FINAL THESIS REPORT

PENN STATE AE SENIOR THESIS

PENN STATE MILTON S. HERSHEY MEDICAL CENTER
CHILDREN'S HOSPITAL
HERSHEY, PA 17033

ABDULWAHAB HASAN
CONSTRUCTION MANAGEMENT
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APRIL 07, 2011

ABDULWAHAB HASAN - CONSTRUCTION MANAGEMENT
PENN STATE HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL
HERSHEY, PA

PROJECT TEAM

OWNER: PSU Hershey Medical Center
CM AGENCY: L.F. Driscoll Co, LLC
ARCHITECT: Payette Associates
STRUCTURAL ENGINEER: Gannett Fleming INC
MEP ENGINEER: BR+A Consulting Engineers, LLC
LANDSCAPE ARCHITECT: Hargreaves Associates

DESIGN/ARCHITECTURE

- Ties in to exisiting Cancer Institute Building.
- Aluminum Curtain Wall Facade.
- Granite and Limestone Cladding Facade.
- Out-Door Healing Garden Between the Cancer Institute and Children's Hospital.
- Pharmacy, Blood Bank, and Radiology in basement.
- Lobby, Servery and Dining Areas, as well as hematology/oncology clinic on First Floor.
- Surgery and PACU housed on the Second Floor.
- Medical and Surgical Rooms on the Third Floor.
- PICU and PIMCU Rooms on the Fourth Floor.
- Office Fitout on the Fifth Floor.

STRUCTURAL SYSTEM

- Foundation: Column Piers + Grade Beams on Micropiles.
- 6" SOG with 5" and 8" transitions at some locations.
- 2" deep, 20 gage composite metal deck with 4-1/2" topping slab.
- Steel bay construction
- Multiply-Asphalt Built-Up roofing with EPDM membrane
- Designed to accomodate 2 future floors.

PROJECT INFO

NUMBER OF STORIES: 5 Stories + 1 Underground
BUILDING AREA: 262,587 GSF
CONTRACTED GMP: $115,726,613
CONSTRUCTION DATES: March 2010 - August 2012

CONSTRUCTION LOGISTICS

- 6-Detailed construction phases will take place during the construction of the new facility:
  - Initial Start
  - Sub-Grade Preparation
  - Superstructure Erection
  - Structural Skin Erection
  - Building Water Tight / Fitouts
  - Site Improvements
- ILS/ICRA plans on all construction activities is mandated per contract.
- Excessive noise and vibrations must be coordinated with Cancer Institute Facility to insure no distractions to surgical rooms, patients, and labs.

MECH/ELEC SYSTEMS

- 5-Major AHU's supplying 350,000 CFM to CAV and
- VAV boxes.
- 2-Fans per AHU with 35,000 CFM output per fan.
- 2-Primary Chilled Water Pumps @ 3300 GPM each.
- 2-Primary Hot Water Pumps @ 1200 GPM each.
- Electrical power supplied by 15KV feeder.
- 13.8KV "K" Dry Type Transformer on 3-Phase 480/277 Circuit supplying power to the Hospital.

PENNSTATE HERSHEY Milton S. Hershey Medical Center
L.F. Driscoll Co., LLC
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http://www.engr.psu.edu/ae/thesis/portfolios/2011/amh440/index.html

1.0 EXECUTIVE SUMMARY

The Senior Thesis Final Report discusses the research and findings of the three analyses proposed in the proposal for the Penn State Milton S. Hershey Medical Center's new Children's Hospital. The newest addition to the Hershey Medical Center is the state of the art 262,587 SF Children's Hospital serving the Children of central Pennsylvania. The $115 Million facility broke ground on 4/12/2010 and is scheduled to be completed on 8/20/2012. The central focus of the three following analyses will be to improve efficiency in the construction industry as well as studying new sustainable technologies. This thesis report has satisfied the four core requirements of: Critical Issues Research, Value Engineering Analysis, Constructability Review, and Schedule Reduction.

Analysis # 1: Schedule Acceleration through Multi Trade Prefabrication

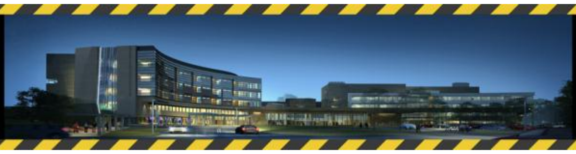
With the increased congestion inside the building, the potential for accidents, conflicts between trades, and reduction in productivity will be highly likely. The usage of BIM on this project has not been utilized beyond the limits of 3D coordination. This analysis showed that a prefabrication effort of the patient bathroom pods, the patient headwalls, and patient footwalls are very possible. In fact the analysis has shown that 58 days can be saved from prefabricating the units in an off-site facility helping recovering from any potential delays or even completing the project ahead of schedule. Thorough research has been conducted to determine savings in General Conditions, additional costs to be considered, and even the benefits for the owner and the entire project team.

Analysis # 2: Eliminating Inefficiency of Cost Estimating Through 3D Modeling

During the Design and Development of the Children's Hospital project, a total of three 3rd party estimators were hired to estimate the costs of the project as the Architects progressed through the design. In addition, to the three 3rd parties involved, each contractor bidding for the project had to develop and estimate the project costs. The Children's Hospital is a large project with many systems to be estimated and evaluated. The lengthy process of conducting manual hand take-offs on 2D drawings could negatively impact the entire project team during construction. This analysis went in depth in methods of utilizing BIM to reduce the time to estimate to provide more time for constructability review. A survey sent out to industry professionals has supported the advantages of utilizing BIM based estimating methods on a construction project. The most important finding was that although BIM can expedite the time to conduct quantity take-offs, it however cannot be completely relied on as models are not designed the way the building is built.

Analysis # 3: Viability of Incorporating Solar Photovoltaic Systems

The new facility will require enormous amount of electric loads to run the building. Diesel powered generators provide backup power in the case of power loss. The new project is on the borderline of achieving a LEED Silver Rating and the diesel powered generators are not providing any points to help out. The intent of this study was to eliminate at least one diesel generator; however, this was not possible due to insufficient roof space for PV-Panels. The analysis shifted to an effort to sustainably power the office equipments which compromise 1% of the total electric demand. A system layout was designed, structural load calculations proved building can sustain additional loads, and an energy analysis proved the system will work. The total system cost came out to be $269,000 with a payback period of approximately 11 years.



2.0 ACKNOWLEDGEMENTS

Throughout the course of my Senior Thesis Project, many people have aided and assisted in accomplishing my thesis goals. I would like to use this section of my Final Thesis Report to personally thank and acknowledge all the individuals that provided me with assistance over the past two semesters. Without the help of all the individuals, I would have not been able to accomplish what I have been working on for the past year.

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Dr. Kevin Parfitt
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Prof. Robert Holland

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Mr. John Bechtel
Mr. Earl Roberts

L.F. Driscoll Co, LLC

Mr. James Carpenter
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Mr. John Cattie
Mr. Anthony Cappelo
Mr. Mike Fredette
Mr. Jerry Seitzinger
Mr. Andy Walters
Mrs. Jenn Weitzel
Mr. Jeff Hunt
Mr. Pat Delagol

Payette Associates

Mr. Carl Romig
Mr. Steven do Rego
Ms. Ember Magdalinski

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For Sponsoring my Entire Studies at Penn State

I would like to thank and dedicate all my academic works to my loving family for their everlasting support during my five year study at Penn State. I would also like to thank all of my dear friends for their moral support and standing by my side during the course of my study. Finally, I would like to thank my fellow AE classmates for providing me with technical support whenever needed.

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4.0 PROJECT OVERVIEW

4.1 INTRODUCTION

BUILDING NAME	**PSU Hershey Medical Center Children's Hospital**
LOCATION	500 University Drive, Hershey, PA 17033
PRIMARY OCCUPANY TYPE	Medical
GROSS BUILDING AREA	263,556 SF
NUMBER OF STORIES	5 Stories (Above Grade) / 1 Story (below Grade)
CONSTRUCTION DATES	03/17/2010 - 08/20/2012
CONTRACTED GMP AMOUNT	$115,726,613 overall
PROJECT DELIVERY METHOD	DESIGN-BID-BUILD WITH CM AGENCY @ RISK

Children's Hospital is the latest addition to the Hershey Medical Center campus. Penn State Hershey, a branch campus for The Pennsylvania State University, owns the new Children's Hospital. Penn State Hershey broke ground in 1966 upon approval from Penn State to establish a new Medical School, teaching hospital, and research centers. Since 1970, Penn State Hershey expanded from 218 acres to 550 acres. Today, the Hershey Medical Campus has carefully planned and constructed state of the art buildings that reflect the steady increase in patient demand for services as well as expanding research and teaching programs. The medical center owns 484 licensed beds, performs 23,230 surgical procedures annually, and receives about 820,000 clinic visits per year. As the only Level I pediatric trauma center between Philadelphia and Pittsburg, the Children's Hospital serves the most populous rural region in the nation, with more than a million children in their referral area.

The construction schedule for the Penn State Hershey Medical Center Children's Hospital is relatively straight forward despite the complexity of the project. L.F. Driscoll officially signed their CM @ Risk GMP contract with the Penn State Hershey Medical Center on 3/8/2010 and broke ground on 4/5/2010 and is scheduled to be completed on 8/20/2012. Having an almost complete set of drawings prior to construction has been a great success for L.F. Driscoll due to their ability to schedule activities and plan logistics early prior to breaking ground. This led the CM to not expect any major additions in the scope as they have already considered the new Bulletins to be issued with two new shell space fit-outs. Shortly after receiving an official Notice to Proceed on 3/17/2010, L.F. Driscoll mobilized with three Construction Trailers at the Job Site's main gate access area.

IMAGE 4-1 PSU HMC Campus Map

The site for the new Children's Hospital is surrounded by 2 major buildings. Just north of the Children's Hospital lays the existing Cancer Institute Building that directly joins with the new Children's Hospital. On the west side the Children's Hospital joins with the existing Main Hospital Building. The new Children's Hospital is the latest addition to the expansion of the medical center's state of the art health care. The site has been disturbed during the construction of the Cancer Institute and some foundation elements have been already in place by the previous contractor. Among the major issues with the building site are vehicular access, tower crane operations, and the Main Hospital's Helicopter paths.

To complete the construction of the $115 million state of the art facility, Hershey Medical Center contracted with L.F. Driscoll, Co LLC as the Construction Manager at Risk with a GMP contract. The Construction Manager is in direct contractual agreements with the subcontractors on-board. The general liability insurance is covered by L.F. Driscoll under a Contractor Controlled Insurance Program (CCIP). The project substantial completion of the Children's Hospital is scheduled to be on 8/20/2012.

IMAGE 4-2 New Children's Hospital at the Penn State Milton S. Hershey Medical Center (courtesy of Payette Associates)

4.2 CLIENT INFORMATION

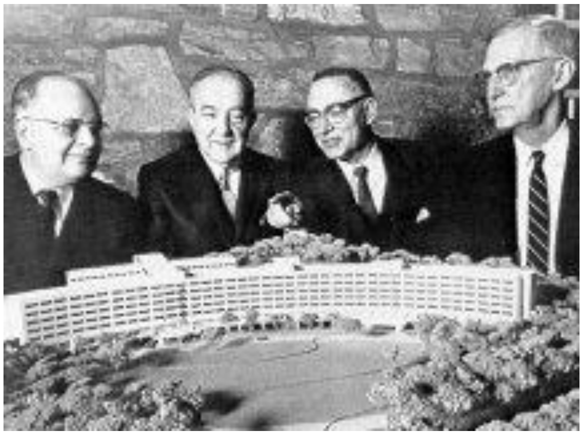


IMAGE 4-3 The founding fathers of the Medical Center and College of Medicine (from left): Arthur Whiteman, president of the Hershey Trust Company; Samuel Hinkle, president of the Hershey Chocolate Corporation; Eric Walker, president of Penn State University; and George Harrell, M.D., founding dean and CEO.

Children's Hospital is the latest addition to the Hershey Medical Center campus. Penn State Hershey, a branch campus for The Pennsylvania State University, owns the new Children's Hospital. Penn State Hershey broke ground in 1966 upon approval from Penn State to establish a new Medical School, teaching hospital, and research centers. Since 1970, Penn State Hershey expanded from 218 acres to 550 acres. Today, the Hershey Medical Campus has carefully planned and constructed state of the art buildings that reflect the steady increase in patient demand for services as well as expanding research and teaching programs. The medical center owns 484 licensed beds, performs 23,230 surgical procedures annually, and receives about 820,000 clinic visits per year. As the only Level I pediatric trauma center between Philadelphia and Pittsburg, the Children's Hospital serves the most populous rural region in the nation, with more than a million children in their referral area.

Given the nature of the construction project on Health Care facilities, schedule is a major concern when discussing expectations with the owner. The project is to be completed over three years without phased occupancy due to the infection control risk associated with phased occupancy in a Children's Hospital. All parties on board are committed to complete the project and turning it over to the owner by August of 2012. Due to the urgency of having a complete facility turned over on time, the contract states liquidated damages start 30 days after substantial completion with value of $5,000 per day.

Project cost and budget is critical in meeting the owner's expectation. Due to the fact that this project is state funded and has received numerous donation from donors and investors, it is critical to be on budget to satisfy the owner as well as all of the contributors. Monthly status reports are required every month to show the progress and budget used to be able to control the cash flow of the project.

Managing a clean and safe site is of a major concern on this project. Since the new Children's Hospital will connect with the existing Cancer Institute and the main hospital, Infection Control Risk Assessment (ICRA) will be a driving factor to the success of the project. Every construction activity will need to comply with the ICRA plan to ensure patient safety during construction. The ICRA plan identifies 4 risk degree levels based on the level of contamination from construction dust and debris. Critical activities within the risk zone will be assigned one of the risk levels, which would then identify the precautionary measures that must be taken prior to starting construction.

Delivering this new Children's Hospital will be no easy task for the project team due to the adjacencies and connections into 2 different buildings. Executing this project safely and on time and budget will be the driving factors for the success of all parties on board including the owner.

4.3 PROJECT DELIVERY SYSTEM

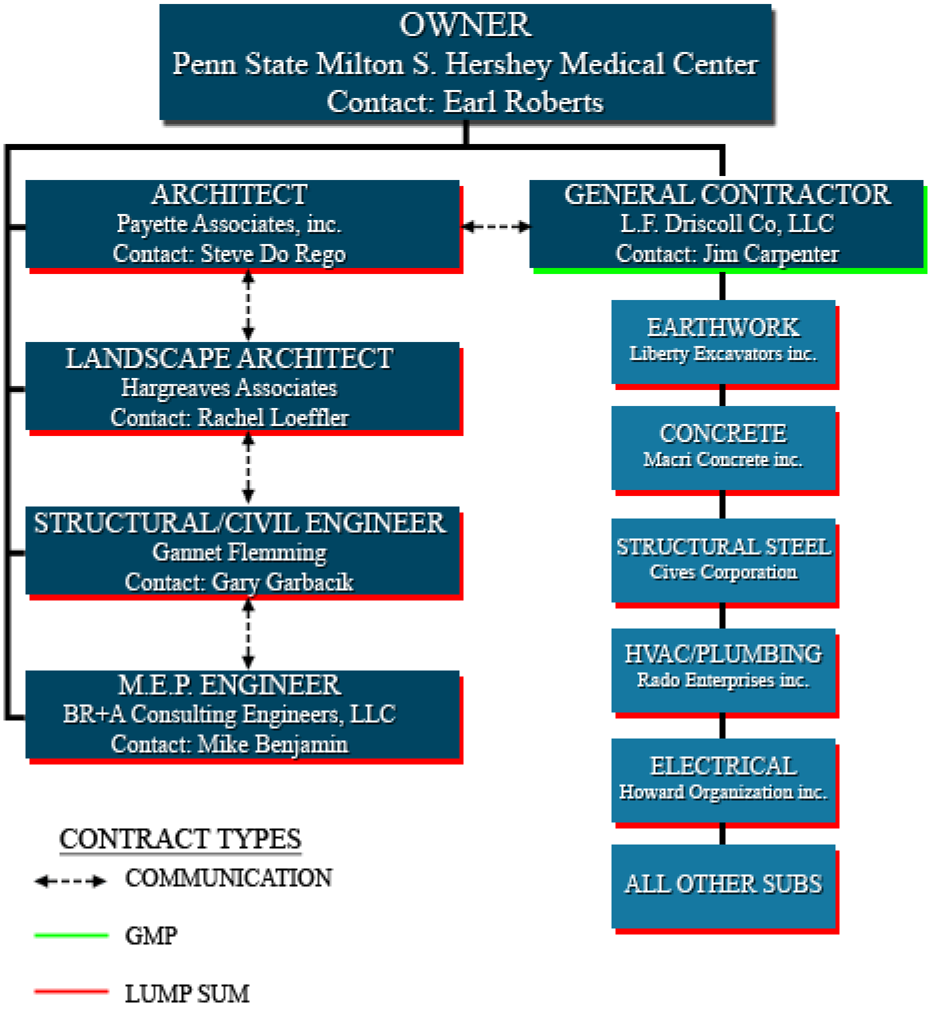


IMAGE 4-4 Children's Hospital Organizational Chart

The project delivery system for the Children's Hospital is a traditional DESIGN-BID-BUILD system. L.F. Driscoll's contract for Construction Management services is a negotiated guaranteed maximum price (GMP). Previously on the Cancer Institute Project, Penn State Hershey Medical Center utilized a different delivery system. Gilbane was contracted as a Construction Management Agency representing the owner without contractual agreements with the contracting firms. This delivery system complicated the project with Penn State and ended up exceeding the project budget. To avoid similar problems, Penn State decided to proceed with the traditional delivery system having the Construction Manager be the constructor of the project and holding direct contractual agreements with all the subcontractors. This method enables the owner to pursue a GMP with the

Construction Manager and have better control on costs since the construction manager must stay on budget to make the fee on the project. This delivery system was also utilized due to the fact that the Office of Physical Plant at Penn State has gained a lot of experience on health care construction.

Penn State Office of Physical Plant is representing the owner on the Children's Hospital with an experienced staff of Project Managers. To back up the efforts of the Office Physical Plant, the owner has contracted with Leach Wallace as the Owner's Commissioning Agent. The owner has also contracted with Hillis-Carnes Engineering Associates as the Owner's Testing Agency. The two mentioned entities help support the Office of Physical Plant by testing the constructed systems and insuring everything is constructed per Construction Documents and Specifications.

The design team contracted with the Penn State Hershey Medical Center is led by Payette Associates based in Boston, MA. Payette has been an active player at the Medical since 2002 where they have developed a comprehensive Master Plan for the Hershey Medical Center. Payette is in contract with the owner on a Lump Sum contract. Leading the structural and civil designs on the project is Gannet Flemming on a Lump sum contract, M.E.P. Engineering designs led by BR+A Consulting Engineers also on a Lump sum contract.

During this phase of constructing the foundation systems, 37 out of 44 bid packages have been awarded to different subcontractors. The Children's Hospital project is under a Contractor Controlled Insurance Program (CCIP). This insurance program helps out the contractor make a lot of profit; however, many subcontractors have been delayed to get on board due to strict requirements that must be met prior to starting work on the jobsite. This has caused some minor delays; however, L.F. Driscoll has managed to manipulate the project schedule to be back on track.

4.4 PROJECT STAFFING PLAN

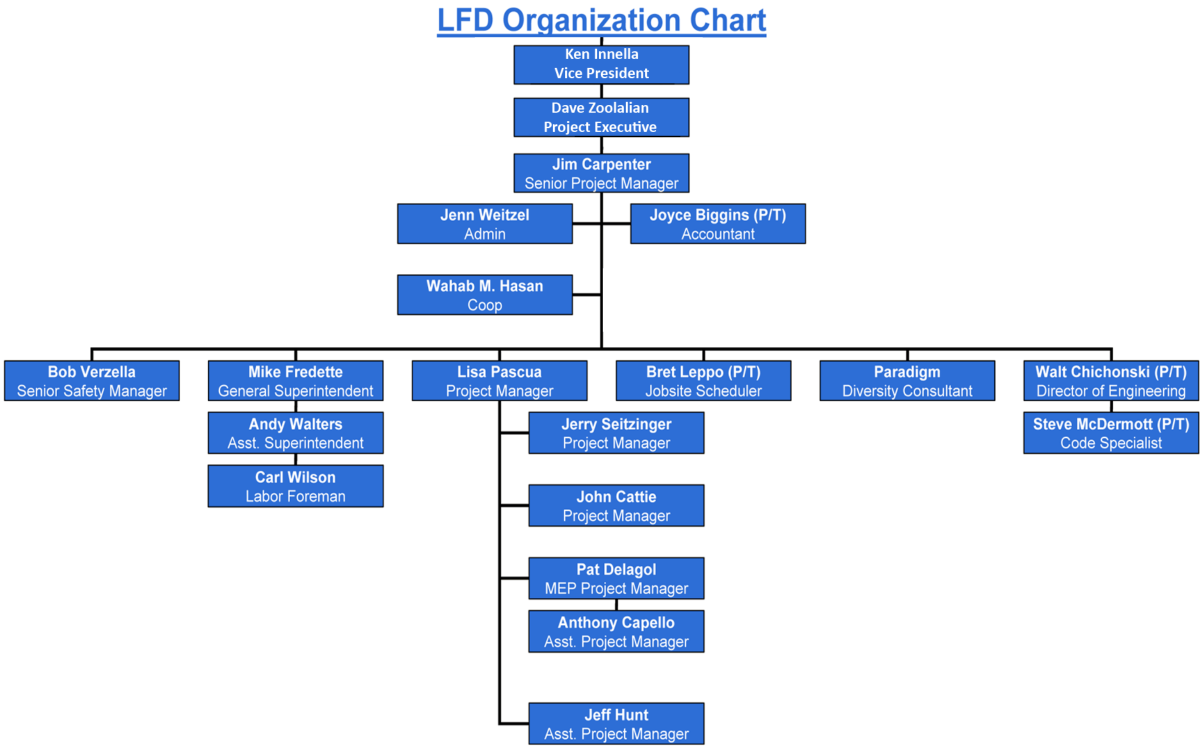
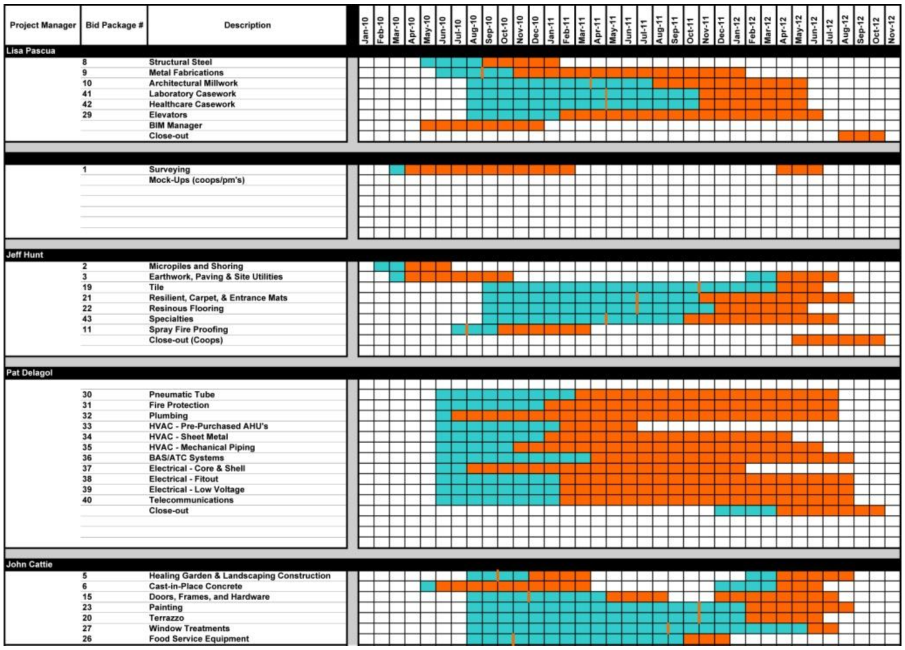


IMAGE 4-5 L.F. Driscoll Staffing Plan

The Children's Hospital staffing plan was organized in a way to assess full time work for the entire personnel over the construction period. The project is led by three top level managers. The Vice President receives direct correspondence from the Project Executive which typically oversees 3-4 projects at a time. The Senior Project Manager is typically the person in charge of overseeing the project organization, scheduling, and its implementation as well as plan direct and coordinates construction activities.

The allocation of the staff workload at the jobsite was strategically planned by the senior project manager. A schedule was developed comparing the project length versus each staff member's workload. The main idea was to distribute the bid packages among each project manager so that everybody has a doable workload over the entire construction period. It was planned so that each project manager on the job does not get overloaded at any point in time, hence increasing the productivity of each manager (see *Image 4-6* for allocation of bid packages schedule). Overall, the project management team is sufficient for the project's scope of work.



Project Manager	Bid Package #	Description
Lisa Pascua		
	8	Structural Steel
	9	Metal Fabrications
	10	Architectural Millwork
	41	Laboratory Casework
	42	Healthcare Casework
	29	Elevators
		BIM Manager
		Close-out
	1	Surveying
		Mock-Ups (coops/pm's)
Jeff Hunt		
	2	Micropiles and Shoring
	3	Earthwork, Paving & Site Utilities
	19	Tile
	21	Resilient, Carpet, & Entrance Mats
	22	Resinous Flooring
	43	Specialties
	11	Spray Fire Proofing
		Close-out (Coops)
Pat Delagol		
	30	Pneumatic Tube
	31	Fire Protection
	32	Plumbing
	33	HVAC - Pre-Purchased AHU's
	34	HVAC - Sheet Metal
	35	HVAC - Mechanical Piping
	36	BAS/ATC Systems
	37	Electrical - Core & Shell
	38	Electrical - Fitout
	39	Electrical - Low Voltage
	40	Telecommunications
		Close-out
John Cattie		
	5	Healing Garden & Landscaping Construction
	6	Cast-in-Place Concrete
	15	Doors, Frames, and Hardware
	23	Painting
	20	Terrazzo
	27	Window Treatments
	26	Food Service Equipment

IMAGE 4-6 Allocation of Bid Packages among Project Managers

The List of Duties of the Primary Project Personnel is as follows:

Senior Project Manager

- Participate in the conceptual development of the project.
- Oversee project organization, scheduling, and its implementation.
- Plan, direct, coordinate construction activities.
- Liaison between Owner, Architect and Subcontractors

Accountant

- Coordinates the Billing Process
- Assists Sr.PM and PMs in generating job cost reports
- Assists Sr.PM and PMs in processing costs

Project Manager/BIM Manager

- Manage and coordinate BIM Process
- Plan, manage and coordinate Specific Trade Contracts.
- Mitigate costs.
- Review and Process Subcontract Submittals and Request for Information.

