt mist test ● Light and water-exposure test ● Field exposure test

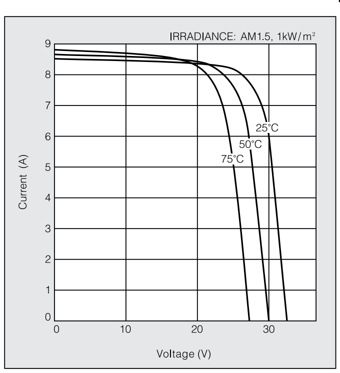
LIMITED WARRANTY

※1 year limited warranty on material and workmanship
※20 years limited warranty on power output: For detail, please refer to "category IV" in Warranty issued by Kyocera

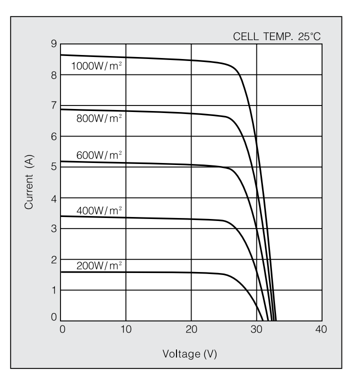
(Long term output warranty shall warrant if PV Module(s) exhibits power output of less than 90% of the original minimum rated power specified at the time of sale within 10 years and less than 80% within 20 years after the date of sale to the Customer. The power output values shall be those measured under Kyocera's standard measurement conditions. Regarding the warranty conditions in detail, please refer to Warranty issued by Kyocera)

ELECTRICAL CHARACTERISTICS

Current-Voltage characteristics of Photovoltaic Module KD210GX-LP at various cell temperatures

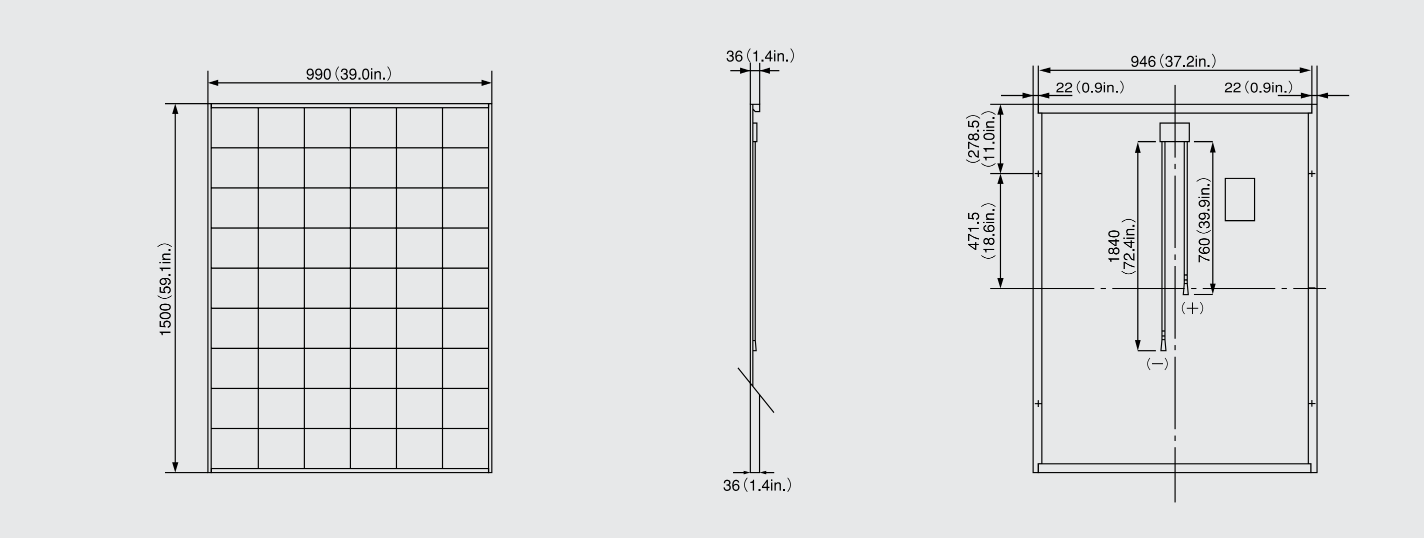


Current-Voltage characteristics of Photovoltaic Module KD210GX-LP at various irradiance levels



Physical Specifications

Unit : mm (in.)