Project Manager

- Plan, manage and coordinate Specific Trade Contracts.
- Mitigate costs.
- Review and Process Subcontract Submittals and Request for Information.

M.E.P. Project Manager

- Plan, manage and coordinate Mechanical, Electrical Plumbing and Fire Protection Trade Contracts.
- Mitigate costs.
- Review and Process M/E/P/FP Submittals and Request for information

Assistant Project Manager

- Assist Project Managers and MEP coordinator with Submittal processing
- Manage and Track LEEDs submission process

General Superintendent

- Manage Safety, Quality and Productivity
- Promote company objectives and direct staff to perform
- Ensure quality and safety standards to meet Owner expectations
- Manage Safety, Quality and Productivity
- Execute Specifications and Drawings
- Implement and Monitor Project Schedule

Assistant Superintendent

- Manage safety, quality and productivity
- Manage specific trades designated by supervisors
- Have direct contact with labor foreman

5.0 DESIGN AND CONSTRUCTION OVERVIEW

5.1 CONSTRUCTION SEQUENCE

5.1.1 Foundation Sequence

The Foundation system consists of a variety of structural elements such as (micropiles, pile caps, grade beams, column piers, and foundation walls). Following the excavation of the jobsite, it was necessary to shore the south side of the project with a beam lagging system to support the excavation from trenching downwards. On the north side of the project lays the Cancer Institute Building where soil nailing and shotcrete was a must to insure the foundation system of the Cancer Institute was not influenced. Micropile drilling and grouting activities began as soon as the support of the excavation was completed starting from the North-West corner of the building and working downwards toward the south side and then moving across the length of the building reaching the east side as shown in *Image 5-1*. Half way through the micropile drilling, the Concrete Subcontractor phased the work to insure that the pile caps commenced whenever ready followed by grade beams, foundation walls, and column piers.

5.1.2 Structural Sequence

As the Foundation system approaches completion, the structural steel erection begins. A tower crane overlooking the entire site will pick the column and beam members into the desired locations. The sequencing of the structural steel will be as shown in *Image 5-2*. Once the first level of structural steel is in place, the SOG will be poured in 3 sections as shown in *Image 5-3*. Metal decks will immediately be placed as soon as the column pieces supporting the next level are in place. There will be a high priority of pouring the 5th floor's slab first so that the mechanical room area is ready to have all the equipment boomed into place prior to inclosing the building. This will enable the contractor to begin the fit-out of the building in a top-down fashion.

5.1.3 Finishing Sequence

As mentioned in the structural sequence; the finishing sequence of the building will be in a top-down method. All trades will be working on the highest level and downward until they exit the building. This method insures minimum damage, cleanup, and re-work as the GC is able to fully punch-out and close the whole floor once completed and move down to the lower level.

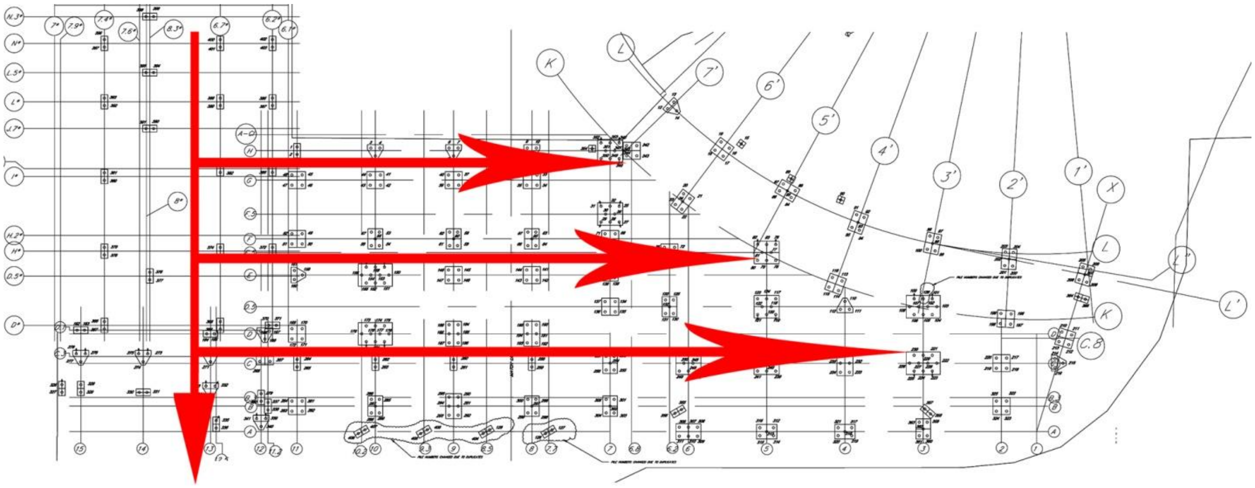


IMAGE 5-1 Micropile Drilling/Grouting Workflow

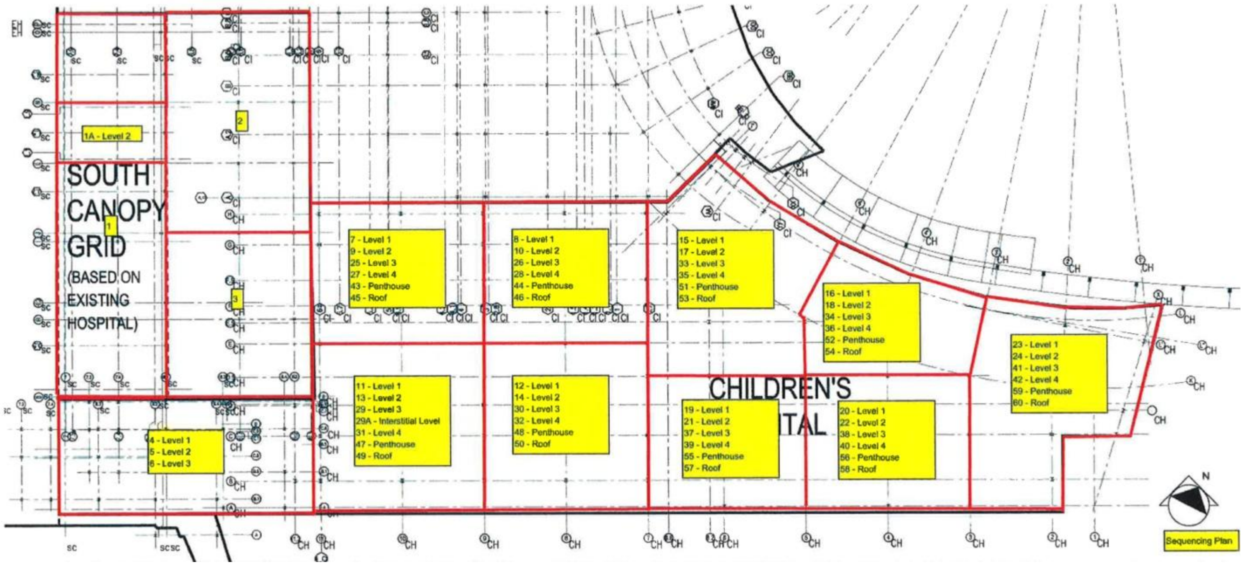


IMAGE 5-2 Structural Steel Erection Sequence

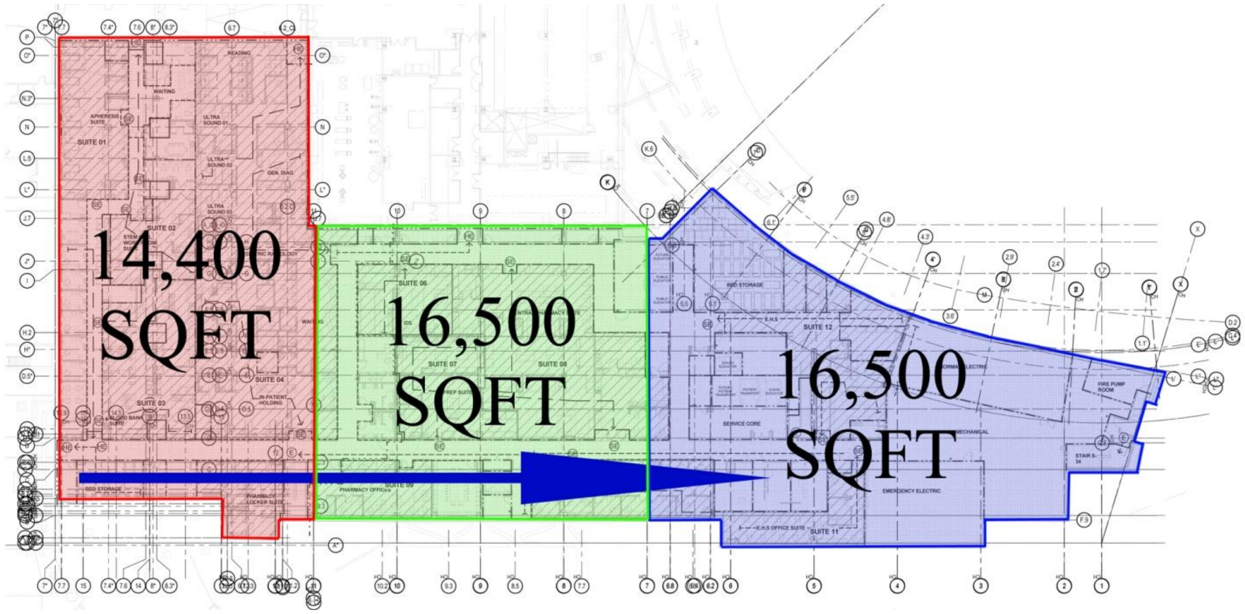


IMAGE 5-3 SOG Pouring Sequence

5.2 BUILDING SYSTEMS

5.2.1 Demolition

The Children's Hospital will not be involved in critical demolitions. The abandonment and removal work as specified is not intended to be a major wrecking operation but as a preparatory work relative to the performance of the various construction operations of the project. Some of the major demolition activities will include the demo of existing grade beams, plugging and filling existing utilities, removal of valves, removal of hydrants, removal of water fountain, removal of electric services and duct-bank including vaults, hand-holes, and transformers.

5.2.2 Structural Steel Frame

The structural steel framing of the Children's Hospital is designed as a type 2, simple framing with composite steel decks for the elevated slabs. The structural system including the infrastructure has been designed to accommodate two additional full sized floors for future expansion of the Children's Hospital. The majority of the structural steel is composed of W-shaped beams and columns detailed with high-strength bolts as well as field welds for moment connections.

Beam Sizes Range From: W16x26 to W24x55 mostly spanning about 40 feet.
Girder Sizes Range From: W16x26 to W27x84 mostly spanning about 34 feet.
Column Sizes Range From: W10x33 to W14x233 with splices every other floor.
(See *Image 5-4* for Column splices).
The Structural steel Package is to be erected sequentially using a stationary tower crane that overlooks the entire jobsite.

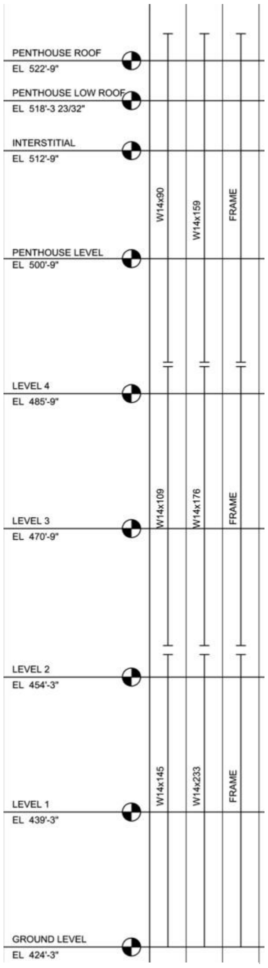


IMAGE 5-4 Column Schedule

5.2.3 Cast in Place Concrete

The majority of the concrete used throughout The Children's Hospital is Cast-in-Place concrete. CIP Concrete is used for micropiles, pile-caps, concrete walls, grade beams, wall footings, piers, SOG, as well as the elevated slabs. All CIP concrete is to be air entrained with 4000psi at 28 days. The SOG is to be placed on top of 6" compacted Penndot 2A coarse aggregate. The slab on grade is primarily a 6 inch thick slab with 5" and 8" transitions in some areas. On the other hand, the elevated slabs consists of a (2" deep, 20 gage composite metal deck with a 4-1/2" thick topping slab reinforced with 6x6 W2.1xW2.1 WWF) a total of 6-1/2" thick slabs. In many cases the concrete will be pumped using the pump trucks while in many other cases the trades will use the traditional crane and bucket method.

5.2.4 Mechanical System

The HVAC system at the Children's Hospital is primarily a VAV system consisting of 5 major Air Handling Units located in the Penthouse level. The air handlers feed the building with 100% outside air due to the facility being very critical. The total output of the air handlers is around 350,000 CFM providing the Children's Hospital adequate and proper air circulation. Each air handler is equipped with two fans each supplying 35,000 CFM. The AHU's are all connected to an emergency power system which will run a single fan per AHU in case of an emergency. All air handlers will be mounted on a 4" concrete pad.

The primary chilled water pumps are located at the ground floor level. Each pump is rated at 3300 GPM 88.3 BHP at 1750 RPM. On the other hand, the two primary hot water pumps located at the penthouse level are rated at 1200 GPM 35.8 BHP at 1750 RPM.

5.2.5 Electrical System

The Penn State Hershey Medical Center provides two high voltage loop circuits that feed the entire campus. The new Children's Hospital will run on a15 KV feeder that branches off from the primary campus loop. Feeding power to the hospital will be a 13.8 KV "K" Factor Dry Type Transformer running a 3 phase (4-wire) 480/277V circuit. The emergency backup power will be provided by a natural gas-powered generator.

The lighting system for the Children's Hospital varies across the different areas of the building. Each area will be served with specific light fixtures that will satisfy the aesthetics as well as efficiency in lighting up the spaces. All fluorescent fixtures are to be utilized with T8 lamps and electronic ballasts. In case of compact fluorescent fixtures, all ballasts must be high power factor ballasts with end of life sensing circuitry.

The Children's Hospital lighting fixture schedules include over a hundred different types of fixtures. The fixtures range from general troffers and pendants to high end surgical room fixtures.

5.2.6 Masonry

The Façade of the Children's Hospital does not incorporate veneer brick. The Façade primarily consists of Limestone and Granite Cladding, an Aluminum curtain wall, and metal panels. The exterior façade is however backed up by 6" concrete masonry units (CMUs) with air and vapor barriers as well as air cavities (see *Image 5-5* for a wall detail).

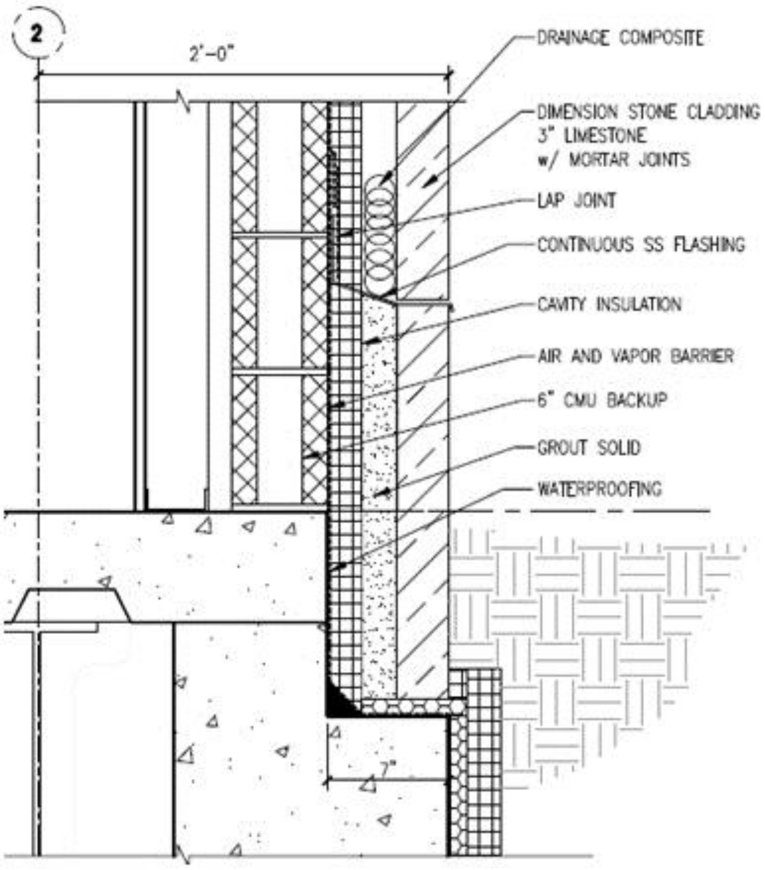


IMAGE 5-5 Exterior Wall Detail

5.2.7 Curtain Wall

The aluminum curtain wall designed by Payette Associates is aimed to be identical to the system currently existing in the adjacent Cancer Institute Building. Although the design was completed by Payette Associates, connections details are to be submitted by the curtain wall subcontractor i.e. National Glass and Metal Co, INC. This was primarily due to the custom requirements the owner is looking for in the curtain wall system. The Mullions are to incorporate special LED lighting to give a very modern look for a state of the art hospital

5.2.8 Support of Excavation

The Children's Hospital is a complex project in many different ways. Due to the building adjacencies the Structural Engineers had to carefully design the support of excavation systems. Just north of the Excavation lies the new Cancer Institute Building at the Hershey Medical Center, and to the South lies an adjacent road about 100 feet from the excavation wall. Since the Cancer Institute Building is currently occupied, the design of the excavation support mandated that a wall tie back system be installed into the soil to support the foundation system of the adjacent building. Upon completion of the wall tie back system, the contractor had to shotcrete the entire excavation wall (see *Image 5-7* for a soil nailing detail). This labor intensive system was designed over the design loads to add an extra margin of protection for the adjacent Hospital. On the southern side however, the Engineers designed a Soldier Pile Wall system to support the service road on top of the excavation wall. This method was chosen so that the contractor can use up to 250 psf of loads on top of the excavation (see *Image 5-6* for acceptable loads on the soldier pile wall).

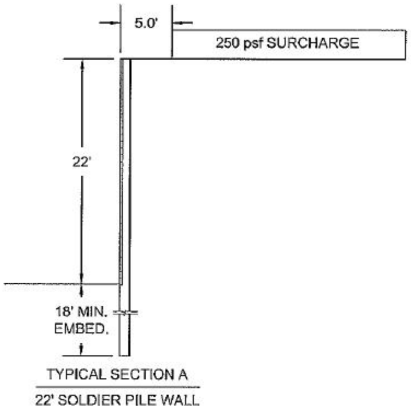


IMAGE 5-6 Soldier Pile System (Acceptable Load on wall)

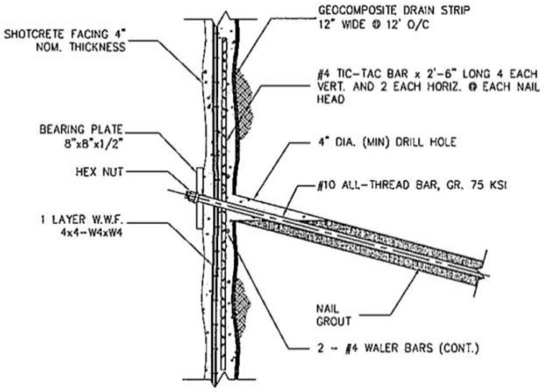


IMAGE 5-7 Soil Nailing Detail

5.3 DETAILED STRUCTURAL STEEL ESTIMATE

**** See APPENDIX A for the complete Quantity Take-offs and Estimates***

The superstructure for the new Children's Hospital at the Penn State Hershey Medical Center is primarily a steel moment resisting frame with composite floor systems. The majority of the Cast-in-Place Concrete is concentrated in the foundation system of the building. An estimate for the structural system was developed using a Revit model that modeled the entire structural system. Quantity Take-Off (QTO) Schedules were developed in Revit to extract the entire structural system piece by piece with detailed descriptions including Type of Member, length, weights, reference levels, etc. Upon developing the schedules and organizing them in an excel sheet; RS MEANS COSTWORKS was used to develop a detailed Unit Price Estimate of the entire system (see *Table5- 1* for a comparison of the actual vs. estimated costs).

Table 5-1 : Estimated vs. Actual Cost Comparison

	RS MEANS COSTWORKS ESTIMATE		ACTUAL COSTS	
SYSTEM	**$/SF**	**TOTAL**	**$/SF**	**TOTAL**
CIP CONCRETE	$11.90	$3,127,400	$13.54	$3,555,788
STRUCTURAL STEEL	$19.81	$5,200,900	$21.31	$5,597,000

Counting reinforcing steel in concrete members was a very tedious task for this project. For the purpose of this assignment all rebar take-offs were omitted due to the long time associated with counting them all; however, WWF reinforcing was estimated in all slabs. A quick look at *Table5- 1* shows that the estimated concrete cost was 12% less than the actual cost. On the other hand the estimated structural steel estimate was 7.1% less than the actual cost.

The cast-in-place concrete system came shorter than the actual cost is justifiable. One aspect that significantly altered the estimate was omitting all concrete reinforcing steel. Have reinforcing been accounted for, the estimate would have been increased up to $750k-$1M assuming the project would include 500 tons of reinforcing steel at a unit price of $1500-$2000. Having included the exact number of rebars would have eventually caused my estimate to run approximately 9-16% higher than the actual cost. Some of the other items that were mentioned in the subcontractor's estimate however omitted in this estimate due to lack of information available include tower crane foundation, mockup concrete, shaft curbs, and caulking.

On the other hand the structural steel estimate cost came shorter than the actual cost due to many reasons of which RS MEANS had the largest impact. Using RS MEANS COSTWORKS many of the

steel members that are used in the Children's Hospital were not available in the COSTWORKS database. This led to many discrepancies since many members had to be priced under different members. For example members like (W21X101, W24X104, W27X94, W30X108) had to be grouped and priced as W18x106 since the lb/lf were very close. This was the case for many steel members including many HSS members that were not an exact match in the COSTWORKS database. Had there been exact costs for many of the members, the price would have slightly increased and matched up with the actual price. Besides the fact that RS MEANS lacked many member sizes, some other aspects that were included in the actual structural steel package were not estimated such as tower crane rental, undersigned structural steel allowance, spandrel steel allowance, as well as steel connections. *Table 5-2* will summarize the costs utilizing CSI Masterformat divisions.

Table 5-2: Estimate Summary by CSI Divisions

COMPONENT	**COST**
031100 – Concrete Formwork	$850,442.90
032100 – Concrete Reinforcing Steel (WWF)	$166,914.00
033000 – CIP Concrete	$891,900.00
053100 – Steel Decking	$683,700.00
051223 – Steel Columns	$1,215,888.65
051223 – Steel Beams	$3,985,010.60

This estimate was developed utilizing RS MEANS COSTWORKS online tool for all material, labor and equipment unit costs. The pricing data was released in quarter 3 of 2010, which is about 3 quarters newer than the data that was available when the subcontractors were pricing the systems; which might have been another factor impacting the overall estimate. The location factor was set to Harrisburg, Pa since COSTWORKS doesn't have factors for the actual city of Hershey, Pa. Although Harrisburg and Hershey are about 10-20 miles apart, costs could have been impacted especially due to the fact that the majority of the laborers had to commute on a daily basis to Hershey.

In conclusion, this estimate has shown that should have all pricing data been available for all member sizes, costs could have been much closer to the actual costs. In addition to the lack of cost data in COSTWORKS, additional time for this assignment would have helped to precisely estimate all the reinforcing steel incorporated in the concrete work. Overall, COSTWORKS has proven to be a very user-friendly online tool that helps setup a very organized estimate. However, one should watch out that this tool is good for a preliminary estimate but not for actual final pricing to be submitted to a client.

5.4 PROJECT COST EVALUATION

The following project costs are the actual tabulated costs provided by L.F. Driscoll. All costs are actual costs contracted between L.F. Driscoll and their respective subcontractors.

Table 5-3 : Gross Building Area by Floor

Ground Floor	56,785 SF
1st Floor	48,733 SF
2nd Floor	40,594 SF
3rd Floor	38,071 SF
4th Floor	38,136 SF
5th Floor	37,052 SF
Mechanical Mezzanine	3,216 SF
TOTAL	**262,587**

Table 5-4 : Basic Overall Cost Information

Type	Cost ($)	Cost/SQFT ($/SQFT)
Construction (CC)	$92,139,328	$350.89
TOTAL (TC)	$115,726,613	$440.72

Table 5-5 : Major Building System's Cost

System Name	System Cost
Micropiles & Shoring	$1,750,000
Earthwork, Paving & Site Utilities	$1,457,990
Cast-In Place Concrete	$3,555,788
Stone and Masonry	$1,623,000
Structural Steel	$5,597,000
Metal Fabrications	$1,007,700
Spray Fireproofing	$444,000
Composite Metal Panels	$2,474,192
Roofing and Garden Roofs	$2,242,916
Doors, Frames & Hardware	$1,074,800
Aluminum, Glass & Glazing	$5,230,360
Carpentry, Drywall & Acoustical	$6,898,700
Elevators	$1,997,500
Fire Protection	$1,119,118
Plumbing	$5,760,000
HVAC System	$18,823,506
Electrical System	$18,602,000

5.5 LOCAL CONDITIONS

** See APPENDIX B for Existing Conditions Site Plan*

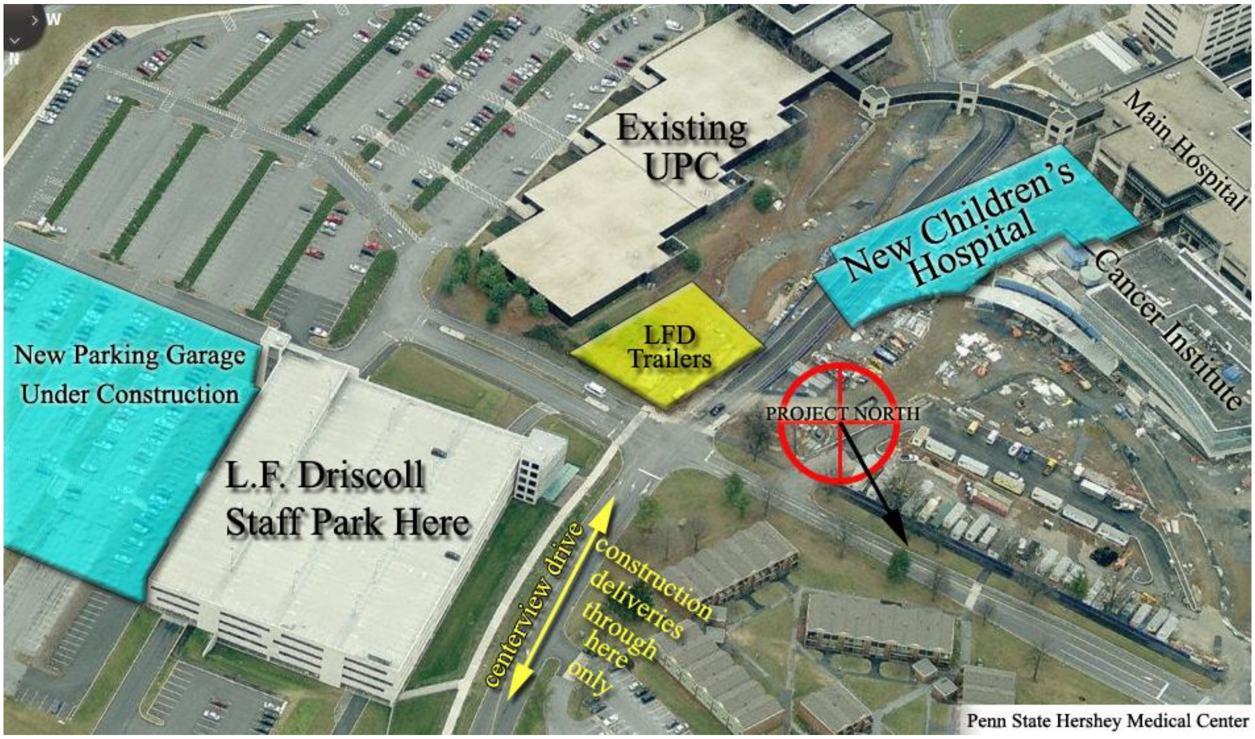


IMAGE 5-8 PSU HMC Campus Bird's Eye View (Courtesy of bing.com)

The new Children's Hospital is located on 500 University Drive in Hershey, Pa. Spread out over a 550-acre campus; Hershey Medical Center serves the Central Pennsylvania area. The Penn State Campus is commonly known for using structural steel for structural systems on most campus buildings. Due to the vast area of the HMC campus, the project site has access to numerous areas for subcontractor trailers as well as lay down areas. The main concern is the safety of the vehicular and pedestrian traffic throughout the campus due to the daily activities at the existing hospitals, student dormitories, and the school of medicine. As shown in *Image 5-8* the new addition shown in blue is being constructed between the Cancer Institute, Main Hospital, and the UPC Buildings. Due to the congested area where the new addition is located, the L.F. Driscoll trailers will be the only ones next to the project site with minimal parking area. To resolve this issue, the Office of Physical Plant granted access for all LFD personnel to park at the existing parking deck while all subcontractors park just south of the new parking garage expansion. The subcontractors will also be able to setup all trailers just south of the new parking garage.

The Geotechnical investigation of the project site was conducted by CMT Laboratories, INC. A total of 21 test borings were taken. Of the 21 test borings, 7 borings encountered ground water at approximately 47 feet into the soil. According to the report, the ground water encountered was perched or trapped water above underlying limestone bedrock and not indicative of ground water table. Bedrock is composed of very finely crystalline medium-grey limestone interbedded with dolomite. Bedrock is moderately resistant to weathering and is slightly weathered to a shallow depth.

Actual costs of trash removal at Hershey, Pa were not able to be identified. L.F. Driscoll has however accounted for it in their general conditions budget. The project budgeted for trash removal once a week for a total of 138 weeks. L.F. Driscoll considered 3.5 units at a rate of $650 per week for a subtotal of $313,950 over the life of the construction project.

5.6 DETAILED PROJECT SCHEDULE

**** See APPENDIX C for the Detailed Project Schedule***

The construction schedule for the Penn State Hershey Medical Center Children's Hospital is relatively straight forward despite the complexity of the project. L.F. Driscoll officially signed their GMP contract with the Penn State Hershey Medical Center on **3/8/2010** and broke ground on **4/5/2010** and is scheduled to be completed on **8/20/2012.** Having an almost complete set of drawings prior to construction has been a great success for L.F. Driscoll due to their ability to schedule activities and plan logistics early prior to breaking ground. This led the CM to not expect any major additions in the scope as they have already considered the new Bulletins to be issued with two new shell space fit-outs. Shortly after receiving an official Notice to Proceed on **3/17/2010,** L.F. Driscoll mobilized with three Construction Trailers at the Job Site's main gate access area.

The Children's Hospital contract dictates a 31 month period to construct the entire facility. Upon mobilizing the GC trailers and fencing the entire site, the initial excavation and shoring will take place making it possible for the foundation systems to be placed. Shortly upon completing the foundation systems, the structural steel crew will utilize the tower crane placed on site to erect the structural steel system. The project site will be divided into 24 sections to sequence the erection of the structural steel with a workflow from west to east as explained earlier in *Technical Report One*. Upon completing the first tier, the concrete crew will start pouring the slab on grade followed by elevated slabs as soon as each level of metal deck is prepared for concrete placement. The ultimate goal is to get the mechanical room on the 5th floor up and running as soon as the project reaches building watertight. Following the installation of the building skin, the interior fit-out process will commence starting from the 5th floor down to the ground floor with a workflow of east to west on each level.

The top-down fit-out process has been elected as the workflow to reduce the need of having to access finished floors to climb to upper floors. By doing so the GC would ultimately punch-out an entire floor without the need of going back for additional rework due to possible damages that may occur. Upon completion of the building fit-out, site work activities will take place prior to handing over the building to the owner. Finally, commissioning, L & I, and Department of Health inspections will take place prior to issuing the Certificate of Occupancy to the owner.

5.7 SITE LAYOUT PLANNING

** See APPENDIX D for the Superstructure Site Logistics Plan*

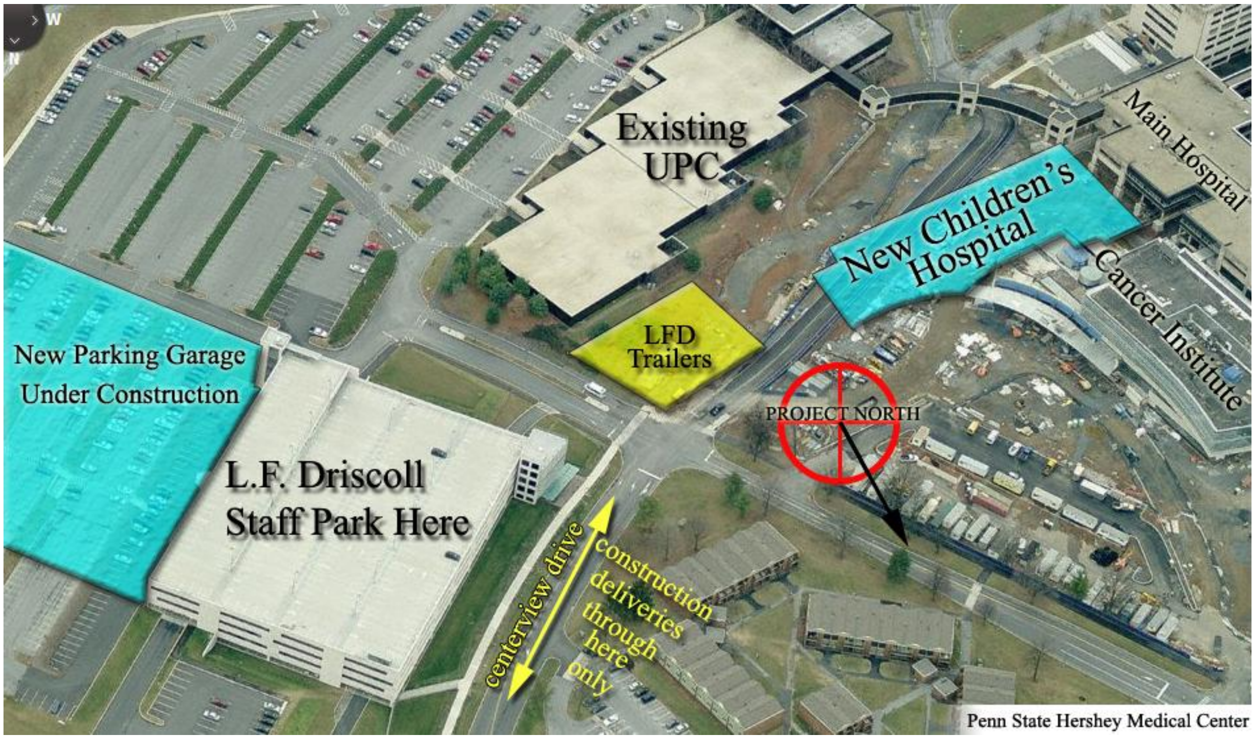


IMAGE 5-9 PSU HMC Campus Bird's Eye View (Courtesy of bing.com)

The Site for the New Children's Hospital at the Penn State Hershey Medical Center is located between the Cancer Institute Building and the Main Hospital Building. The new Children's Hospital is the latest addition to the expansion of the medical center's state of the art health care. The site has been disturbed during the construction of the Cancer Institute and some foundation elements have been already in place by the previous contractor. Among the major issues with the building site are vehicular access, tower crane operations, and the Main Hospital's Helicopter paths.

In general, all traffic enters the site via Center View Drive only. Due to the congestion of traffic and pedestrian flow throughout the campus on a daily basis, deliveries must be coordinated with the Office of Physical Plant to ensure all safety measures are in place and to reduce the risk of catastrophic accidents. The L.F. Driscoll's trailers will be located just outside the fencing area of the jobsite due to the site congestions. This location has also been chosen to provide safe access to Postal Service Deliveries as well as providing a clear landmark for all truck deliveries to locate the jobsite without having to drive around the campus roads.

Subcontractors have been assigned to set-up their trailers off-site just south of the existing parking garage to reduce the congestion on site. However, due to some unused site space, it would be recommended to have 4 trailers on site for the major subcontractors and 3rd party consultants that are on-site every day.

Material lay-down and staging areas have been strategically placed to be in the reach of the tower crane as well as the ability to easily use the hoist in the south-west area of the project. The two locations make it possible to utilize the two different gates very efficiently to reduce congested truck activity on-site.

Portable Toilets have been placed in two areas both close to the jobsite gate area. Those locations were chosen to reduce the risk of accidents that may develop if they were placed in a congested working area. Dumpsters are also spread out on the job-site to ensure that each subcontractor provides trash cans for their laborers to dispose the trash in the dumpsters leaving the jobsite clean and safe to work in.

The Structural steel system will be erected using a tower crane that overlooks the center and east portions of the building. The west side of the building will be erected early on during the foundation stage as it primarily supports the cantilevered section of the existing main hospital. The cantilevered section once sat on grade; however, due to utility tie-ins, the Children's Hospital will utilize the area below grade for that purpose hence the need for structural steel members replacing the grade beams. The west side will be erected during the foundation stage utilizing a mobile crane.

The tower crane on-site will be used by the structural steel subcontractor to erect the entire center and east side of the building. A portion of the east side will not be in the reach of the tower crane and will need to be erected separately by a mobile crane as shown on the site plan in the appendix.

Slabs will be placed using concrete pumps as well as the traditional crane and bucket for areas hard to reach with the concrete pump trucks.

Upon completing the Structural steel and the skin of the building, the trades involved with all MEP rough-ins and interior fit-outs will utilize the hoist located just south of the building to deliver their materials to the corresponding floors. Material storages are also located south-west of the building for trades that are not able to store materials out in the field. Toolboxes are available south-west as well as north of the building.

5.8 GENERAL CONDITIONS ESTIMATE

**** See APPENDIX E for the complete General Conditions Estimates***

The General Conditions estimate was developed with four primary categories in mind. The four categories consist of: Supervision and Personnel, Field Office Expense, Temporary Facilities, and Miscellaneous Costs. Supervision and Personnel includes the entire L.F. Driscoll staff for the Children's Hospital Project which consists of primary positions such as the Project Executive, Project Managers, and Superintendents. Second category Field Office Expense includes items such as office trailers setup and rentals, trailer alarm systems, mobile phone plans for the general staff, furniture, and office supplies. Third category Temporary Facilities includes items such as Porta-Potties, temporary storage trailers, and temporary fire extinguishers, etc. The fourth and final category Miscellaneous Costs includes items such as tool rentals, meeting expenses, housing and travelling expenses, etc.

Note that many temporary items such as temporary water, electricity, lighting, etc have been transferred to be included in the scope of works of the different trades. This way, the GC will not be sending high bills to the owner as well as helping the GC transfer some of the risks of self-performing some of the general conditions items.

Table 5-6 summarizes the Project's General Conditions costs based on the four given categories. The developed costs do not represent the actual amounts contracted between L.F. Driscoll and Penn State Hershey Medical Center. This estimate was developed to calculate the effect of schedule acceleration scenarios on general condition costs in later reports.

Table 5-6: GENERAL CONDITIONS SUMMARY

ITEM	QUANTITY	UNIT	UNIT RATE	COST
SUPERVISION AND PERSONNEL	31 MOS	1	$ 170,772.31	$ 5,293,941.68
FIELD OFFICE EXPENSE	31 MOS	1	$ 15,056.71	$ 466,758.00
TEMPORARY FACILITIES	31 MOS	1	$ 2,782.48	$ 86,257.00
MISCELLANEOUS COSTS	31 MOS	1	$ 24,954.29	$ 773,583.00
TOTAL	**31 MOS**	**1**	**$ 213,565.79**	**$ 6,620,539.68**

As Shown in Table 3, the Supervision and Personnel costs account for about 79% of the total General Conditions which is fairly typical on a project of this scale. The total general conditions costs of $6.62 million is about 5.75% of the total project cost of $115 million.

6.0 ANALYSIS #1: Schedule Acceleration through Multi Trade Prefabrication

6.1 PROBLEM IDENTIFICATION

With the sophistication of all interior fit-outs and rough-ins, the Children's Hospital will encounter major issues such as lack of space for different trades to be working in as well as insufficient material lay down areas. With the increased congestion inside the building, the potential for accidents, conflicts between trades, and reduction in productivity will be highly likely. The usage of BIM on this project has proven to be very successful in coordinating the MEP systems to avoid on-site system clashes; however, BIM does not coordinate the flow of work of different trades as all crews will be racing to meet their schedule deadlines causing major congestions.

6.1.1 RESEARCH GOAL

The goal of this analysis is to determine the cost and schedule time benefits of prefabricating patient rooms due to the repetition of the design.

6.1.2 METHODOLOGY

- Research similar Health care Projects that have utilized prefabrication in an effort to reduce schedule time.
- Research and gather information on the work associated with a single patient room to determine the items to be prefabricated.
- Determine the advantages of prefabrication on the Children's Hospital.
- Research and locate the nearest facility able to prefabricate the patient rooms.
- Determine the means and methods for delivering and rigging the prefabricated units.
- Determining how Building Information Modeling (BIM) could potentially aid prefabrication as well as eliminating inefficiencies.

6.1.3 RESOURCES

- AE- CM Faculty at Penn State.
- Applicable Literature.
- Current project schedule and estimates.
- Case Studies of previous projects utilizing prefabrication.
- L.F. Driscoll Project Team.
- Industry Professionals.

6.1.4 EXPECTED OUTCOME

This analysis will thoroughly investigate the feasibility of prefabricating all patient rooms on the 3rd and 4th floor of the Children's Hospital. The expected results are believed to significantly cut down the interior fit-out schedule time as well as reducing major congestions within the fit-out floors. On the other hand, costs are expected to be higher due to extra costs associated with storing the prefabricated units in an off-site facility in addition to the transportation costs to deliver the units on-site.

6.2 BACKGROUND INFORMATION

As in all Healthcare facilities, the interior fit-outs provide an intense amount of frustrations from coordination to actual on-site construction due to multiple trades working in confined areas. In the case of the Children's Hospital, 3D modeling has been the method to coordinate the entire MEP system. The use of BIM on this project has very quickly proven how much easier it is to coordinate the MEP systems ahead of construction to very accurately locate points of system clashes and being able to make the adjustments virtually instead of on the field.

Although, the coordination process has been working out very well for all the parties involved; it would be very worth the time and effort to determine whether it is possible to take the 3D models to the next level i.e. Prefabrication. Prefabrication allows the project team to erect selected systems in an off-site facility that would be delivered to the project site and simply be connected like a puzzle. This approach improves quality and safety, as well as reducing manpower peak demands and schedule time. This analysis will look at the possibility of prefabricating patient rooms in an effort to reduce conflicts between multi-trade crews as well as reducing schedule time.

6.3 CASE STUDY: A SUCCESSFUL APPLICATION OF PREFABRICATION

Miami Valley Hospital (Dayton, OH)
484,000 SF

Project's Success
- 2-Month Schedule Cut
- 1-2% Dollar Savings

Prefabricated Parts
- 178 Patient Rooms
- 120 Corridor Utility Racks

Rough-In Facts
- 8 Hours: 33 Patient Bathroom Pods
- 1.5 Weeks: 30,000SF Patient Floor

The Miami Valley Hospital in Dayton, Oh is currently nearing completion. The 484,000SF, 12-story addition will provide state of the art cardiac treatment to the Ohio region. The new facility will become the first major hospital project in the United States to have made extensive usage of prefabrication during the design and construction. Prefabrication on this job has yielded a high quality construction in a safe climate controlled environment. Due to the early planning the construction team was able to prefabricate 5 key components: Patient room toilets, Integrated MEP racks above corridors, modular workstations for staff, unitized curtain wall sections, and a temporary pedestrian footbridge.

Unforeseen soil conditions forced the project team to remove 10 footings and had to redesign a new foundation system due to the discovery of sandy seam soils. The 14 week delay was a tough situation for the project team to handle and this is when prefabrication ideas started to spur among the major parties involved. The initial step was an effort to prefabricate major components of the patient rooms due to the repetitive design. As seen in *Image 6-1* the team decided to prefabricate what they called the patient room "blades" that would divide 178 patient rooms. The blades were composed of three components: headwall, casework, and toilet pods. Once prefabricated, those blades can be placed and they would automatically split the room spaces. This approach was clever in a way that only the blades had to be prefabricated and not an entire room.

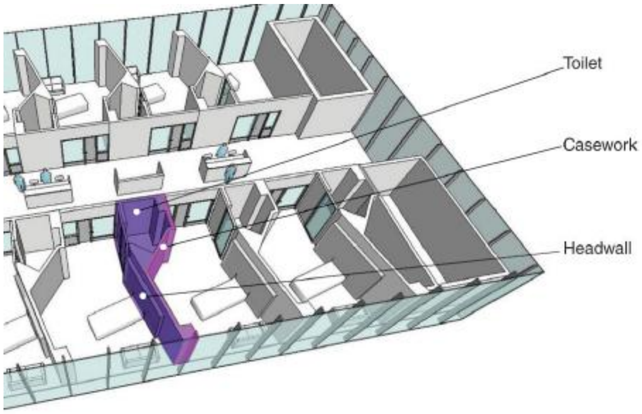


IMAGE 6-2: Patient Room "Blades". *Courtesy of NBBJ*

6.3.1 MANUFACTURING THE COMPONENTS

The decision to prefabricate and the planning stage initiated very smoothly with interest from the entire project parties including the owner. Manufacturing issues soon became a nightmare. The architects started looking for off-the-shelf bathroom modules; however, nothing met their standard for quality. Modular MEP racks were not even being found in the market. The only possible solution


IMAGE 6-3: Typical Prefab Activities

was that Skanska being the general contractor along with their subcontractors had to manufacture all the components by themselves. An old furniture warehouse was rented to serve as the prefab shop were the subcontractors worked on manufacturing all the modules as they would conventionally on-site only this time in an off-site climate controlled area. All building materials were ordered to specific lengths and sizes efficiently reducing construction waste materials to just one dumpster for the entire prefab job. The prefab work was entirely completed by a crew of 18 workers only.

6.3.2 DELIVERY AND HOISTING

To avoid the cost and hassle of securing special highway permits for oversized loads, the team decided to ensure that all prefabricated units can be delivered to site on a standard flatbed truck. Other factors affecting the delivery were weight and bulk of the components to ensure that the workers on-site can hoist the units and put them in place. This was the primary reason why the patient room blades were split into three components as well as confining the MEP racks to a standard size of 8'x22'.

Due to site congestions, truck deliveries were scheduled to arrive on-site and directly hoisting the components using the tower crane as lay down areas were limited. The crews inside the building intercepting the hoisted components built a custom dolly to position the blades after they were lifted into the building. Notches in the concrete slab were made where the bathroom modules were placed as an effort to ensure precision. *Image 6-2* shows the typical sequencing of prefabricating and putting in place the toilet pods.

In the following sections, a prefabrication analysis on the Children's Hospital will be conducted to determine the feasibility of this approach.

6.4 MATERIAL QTO OF A PATIENT ROOM

In order to realistically determine the specific systems to be prefabricated in the patient rooms, it is necessary to investigate what exactly exists in each patient room. This analysis will use a typical patient room on the third floor of the Children's Hospital in an effort to examine the feasibility and advantages of prefabricating selected systems. See *Image 6-3* for a plan and elevation view of the selected patient room.

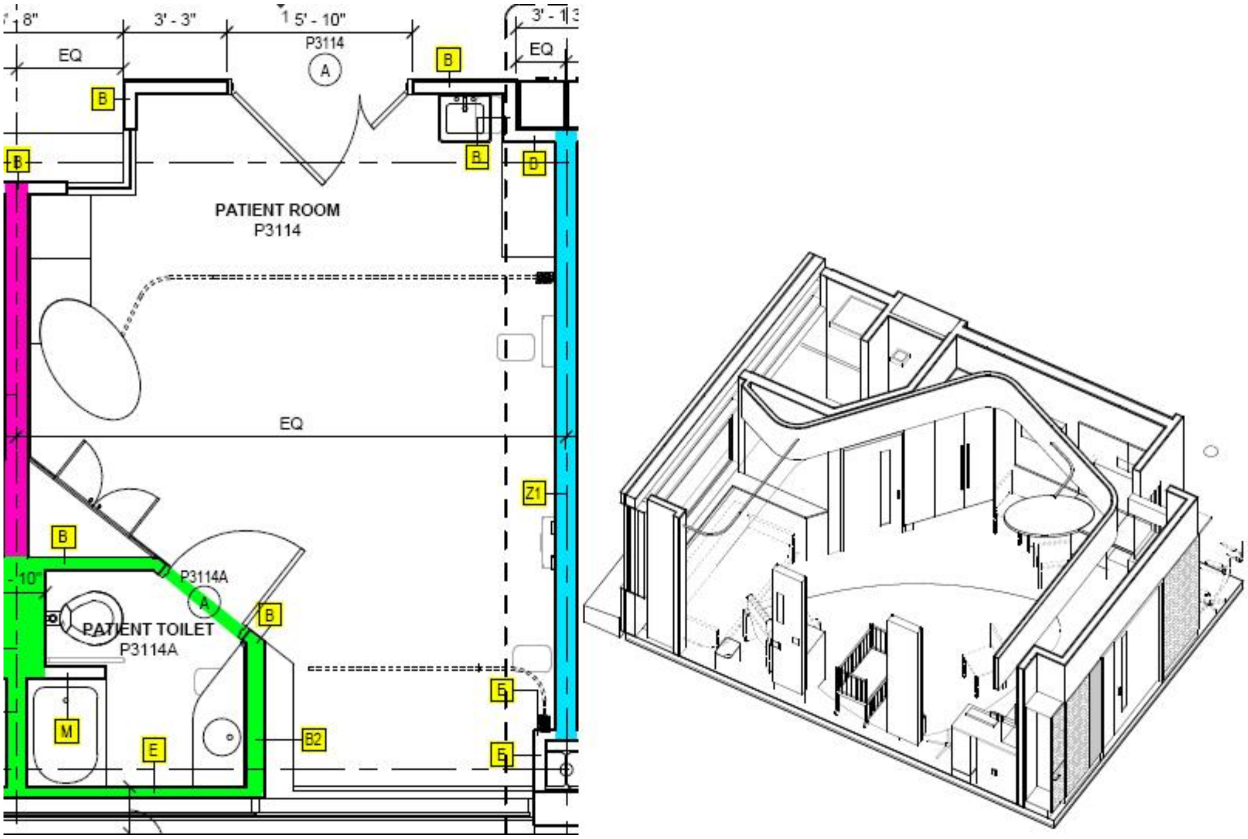


IMAGE 6-4: Plan and 3D View of a Typical Patient Room

Looking at the plan view of a single patient room, it is very possible to prefabricate the toilet pod highlighted in green as a separate unit, the patient head wall highlighted in blue, and the patient footwall highlighted in pink. This strategy would work very well especially due to the repetitive pattern of the patient rooms. By prefabricating the three systems, it will be possible to have a large percentage of the interior work constructed ahead of the schedule and rigged into place when the patient floors are ready.

Table 6-1 will identify the room number and dimensions. Also included will be the detailed material involved in a single patient room. The materials will be listed without actual quantities in an effort to effectively select the systems worth being prefabricated in terms of amount of work and conflicts involved with on-site stick-build construction method.