Specifications

Electrical Performance under Standard Test Conditions (*STC)	
Maximum Power (Pmax)	210W (+5%/−5%)
Maximum Power Voltage (Vmpp)	26.6V
Maximum Power Current (Impp)	7.90A
Open Circuit Voltage (Voc)	33.2V
Short Circuit Current (Isc)	8.58A
Max System Voltage	600V
Temperature Coefficient of Voc	−0.120 V/℃
Temperature Coefficient of Isc	5.15×10^{-3} A/℃

*STC : Irradiance 1000W/m^2, AM1.5 spectrum, cell temperature 25℃

Electrical Performance at 800W/m^2, *NOCT, AM1.5	
Maximum Power (Pmax)	148W
Maximum Power Voltage (Vmpp)	23.5V
Maximum Power Current (Impp)	6.32A
Open Circuit Voltage (Voc)	29.9V
Short Circuit Current (Isc)	6.98A

*NOCT (Nominal Operating Cell Temperature) : 49℃

Cells	
Number per Module	54

Module Characteristics	
Length × Width × Depth	1500mm(59.1in)×990mm(39.0in)×36mm(1.4in)
Weight	18.5kg(40.8lbs.)
Cable	(+)760mm(29.9in),(-)1840mm(72.4in)

Junction Box Characteristics	
Length × Width × Depth	100mm(3.9in)×108mm(4.3in)×15mm(0.6in)
IP Code	IP65

Others	
*Operating Temperature	−40℃～90℃
Maximum Fuse	15A

*This temperature is based on cell temperature.

Please contact our office for further information

KYOCERA

KYOCERA Corporation

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http://www.kyocera.com/

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7812 East Acoma Drive
Scottsdale, AZ 85260, USA
TEL:(1)480-948-8003 or (800)223-9580 FAX:(1)480-483-6431
http://www.kyocerasolar.com/

● **KYOCERA Solar do Brasil Ltda.**
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22790-200, Recreio dos Bandeirantes, Rio de Janeiro, Brazil
TEL:(55)21-2437-8525 FAX:(55)21-2437-2338
http://www.kyocerasolar.com.br/

● **KYOCERA Solar Pty Ltd.**
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N.S.W. 2113, Australia
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● **KYOCERA Fineceramics GmbH**
Fritz-Muller-Strasse 107, 73730 Esslingen Germany
TEL:(49)711-93934-999 FAX:(49)711-93934-950
http://www.kyocerasolar.de/
solar@kyocera.de

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Central Plaza, Singapore 168730
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● **Kyocera Asia Pacific Ltd.**
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● **KYOCERA Asia Pacific Pte. Ltd., Taipei Office**
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● **KYOCERA (Tianjin) Sales & Trading Corp.**
(Beijing Office)Room 2107, Beijing Huabin International Building,
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Beijing, 100022, China
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http://www.kyocera.com.cn/

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Seocho-2Dong, Seocho-Ku,Seoul, 137-072, Korea
TEL:(82)2-3463-3538 FAX:(82)2-3463-3539
http://www.kyocera.co.kr/

Appendix F: MEP Installation Durations

MEP System Duration Reduction

Activity Name	Original Duration	Prefabricated Duration	Reduction in Schedule
	(Days)	(Days)	(Days)
First Floor MEP Work			
First Floor Ductwork			
Install S.A. Main Duct- AHU#1	10	5	5
Install R.A. Main Duct- AHU#1	10	5	5
Install Relief Main Air Duct	5	3	2
Install S.A. Main Duct- AHU#6	3	2	1
Install S.A. Main Duct- AHU#7	3	2	1
First Floor Mechanical Piping			
Install Main Mechanical Piping	5	3	2
First Floor Plumbing			
Install Rough-In Waste/Vent/Storm	10	5	5
Install Rough-In Domestic Water	10	5	5
Install Rough-In Med Gas Piping	4	2	2
First Floor Fire Protection	10	5	5
First Floor Electrical			
Install Power Distribution Conduit	10	5	5
Install Power Distribution Wire	5	3	2
Install Overhead Low Voltage	10	5	5
Third Floor MEP Work			
Third Floor Ductwork			
Install 3S S.A. Main Duct-AHU#1	4	2	2
Install 3S R.A. Main Duct- AHU#1	4	2	2
Install 3S S.A. Main Duct-AHU#4	4	2	2
Install 3S R.A. Main Duct-AHU#4	4	2	2
Install 3S S.A. Main Duct-AHU#5	4	2	2
Install 3S R.A. Main Duct-AHU#5	4	2	2
Install 3N S.A. Main Duct-AHU#2	4	2	2
Install 3N R.A. Main Duct-AHU#2	4	2	2
Install 3N S.A. Main Duct-AHU#3	4	2	2
Install 3N R.A. Main Duct-AHU#3	4	2	2
Third Floor Mechanical Piping			
Install 3S Main Mechanical Piping	10	5	5
Install 3N Main Mechanical Piping	11	6	5
Third Floor Plumbing			
Install 3S Plumbing Rough-In W/V/S	15	8	7
Install 3S Rough-In Domestic Water	10	5	5
Install 3S Rough-In Med. Gas Piping	16	8	8
Install 3N Plumbing Rough-In W/V/S	16	8	8
Install 3N Rough-In Domestic Water	10	5	5