TABLE 6-1: MATERIAL INVOLVED WITH THE PATIENT ROOM

Room Selected	**P3114**
Room Dimensions	**17'3" x 22'8"**
Head Wall	**Wall-Z** • Thickness 8 ½" • 6" Metal Stud 20 Gauge • 2 Layers of 5/8" GWB • 3 ½" Sound Attenuation Insulation • MEP Rough-ins and outlets
Foot Wall	**Wall-B** • Thickness 4 7/8" • 3 5/8" Metal Stud 20 Gauge • Sound Attenuation Insulation • 5/8" Gypsum Wall Board each side (single) • MEP Rough-ins and outlets
Toilet Pod	**Wall-M** • Thickness 4 7/8" • 3 5/8" Metal Stud 20 Gauge • 5/8" Gypsum Wall Board each side (single) • MEP Rough-ins and outlets **Wall-B** • Thickness 4 7/8" • 3 5/8" Metal Stud 20 Gauge • Sound Attenuation Insulation • 5/8" Gypsum Wall Board each side (single) • MEP Rough-ins and outlets **Wall-E** • Single Sided • 3 5/8" Metal Stud 20 Gauge • 5/8" Gypsum Wall Board • MEP Rough-ins and outlets

6.5 CONSTRUCTION SEQUENCE OF TYPICAL WALLS

Patient rooms tend to have sophisticated amount of work associated with them. A typical patient room would undergo the following activities prior to starting the finishing and installing of owner equipment:

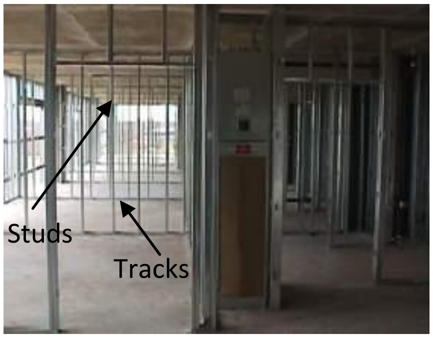


IMAGE 6-4: Tracks and Steel Studs

1. As soon as the slab is cured and the next trades are able to work on it, the framing/drywall trade is to come and mark down all the floors with all their measurements and layout locations to ensure no other trades come and obstruct their access around the whole floor.
2. Next, a couple of crewmen would start laying down the tracks on the floors and matching them on the bottom face of the upper floor to insure that the metal studs would stand perpendicular to the floors. (see *Image 6-4*)
3. Once the tracks have been setup, the next crewman would start framing the layout of the rooms by placing all the metal studs up.
4. As soon as the framing is been installed the, mechanical and electrical contractors would send their crewmen to install all their piping, electrical fixtures and conduits (see *Image 6-5*), and medical systems (nurse call system, etc).
5. Next, a code inspector would have to come and inspect all the piping, conduits, framing, and bracing of the systems to make sure everything is built to specs/code.
6. Once all the mechanical and electrical systems have been integrated between the framing, the drywall crewman would start putting down their insulation and start cutting out their drywall sheets to match all the exposed receptacles and medical systems and hang them to cover the framings.
7. Finally, the last group of the drywall crew would start finishing the drywalls.

IMAGE 6-5: Electrical conduits/Receptacle

Without further discussions, it is very obvious at this point that a prefabrication effort would be very successful if implemented from step 1-6 in an off-site facility instead of on-site. By having the entire studs and tracks of the toilet pods, headwalls, and footwalls completely roughed-in and delivered to the site, the project team will be able to significantly cut down time by weeks or even a month of schedule time. Step 7 would not be preferred to be prefabricated into the units as problems such as cracking and breaking would be potential problem during transportation and rigging.

6.6 BENEFITS TO PREFABRICATE AT THE CHILDREN'S HOSPITAL

Prefabricating elements at the Children's hospital can have tangible and intangible benefits. Although prefabrication in most cases may yield higher costs to the owner due to transportation costs as well as insurance and oversized highway delivery permits, the benefits can by far justify the costs. Among the primary reasons why contractors turn to prefabrication is to save schedule time or even get back on schedule upon hitting an unexpected delay. As discussed in the case study earlier, the benefits could exceed schedule time savings which raises the question, why not prefabricate whenever possible? This section will discuss the tangible, intangible, and schedule time savings of prefabrication on the Children's Hospital.

6.6.1 TANGIBLE and INTANGIBLE BENEFITS

A prefabrication effort at the Children's Hospital could potentially provide many tangible benefits. The number one tangible benefit would be that 68 patient rooms will be fabricated in an off-site facility cutting down intense amount of schedule time as will be discussed later.

Using prefabrication on the Children's Hospital allows the project team to reduce the amount of time working on-site and interrupting the daily life of the Hershey Medical Center. Site work is usually very vulnerable to inclement weather that may cause additional delays. Undergoing construction work in an off-site facility can dramatically reduce the risks of performing work on a jobsite, it can also reduce time depending on the scope of work being prefabricated i.e. the more prefabrication being done the less time it would take to finish a project.

The potential to save money is not always highly likely especially if prefabrication was elected to be the method of construction after the design stage has been completed. Prefabrication needs to be carefully planned during the design stages to address any constructability issues. Any design changes after prefabrication can be very problematic to the owner as increased costs would be applied to satisfy the changes. In most cases, cost savings can come from a dramatic increase in labor productivity as well as the dramatic reduction in construction waste products. Although savings can be made, one must be careful when planning as transportation costs may offset the savings made. Indirect savings include reduced site supervision, reduced general conditions, reduced rework due to high quality products constructed in a comfortable climate controlled facility, also simplified inspection can save money on-site as quality control and assurance is much higher than constructing on-site.

The overall quality of the prefabricated units would be higher than the conventional on-site construction. A stable working force performing work in factory conditions as well as off-site pre-commissioning usually drive the quality of the product far higher than on-site construction. Comfortable and safe factory conditions allow workers to work with high motivation which would reflect on the quality of their work.

6.6.2 SCHEDULE TIME BENEFITS

Estimating the schedule benefits was a big challenge as no resource can provide a complete list of average construction durations for setting up metal studs, MEP rough-ins, insulations etc. Through thorough research efforts, it has been assumed that the daily construction output for one crew to lay down the metal tracks and studs as well as completely fitting out the walls and insulating it would approximately be 250SF of wall per day. RS Means and industry professionals were consulted to verify if that this would be a reasonable number for the job. To estimate the schedule time benefits, it will be assumed that two on-site crews would be utilized bumping the daily output to 500SF of wall per day. The assumption is that each activity will follow as soon as enough space has been constructed by the previous responsible crew in order to simplify the schedule time calculations. *Table 6-2* will calculate the total time needed to construct the units on-site.

TABLE 6-2: TOTAL TIME NEEDED TO CONSTRUCT UNITS (ON-SITE)

	UNIT	QUANTITY	SF OF WALL PER UNIT	TOTAL SF	TIME TO CONSTRUCT
3RD FLOOR	BATHROOM POD	34	180 SF	6120 SF	16 DAYS
	HEADWALL	21	160 SF	3360 SF	9 DAYS
	FOOTWALL	17	90 SF	1530 SF	4 DAYS
	SUB TOTAL			11010 SF	29 DAYS
4TH FLOOR	BATHROOM POD	34	180 SF	6120 SF	16 DAYS
	HEADWALL	21	160 SF	3360 SF	9 DAYS
	FOOTWALL	17	90 SF	1530 SF	4 DAYS
	SUB TOTAL			11010 SF	29 DAYS
TOTAL	**3RD AND 4TH**			**22020 SF**	**58 DAYS**

The calculation of the total time needed to construct the systems on-site was found to be 58 days. In an effort to cut down on schedule time, the L.F. Driscoll team may be interested in prefabricating the systems discussed in this analysis as an approximate 58 days can be shaved off the construction schedule to recover from any delays, free up more time for more challenging activities, or even achieve substantial completion ahead of the scheduled date. The calculated saved days would need to be re-evaluated in more depth and input from each subcontractor if prefabrication is to be used.

6.6.3 GENERAL CONDITIONS BENEFITS

Among the important benefits associated with prefabricating systems in an off-site facility are savings in the project's General Conditions. As previously shown, the project's General Conditions were estimated at $6.62 Million. Considering this cost is associated with a 31 month project schedule, an average of $213.5 K would be allocated per month if the costs were to be equally distributed over the length of the project. The previous section has shown a prefabrication effort would potentially shave off 2 months worth of project schedule time. Assuming the previous discussion is true, total general conditions costs of $427 K would potentially be saved.

6.7 PREFAB SHOPS NEAR CHILDREN'S HOSPITAL

Due to this project being a Design-Bid-Build type of project delivery system, it would be very difficult to have a separate entity to prefabricate the units. This is mainly due to subcontractors already been in contract with L.F. Driscoll. The best case scenario would have been if the project was under a design-build delivery system or if the scope of work originally demanded prefabrication. In the case of the Children's Hospital, the best solution would be to convince the project team and subcontractors to change the scope of work and engage in a prefabrication effort.

In order to get the subcontractors on-board to prefabricate units, an off-site space is to be provided. Upon research in the Hershey area, a warehouse was found just about 11 miles away from the jobsite. *Table 6-3* analyzes the major features of the warehouse space.

TABLE 6-3: WAREHOUSE INFORMATION

Warehouse Name:	Turnpike Business Center
Address:	1235 S. Harrisburg St. Harrisburg, Pa 17113
Distance to Jobsite:	~11 Miles
Size:	50,000 SF Available
Ceiling Height:	18 FT
Dock Available:	Yes
Rate:	$5.25/SF

In order to completely prefabricate all the units in the warehouse, an estimated square footage required would be 20,000SF. This space can be rented for two months prior to the actual date of the 3rd and 4th floor fit-out for a total cost of $105,000. Additional costs would be applied for delivery of the units to the jobsite as will be outlined in *Table 6-4*.

TABLE 6-4: TRUCK LOADS REQUIRED

UNIT	UNITS PER TRUCK LOAD	TOTAL TRUCK DELIVERIES NEEDED
BATHROOM PODS	2 UNITS	34 DELIVERIES
PATIENT HEADWALLS	2 UNITS	21 DELIVERIES
PATIENT FOOTWALLS	4 UNITS	9 DELIVERIES
TOTAL DELVERIES REQUIRED		**64 DELIVERIES**

Based on (fairtran.com) a truck delivery company, it would cost approximately $3.20 per mile for a flatbed truck delivery between Harrisburg and Hershey. To deliver the 64 flatbed trucks needed between the warehouse at Harrisburg and the jobsite at Hershey the total mileage would be approximately 1408 miles since the company charges for roundtrips. Therefore, the total cost of delivery would be approximately $4,500.

Although many added costs result from prefabrication, the main decision will be the urgency of needing to save schedule time. In some cases were a project is delayed, liquidated damages may be very high that prefabrication would be a less of a penalty. Prefabrication can sometimes be more expensive than constructing on-site; however, if planned carefully and early on in the process, savings may be possible as seen earlier in the Miami Valley Hospital.

6.8 SITE LOGISTICS FOR DELIVERIES

Site logistics for the delivery of the prefabricated units will be very similar to the rest of the deliveries set for the Children's Hospital. All deliveries will have to be coordinated with the Office of Physical Plant at the Hershey Medical Center to insure safety of the campus pedestrians. The prefabricated unit will be delivered on flatbed trucks on Service Drive as shown in *Image 6-6*. The tower crane operator will then directly rig the units from the truck and straight into the building where a temporary opening in the third and fourth floors will be left out for the laborers to intercept the prefabricated units into the building.

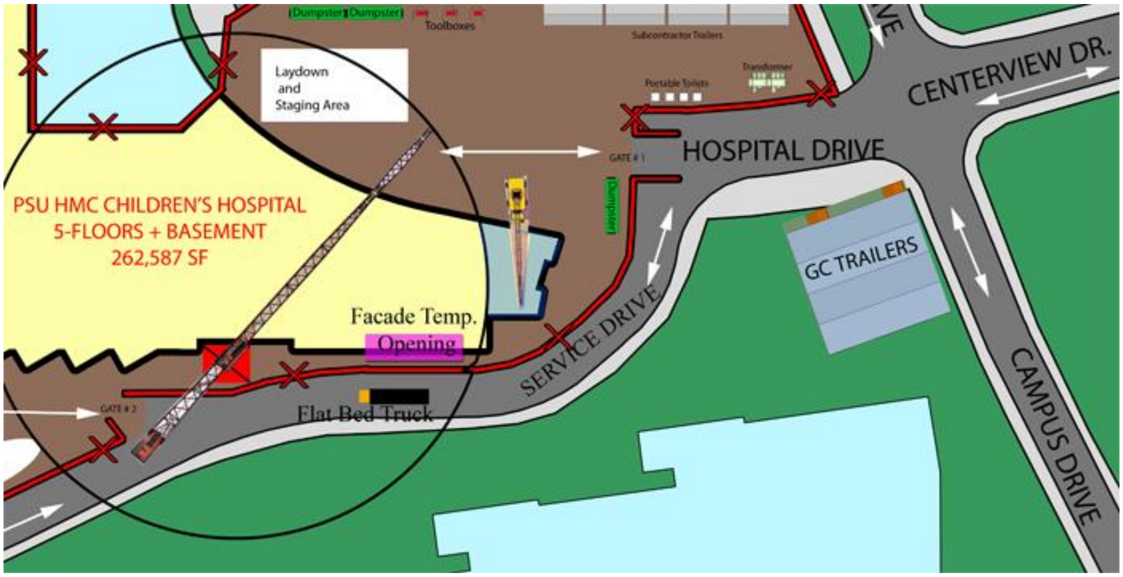


IMAGE 6-6: Site Logistics of Prefabricated Units Delivery

6.9 EFFECTIVENESS OF BIM ON PREFABRICATION

Prefabrication in the United States has been traced to over 130 years ago when home builders started using machine cut nails as a replacement for hand forged nails in wood framing. The development of the power saw also introduced the prefabrication of standardized wood for structural framing, sheathing, and sidings. During the 20th century, the building industry realized how prefabrication perfectly suits the effort of reducing on-site labor and construction costs.

Upon the development of 2D CAD software, contractors tried to coordinate the work and designs of multiple trades in an effort to fabricate elements in an off-site facility. However, coordination techniques raised issues in certainty and precision as clashes were still likely to occur during construction. Prefabrication has not been fully taken advantage of due to the high risks of facing

major problems when installing the units on-site. Contractors have always tried to utilize prefabrication but were not willing to deeply invest in the idea. Structural steel fabrication has been the dominator of prefabrication due to the simplicity and standardization of member sizes. Apart from structural steel, precast concrete has been casted off-site in many projects also. Contractors have not fully made use of prefabrication for interior rough-ins, over-head MEP systems, nor assembled wall units due to the risks associated with multi-trade coordination issues.

Within the past 10 years, Building Information Modeling has been undergoing major research and investments from design and construction firms as well as academic programs to improve the way builder's build. Building Information Modeling has been initially used to serve as a virtual 3D model for presentation purposes and to better portray the design intent to the client. As software developers merged in an effort to make better use of Building Information Modeling, contractors today are able to coordinate multi-trade systems virtually to represent 100% the expected results on-site. Through the use of Autodesk Navisworks revolutionary Clash Detective tool, subcontractors would link their 3D models and run a clash detection test to locate points of system clashes. By doing so, the construction team can very accurately issue coordinated drawings for construction. With the help of BIM, MEP construction today is very confidently constructed with no field tensions as a full virtual model has insured no clashing would occur if installed per the tolerances set.

Building Information Modeling gives contractors the ability to input component details, 3D geometry, material specifications, finishing requirements, delivery sequence, and timing before and during the fabrication process. With the ability to fully coordinate complex multi-trade systems using BIM, contractors in the United States today feel more confident in taking initiative to prefabricate major units in an effort to cut schedule time. The reduced risk of parts not fitting properly when installed is what BIM is trying to advertise. Different subcontractors are buying into the idea of prefabricating today more than ever before simply because of the assurance and knowledge that all systems have been coordinated virtually using a 3D clash detection tool. BIM tools are not only enabling greater degrees of prefabrication but also prefabrication of building parts that were previously assembled on-site. For example, the Miami Valley Hospital discussed earlier in the analysis became the first project in the United States to prefabricate patient rooms.

Many contractors seem to be just waiting for someone to take the first shot at a new prefabrication idea to avoid the challenges and risks due to being the first at doing something new. However, the

construction market has proven that regardless of the risks, someone will always begin a new innovative approach that would potentially become the norm of how to construct in the future. Off-course, without BIM prefabrication would be near impossible; thanks to the help of BIM, contractors, subcontractors, and designers can better communicate to produce high quality products in an off-site facility.

6.10 RECOMMENDATIONS AND CONCLUSION

As shown in this analysis, prefabricating the bathroom pods, patient head walls, and patient footwalls would be greatly advantageous and recommended for the Children's Hospital. Although a definite cost analysis was neglected due to no resources available at this time, the 58 days of schedule time reduction would compensate for any possible increased overall cost.

Prefabricating complex systems such as patient walls can revolutionize the way contractors build hospitals. L.F. Driscoll would benefit the most of prefabricating patient room units as it would be among the first contractors in the United States beside Skanska to ever take the initiative. This would obviously increase the competitive advantage of the construction company and would be very attractive for future owners.

The Penn State Hershey Medical Center would also see great advantages as future building expansions and additions can focus on as much prefabrication as possible through the initial designs to minimize construction durations. Reducing schedule time would always benefit the client due to the ability of opening the facility earlier and starting to generate money to payback for the construction costs.

Although it is challenging to attempt multi-trade prefabrication at this time during the construction process, it would be worth a while investigating it. If the owner and the contractor decide to prefabricate, it will be necessary to discuss the initiative with the design team as well as the involved subcontractors to have a smooth transition for changing the scope of work.

In conclusion, attempting to prefabricate labor intensive systems will be very advantageous for all parties at the Children's Hospital as saving time, reducing site congestions, reducing waste, and constructing quality systems in an off-site facility will off-set the overall success of the project.

7.0 ANALYSIS #2: Eliminating Inefficiency of Cost Estimating Through 3D Modeling

7.1 PROBLEM IDENTIFICATION

During the Design and Development of the Children's Hospital project, a total of three 3rd party estimators were hired to estimate the costs of the project as the Architects progressed through the design. In addition, to the three 3rd parties involved, each contractor bidding for the project had to develop and estimate the project costs. The Children's Hospital is a large project with many systems to be estimated and evaluated. The lengthy process of conducting manual hand take-offs on 2D drawings could negatively impact the entire project team during construction. The biggest risk of conducting manual take-offs during construction is when the owner's team decides to change scope of work or add new bulletins. Manual take-offs can greatly hurt the project schedule and costs if not conducted in a quick and efficient manner.

7.1.1 RESEARCH GOAL

The primary goal of this analysis is to utilize 3D modeling software to conduct material Quantity Take-offs and pricing. Software will be used to analyze the benefits of utilizing 3D Estimating techniques in developing accurate and quick estimates. The analysis will compare 3D software estimating techniques to the traditional commonly used manual estimating methods.

7.1.2 METHODOLOGY

- Conduct a survey to be sent out to multiple contractors utilizing 3D estimating software to see the overall benefits and challenges associated with this technique.
- Different 3D Software will be researched to identify the one with the most beneficial features.
- Upon selecting the ideal 3D software to be used, a specific building system will be selected as the benchmark for the study.
- Using RS MEANS COSTWORKS, the system will be estimated utilizing the traditional material take-off technique.
- The same system will then be estimated utilizing 3D software to extract the materials take-offs.
- A comparison will then be conducted to determine the optimal solution to estimating efficiently.
- Perform final analysis explaining how 3D estimating can potentially eliminate inefficiencies during the construction of the Children's Hospital.

7.1.3 RESOURCES

- RS MEANS COSTWORKS 2010.
- Multiple 3D Software available in the AE Computer Labs.
- Applicable Literature.
- Estimating team at L.F. Driscoll, Co LLC.
- Industry Professionals to conduct my survey.

7.1.4 EXPECTED OUTCOME

This analysis will determine the answers to whether or not 3D estimating will be beneficial. It is expected that using 3D estimating techniques will efficiently decrease the time required to assemble an entire estimate. It is also expected that this technique will help eliminate estimation busts that occur on some projects were upon bid award the team discovers that a major system has not been accounted for. Utilizing this technique will prove nothing but faster and more efficient estimating compared to traditional methods.

7.2 BACKGROUND INFORMATION

Building models have been developing very quickly leaving professionals playing catch up games in order to keep up with the ever developing technologies. Professionals have relied very heavily on BIM as a tool to 3D coordinate multiple systems; however, many of the other benefits have not yet been efficiently utilized such as: design reviews, site analysis, 4D phase planning, 3D cost estimating, digital fabrication, disaster planning, etc. The purpose of this analysis is to determine the benefits and advantages of utilizing building models to develop and update precise cost estimates during construction.

Cost estimation is not merely taking off quantities from 2D drawings as most people think. On average it takes about 50-80% of the time needed to create a cost estimate juts on quantification. Estimators bring more to the table than just quantifying amount of materials. Traditional estimating methods using 2D drawings and manual take-offs introduce the potential for human error and proliferate any inaccuracies in the original drawings. Through the use of building models, quantity take-offs can be generated directly from the model using computer aided software. This method provides a more accurate estimate as well as consistency with the design. Cutting down quantification times allow the estimators to bring more benefits to the table such as: identifying construction assemblies, generating pricing, and factoring risks to develop high quality estimates.

7.3 SURVEY SAMPLE

In order to adequately get industry professional's opinions on 3D estimating methods, it is essential to conduct some type of survey, questionnaire, or interviews. Due to time limitations on this thesis project, this step needs to be conducted very early in order to be able to get feedbacks right on time prior to reaching the project deadlines. In this analysis, an online survey tool will be utilized to obtain industry feedback on this analysis. The survey will contain several questions pertaining to the benefits, advantages, disadvantages, drawbacks, critical issues, as well as challenges with using building models as a tool to conduct project cost estimates. The following list of questions will include multiple choice questions in addition to an empty field to be used for additional elaboration on the answers chosen in an effort to get as much feedback as possible. Later in the analysis, the survey results will be discussed in conjunction with the recommendations and conclusion of the analysis.

TABLE 7-1: SURVEY QUESTIONS

1.	**Does your firm utilize 3D estimating techniques?**	- Yes - No
2.	**When do you see the greatest advantage in 3D estimating?**	- Schematic Phase - Design Development Phase - Procurement Phase - Value Engineering Practices, addendums, bulletins, etc. - All the Above
3.	**Approximately how much time can be saved using 3D estimating rather than the traditional manual hand take-offs?**	- 10-20% Time Saving - 30-40% Time Saving - 50-60% Time Saving - 70-80% Time Saving - 90-100% Time Saving
4.	**Can 3D estimating potentially eliminate the traditional estimating methods?**	- Yes, no need for traditional method - No, Both must be used
5.	**List some advantages/disadvantages from your experience or your firms experience in 3D estimating.**	- Open Ended question
6.	**What are some challenges or drawbacks from using 3D estimating?**	- Open Ended question

Survey Web Page: http://www.surveymonkey.com/s/XS7FY8T

7.4 3D ESTIMATING METHODS

Building Information Modeling (BIM) does not offer direct cost estimating. BIM does not generate automatic cost estimates; in fact, all BIM offers is a more accurate and time saving method to perform the quantity take-offs. It is necessary to integrate the quantities and material definitions out of a building information model into a cost estimating system. There are many different ways of integration between a BIM model and a cost estimating system. This analysis will briefly look at three different methods and concluding with a single method to be performed on a selected system at the Children's Hospital to determine the time and accuracy benefits over the traditional manual hand take-offs.

7.4.1 APPLICATION PROGRAMMING INTERFACE (API)

Application Programming Interface integrates with estimating software such as U.S. COST or Innovaya which then integrates with Timberline Office Estimating. In brief description, this approach uses a direct link between the costing software and Revit. The user would export the building model from Revit using the costing program's data format and sends it to the estimator to begin the costing process.

Through an API link, the quantities are automatically associated with the Revit model; in other words, Innovaya software can instantly detect design changes from the Revit model helping the estimating department update their quantities due to the changes in design. In manual hand take-offs, the estimator would have to manually check the design revisions to update the numbers. With API, the estimators would just re-export the Revit model to Innovaya to detect the new changes.

7.4.2 ODBC CONNECTION

ODBC Connection integrates with estimating software such as CostX or ITALSOFT. ODBC is useful in that it integrates specification management and cost estimating with BIM. In this approach, the ODBC database is used to access the information in the BIM model and would then use exported 2D or 3D CAD files to access dimensional data.

Similar to API, ODBC Connection uses a Revit-to-CostX integration to compare and evaluate pricing changes due to design changes. The estimators once again do not need to compare drawings and re-take quantities. The link between Revit and CostX automatically detects the changes and graphically displays the results.

7.4.3 OUTPUT TO EXCEL

In a much simpler method to conduct quantity take-offs using a building information model, Revit can directly produce quantity take-off schedules that can be exported to MS EXCEL. Although this method is less complex, it only updates the quantity schedules with design changes without showing what has been changed. This method is more widely used for specific system take-offs where material take-offs are directly exported to MS EXCEL for the estimator to input the costs.

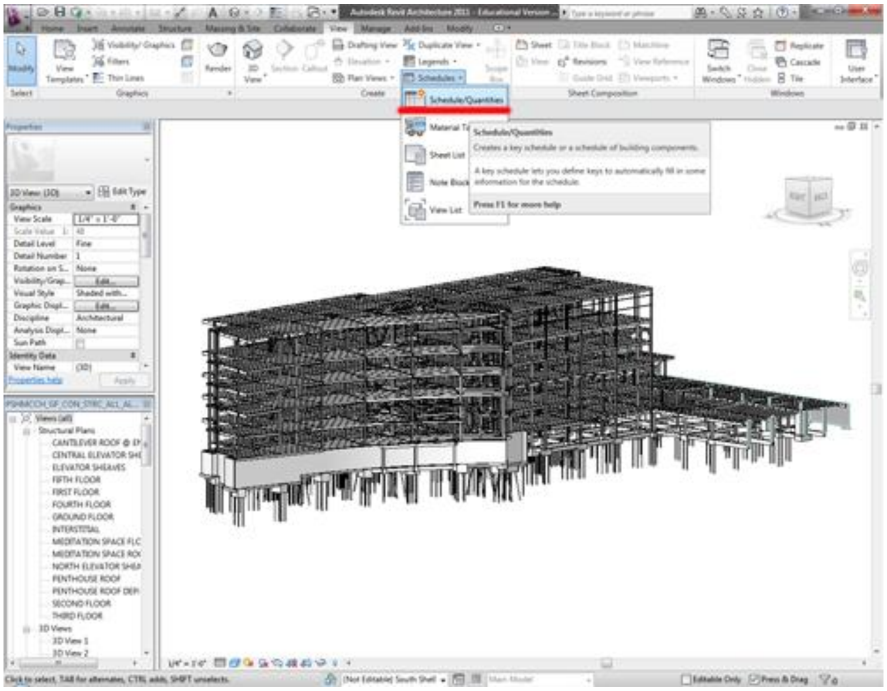
7.4.4 SELECTED METHOD FOR THIS ANALYSIS

There really is no right or wrong approach in selecting which method to pursue in cost estimating. Each method has its advantages and disadvantages. Some methods require professional training to be able to use the different software fluently while others are very simple to learn. In short, each integration method depends on the firm's cost solution software in place, the pricing databases used, and so on.

Due to time limitation on this senior thesis project, it would be impossible to apply API or ODBC methods on a selected system at the Children's Hospital. Therefore, the best way to test 3D estimating methods is by using the Output to Revit method. The main purpose of this study is to determine whether or not the use of building information modeling can develop a more accurate estimate with less time than the traditional manual hand take-off method. This analysis will conduct an estimate comparison using both the traditional hand take-offs and Revit take-offs on the structural steel system of the building.

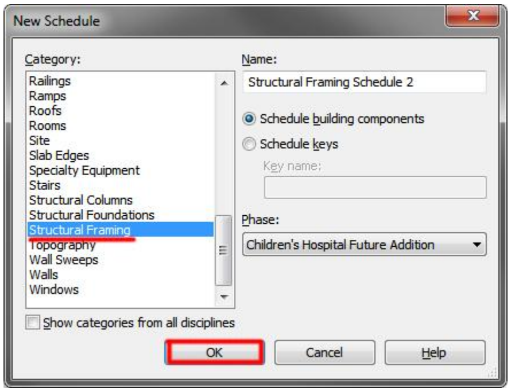
7.5 HOW TO DEVELOP AND EXPORT QUANTITY SCHEDULES IN REVIT

In order to effectively use the Output-to-Excel method for quantity take-offs, it is necessary to briefly explain how to perform the entire task from Revit and finally into MS Excel.



Schedule/Quantities
Creates a key schedule or a schedule of building components.
A key schedule lets you define keys to automatically fill in some information for the schedule.
Press F1 for more help

STEP 7-5: Open Revit File and Create New Schedule



New Schedule

Category:
Railings
Ramps
Roofs
Rooms
Site
Slab Edges
Specialty Equipment
Stairs
Structural Columns
Structural Foundations
Structural Framing
Topography
Wall Sweeps
Walls
Windows

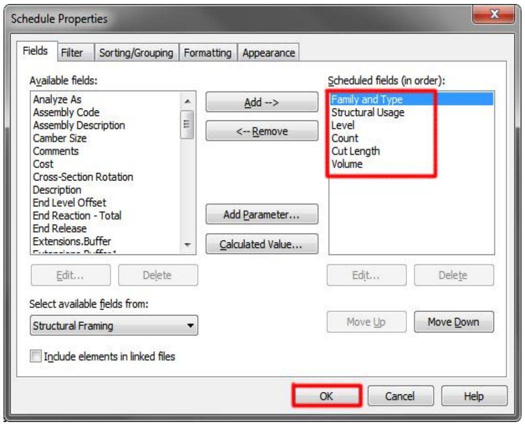
Name: Structural Framing Schedule 2

● Schedule building components
○ Schedule keys
Key name:

Phase: Children's Hospital Future Addition

☐ Show categories from all disciplines

STEP 7-6: Select Building System Category



Schedule Properties

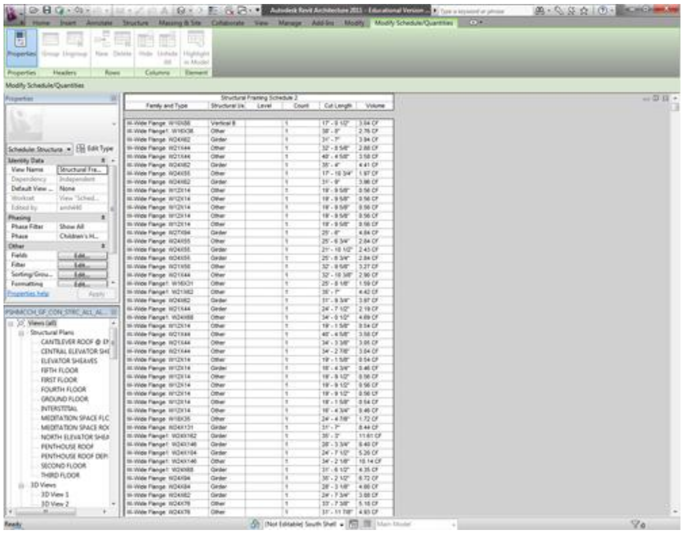
Available fields:
Analyze As
Assembly Code
Assembly Description
Camber Size
Comments
Cost
Cross-Section Rotation
Description
End Level Offset
End Reaction - Total
End Release
Extensions.Buffer

Scheduled fields (in order):
Family and Type
Structural Usage
Level
Count
Cut Length
Volume

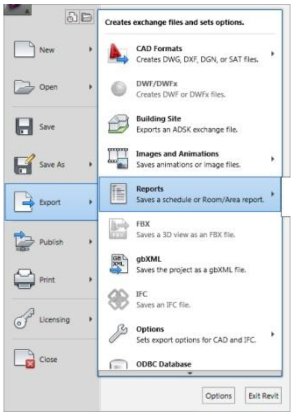
Select available fields from: Structural Framing

☐ Include elements in linked files

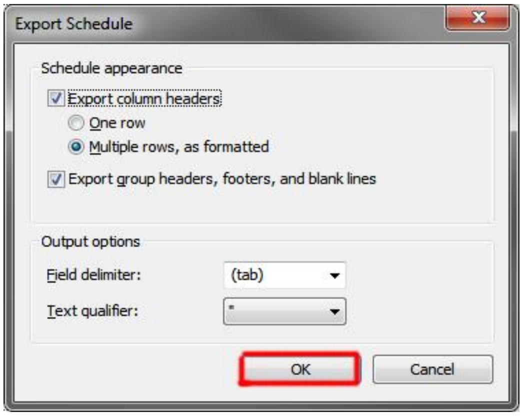
STEP 7-7: Modify Schedule Fields and Parameters



STEP 7-4: Revit Quantity Schedule will be Instantly Developed



STEP 7-5: Export the Schedule to a Text File


Export Schedule

Schedule appearance

☑ Export column headers

○ One row

● Multiple rows, as formatted

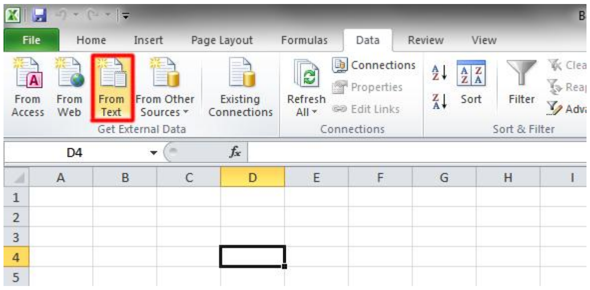
☑ Export group headers, footers, and blank lines

Output options

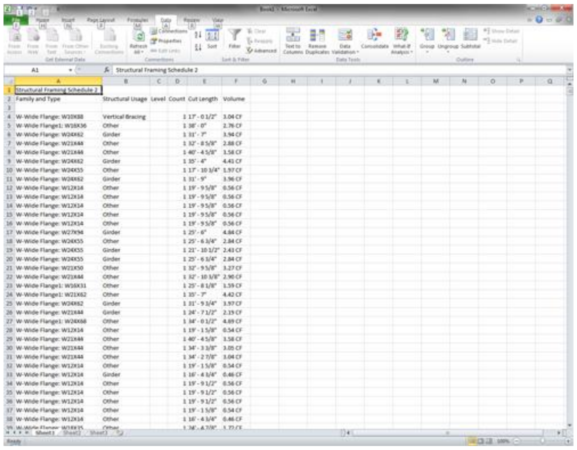
Field delimiter: (tab)

Text qualifier: "

STEP 7-6: Confirm Schedule Format



STEP 7-7: Insert Data from Text File in MS Excel



STEP 8-8: Revit Schedule Exported to Excel for Cost Inputs

7.6 SELECTING A SYSTEM AS A BENCHMARK

The most optimum case to conduct this study is to have an original design of a specific system and the revised design of the same system. This would be optimum due to the fact that many design revisions and changes occur during the course of construction. Whenever design is revised or changed, the construction team need to quickly react to the situation and perform new quantity take-offs as well as pricing to issue change orders. The more accurate the quantity take-off method is, the lower the chance of facing a bust in the change order requested. Due to minimal design changes on the Children's Hospital that have an actual building model, this analysis cannot be conducted as planned. An alternative way of showing the same result, the structural steel system at the Children's Hospital will be used as a benchmark for this analysis as the building model has been previously been requested to be used in Technical Assignment Two.

7.7 STRUCTURAL STEEL QTO THROUGH TRADITIONAL METHOD

This analysis began quantifying the amount of structural steel pieces that consist the entire structural framing and columns of the Children's Hospital. It was a very tedious, length, and unorganized way to conduct quantity take-offs. Over 20 2D construction drawings had to be closely looked at to be able to quantify the structural pieces along with their sizes and lengths. One of the biggest challenges was the need to use a scaled ruler to determine the lengths of each element which may have contributed to human error. Upon completion of the quantifying procedure, the results were inputted into an excel sheet to calculate the total cost of the system. *Table7- 2* summarizes the result of the traditional quantity take-off method.

TABLE 7-2: COSTS OF STRUCTURAL STEEL SYSTEM USING TRADITIONAL QTO PROCEDURE

	RS MEANS COSTWORKS ESTIMATE		ACTUAL COSTS	
SYSTEM	**$/SF**	**TOTAL**	**$/SF**	**TOTAL**
STRUCTURAL STEEL	$20.49	$5,380,000	$21.31	$5,597,000

As shown the total estimate of the structural steel system came to a value of 3.87% less than the actual contracted structural steel package at the Children's Hospital. Although the estimate seemed reasonable, a closer look will be taken in the next section when using a more accurate method.

7.8 STRUCTURAL STEEL QTO THROUGH REVIT MODEL

Using the existing structural steel Revit Model to quantify all of the structural steel components of the Children's Hospital was a very easy and time saving experience. It only took multiple mouse clicks to get a comprehensive schedule with all of the steel framing and column pieces including the designation, lengths, volumes, weight and many other parameters. The next step was to simply export the schedule to an excel sheet and assigning the correct cost code for each component. This process has little or no human error compared to the traditional method. *Table 7-3* summarizes the result of the Revit aided quantity take-off method.

TABLE 7-3: COSTS OF STRUCTURAL STEEL SYSTEM USING REVIT QTO PROCEDURE

	RS MEANS COSTWORKS ESTIMATE		ACTUAL COSTS	
SYSTEM	**$/SF**	**TOTAL**	**$/SF**	**TOTAL**
STRUCTURAL STEEL	$19.81	$5,200,900	$21.31	$5,597,000

As shown the total estimate of the structural steel system came to a value of 7.1% less than the actual contracted structural steel package at the Children's Hospital. Although the traditional quantity take-off method appeared to be closer to the actual costs it might have been actually over priced due to inaccuracies during the QTO process. The next section will compare and contrast both methods as well as justifying any discrepancies.

7.9 THE VERDICT?

Upon completion of both quantity take-off methods, there were notable differences in both methods. The amount of time to perform each method as well as the level of accuracy were major differentiators between the two approaches to quantify the materials. Each method was compared to the actual contracted costs to determine the accuracy of each method. Although the traditional manual quantity take-off procedure yielded a closer number to the contracted price, this does not necessary means it was the most accurate as will be discussed later.

The traditional manual quantity take-off method yielded a price of $5,380,000 which was 3.87% less than the actual contracted price. On the other hand, the Revit aided quantity take-off yielded a price of $5,200,900 which was 7.1% less than the contracted price. By simply examining the results it would be obvious that the traditional QTO method yielded a more accurate price. However, since the Revit model was developed by the structural engineer, it meant that the model was 100% accurate in the number of members as well as their lengths. When comparing the lengths of the

traditional QTO method to the Revit QTO method, it was found that on average the traditional method yielded a 15% increase in lengths which meant there was a high margin of error during the traditional QTO method.

Sources of error during the traditional method could have been a result of the following reasons: misreading values from the scale used when measuring structural steel members, also having to pause work over multiple hours and even days may have resulted in over counting steel members. Human error was obviously a big differentiator in this analysis. Assuming there were not strict time limitations on this study, the values would have been much closer to the Revit quantities. Using Revit to quantify the members has clearly provided by far more accurate quantities in this analysis.

The time required to conduct each method was a big differentiator as discussed earlier. The traditional QTO method required a total of 25 hours to completely quantify the entire structural members. Approximately 5 days of 5 hours each were spent to quantify the entire members and their lengths. On the other hand, Revit has proven to be a time saver as it only took approximately 15 minutes to fully develop and format the quantity schedule in Revit, and an extra 1.75 hours to export the quantities into excel and price each group of members. The Revit QTO method once again proved to be a time saver as it required 12.5 times less time than the traditional method which realistically saved 1250% of the time used in the traditional method. *Table 7-4* below summarizes the results of this analysis.

TABLE 7-4: SUMMARY OF FINAL COMPARISON BETWEEN TRADITIONAL VS REVIT QTO

	Traditional QTO	Revit QTO	LFD Contract
Time Required	25 hrs	2 hrs	-
Percentage of Discrepancy	15%	0%	-
Cost of System	$5,380,000	$5,200,900	$5,597,000
% Difference to Actual	- 3.87%	- 7.1%	0%
Level of Accuracy Achieved	85%	100%	100%

7.10 ANALYSIS OF SURVEY RESULTS

The survey conducted early in the analysis has been completed. *Table 7-5* below will analyze the results showing the percentages of selected answers in the multiple choice questions as well as including some of the comments industry professionals had on each question. A brief analysis on the results will be discussed after *Table 7-5*.

TABLE 7-5: RESULTS OF SURVEY QUESTIONS

1. Does your firm utilize 3D estimating techniques?	- Yes – **50%** - No – **50%**
2. When do you see the greatest advantage in 3D estimating?	- Schematic Phase – **10%** - Design Development Phase – **50%** - Procurement Phase – **10%** - Value Engineering Practices, addendums, bulletins, etc. – **30%**
ADDITIONAL COMMENTS MADE: - 3D is a powerful tool that can help early in a project with coordination and difficult construction and design issues that can lead to unforeseen costs later in design. - There is little value to 3D estimating, 3D objects do not contain intelligence - utilizing intelligent objects from a BIM is where the real savings exists. - One of the biggest challenges faced when estimating a project is visualizing in your head what the blue prints are trying accomplish and capturing all of the steps required to build a project. In every phase of estimating and buying out a project the 3D image helps visualize how things will need to get built. - It is important to have human interaction during estimates because of scope issues that will arise during the project. Having a program ready to go that can quickly show the cost impacts on RFI, bulletins, etc., can be a good tool to help save the project money without sacrificing too much human interaction.	
3. Approximately how much time can be saved using 3D estimating rather than the traditional manual hand take-offs?	- 10-20% Time Saving – **60%** - 30-40% Time Saving – **20%** - 50-60% Time Saving – **20%** - 70-80% Time Saving – **0%** - 90-100% Time Saving – **0%**
ADDITIONAL COMMENTS MADE: - Time savings will improve as consistency in modeling improves - It really just allows for less counting and more constructability review - At this point in time I don't believe that anyone will rely on estimates from a model, the numbers from the model will need to be verified.	

4. Can 3D estimating potentially eliminate the traditional estimating methods?

- Yes – **11.1%**
- No – **88.9%**

ADDITIONAL COMMENTS MADE:

- Some systems and assemblies will never be modeled (or shouldn't be at least) and will always have to be calculated through manual take-offs.
- Must verify and all models are not always that complete.
- Eventually when all models are intelligent and architects model the way that things are actually built. Currently models are schematic or inaccurate - walls are modeled from deck to deck but will not be installed that way.
- 3D estimating is not fail safe. The reality is that times do come up where the traditional method is necessary to check your work.

5. List some advantages/disadvantages from your experience or your firms experience in 3D estimating.

- When a contractor is brought on towards the tail end of the design phase, it is difficult to fully understand or rely on the level of detail or accuracy of a model supplied by the design team.
- Not utilizing the tool effectively to allow for quantity take offs so MTO still required.
- Advantage: saves time/effort as teams get used to process and applications.
  Disadvantage: Few firms do modeling in all design disciplines, thus inefficiencies due to different estimating and review needed for different disciplines.
- Simple things like doors and finish schedules make a big difference. Not all models are created equally; this can create a big problem.
- very accurate once the model is built , but it take a lot of effort to get to that point and time is always a factor
- Our firm does not use 3D estimating. This is a disadvantage. There is definitely a time savings.

6. What are some challenges or drawbacks from using 3D estimating?

- Models often aren't awarded until award of a project. In a competitively bid project, estimating is completed during the bid phase prior to the model being transferred.
- Getting all disciplines to be fully into the model.
- Trying to create accurate (to-be-built) models, adding intelligence during design that can be leveraged for estimating.
- From what I understand it is a very useful tool on complicated project but the time it takes to building the model can be extensive and thus reduce the benefit from a contractor point during the bidding phase. If it is already built and can be shared it is very useful but typically the industry is not sharing these tools during that phase.
- I'd say not enough people in the industry have been exposed to 3D estimating, especially those people over 30 years old. It is great to see the Universities educating students on this. I do see this as a useful tool and will become more of a standard in the industry.

As seen in the survey results, many industry professionals agree that 3D estimation has many benefits including time savings. The purpose of this analysis was to determine whether or not 3D estimation would be beneficial during construction especially when new bulletins appear or Value Engineering ideas are being examined. The survey showed that 30% of the industry professionals believed that 3D estimating would be most advantageous during Value Engineering Practices, addendums, bulletins, etc. This is a large percentage supporting the goals of the analysis especially that it came second in ranking compared to number one being during the Design Development Stage.

The survey has also shown many unexpected results. On numerous survey results, professionals saw that although 3D estimating is proven to be a time savings tool, it cannot however eliminate the traditional manual take-off method. Reasons that supported their claims were that to this day architects do not model the building the way it is built. One participant claimed that architects still model interior walls from deck to deck and that is not how they are built which can cause many estimating issues. Another participant claimed that it is not necessarily faster especially if the contractor had to model the building due to architects not passing along the models. Among the best arguments was that due to the common design-bid-build project delivery system, the general contractors would be brought on-board after the design during the bid process. During the bid process, no models from the architects are transferred to the bidders which makes it a must to use the traditional manual take-offs from 2D drawings. Usually 3D models from the design team are transferred upon awarding the project.

Time savings due to 3D estimating were also argued. Although everybody agreed that time savings would fall anywhere from 10-60%, all participants believed that time savings would improve as consistency and accuracy of the design models improve. Many participants also agreed that 3D estimating methods helps reduce amount of counting and give more time for constructability review. One participant claims that at this time nobody would rely completely on a 3D model estimate as the numbers almost always have to be verified through the traditional method.

An interesting point of view was from a participant that claimed that many people in the industry over the age of 30 years are not exposed heavily on new technologies which ultimately slows the transition of using such methods. The participant believes that Universities should educate their students on new technologies to help the industry adapt to the new methods and help enforce new standards.

7.11 GUIDELINES FOR IMPLEMENTING 3D ESTIMATION

In order to be able to implement BIM based estimation, it is necessary that the project team comprehends the abilities of BIM models in supporting quantity take-offs by reducing counting and human errors as well as improving the overall accuracy of the take-offs. As discussed earlier BIM would also help estimators respond to any design changes very easily especially when time is critical. To implement BIM estimating on a project, it will be necessary to understand and abide by the following guidelines.

I. BIM is only an estimation aid and cannot be totally dependent on. It is necessary to understand that BIM will not develop a complete accurate estimate as models are not always designed the way they are to be constructed. For the most part BIM will offer accurate take-offs for many different systems; however, the data needs to be completed by additional cost and rules of thumb by the estimator.

II. If BIM tools are new to the firm, attempt utilizing digital take-offs through the use of Autodesk Quantity Take-Offs to understand exactly how the BIM softwares quantify items. Once confident with the use of a computer aided quantifying methods, a BIM model can be utilized for quantifying materials.

III. Always test the BIM model and software by conducting quantity take-offs of items that can be counted such as doors, windows, frames, etc. as this is the easiest way to check against the traditional method to see if the model is properly designed for quantifying purposes.

IV. Do not attempt to use an integrative approach of linking data with multiple softwares as this will potentially cause translation errors between different softwares. It is best to understand how softwares are designed to be able to know whether data transferred between different softwares will be translated the same way or not.

V. It is necessary to know that BIM models will not quantify everything the estimator needs to know, this is due to models usually not including every single detail. For example models typically don't show shear studs in elevated slabs, therefore the estimator must understand that the BIM quantities will not include those items and they will need to be quantified in the traditional method. Thus, expectations of quantifying using a BIM model need to be clearly set.

VI. Finally, as the firm becomes more comfortable with BIM usage for quantifying assemblies, a set standard for different assemblies can be made to be able to accurately quantify and estimate assembly costs. Upon gaining confidence in using BIM for estimation purposes, the firm will be able to standardize building components to accurately quantify subcomponents of specific assemblies. For example, accurately estimating metal studs in a typical interior wall.

7.12 RECOMMENDATIONS AND CONCLUSION

As shown in the analysis, using BIM beyond its abilities can be very advantageous and increase the construction firm's competitive advantage. Using BIM to develop cost estimates is a new approach few construction firms have been utilizing. It is recommended that the L.F. Driscoll team invest in training their personnel to adapt to the ever developing technologies to increase their profits and have an added incentive over other competitors.

Building Information Modeling has shown great successes in 4D site planning, 3D MEP coordination, and serving the purpose of a visual tool for constructors. It is time for contractors to learn and implement 3D estimation in their estimating departments to reduce the time of counting materials and focus on constructability reviews. With minimal time offered during the bidding process and during updated designs during construction, it is necessary for the construction team to make the most out of time i.e. planning and performing constructability reviews rather than counting materials.

As shown in the analysis and the survey results, BIM models will have to be better designed to show how the building is actually constructed rather than simply showing how the design would look like. Collaboration between the design and construction team must be made very early on in the process to make the most out of this process. Just like any new means and methods, time need to be invested to perfect the method.

The Children's Hospital would greatly appreciate utilizing this method as it would save critical time especially that design changes have been issued multiple times already. The owner would benefit from this method by having the designers fully design any new design changes or value engineering concepts in BIM and passing it to the construction team to perform quick estimates and provide insight in constructability reviews much quicker than before.

8.0 ANALYSIS #3: Viability of Incorporating Solar Photovoltaic Systems

8.1 PROBLEM IDENTIFICATION

The Children's Hospital project at the Penn State Milton S. Hershey Medical Center is a state of the art facility with high end patient care systems. The new facility will require enormous amount of electric loads to run the building. Diesel powered generators provide backup power in the case of power loss. The new project is on the borderline of achieving a LEED Silver Rating and the diesel powered generators are not providing any points to help out. Incorporating a solar photovoltaic system to help reduce the dependency on grid power as well as the possibility to eliminate some diesel generators will provide a great sustainable benefit to the Hershey Medical Center. The Children's Hospital joins with two other buildings with a vast amount of roof space, hence the idea of incorporating PV Panels.

8.1.1 RESEARCH GOAL

The primary goal of this analysis is to perform a design for a roof mounted photovoltaic system and determining the payback period as well as the amount of energy produced. The analysis will determine whether or not a photovoltaic system is viable on the Children's Hospital.

8.1.2 METHODOLOGY

- Develop a solar study on the Children's Hospital to determine the optimum angles and directions of solar energy for PV panels.
- Research photovoltaic panel technologies and manufacturers to determine the most applicable system available.
- Select the most applicable system and determine the marginal power able to be produced over the given area of the roof and the possibility of eliminating one of the diesel generators.
- Analyze the existing structure of the roof to determine the viability of installing the PV panels without redesigning the structural system.
- Develop a brief cost analysis determining the financial benefits and the payback period.

8.1.3 RESOURCES

- AE Faculty at Penn State.
- Applicable Literature.
- Manufacturers of PV Panels.
- Case Studies of previous projects utilizing photovoltaic.

8.1.4 EXPECTED OUTCOME

This analysis will thoroughly investigate the viability of applying photovoltaic system on the Children's Hospital. Although it is not expected that the photovoltaic system would support the entire building electric loads, it is however expected to effectively reduce the dependency on grid supplied power. It is expected that the building structure will be able to support the additional roof dead load incurred by installing PV panels. It is also expected that the financial analysis will prove that this system will be financially affordable and worth the payback period.

8.2 BACKGROUND INFORMATION

The essential goal of this analysis is to design a photovoltaic system that can be used to eliminate one of the three emergency diesel generators utilized for the new Children's Hospital. The Hershey Medical Center intends to own and operate the Children's Hospital for over 50 years as other buildings on campus for a much longer time. Photovoltaic systems automatically become an attractive investment considering payback periods usually range between 10-20 years of operation. A photovoltaic system will significantly assist in the achievement of a LEED certification as well as provide the first steps towards energy independence on the Hershey Medical Center.

Photovoltaic systems are being produced cheaper and more efficient than ever before. With federal benefits and support, this ever developing technology has become a very attractive choice by many owners. PV systems could potentially be a very successful investment for the Hershey Medical Center due to their access to vast amount of roof space as well as their generous owned land space of 550 acres. Investing in photovoltaic systems at the Hershey Medical Center has many advantages such as: benefiting from free solar energy, reducing dependency on the electric grid, promotes a much more realistic opportunity for the Engineering departments at Penn State to conduct research and further develop this technology. With this investment the Hershey Medical Center will share mutual benefits in terms of energy bills and campus wide research opportunities. This analysis will investigate and provide an initial design of how such a system can benefit the Children's Hospital at the Penn State Hershey Medical Center. It is expected that the outcomes be advantageous and financially feasible.