Install 3N Rough-In Med. Gas Piping	10	5	5
Third Floor Fire Protection			
Install 3S Overhead Sprinkler	15	8	7
Install 3N Overhead Sprinkler	15	8	7
Third Floor Electrical			
Install 3S Power Distribution Conduit	10	5	5
Install 3S Power Distribution Wire	5	3	2
Install 3N Power Distribution Conduit	10	5	5
Install 3N Power Distribution Wire	5	3	2
Install 3S Low Voltage Overhead	10	5	5
Install 3N Low Voltage Overhead	10	5	5
Fifth Floor MEP Work			
Fifth Floor Ductwork			
Install 5S S.A. Main Duct-AHU#1	5	3	2
Install 5S R.A. Main Duct- AHU#1	5	3	2
Install 5N S.A. Main Duct-AHU#2	3	2	1
Install 5N R.A. Main Duct-AHU#2	4	2	2
Install 5N S.A. Main Duct-AHU#3	3	2	1
Install 5N R.A. Main Duct-AHU#3	3	2	1
Fifth Floor Mechanical Piping			
Install 5S Main Mechanical Piping	10	5	5
Install 5N Main Mechanical Piping	11	6	5
Fifth Floor Plumbing			
Install 5S Plumbing Rough-In W/V/S	10	5	5
Install 5S Rough-In Domestic Water	10	5	5
Install 5S Rough-In Med. Gas Piping	15	8	7
Install 5N Plumbing Rough-In W/V/S	16	8	8
Install 5N Rough-In Domestic Water	10	5	5
Install 5N Rough-In Med. Gas Piping	15	8	7
Fifth Floor Fire Protection			
Install 5S Overhead Sprinkler	15	8	7
Install 5N Overhead Sprinkler	15	8	7
Fifth Floor Electrical			
Install 5S Power Distribution Conduit	11	6	5
Install 5S Power Distribution Wire	5	3	2
Install 5N Power Distribution Conduit	10	5	5
Install 5N Power Distribution Wire	5	3	2
Install 5S Low Voltage Overhead	10	5	5
Install 5N Low Voltage Overhead	10	5	5
Sixth Floor MEP Work			
Sixth Floor Ductwork			
Install 6S S.A. Main Duct-AHU#1	4	2	2
Install 6S R.A. Main Duct- AHU#1	4	2	2

Install 6N S.A. Main Duct-AHU#2	3	2	1
Install 6N R.A. Main Duct-AHU#2	3	2	1
Install 6N S.A. Main Duct-AHU#3	3	2	1
Install 6N R.A. Main Duct-AHU#3	3	2	1
Sixth Floor Mechanical Piping			
Install 6S Main Mechanical Piping	10	5	5
Install 6N Main Mechanical Piping	10	5	5
Sixth Floor Plumbing			
Install 6S Plumbing Rough-In W/V/S	15	8	7
Install 6S Rough-In Domestic Water	11	6	5
Install 6S Rough-In Med. Gas Piping	15	8	7
Install 6N Plumbing Rough-In W/V/S	15	8	7
Install 6N Rough-In Domestic Water	10	5	5
Install 6N Rough-In Med. Gas Piping	15	8	7
Sixth Floor Fire Protection			
Install 6S Overhead Sprinkler	15	8	7
Install 6N Overhead Sprinkler	15	8	7
Sixth Floor Electrical			
Install 6S Power Distribution Conduit	10	5	5
Install 6S Power Distribution Wire	5	3	2
Install 6N Power Distribution Conduit	10	5	5
Install 6N Power Distribution Wire	5	3	2
Install 6S Low Voltage Overhead	10	5	5
Install 6N Low Voltage Overhead	12	6	6
Seventh Floor MEP Work			
Seventh Floor Ductwork			
Install 7S S.A. Main Duct-AHU#1	4	2	2
Install 7S R.A. Main Duct- AHU#1	4	2	2
Install 7N S.A. Main Duct-AHU#2	3	2	1
Install 7N R.A. Main Duct-AHU#2	3	2	1
Install 7N S.A. Main Duct-AHU#3	3	2	1
Install 7N R.A. Main Duct-AHU#3	3	2	1
Seventh Floor Mechanical Piping			
Install 7S Main Mechanical Piping	10	5	5
Install 7N Main Mechanical Piping	10	5	5
Seventh Floor Plumbing			
Install 7S Plumbing Rough-In W/V/S	16	8	8
Install 7S Rough-In Domestic Water	10	5	5
Install 7S Rough-In Med. Gas Piping	15	8	7
Install 7N Plumbing Rough-In W/V/S	15	8	7
Install 7N Rough-In Domestic Water	10	5	5
Install 7N Rough-In Med. Gas Piping	15	8	7

Seventh Floor Fire Protection			
Install 7S Overhead Sprinkler	15	8	7
Install 7N Overhead Sprinkler	15	8	7
Seventh Floor Electrical			
Install 7S Power Distribution Conduit	10	5	5
Install 7S Power Distribution Wire	5	3	2
Install 7N Power Distribution Conduit	10	5	5
Install 7N Power Distribution Wire	5	3	2
Install 7S Low Voltage Overhead	10	5	5
Install 7N Low Voltage Overhead	10	5	5

	Original Duration	**Prefabricated Duration**	**Reduction**
Total Duration	**918 Days**	**483 Days**	**435 Days**

MEP Duration Reduction