8.3 HOW DOES A PV-SYSTEM WORK?

There are many components that make up a complete solar photovoltaic system. In an off-grid system the primary components are solar modules, charge controllers, batteries, and inverters. The solar modules are physically mounted on the roof for optimum solar exposure. The power produced from the solar modules is direct currents (DC). Prior to delivering the power to the batteries, the solar modules are wired through charge controllers. Charge controllers serve two primary functions; to prevent the battery from being over charged and to eliminate reverse current flow from the batteries back to the solar modules over night. The batteries serve the purpose of storing the energy produced by the solar array during the day for use at anytime during the day or night. Finally, the inverter takes the DC energy stored in the batteries and inverts it to 120 VAC or 240 VAC to power any AC appliance. See *Image 8-1* for the flow diagram of a solar panel.

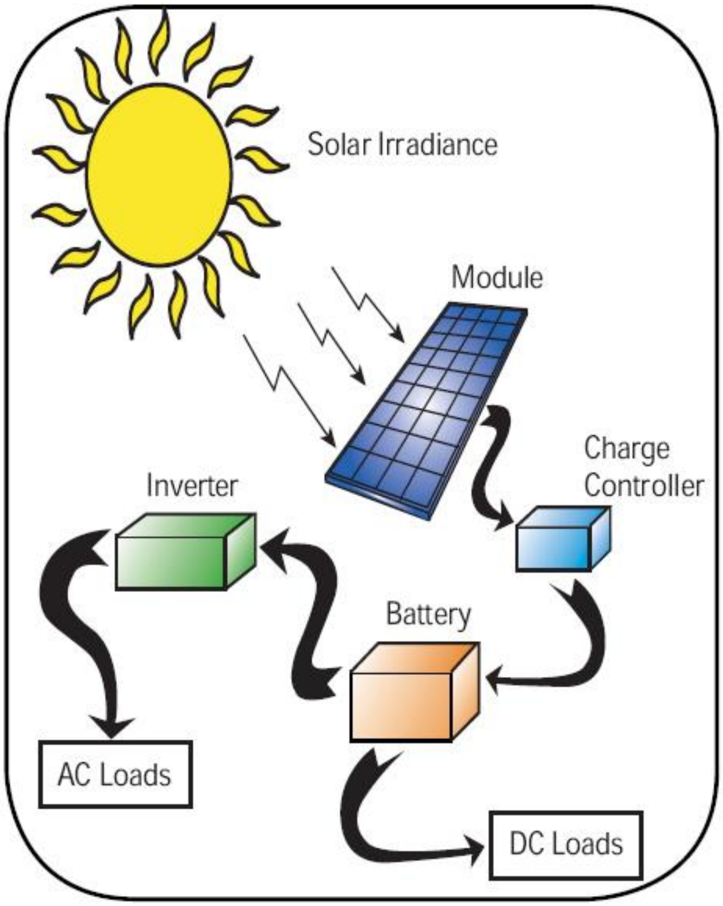


FIGURE 8-9: Flow Diagram of a Solar PV System

8.4 SOLAR ANALYSIS

The new Children’s Hospital at the Hershey Medical Center is being constructed in a strategic area that promotes ideal usage of a roof mounted solar photovoltaic system. As shown in *Image 8-2* the surrounding buildings have no shading effects on the roof of the Children’s Hospital due to the lower number of stories compared to the 5-story Children’s Hospital. The flat roof provides flexibility and ease of mounting the solar panels without hindering the architectural aesthetics of the building as they will not be visible to the public; hence, the proposing idea of implementing a solar photovoltaic system.

In order to design a photovoltaic system, certain parameters such as optimum tilt angles, elevation, sun hours per day, slope of roof, and optimum system orientation. The following parameters will be summarized in the following *Table 8-1*.

TABLE 8-1: PARAMETERS FOR SOLAR PV DESIGN

Building Location	Hershey, Pa
Elevation at Roof	85 Ft
Latitude and Longitude	N 40°15’ / W 76°46’
Sun Hours Per Day for Building Location	(4.44) No available data for Hershey, Pa therefore State College, Pa value will be used. http://www.solar4power.com
Optimum System Orientation	South Facing Side
Optimum System Tilt Angles	Summer: 25°15’ Winter: 55°’ *Latitude ± 15°*

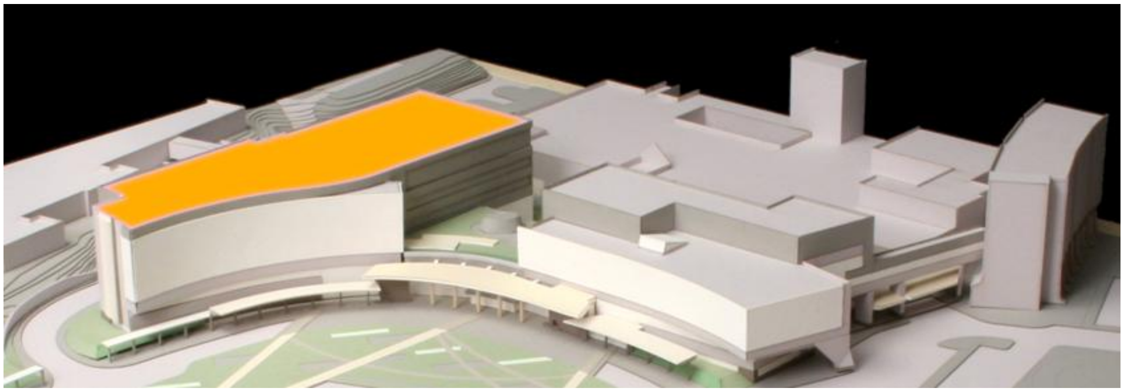


IMAGE 8-10 No shadow Interference from Surrounding Buildings

8.5 PV-SYSTEM MANUFACTURERS

According to Madison Gas and Electric Company, hospitals in the United States consume an average of 27.5 kWh of electricity per square foot annually. In typical hospitals, lighting, heating, and hot water represent about 72 percent of the total energy use, making the corresponding systems the best targets for energy savings.

In order to select multiple PV-systems to compare and contrast the most optimum manufacturer, it is necessary to know the average electric demand per day the Children's Hospital uses.

Annually $$27.5\frac{kWh}{Sq.Ft}\times 262{,}587\ Sq.Ft = 7{,}221{,}143\ \frac{kWh}{year}$$

Monthly $$7{,}221{,}143\ \frac{kWh}{Year}\times\frac{1\ year}{12\ months} = 601{,}762\frac{kWh}{month}$$

Daily $$7{,}221{,}143\ \frac{kWh}{Year}\times\frac{1\ year}{365\ days} = 19{,}784\frac{kWh}{day}$$

The following three manufacturers will be evaluated given the average daily electric demand to determine the most efficient system.

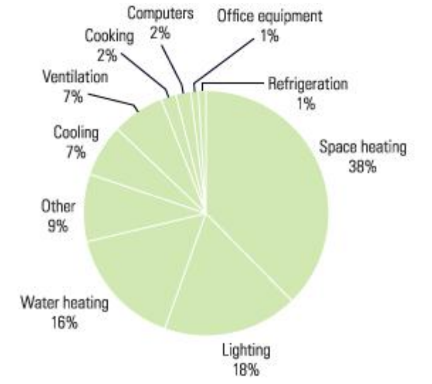
TABLE 8-2: NUMBER OF PANEL REQUIRED PER SYSTEM

	Kyocera KD235GX-LP	BP Solar BP 3230T	Suntech STP210-18
Sun Hours Per Day	4.44	4.44	4.44
Watt Hours Per Day	19784000	19784000	19784000
Watts Per Hour of Sunlight	4455856	4455856	4455856
Rate of Power Per Panel	235W	230W	210W
# of Panels Required	**18961**	**19373**	**21218**

As shown in *Table 8-2* the most efficient system would be the Kyocera KD235GX-LP due to the fewer amount of panels required. Although, this system is the one to be utilized, it is impossible to mount 18,961 panels on the roof of the Children's Hospital. It would require an approximate area of 474,025SF which is 12 times more than what is available. To achieve a more realistic goal, the following section will determine # of panels required based on the average percentage of end use energy provided by the U.S. Energy Information Administration.

**** See APPENDIX F for PV-Panel Product Details.***

8.6 A REALISTIC APPROACH TO NUMBER OF PANELS REQUIRED (ELECTRICAL BREADTH)



Note: Percentages may not add up to 100% due to rounding.

© E SOURCE; data from the U.S. Energy Information Administration (2003)

FIGURE 8-11: End Use Energy Consumption in Hospital

As discussed in the previous section, eliminating the diesel generators would be unrealistic due to the amount of solar panels required which exceeds the available roof area. To be more realistic in choosing the number of panels required to be able to power specific systems at the Children's Hospital, a resource from the U.S. Energy Information Administration shows the end use energy consumption data for hospital buildings. *Figure 8-3* shows a percentage breakdown for end use energy consumption at hospitals. In this section, a brief analysis will look at each division and determine the number of solar panels required to power the division.

TABLE 8-3: NUMBER OF PANEL REQUIRED PER DIVISION

DIVISION	End Use Percentage	Watt Hours Per Day	# of Panels Req'd	Is it Feasible?
Office Equipment	1%	197840	189.61	YES
Refrigeration	1%	197840	189.61	YES
Space Heating	38%	7517920	7205.18	NO
Lighting	18%	3561120	3412.98	NO
Water Heating	16%	3165440	3033.76	NO
Cooling	7%	1384880	1327.27	NO
Ventilation	7%	1384880	1327.27	NO
Cooking	2%	395680	379.22	YES
Computers	2%	395680	379.22	YES
Others	8%	1582720	1516.88	NO
TOTAL	**100%**	**19784000**	**18961**	

As shown in *Table 8-3*, one of the four feasible divisions may be fully powered by a solar photovoltaic system. Upon intensive review of the roof structure and obstructions it appears to be extremely difficult to utilize the entire roof area for solar panels as unexpected conditions have been discovered. Systems such as air cooled chillers, smoke and air vents, stair tower, roof drains and many other systems obstruct major areas. In an effort to minimize clashing with other systems, the largest free of obstructions area was 4180SF. Given the dimensions of the Kyocera KD235GX-LP being 38"x66", the maximum amount of panels in the 4180SF area would be limited to 240 Panels only. Therefore the photovoltaic system will be selected to power all of the office equipments that require 190 panels. The additional 50 panels will be incorporated to account for any system inefficiencies.

8.7 LAYOUT OF THE PV SYSTEM

As shown in *Image 8-4*, each Kyocera KD235GX-LP panels with a size of 38"x66" will be mounted on the roof of the Children's Hospital. The selected area of 4180 SF will be sufficient to mount 240 panels in columns of 20 panels and a total of 12 rows. The spacing between each row was set at 3 feet to enable easy access for maintenance and cleaning purposes. Each row of panels will be set directly on top of the beams spanning two bays. This placement was elected to simplify the structural impact analysis of the system.

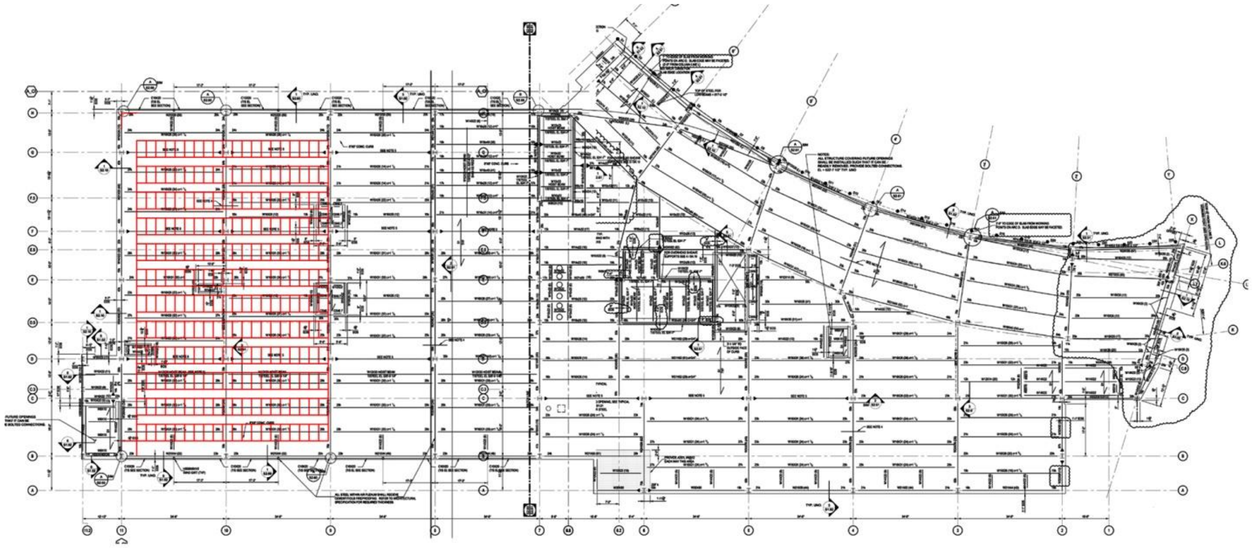


IMAGE 8-12: Layout of the PV-Panels on the Roof of the Children's Hospital

8.8 ELECTRICAL ENERGY PRODUCTION (ELECTRICAL BREADTH)

TABLE 8-4: STATION IDENTIFICATION

State:	Pennsylvania
Latitude:	N 40°15'
Longitude:	W 76°46'
PV System Specifications	
DC Rating:	56.4 kW
DC to AC Derate Factor:	0.770
AC Rating:	47.4 kW
Array Type:	Fixed Tilt
Array Tilt:	40.0 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.3 ¢/kWh

In order to determine the potential energy production for the Kyocera KD235GX-LP panels, it was necessary to find the AC energy output for the entire system. Researching and reading many PV solar guides led to the National Renewable Energy Laboratory website (nrel.gov) where a photovoltaic system calculator that calculates annual AC energy produced was found. As shown in *Table 8-4* the calculator required the input of building location, DC rating of entire system, DC to AC Derate Factor (kept as default value), array type and tilt, and finally the cost of electricity for the location. The cost of electricity of 9.3¢/kWh was determined from the U.S. Energy Information Administration website. Upon entering all of the initial values, the calculator then calculated the solar insolation values for each month, the AC energy production, as well as the value of the produced energy as shown in *Table 8-5*.

TABLE 8-5: ELECTRIC ENERGY PRODUCTION RESULTS

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	3.12	4679	$ 436.08
2	3.75	5040	$ 469.73
3	5.03	7298	$ 680.17
4	5.14	6960	$ 648.67
5	5.43	7239	$ 674.67
6	5.54	6962	$ 648.86
7	5.33	6876	$ 640.84
8	5.25	6813	$ 634.97
9	4.93	6316	$ 588.65
10	4.49	6180	$ 575.98
11	3.27	4495	$ 418.93
12	2.79	4111	$ 383.15
Year	**4.51**	**72969**	**$ 6800.71**

The 72969 kWh of annual AC electric energy produced is adequate to power the office equipments for the Children's Hospital which requires approximately 72211 kWh of AC electric energy annually.

8.9 STRUCTURAL IMPACT (STRUCTURAL BREADTH)

**** See APPENDIX F for Structural Calculations***

In order to determine the feasibility of installing 240 solar photovoltaic panels on the roof of the Children's Hospital, it is essential to determine the structural impact on the roof. A typical beam and girder will be evaluated to determine if the shear and moment reactions are within the acceptable AISC Manual of Steel Construction values.

The structural calculations will be performed as outlined below:

- Determine the weight of the PV-Panels based on the layout used
- Determine roof assembly weight
- Calculate load combinations
- Determine ultimate moment, M_u
- Calculate required cross-section $Z_{x\text{-req'd}}$ and compare with AISC values to ensure safe range
- Calculate maximum deflection and compare with AISC values to ensure safe range

From the Kyocera product specifications, the selected KD235GX-LP panels weigh 46.3 lbs each and the mounts weigh approximately 59.9 lbs each. *Table 8-6* calculates the loads for the panels based on the PV-Panel layout shown in *section 8.7*.

TABLE 8-6: CALCULATION OF PV SYSTEM LOADS

COMPONENT	WEIGHT (lb)	TRIB. AREA (ft)	# PANELS/BEAM	LOAD (lbs)	BEAM LENGTH (ft)	LINE LOAD (plf)
PV- PANEL	46.3	8	10	463	34.5	**13.42**
PANEL MOUNT	13.6	8	10	136	34.5	**3.94**
TOTAL	**59.9**	**8**	**10**	**599**	**34.5**	**17.36**

The total line load value of 17.36 plf seems to be easily supportable by the structural system if the Children's Hospital. However, a detailed structural calculation pertaining to the structural breadth will be performed to ensure the feasibility of the system on the building's structure.

The roof structure was evaluated at a typical bay of equal sized beams and girders. Due to this structural analysis being a breadth study only, the scope of the calculations will be focused only on an analysis of a single beam and a single girder.

Based on the structural analysis detailed in **Appendix G**, the steel beam and girder will be able to sustain the loads of the designed solar photovoltaic panels. *Table 8-7* will summarize the results of the conducted calculations.

TABLE 8-7: SUMMARY OF STRUCTURAL CALCULATIONS

	Shear, V_x	**Max Shear, V_{nx}**	**Conclusion**
BEAM W16X36	21.959 kips	140 kips	Within Range ∴ OK
	Moment, M_u	**Max Moment, M_{px}**	**Conclusion**
	189.399 k-ft	240 k-ft	Within Range ∴ OK
	Cross-Section, $Z_{x\text{-req'd}}$	**Max Cross-Section, Z_x**	**Conclusion**
	33.675 in^3	64 in^3	Within Range ∴ OK
	Deflection, Δ	**Max Deflection, Δ_{max}**	**Conclusion**
	0.006705 in^2	0.4 in^2	Within Range ∴ OK
	Shear, V_x	**Max Shear, V_{nx}**	**Conclusion**
GIRDER W16X36	21.96 kips	140 kips	Within Range ∴ OK
	Moment, M_u	**Max Moment, M_{px}**	**Conclusion**
	175.68 k-ft	240 k-ft	Within Range ∴ OK
	Cross-Section, $Z_{x\text{-req'd}}$	**Max Cross-Section, Z_x**	**Conclusion**
	46.857 in^3	64 in^3	Within Range ∴ OK
	Deflection, Δ	**Max Deflection, Δ_{max}**	**Conclusion**
	0.5298 in^2	1.725 in^2	Within Range ∴ OK

Based on the summary of the calculations conducted, the photovoltaic system designed for the Children's Hospital is structurally feasible. The next section will discuss the financial costs, benefits, and payback period of the designed system.

8.10 FINANCIAL ANALYSIS

As discussed in the previous sections, the designed photovoltaic system is structurally feasible and is able to generate enough energy to power the office equipment systems. Essentially, this entire system may be feasible; however, it is necessary to conduct a financial analysis to determine whether the system is worth the investment or not.

Based on the U.S. Department of Energy annual report, a photovoltaic system costs approximately \$7500/KW-DC. Based on this average costs, the cost of the designed 56.4 KW-DC photovoltaic system will be determined.

$$\boldsymbol{PV\ System\ Cost} = 56.4\ KW \cdot DC\ \times \frac{\$7500}{KW \cdot DC} = \mathbf{\$423{,}000}$$

Although this may seem to be a high cost for this system, Federal benefits and rebates are offered in the State of Pennsylvania for owners that invest in green and sustainable technologies such as solar photovoltaic systems. The following rebates outlined in *Table 8-8* can be applied for the Children's Hospital and will significantly lower the cost of the system.

TABLE 8-8: SUMMARY OF SYSTEM COSTS – INCLUDING ALL REBATES

SYSTEM COST			**\$423,000**
INCENTIVES	PA Sunshine PV Rebate (Com. >10-100 kW)	\$25,000	
	PA Sunshine PV Rebate (Com. 3-10 kW)	\$7,500	
	Federal PV Tax Credit (Com.) (Jan. 2006)	\$135,000	
	less Total Incentives		**- \$167,500**
INCREASED TAXES	PA Sunshine PV Rebate (Com. >10-100 KW)	\$10,148	
	PA Sunshine PV Rebate (Com. 3-10 kW)	\$3,045	
	plus Total Tax Increase		**+ \$13,193**
NET SYSTEM COST			**\$268,693**

As calculated in *Table 8-8*, the total cost of the designed PV System will be reduced to \$268,693 after applying all rebates and incentives. A \$154,307 federal savings on the new system would certainly lure the owner to consider investing in this sustainable system.

More importantly to the owner are the actual system life cycle costs and payback periods. The length of the payback period almost always dominates the final decision as to whether to implement the new sustainable system or not.

When looking at savings on the electric bill alone, it would take approximately 32 years for the system to payback its up-front cost. However, upon considering Solar Renewable Energy Certificates (SRECs) in the State of Pennsylvania, savings can be significantly more than the electric bill savings. SRECs are given to dedicated owners that can guarantee that their solar produced power does not fall short of the designed values. SRECs are granted for every metered 1000 KWh produced by the PV-Panels. According to srectrade.com, the cost to trade or sell SREC's in the State of Pennsylvania falls in the range of $200-$300 depending on the demands of the market. Due to the designed system being able to generate approximately 72,000 KWh per year, it is possible to claim 72 SREC's annually. *Table 8-9* below calculates the savings from SREC's as well as electric bill savings.

Table 9 below has multiple assumptions and parameters to determine the total savings and payback period. Among the major assumptions and parameters are:

- Cost of Electricity = $0.093/KWh
- Annual Escalation % = 1.5%
- Value of AEC = $250 per 1000 KWh
- System size = 56.4 KW-DC
- System AC Energy Production: 72969 KWh/yr
- Cost of system after incentives: $268,693
- Owner will pay up-front without seeking loans is assumed!

TABLE 8-9: FINANCIAL SAVINGS – 25 YEARS LOOK-AHEAD

YEAR	$/KWH	SREC	$ Savings/yr	Total Savings/yr	Cumulative Savings	Cash Flow
1	$0.09	$18,000.00	$6,713.15	$24,713.15	$24,713.15	**-$243,979.85**
2	$0.09	$18,000.00	$6,813.85	$24,813.85	$49,526.99	**-$219,166.01**
3	$0.09	$18,000.00	$6,916.05	$24,916.05	$74,443.05	**-$194,249.95**
4	$0.10	$18,000.00	$7,019.79	$25,019.79	$99,462.84	**-$169,230.16**
5	$0.10	$18,000.00	$7,125.09	$25,125.09	$124,587.93	**-$144,105.07**
6	$0.10	$18,000.00	$7,231.97	$25,231.97	$149,819.90	**-$118,873.10**
7	$0.10	$18,000.00	$7,340.45	$25,340.45	$175,160.34	**-$93,532.66**
8	$0.10	$18,000.00	$7,450.55	$25,450.55	$200,610.90	**-$68,082.10**
9	$0.10	$18,000.00	$7,562.31	$25,562.31	$226,173.21	**-$42,519.79**
10	$0.11	$18,000.00	$7,675.75	$25,675.75	$251,848.95	**-$16,844.05**
11	$0.11	$18,000.00	$7,790.88	$25,790.88	$277,639.84	**$8,946.84**
12	$0.11	$18,000.00	$7,907.75	$25,907.75	$303,547.58	**$34,854.58**
13	$0.11	$18,000.00	$8,026.36	$26,026.36	$329,573.94	**$60,880.94**
14	$0.11	$18,000.00	$8,146.76	$26,146.76	$355,720.70	**$87,027.70**
15	$0.11	$18,000.00	$8,268.96	$26,268.96	$381,989.66	**$113,296.66**
16	$0.12	$18,000.00	$8,392.99	$26,392.99	$408,382.65	**$139,689.65**
17	$0.12	$18,000.00	$8,518.89	$26,518.89	$434,901.54	**$166,208.54**
18	$0.12	$18,000.00	$8,646.67	$26,646.67	$461,548.21	**$192,855.21**
19	$0.12	$18,000.00	$8,776.37	$26,776.37	$488,324.58	**$219,631.58**
20	$0.12	$18,000.00	$8,908.02	$26,908.02	$515,232.60	**$246,539.60**
21	$0.12	$18,000.00	$9,041.64	$27,041.64	$542,274.24	**$273,581.24**
22	$0.13	$18,000.00	$9,177.26	$27,177.26	$569,451.50	**$300,758.50**
23	$0.13	$18,000.00	$9,314.92	$27,314.92	$596,766.42	**$328,073.42**
24	$0.13	$18,000.00	$9,454.64	$27,454.64	$624,221.06	**$355,528.06**
25	$0.13	$18,000.00	$9,596.46	$27,596.46	$651,817.53	**$383,124.53**
TOTAL		**$450,000.00**	**$201,817.53**	**$651,817.53**		

Based on the summary of the financial calculations conducted, the photovoltaic system designed for the Children's Hospital is financially feasible with a payback period in the 11th year. Considering most PV arrays are warranted for 25 years, 11 years of payback is very plausible leaving 14 extra years of generating revenue for the Children's Hospital.

8.11 RECOMMENDATIONS AND CONCLUSION

Any increased costs on the project would typically raise questions to the owner. Installing a solar photovoltaic system at the Children's Hospital may not seem to be attractive to the owner due to the increased costs. However, after thoroughly researching and investigating the implementation of the solar photovoltaic system, there is no reason to deny that this system would generate more revenue for the hospital in the long run. The owner of the Children's Hospital may not be interested in spending money up-front; however, the Penn State Hershey Medical Center can easily start a fundraiser that would promote implementation of sustainable technologies at the Medical Campus. Penn State's Alumni Association being one of the largest alumni networks in the country can easily generate enough money to install the new system. It is necessary that the Hershey Medical Center not only limit their decision to the up-front costs; instead, the following benefits shall be of more interest:

- 1% of electric energy sustainably generated.
- $6,800 in annual electric bill savings.
- Solar Renewable Energy Certificates worth $18,000 annually.
- Payback period of only 11 years!
- 14 years of pure money generating due to early payback.
- 25 year system warranty.
- High energy production.
- No structural impact on building.
- Easily mounted with sufficient space for maintenance.

Upon completion of this analysis, it is highly recommended that the Penn State Hershey Medical Center considers investing in sustainable technologies as it not only save and generate money but even enhance the public image. Federal incentives and tax breaks today may not be offered in the future due to higher awareness from future owners making sustainable technologies a norm. Installing the PV arrays at the Children's Hospital may also potentially help the Engineering Departments at Penn State research sustainable technologies more realistically and break new grounds in advanced technologies. Investing in sustainable technologies may open new doors for Penn State to better plan for future sustainable projects on campus.

9.0 FINAL RECOMMENDATIONS AND CONCLUSION

The Senior Thesis Capstone Project conducted over the course of the Fall and Spring semester provided a better understanding of the depth of the Children's Hospital project. Individual research and investigations have provided better insight and areas to improve the efficiency and means and methods to perform specific tasks. The three topics discussed in the final report were: **Schedule Acceleration through Multi Trade Prefabrication, Eliminating Inefficiency of Cost Estimating Through 3D Modeling, and the Viability of Incorporating Solar Photovoltaic Systems.** The research conducted and the findings were only meant to serve educational purposes and meeting the goals of the Senior Thesis Capstone Project and are in no way criticizing or perceiving inefficiencies in the outstanding work of the entire project team.

The first analysis aimed at a goal of reducing the project schedule through prefabricating bathroom, pods, patient headwalls, and patient footwalls. This analysis covered a large portion of critical industry issues by discussing how prefabricating new systems is risky to many contractors until someone actually takes the risks and changes the way contractors construct new buildings. The analysis looked at how prefabricating patient rooms can save substantial time on the construction schedule. Among the important findings was that although prefabricating may save time, it can also be disastrous if not planned out early on in the project. Although, it is much recommended for the project team to consider prefabrication in case of a major delay, it would have been more realistic if contractors and subcontractors were brought on-board during the design phase of the project to realistically be able to prefabricate. An important note to be taken for any project considering prefabrication is that the end product of prefabricating must meet the design intent. Also, scope of work in the contracts should indicate the method of construction in order to be able to choose the most qualified subcontractors. Ultimately, prefabrication in most cases saves major time on a project schedule; however, it is not necessary true to save money as increased costs such as utilizing a warehouse and delivering the units must be considered.

The second analysis attempted to investigate methods to reduce the time to quantify building materials and cost estimation in favor of increasing the time for constructability review. With the advent of technology and Building Information Modeling, quantity take-offs and cost estimation can finally be conducted in new efficient methods. The analysis investigated the different methods that can be used to conduct 3D estimates. Due to time limitation on this project, the simplest method of extracting quantity take-offs from a 3D Revit model was used. Setting the structural steel framing of

the building as the benchmark for the study, it was shown that a complete quantity take-off of the structural framing was more accurate and required less time than the traditional manual hand take-offs. It was assumed that this method can be utilized for all building materials and systems; however, upon analyzing the results of a survey sent out to industry professionals, it was found that 3D estimating cannot be depended on for all cases. Industry input in this analysis has changed the expectations of this analysis as it was found that 3D models designed by architects to do not resemble how many systems are actually constructed. For the most part, 3D models are made to serve as a visual tool for the clients instead of being utilized for estimating purposes. It is recommended that clients such as the Penn State Hershey Medical Center mandate that models be designed to resemble actual construction in their future projects. By doing so, the 3D models may be passed on to contractors to make more efficient uses out of them such as conducting quantity take-offs, 4D scheduling, clash detection, and even site logistics planning.

The third analysis aimed at adding sustainable technologies at the Children’s Hospital project. A proposed photovoltaic system was analyzed to determine whether it would viable or not. A solar study proved that the Children’s Hospital is ideal for incorporating a solar PV system due to no shadowing effects from nearby buildings or objects. A 56.4 kW solar photovoltaic system was designed to sustainably power the office equipments at the Children’s Hospital compromising 1% of the total electric energy demand. A total of 240 panels would need to be mounted on the roof of the Children’s Hospital. A structural analysis of a typical roof bay was analyzed and has proved that no structural changes need to be made as expected due to the oversized structural design of the building. The electrical analysis has shown that the photovoltaic system would be able to power the office equipments annually; thus saving the electric bill approximately $6,800 annually in addition to SRECs that can be sold annually for a total value of $18,000 per year. The system total costs after applying the federal incentives and rebates came out to be $269,000 with a short payback of 11 years. It is highly recommended that the Hershey Medical Center considers a photovoltaic system as it would increase the publicity of the hospital as well as having a win-win situation due to a short payback period considering the system is good for 25 years.

In conclusion, the Senior Thesis Capstone project has provided insight and increased knowledge in the AEC industry. Showcasing a prefabrication effort at the Children’s Hospital has proven advantageous results in time savings as well as site logistics. The utilization of BIM for quantifying building materials has shown significant time savings as well as accuracies; however, designers

must design the models the way they are built in order to fully benefit from BIM estimation methods. Finally, incorporating a photovoltaic system has proven to be financially feasible with relatively quick payback time. It is believed that all the analyses have addressed major issues in the building construction industry.

10.0 RESOURCES

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APPENDIX A: QUANTITY TAKE-OFFS & COSTWORKS REPORTS

STRUCTURAL CONCRETE – RS MEANS COSTWORKS REPORT

LineNumber	Quantity	Unit	Description	Crew	Daily Output	Labor Hours	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Mat. O&P	Labor O&P	Equip. O&P	Total O&P	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P
033105000000			Normal Weight Structural Concrete																			
033105350012			Structural concrete, ready mix, normal weight																			
033105350300	9000	C.Y.	Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments				$ 90.33	$ -	$ -	$ 90.33	$ 812,970.00	$ -	$ -	$ 812,970.00	$ 99.10	$ -	$ -	$ 99.10	$ 891,900.00	$ -	$ -	$ 891,900.00
033105700020			Structural concrete placing, includes labor and equipment to place, strike off and consolidate, excludes material																			
033105701400	3500	C.Y.	Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike off & consolidation, excludes material	C20	140	0.457	$ -	$ 15.68	$ 6.59	$ 22.27	$ -	$ 54,880.00	$ 23,065.00	$ 77,945.00	$ -	$ 23.72	$ 7.28	$ 31.00	$ -	$ 83,020.00	$ 25,480.00	$ 108,500.00
033105701950	310	C.Y.	Structural concrete, placing, continuous footing, shallow, pumped, includes strike off & consolidation, excludes material	C20	150	0.427	$ -	$ 14.62	$ 6.18	$ 20.80	$ -	$ 4,532.20	$ 1,915.80	$ 6,448.00	$ -	$ 22.26	$ 6.76	$ 29.02	$ -	$ 6,900.60	$ 2,095.60	$ 8,996.20
033105703250	130	C.Y.	Structural concrete, placing, grade beam, pumped, includes strike off & consolidation, excludes material	C20	180	0.356	$ -	$ 12.20	$ 5.13	$ 17.33	$ -	$ 1,586.00	$ 666.90	$ 2,252.90	$ -	$ 18.59	$ 5.65	$ 24.24	$ -	$ 2,416.70	$ 734.50	$ 3,151.20
033105703750	110	C.Y.	Structural concrete, placing, pile caps, pumped, under 5 CY, includes strike off & consolidation, excludes material	C20	110	0.582	$ -	$ 19.84	$ 8.38	$ 28.22	$ -	$ 2,182.40	$ 921.80	$ 3,104.20	$ -	$ 30.49	$ 9.25	$ 39.74	$ -	$ 3,353.90	$ 1,017.50	$ 4,371.40
033105703900	110	C.Y.	Structural concrete, placing, pile caps, pumped, 6 C.Y. to 10 C.Y., includes strike off & consolidation, excludes material	C20	200	0.32	$ -	$ 10.99	$ 4.62	$ 15.61	$ -	$ 1,208.90	$ 508.20	$ 1,717.10	$ -	$ 16.70	$ 5.09	$ 21.79	$ -	$ 1,837.00	$ 559.90	$ 2,396.90
033105704050	820	C.Y.	Structural concrete, placing, pile caps, pumped, over 10 CY, includes strike off & consolidation, excludes material	C20	240	0.267	$ -	$ 9.15	$ 3.85	$ 13.00	$ -	$ 7,503.00	$ 3,157.00	$ 10,660.00	$ -	$ 13.94	$ 4.23	$ 18.17	$ -	$ 11,430.80	$ 3,468.60	$ 14,899.40
033105704300	1000	C.Y.	Structural concrete, placing, slab on grade, direct chute, up to 6" thick, includes strike off & consolidation, excludes material	C6	110	0.436	$ -	$ 14.57	$ 0.64	$ 15.21	$ -	$ 14,570.00	$ 640.00	$ 15,210.00	$ -	$ 22.26	$ 0.71	$ 22.97	$ -	$ 22,260.00	$ 710.00	$ 22,970.00
031113350010			FORMS IN PLACE, ELEVATED SLABS																			
031113357000	9600	L.F.	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	C1	500	0.064	$ 0.11	$ 2.24	$ -	$ 2.35	$ 1,056.00	$ 21,504.00	$ -	$ 22,560.00	$ 0.12	$ 3.46	$ -	$ 3.58	$ 1,152.00	$ 33,216.00	$ -	$ 34,368.00
031113650010			FORMS IN PLACE, SLAB ON GRADE																			
031113653000	1500	L.F.	C.I.P. concrete forms, slab on grade, edge, wood, to 6" high, 4 use, includes erecting, bracing, stripping and cleaning	C1	600	0.053	$ 0.26	$ 1.87	$ -	$ 2.13	$ 390.00	$ 2,805.00	$ -	$ 3,195.00	$ 0.29	$ 2.88	$ -	$ 3.17	$ 435.00	$ 4,320.00	$ -	$ 4,755.00
031113653050	50	SFCA	C.I.P. concrete forms, slab on grade, edge, wood, 7" to 12" high, 4 use, includes erecting, bracing, stripping and cleaning	C1	435	0.074	$ 0.56	$ 2.58	$ -	$ 3.14	$ 28.00	$ 129.00	$ -	$ 157.00	$ 0.62	$ 3.97	$ -	$ 4.59	$ 31.00	$ 198.50	$ -	$ 229.50
031113450010			FORMS IN PLACE, FOOTINGS																			
031113450020	14900	SFCA	C.I.P. concrete forms, footing, continuous wall, plywood, 1 use, includes erecting, bracing, stripping and cleaning	C1	375	0.085	$ 5.01	$ 3.00	$ -	$ 8.01	$ 74,649.00	$ 44,700.00	$ -	$ 119,349.00	$ 5.49	$ 4.62	$ -	$ 10.11	$ 81,801.00	$ 68,838.00	$ -	$ 150,639.00
031113453000	17500	SFCA	C.I.P. concrete forms, pile cap, square or rectangular, plywood, 1 use, includes erecting, bracing, stripping and cleaning	C1	290	0.11	$ 2.05	$ 3.87	$ -	$ 5.92	$ 35,875.00	$ 67,725.00	$ -	$ 103,600.00	$ 2.25	$ 5.96	$ -	$ 8.21	$ 39,375.00	$ 104,300.00	$ -	$ 143,675.00
031113454000	1770	SFCA	C.I.P. concrete forms, pile cap, triangular or hexagonal plywood, 1 use, includes erecting, bracing, stripping and cleaning	C1	225	0.142	$ 2.39	$ 4.98	$ -	$ 7.37	$ 4,230.30	$ 8,814.60	$ -	$ 13,044.90	$ 2.63	$ 7.69	$ -	$ 10.32	$ 4,655.10	$ 13,611.30	$ -	$ 18,266.40
031113500010			FORMS IN PLACE, GRADE BEAM																			
031113500020	5750	SFCA	C.I.P. concrete forms, grade beam, plywood, 1 use, includes erecting, bracing, stripping and cleaning	C2	530	0.091	$ 2.20	$ 3.26	$ -	$ 5.46	$ 12,650.00	$ 18,745.00	$ -	$ 31,395.00	$ 2.42	$ 5.02	$ -	$ 7.44	$ 13,915.00	$ 28,865.00	$ -	$ 42,780.00
031113850010			FORMS IN PLACE, WALLS																			
031113854200	33000	SFCA	C.I.P. concrete forms, wall, radial, smooth curved, below grade, job built plywood, to 8' high, 1 use, includes erecting, bracing, stripping and cleaning	C2	225	0.213	$ 1.80	$ 7.69	$ -	$ 9.49	$ 59,400.00	$ 253,770.00	$ -	$ 313,170.00	$ 1.99	$ 11.82	$ -	$ 13.81	$ 65,670.00	$ 390,060.00	$ -	$ 455,730.00
033923130010			CHEMICAL COMPOUND MEMBRANE CONCRETE CURING																			
033923130300	3500	C.S.F.	Concrete surface treatment, curing, sprayed membrane compound	2 Clab	95	0.168	$ 5.35	$ 5.37	$ -	$ 10.72	$ 18,725.00	$ 18,795.00	$ -	$ 37,520.00	$ 5.92	$ 8.32	$ -	$ 14.24	$ 20,720.00	$ 29,120.00	$ -	$ 49,840.00
033500000000			Concrete Finishing																			
033529000000			Tooled Concrete Finishing																			
033529300015			Concrete finishing, floors, basic finishing for unspecified flatwork, excludes placing, striking off & consolidating																			
033529300200	310000	S.F.	Concrete finishing, floors, basic finishing for unspecified flatwork, bull float, manual float & manual steel trowel, excludes placing, striking off & consolidating	C10	1265	0.019	$ -	$ 0.69	$ -	$ 0.69	$ -	$ 213,900.00	$ -	$ 213,900.00	$ -	$ 1.03	$ -	$ 1.03	$ -	$ 319,300.00	$ -	$ 319,300.00
053100000000			Steel Decking																			
053113505300	265000	S.F.	Metal floor decking, steel, non-cellular, composite, galvanized, 2" D, 20 gauge	E4	3600	0.009	$ 1.47	$ 0.52	$ 0.05	$ 2.04	$ 389,550.00	$ 137,800.00	$ 13,250.00	$ 540,600.00	$ 1.62	$ 0.91	$ 0.05	$ 2.58	$ 429,300.00	$ 241,150.00	$ 13,250.00	$ 683,700.00
032200000000			Welded Wire Fabric Reinforcing																			
032205500050			Welded wire fabric, sheets																			
032205500200	2700	C.S.F.	Welded wire fabric, sheets, 6 x 6 - W2.1 x W2.1 (8 x 8) 30 lb. per C.S.F., A185	2 Rodm	31	0.516	$ 18.98	$ 25.30	$ -	$ 44.28	$ 51,246.00	$ 68,310.00	$ -	$ 119,556.00	$ 20.71	$ 41.11	$ -	$ 61.82	$ 55,917.00	$ 110,997.00	$ -	$ 166,914.00
			Total								$ 1,460,769.30	$ 943,460.10	$ 44,124.70	$ 2,448,354.10					$ 1,604,871.10	$ 1,475,194.80	$ 47,316.10	$ 3,127,382.00

STRUCTURAL STEEL – RS MEANS COSTWORKS REPORT (1/2)

LineNumber	Quantity	Unit	Description	Crew	Daily Output	Labor Hours	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Mat. O&P	Labor O&P	Equip. O&P	Total O&P	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P
051223170010			COLUMNS, STRUCTURAL																			
051223174550	155	Ea.	Column, structural tubing, 6" x 6" x 1/4" x 12'-0", incl shop primer, cap & base plate, bolts	E2	54	1.037	$ 277.40	$ 57.33	$ 34.68	$ 369.41	$ 42,997.00	$ 8,886.15	$ 5,375.40	$ 57,258.55	$ 303.55	$ 96.56	$ 37.57	$ 437.68	$ 47,050.25	$ 14,966.80	$ 5,823.35	$ 67,840.40
051223174600	54	Ea.	Column, structural tubing, 8" x 8" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	E2	50	1.12	$ 602.43	$ 61.56	$ 36.99	$ 700.98	$ 32,531.22	$ 3,324.24	$ 1,997.46	$ 37,852.92	$ 663.14	$ 104.41	$ 41.04	$ 808.59	$ 35,809.56	$ 5,638.14	$ 2,216.16	$ 43,663.86
051223175700	2	Ea.	Column, structural tubing, 12" x 8" x 1/2" x 16'-0", incl shop primer, cap & base plate, bolts	E2	48	1.167	$ 1,120.80	$ 63.97	$ 38.73	$ 1,223.50	$ 2,241.60	$ 127.94	$ 77.46	$ 2,447.00	$ 1,214.20	$ 108.63	$ 42.77	$ 1,365.60	$ 2,428.40	$ 217.26	$ 85.54	$ 2,731.20
051223177000	331	L.F.	Column, structural, 2-tier, W10x45, A992 steel, incl shop primer, splice plates, bolts	E2	1032	0.054	$ 50.90	$ 2.98	$ 1.80	$ 55.68	$ 16,847.90	$ 986.38	$ 595.80	$ 18,430.08	$ 56.04	$ 5.05	$ 1.98	$ 63.07	$ 18,549.24	$ 1,671.55	$ 655.38	$ 20,876.17
051223177150	96	L.F.	Column, structural, 2-tier, W12x50, A992 steel, incl shop primer, splice plates, bolts	E2	1032	0.054	$ 56.51	$ 2.98	$ 1.80	$ 61.29	$ 5,424.96	$ 286.08	$ 172.80	$ 5,883.84	$ 62.11	$ 5.05	$ 1.98	$ 69.14	$ 5,962.56	$ 484.80	$ 190.08	$ 6,637.44
051223177350	2458	L.F.	Column, structural, 2-tier, W14x74, A992 steel, incl shop primer, splice plates, bolts	E2	984	0.057	$ 83.59	$ 3.14	$ 1.88	$ 88.61	$ 205,464.22	$ 7,718.12	$ 4,621.04	$ 217,803.38	$ 92.00	$ 5.30	$ 2.08	$ 99.38	$ 226,136.00	$ 13,027.40	$ 5,112.64	$ 244,276.04
051223177400	1601	L.F.	Column, structural, 2-tier, W14x120, A992 steel, incl shop primer, splice plates, bolts	E2	960	0.058	$ 135.43	$ 3.21	$ 1.93	$ 140.57	$ 216,823.43	$ 5,139.21	$ 3,089.93	$ 225,052.57	$ 149.44	$ 5.43	$ 2.13	$ 157.00	$ 239,253.44	$ 8,693.43	$ 3,410.13	$ 251,357.00
051223177450	2554	L.F.	Column, structural, 2-tier, W14x176, A992 steel, incl shop primer, splice plates, bolts	E2	912	0.061	$ 198.94	$ 3.38	$ 2.03	$ 204.35	$ 508,092.76	$ 8,632.52	$ 5,184.62	$ 521,909.90	$ 218.56	$ 5.71	$ 2.24	$ 226.51	$ 558,202.24	$ 14,583.34	$ 5,720.96	$ 578,506.54
051223750010			STRUCTURAL STEEL MEMBERS																			
051223750140	52	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W6x20, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 22.42	$ 5.14	$ 3.10	$ 30.66	$ 1,165.84	$ 267.28	$ 161.20	$ 1,594.32	$ 24.75	$ 8.69	$ 3.41	$ 36.85	$ 1,287.00	$ 451.88	$ 177.32	$ 1,916.20
051223750300	305	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 11.30	$ 5.14	$ 3.10	$ 19.54	$ 3,446.50	$ 1,567.70	$ 945.50	$ 5,959.70	$ 12.42	$ 8.69	$ 3.41	$ 24.52	$ 3,788.10	$ 2,650.45	$ 1,040.05	$ 7,478.60
051223750350	111	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W8x21, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 23.82	$ 5.14	$ 3.10	$ 32.06	$ 2,644.02	$ 570.54	$ 344.10	$ 3,558.66	$ 26.15	$ 8.69	$ 3.41	$ 38.25	$ 2,902.65	$ 964.59	$ 378.51	$ 4,245.75
051223750360	12	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W8x24, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	$ 27.09	$ 5.60	$ 3.38	$ 36.07	$ 325.08	$ 67.20	$ 40.56	$ 432.84	$ 29.89	$ 9.47	$ 3.71	$ 43.07	$ 358.68	$ 113.64	$ 44.52	$ 516.84
051223750500	54	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W8x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	$ 35.03	$ 5.60	$ 3.38	$ 44.01	$ 1,891.62	$ 302.40	$ 182.52	$ 2,376.54	$ 38.76	$ 9.47	$ 3.71	$ 51.94	$ 2,093.04	$ 511.38	$ 200.34	$ 2,804.76
051223750600	185	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W10x12, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 13.54	$ 5.14	$ 3.10	$ 21.78	$ 2,504.90	$ 950.90	$ 573.50	$ 4,029.30	$ 14.90	$ 8.69	$ 3.41	$ 27.00	$ 2,756.50	$ 1,607.65	$ 630.85	$ 4,995.00
051223750620	26	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W10x15, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 16.95	$ 5.14	$ 3.10	$ 25.19	$ 440.70	$ 133.64	$ 80.60	$ 654.94	$ 18.63	$ 8.69	$ 3.41	$ 30.73	$ 484.38	$ 225.94	$ 88.66	$ 798.98
051223750700	3010	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	$ 24.75	$ 5.14	$ 3.10	$ 32.99	$ 74,497.50	$ 15,471.40	$ 9,331.00	$ 99,299.90	$ 27.55	$ 8.69	$ 3.41	$ 39.65	$ 82,925.50	$ 26,156.90	$ 10,264.10	$ 119,346.50
051223750740	106	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W10x33, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	$ 37.36	$ 5.60	$ 3.38	$ 46.34	$ 3,960.16	$ 593.60	$ 358.28	$ 4,912.04	$ 41.10	$ 9.47	$ 3.71	$ 54.28	$ 4,356.60	$ 1,003.82	$ 393.26	$ 5,753.68
051223750900	57	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W10x49, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	$ 55.57	$ 5.60	$ 3.38	$ 64.55	$ 3,167.49	$ 319.20	$ 192.66	$ 3,679.35	$ 60.71	$ 9.47	$ 3.71	$ 73.89	$ 3,460.47	$ 539.79	$ 211.47	$ 4,211.73
051223751100	1621	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x16, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	$ 18.07	$ 3.50	$ 2.12	$ 23.69	$ 29,291.47	$ 5,673.50	$ 3,436.52	$ 38,401.49	$ 20.08	$ 5.93	$ 2.32	$ 28.33	$ 32,549.68	$ 9,612.53	$ 3,760.72	$ 45,922.93
051223751300	133	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	$ 24.75	$ 3.50	$ 2.12	$ 30.37	$ 3,291.75	$ 465.50	$ 281.96	$ 4,039.21	$ 27.55	$ 5.93	$ 2.32	$ 35.80	$ 3,664.15	$ 788.69	$ 308.56	$ 4,761.40
051223751500	705	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	$ 29.42	$ 3.50	$ 2.12	$ 35.04	$ 20,741.10	$ 2,467.50	$ 1,494.60	$ 24,703.20	$ 32.22	$ 5.93	$ 2.32	$ 40.47	$ 22,715.10	$ 4,180.65	$ 1,635.60	$ 28,531.35
051223751520	233	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	810	0.069	$ 39.70	$ 3.80	$ 2.29	$ 45.79	$ 9,250.10	$ 885.40	$ 533.57	$ 10,669.07	$ 43.43	$ 6.46	$ 2.52	$ 52.41	$ 10,119.19	$ 1,505.18	$ 587.16	$ 12,211.53
051223751560	32	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	750	0.075	$ 56.51	$ 4.12	$ 2.47	$ 63.10	$ 1,808.32	$ 131.84	$ 79.04	$ 2,019.20	$ 62.11	$ 6.94	$ 2.73	$ 71.78	$ 1,987.52	$ 222.08	$ 87.36	$ 2,296.96
051223751700	17	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W12x72, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	640	0.088	$ 81.26	$ 4.82	$ 2.90	$ 88.98	$ 1,381.42	$ 81.94	$ 49.30	$ 1,512.66	$ 89.66	$ 8.15	$ 3.19	$ 101.00	$ 1,524.22	$ 138.55	$ 54.23	$ 1,717.00
051223751900	3580	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W14x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	990	0.057	$ 29.42	$ 3.11	$ 1.87	$ 34.40	$ 105,323.60	$ 11,133.80	$ 6,694.60	$ 123,152.00	$ 32.22	$ 5.26	$ 2.07	$ 39.55	$ 115,347.60	$ 18,830.80	$ 7,410.60	$ 141,589.00
051223752100	133	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W14x30, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.062	$ 34.09	$ 3.43	$ 2.07	$ 39.59	$ 4,533.97	$ 456.19	$ 275.31	$ 5,265.47	$ 37.36	$ 5.79	$ 2.27	$ 45.42	$ 4,968.88	$ 770.07	$ 301.91	$ 6,040.86
051223752300	48	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W14x34, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	810	0.069	$ 38.29	$ 3.80	$ 2.29	$ 44.38	$ 1,837.92	$ 182.40	$ 109.92	$ 2,130.24	$ 42.50	$ 6.46	$ 2.52	$ 51.48	$ 2,040.00	$ 310.08	$ 120.96	$ 2,471.04
051223752320	40	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W14x43, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	810	0.069	$ 48.57	$ 3.80	$ 2.29	$ 54.66	$ 1,942.80	$ 152.00	$ 91.60	$ 2,186.40	$ 53.24	$ 6.46	$ 2.52	$ 62.22	$ 2,129.60	$ 258.40	$ 100.80	$ 2,488.80
051223752340	139	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W14x53, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	$ 59.78	$ 3.85	$ 2.32	$ 65.95	$ 8,309.42	$ 535.15	$ 322.48	$ 9,167.05	$ 65.85	$ 6.52	$ 2.55	$ 74.92	$ 9,153.15	$ 906.28	$ 354.45	$ 10,413.88
051223752700	13466	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W16x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	1000	0.056	$ 29.42	$ 3.08	$ 1.86	$ 34.36	$ 396,169.72	$ 41,475.28	$ 25,046.76	$ 462,691.76	$ 32.22	$ 5.21	$ 2.05	$ 39.48	$ 433,874.52	$ 70,157.86	$ 27,605.30	$ 531,637.68
051223752900	6517	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.062	$ 35.03	$ 3.43	$ 2.07	$ 40.53	$ 228,290.51	$ 22,353.31	$ 13,490.19	$ 264,134.01	$ 38.76	$ 5.79	$ 2.27	$ 46.82	$ 252,598.92	$ 37,733.43	$ 14,793.59	$ 305,125.94
051223753100	1040	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W16x40, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	$ 45.30	$ 3.85	$ 2.32	$ 51.47	$ 47,112.00	$ 4,004.00	$ 2,412.80	$ 53,528.80	$ 49.50	$ 6.52	$ 2.55	$ 58.57	$ 51,480.00	$ 6,780.80	$ 2,652.00	$ 60,912.80
051223753120	102	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W16x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	$ 56.51	$ 3.85	$ 2.32	$ 62.68	$ 5,764.02	$ 392.70	$ 236.64	$ 6,393.36	$ 62.11	$ 6.52	$ 2.55	$ 71.18	$ 6,335.22	$ 665.04	$ 260.10	$ 7,260.36

STRUCTURAL STEEL – RS MEANS COSTWORKS REPORT (2/2)

LineNumber	Quantity	Unit	Description	Crew	Daily Output	Labor Hours	Material	Labor	Equipment	Total	Ext. Mat.	Ext. Labor	Ext. Equip.	Ext. Total	Mat. O&P	Labor O&P	Equip. O&P	Total O&P	Ext. Mat. O&P	Ext. Labor O&P	Ext. Equip. O&P	Ext. Total O&P
051223753140	7	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W16x67, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	760	0.074	$ 75.65	$ 4.06	$ 2.44	$ 82.15	$ 529.55	$ 28.42	$ 17.08	$ 575.05	$ 83.13	$ 6.88	$ 2.69	$ 92.70	$ 581.91	$ 48.16	$ 18.83	$ 648.90
051223753300	3142	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	$ 39.70	$ 4.65	$ 2.12	$ 46.47	$ 124,737.40	$ 14,610.30	$ 6,661.04	$ 146,008.74	$ 43.43	$ 7.97	$ 2.32	$ 53.72	$ 136,457.06	$ 25,041.74	$ 7,289.44	$ 168,788.24
051223753500	1455	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x40, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	$ 45.30	$ 4.65	$ 2.12	$ 52.07	$ 65,911.50	$ 6,765.75	$ 3,084.60	$ 75,761.85	$ 49.50	$ 7.97	$ 2.32	$ 59.79	$ 72,022.50	$ 11,596.35	$ 3,375.60	$ 86,994.45
051223753520	1859	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x46, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	$ 51.84	$ 4.65	$ 2.12	$ 58.61	$ 96,370.56	$ 8,644.35	$ 3,941.08	$ 108,955.99	$ 56.97	$ 7.97	$ 2.32	$ 67.26	$ 105,907.23	$ 14,816.23	$ 4,312.88	$ 125,036.34
051223753700	2609	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	912	0.088	$ 56.51	$ 4.89	$ 2.22	$ 63.62	$ 147,434.59	$ 12,758.01	$ 5,791.98	$ 165,984.58	$ 62.11	$ 8.39	$ 2.44	$ 72.94	$ 162,044.99	$ 21,889.51	$ 6,365.96	$ 190,300.46
051223753900	1973	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x55, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	912	0.088	$ 62.11	$ 4.89	$ 2.22	$ 69.22	$ 122,543.03	$ 9,647.97	$ 4,380.06	$ 136,571.06	$ 68.18	$ 8.39	$ 2.44	$ 79.01	$ 134,519.14	$ 16,553.47	$ 4,814.12	$ 155,886.73
051223753920	1453	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x65, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	$ 73.32	$ 4.96	$ 2.25	$ 80.53	$ 106,533.96	$ 7,206.88	$ 3,269.25	$ 117,010.09	$ 80.79	$ 8.51	$ 2.47	$ 91.77	$ 117,387.87	$ 12,365.03	$ 3,588.91	$ 133,341.81
051223753940	2676	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x76, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	$ 85.93	$ 4.96	$ 2.25	$ 93.14	$ 229,948.68	$ 13,272.96	$ 6,021.00	$ 249,242.64	$ 94.33	$ 8.51	$ 2.47	$ 105.31	$ 252,427.08	$ 22,772.76	$ 6,609.72	$ 281,809.56
051223753960	850	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x86, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	$ 97.14	$ 4.96	$ 2.25	$ 104.35	$ 82,569.00	$ 4,216.00	$ 1,912.50	$ 88,697.50	$ 106.48	$ 8.51	$ 2.47	$ 117.46	$ 90,508.00	$ 7,233.50	$ 2,099.50	$ 99,841.00
051223753980	3154	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W18x106, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	$ 119.55	$ 4.96	$ 2.25	$ 126.76	$ 377,060.70	$ 15,643.84	$ 7,096.50	$ 399,801.04	$ 131.69	$ 8.51	$ 2.47	$ 142.67	$ 415,350.26	$ 26,840.54	$ 7,790.38	$ 449,981.18
051223754780	170	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W21x122, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1000	0.08	$ 138.23	$ 4.47	$ 2.02	$ 144.72	$ 23,499.10	$ 759.90	$ 343.40	$ 24,602.40	$ 151.31	$ 7.60	$ 2.23	$ 161.14	$ 25,722.70	$ 1,292.00	$ 379.10	$ 27,393.80
051223755780	95	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W24x146, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1050	0.076	$ 165.32	$ 4.25	$ 1.93	$ 171.50	$ 15,705.40	$ 403.75	$ 183.35	$ 16,292.50	$ 181.20	$ 7.24	$ 2.13	$ 190.57	$ 17,214.00	$ 687.80	$ 202.35	$ 18,104.15
051223755940	43	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W27x146, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1150	0.07	$ 165.32	$ 3.87	$ 1.76	$ 170.95	$ 7,108.76	$ 166.41	$ 75.68	$ 7,350.85	$ 181.20	$ 6.64	$ 1.94	$ 189.78	$ 7,791.60	$ 285.52	$ 83.42	$ 8,160.54
051223756520	116	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W30x132, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1160	0.069	$ 149.44	$ 3.85	$ 1.75	$ 155.04	$ 17,335.04	$ 446.60	$ 203.00	$ 17,984.64	$ 164.38	$ 6.58	$ 1.92	$ 172.88	$ 19,068.08	$ 763.28	$ 222.72	$ 20,054.08
051223756560	1388	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W30x173, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1120	0.071	$ 195.21	$ 3.98	$ 1.81	$ 201.00	$ 270,951.48	$ 5,524.24	$ 2,512.28	$ 278,988.00	$ 214.82	$ 6.82	$ 1.99	$ 223.63	$ 298,170.16	$ 9,466.16	$ 2,762.12	$ 310,398.44
051223756700	151	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W33x118, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1176	0.068	$ 133.56	$ 3.79	$ 1.72	$ 139.07	$ 20,167.56	$ 572.29	$ 259.72	$ 20,999.57	$ 146.64	$ 6.52	$ 1.90	$ 155.06	$ 22,142.64	$ 984.52	$ 286.90	$ 23,414.06
051223756900	152	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W33x130, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1134	0.071	$ 146.64	$ 3.93	$ 1.79	$ 152.36	$ 22,289.28	$ 597.36	$ 272.08	$ 23,158.72	$ 161.58	$ 6.76	$ 1.97	$ 170.31	$ 24,560.16	$ 1,027.52	$ 299.44	$ 25,887.12
051223757100	30	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W33x141, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1134	0.071	$ 159.71	$ 3.93	$ 1.79	$ 165.43	$ 4,791.30	$ 117.90	$ 53.70	$ 4,962.90	$ 175.59	$ 6.76	$ 1.97	$ 184.32	$ 5,267.70	$ 202.80	$ 59.10	$ 5,529.60
051223757120	30	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W33x169, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1100	0.073	$ 190.54	$ 4.06	$ 1.84	$ 196.44	$ 5,716.20	$ 121.80	$ 55.20	$ 5,893.20	$ 210.15	$ 6.94	$ 2.02	$ 219.11	$ 6,304.50	$ 208.20	$ 60.60	$ 6,573.30
051223757140	43	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W33x201, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1100	0.073	$ 226.96	$ 4.06	$ 1.84	$ 232.86	$ 9,759.28	$ 174.58	$ 79.12	$ 10,012.98	$ 250.31	$ 6.94	$ 2.02	$ 259.27	$ 10,763.33	$ 298.42	$ 86.86	$ 11,148.61
051223757300	28	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W36x135, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1170	0.068	$ 152.24	$ 3.81	$ 1.73	$ 157.78	$ 4,262.72	$ 106.68	$ 48.44	$ 4,417.84	$ 168.12	$ 6.52	$ 1.91	$ 176.55	$ 4,707.36	$ 182.56	$ 53.48	$ 4,943.40
051223757500	74	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W36x150, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1170	0.068	$ 169.99	$ 3.81	$ 1.73	$ 175.53	$ 12,579.26	$ 281.94	$ 128.02	$ 12,989.22	$ 186.80	$ 6.52	$ 1.91	$ 195.23	$ 13,823.20	$ 482.48	$ 141.34	$ 14,447.02
051223757700	82	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W36x194, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1125	0.071	$ 219.49	$ 3.96	$ 1.80	$ 225.25	$ 17,998.18	$ 324.72	$ 147.60	$ 18,470.50	$ 240.97	$ 6.76	$ 1.98	$ 249.71	$ 19,759.54	$ 554.32	$ 162.36	$ 20,476.22
051223757900	1346	L.F.	Structural steel member, 100-ton project, 1 to 2 story building, W36x231, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1125	0.071	$ 261.52	$ 3.96	$ 1.80	$ 267.28	$ 352,005.92	$ 5,330.16	$ 2,422.80	$ 359,758.88	$ 284.87	$ 6.76	$ 1.98	$ 293.61	$ 383,435.02	$ 9,098.96	$ 2,665.08	$ 395,199.06
051223175550	19	Ea.	Column, structural tubing, 6" x 4" x 5/16" x 12'-0", incl shop primer, cap & base plate, bolts	E2	54	1.037	$ 256.85	$ 57.33	$ 34.68	$ 348.86	$ 4,880.15	$ 1,089.27	$ 658.92	$ 6,628.34	$ 284.87	$ 96.56	$ 37.57	$ 419.00	$ 5,412.53	$ 1,834.64	$ 713.83	$ 7,961.00
051223175600	31	Ea.	Column, structural tubing, 8" x 4" x 3/8" x 12'-0", incl shop primer, cap & base plate, bolts	E2	54	1.037	$ 373.60	$ 57.33	$ 34.68	$ 465.61	$ 11,581.60	$ 1,777.23	$ 1,075.08	$ 14,433.91	$ 410.96	$ 96.56	$ 37.57	$ 545.09	$ 12,739.76	$ 2,993.36	$ 1,164.67	$ 16,897.79
051223175700	21	Ea.	Column, structural tubing, 12" x 8" x 1/2" x 16'-0", incl shop primer, cap & base plate, bolts	E2	48	1.167	$ 1,120.80	$ 63.97	$ 38.73	$ 1,223.50	$ 23,536.80	$ 1,343.37	$ 813.33	$ 25,693.50	$ 1,214.20	$ 108.63	$ 42.77	$ 1,365.60	$ 25,498.20	$ 2,281.23	$ 898.17	$ 28,677.60
051223201200	54	L.F.	Curb edging, structural steel channel w/ anchors, on concrete forms, 8.2 plf, 6", shop fabricated	E4	255	0.125	$ 10.69	$ 7.18	$ 0.66	$ 18.53	$ 577.26	$ 387.72	$ 35.64	$ 1,000.62	$ 11.77	$ 12.61	$ 0.73	$ 25.11	$ 635.58	$ 680.94	$ 39.42	$ 1,355.94
051223201500	569	L.F.	Curb edging, structural steel channel w/ anchors, on concrete forms, 20.7 plf, 12", shop fabricated	E4	140	0.229	$ 26.15	$ 13.10	$ 1.20	$ 40.45	$ 14,879.35	$ 7,453.90	$ 682.80	$ 23,016.05	$ 28.95	$ 22.99	$ 1.33	$ 53.27	$ 16,472.55	$ 13,081.31	$ 756.77	$ 30,310.63
			Total								$ 4,182,778.63	$ 265,509.31	$ 140,104.97	$ 4,588,392.91					$ 4,594,987.01	$ 451,932.51	$ 153,979.73	$ 5,200,899.25

MICROPILES

DIAMETER	AVG LENGTH, (LF)	VOLUME, (CY)	COUNT	TOTAL VOLUME
7"	55	0.54	431	234.64

PILECAPS

PILECAPS	DIMENSIONS	COUNT	VOLUME, (CF)	VOLUME, (CY)	TOTAL VOLUME, (CY)	FORMWORK, (SFCA)	TOTAL FORMWORK, (SFCA)
P1	3'x3'x3.5'	5	31.50	1.17	5.83	51	255
P2	3'x6'4"x3.5'	39	66.47	2.46	96.01	84	3289
P3	Triangular 6' DEEP	14	198.07	7.34	102.70	126	1763
P4	7.5'x7.5'x6'	20	337.50	12.50	250.00	236	4725
P5	6.5'x9'x6'	17	351.00	13.00	221.00	245	4157
P6	7'x11'x6'	5	462.00	17.11	85.56	293	1465
P8	10'x11'x6'	5	660.00	24.44	122.22	362	1810
P10	10'x15'x6'	4	900.00	33.33	133.33	450	1800

STRUT BEAMS

STRUT BEAM	DIMENSIONS	LENGTH, (LF)	VOLUME, (CF)	TOTAL VOLUME, (CY)	FORMWORK, (SFCA)	TOTAL FORMWORK, (SFCA)
1	1.5'x2'8"	2052	8208.1026	304.00	145	14843

*ASSUMPTION: FORMWORK PER 20FT SECTIONS 102.6 SECTIONS

GRADE BEAMS

GRADE BEAM	DIMENSIONS	LENGTH, (LF)	VOLUME, (CF)	TOTAL VOLUME, (CY)	FORMWORK, (SFCA)	TOTAL FORMWORK, (SFCA)
SGB-1	1'x1.5'	108	162	6.00	83	448
SGB-2	1.5'x2'	504	1512	56.00	116	2923
SGB-3	2'x3'	276	1656	61.33	172	2374

*ASSUMPTION: FORMWORK PER 20FT SECTIONS

FOUNDATION WALLS

THICKNESS	AREA, (SF)	VOLUME, (CF)	VOLUME, (CY)		TOTAL FORMWORK, (SFCA)
12"	684	684	25.33		1573
16"	13209	17612	652.30		30381
20"	408	680	25.19		938

*ASSUMPTION: TOOK TOTAL SF AND MULTIPLIED BY 2 FOR THE TWO FACES OF THE WALL IN ADDITION TO 15% WASTE FACTOR

SLAB ON GRADE (SOG)

THICKNESS	AREA	VOLUME (CF)	VOLUME (CY)		PERIMETER, (LF)		TOTAL FORMWORK, (SFCA)
5"	38288	15,953.33	590.86		800		333
6"	21992	10,996.00	407.26		650		325
8"	54	36.00	1.33		65		43
			999.46				

ELEVATED SLABS

LEVEL	THICKNESS	AREA	VOLUME (CF)	VOLUME (CY)	PERIMETER, (LF)		TOTAL FORMWORK, (SFCA)
1	4-1/2"	56,785.00	21,294.38	788.68	1800		675
2	4-1/2"	40,594.00	15,222.75	563.81	1600		600
3	4-1/2"	38,071.00	14,276.63	528.76	1550		581
4	4-1/2"	38,136.00	14,301.00	529.67	1550		581
5	4-1/2"	37,052.00	13,894.50	514.61	1550		581
ROOF	4-1/2"	37,052.00	13,894.50	514.61	1550		581

	TOTAL
FORMWORK	77045 SFCA
CONCRETE	6,821.04 CY

STRUCTURAL STEEL COLUMNS – QUANTITY TAKE-OFFS

FAMILY	TYPE	COUNT	lb/LF	LF	TONS	COSTWORK	QUANTITY
HSS	HSS12X6X5/16	1	36.00	31.15	0.56	12x8x1/2	1.95
HSS	HSS4X4X1/2	2	21.63	7.88	0.09	6x6x1/4	154.23
HSS	HSS4X4X3/8	35	17.27	82.46	0.71	6x6x1/4	
HSS	HSS5X5X1/2	43	28.43	1460.43	20.76	6x6x1/4	
HSS	HSS5X5X3/8	7	22.37	100.21	1.12	6x6x1/4	
HSS	HSS6X6X3/8	15	27.48	199.76	2.74	6x6x1/4	
HSS	HSS7X7X1/2	13	42.05	263.88	5.55	8x8x3/8	53.80
HSS	HSS8X6X1/4	10	22.40	175.71	1.97	8x8x3/8	
HSS	HSS8X6X5/8	4	50.60	65.52	1.66	8x8x3/8	
HSS	HSS8X8X5/8	16	59.32	248.14	7.36	8x8x3/8	
W-Wide Flange	W10X33	17	33.00	257.94	4.26	W10X45	331
W-Wide Flange	W10X45	7	45.00	73.19	1.65	W10X45	
W-Wide Flange	W12X40	4	40.00	33.27	0.67	W12X50	96
W-Wide Flange	W12X65	2	65.00	62.30	2.02	W12X50	
W-Wide Flange	W14X109	18	109.00	281.46	15.34	W14X120	1601
W-Wide Flange	W14X120	30	120.00	422.50	25.35	W14X120	
W-Wide Flange	W14X132	20	132.00	243.46	16.07	W14X120	
W-Wide Flange	W14X145	20	145.00	276.42	20.04	W14X120	
W-Wide Flange	W14X159	2	159.00	19.00	1.51	W14X176	2554
W-Wide Flange	W14X176	8	176.00	122.87	10.81	W14X176	
W-Wide Flange	W14X211	18	211.00	326.96	34.49	W14X176	
W-Wide Flange	W14X283	32	283.00	592.00	83.77	W14X176	
W-Wide Flange	W14X311	16	311.00	252.00	39.19	W14X176	
W-Wide Flange	W14X342	72	342.00	1115.25	190.71	W14X176	
W-Wide Flange	W14X398	8	398.00	125.75	25.02	W14X176	
W-Wide Flange	W14X43	11	43.00	178.88	3.85	W14X74	2458
W-Wide Flange	W14X53	5	53.00	142.50	3.78	W14X74	
W-Wide Flange	W14X61	17	61.00	293.42	8.95	W14X74	
W-Wide Flange	W14X68	10	68.00	204.25	6.94	W14X74	
W-Wide Flange	W14X74	6	74.00	103.92	3.84	W14X74	
W-Wide Flange	W14X82	2	82.00	30.96	1.27	W14X74	
W-Wide Flange	W14X90	96	90.00	1503.76	67.67	W14X74	
W-Wide Flange	W14X99	22	99.00	377.46	18.68	W14X120	

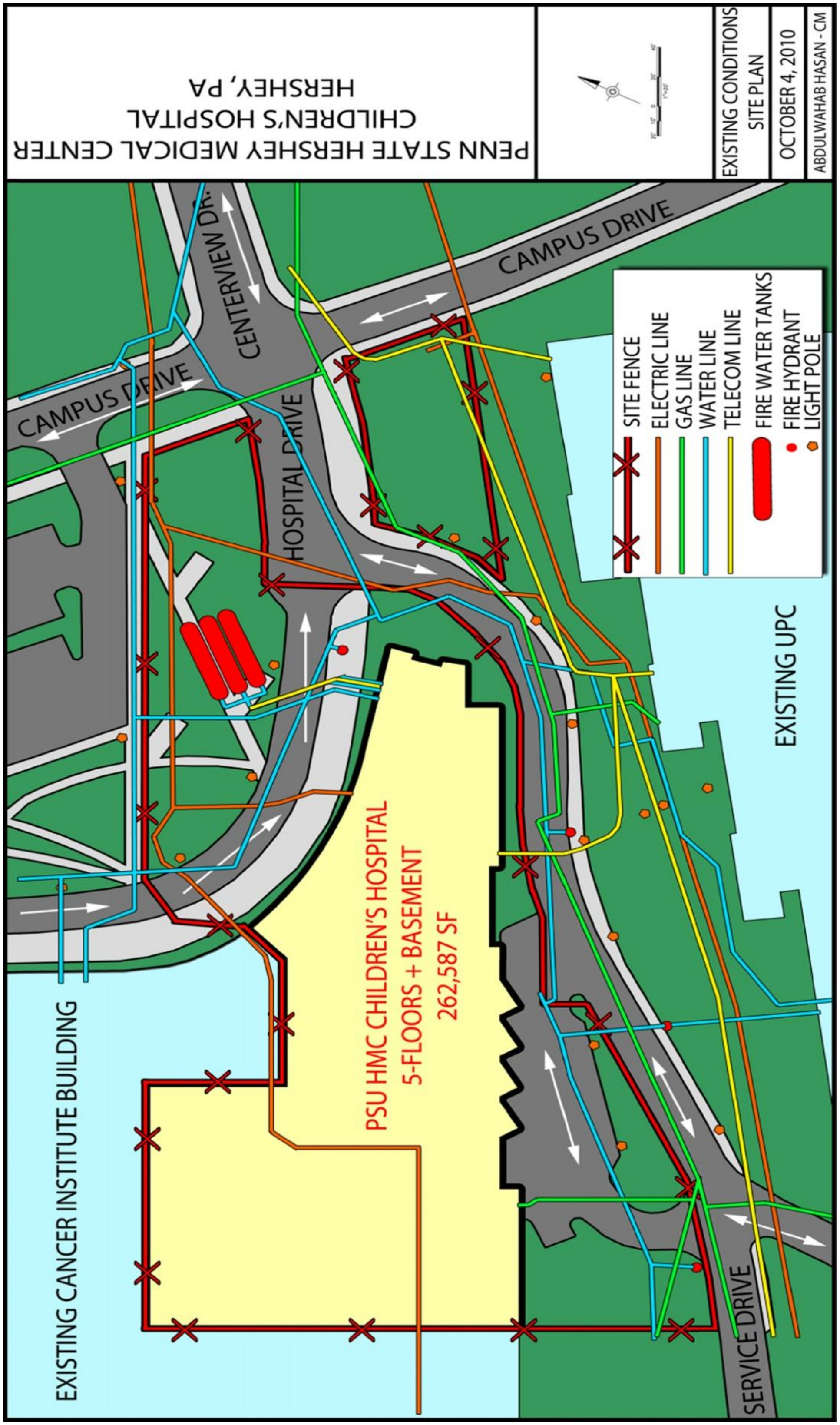
STRUCTURAL STEEL FRAMING – QUANTITY TAKE-OFFS (1/2)

FAMILY	TYPE	COUNT	lb/LF	LF	TONS	COSTWORKS	QUANTITY
W-Wide Flange	W10X112	20	112.00	396.61	22.21	W18X106	3154
W-Wide Flange	W10X12	18	12.00	185.45	1.11	W10X12	185
W-Wide Flange	W10X15	2	15.00	26.00	0.20	W10X15	26
W-Wide Flange	W10X22	297	22.00	3009.77	33.11	W10X22	3010
W-Wide Flange	W10X33	10	33.00	105.93	1.75	W10X33	106
W-Wide Flange	W10X45	4	45.00	57.00	1.28	W10X49	57
W-Wide Flange	W10X88	27	88.00	575.23	25.31	W18X86	850
W-Wide Flange	W12X14	87	14.00	1375.91	9.63	W12X16	1621
W-Wide Flange	W12X16	12	16.00	244.95	1.96	W12X16	
W-Wide Flange	W12X19	8	19.00	133.04	1.26	W12X22	133
W-Wide Flange	W12X26	44	26.00	705.13	9.17	W12X26	705
W-Wide Flange	W12X30	26	30.00	233.29	3.50	W12X35	233
W-Wide Flange	W12X40	2	40.00	32.00	0.64	W12X50	32
W-Wide Flange	W12X65	1	65.00	16.50	0.54	W12X72	17
W-Wide Flange	W14X22	235	22.00	3561.37	39.18	W14X26	3580
W-Wide Flange	W14X26	1	26.00	19.09	0.25	W14X26	19
W-Wide Flange	W14X30	10	34.00	133.36	2.27	W14X30	133
W-Wide Flange	W14X34	2	34.00	47.70	0.81	W14X34	48
W-Wide Flange	W14X43	3	43.00	40.48	0.87	W14X43	40
W-Wide Flange	W14X53	4	53.00	138.65	3.67	W14X53	139
W-Wide Flange	W16X26	472	26.00	13465.85	175.06	W16X26	13466
W-Wide Flange	W16X31	211	31.00	6517.39	101.02	W16X31	6517
W-Wide Flange	W16X36	22	36.00	495.56	8.92	W16X40	1040
W-Wide Flange	W16X40	20	40.00	544.52	10.89	W16X40	
W-Wide Flange	W16X45	4	45.00	70.65	1.59	W16X50	102
W-Wide Flange	W16X50	1	50.00	31.10	0.78	W16X50	
W-Wide Flange	W16X67	1	67.00	7.23	0.24	W16X67	7
W-Wide Flange	W18X35	128	35.00	3141.50	54.98	W18X35	3142
W-Wide Flange	W18X40	42	40.00	1455.46	29.11	W18X40	1455
W-Wide Flange	W18X46	5	46.00	179.84	4.14	W18X46	1859
W-Wide Flange	W18X50	6	50.00	80.49	2.01	W18X50	2609
W-Wide Flange	W18X55	1	55.00	6.76	0.19	W18X55	1973
W-Wide Flange	W18X60	3	60.00	86.50	2.60	W18X65	1453
W-Wide Flange	W21X101	25	101.00	622.38	31.43	W18X106	
W-Wide Flange	W21X111	4	111.00	170.50	9.46	W21X122	170
W-Wide Flange	W21X44	54	44.00	1679.14	36.94	W18X46	
W-Wide Flange	W21X48	8	48.00	177.84	4.27	W18X50	
W-Wide Flange	W21X50	75	50.00	2350.20	58.75	W18X50	
W-Wide Flange	W21X55	1	55.00	24.76	0.68	W18X55	
W-Wide Flange	W21X57	3	57.00	71.79	2.05	W18X65	
W-Wide Flange	W21X62	15	62.00	289.92	8.99	W18X65	
W-Wide Flange	W24X104	6	104.00	167.28	8.70	W18X106	
W-Wide Flange	W24X131	1	131.00	32.83	2.15	W24X146	95

STRUCTURAL STEEL FRAMING – QUANTITY TAKE-OFFS (2/2)

FAMILY	TYPE	COUNT	lb/LF	LF	TONS	COSTWORKS	QUANTITY
W-Wide Flange	W24X146	2	146.00	62.19	4.54	W24X146	
W-Wide Flange	W24X176	41	176.00	1387.84	122.13	W30X173	1388
W-Wide Flange	W24X229	39	229.00	1345.50	154.06	W36X231	1346
W-Wide Flange	W24X55	79	55.00	1941.29	53.39	W18X55	
W-Wide Flange	W24X62	39	62.00	1004.75	31.15	W18X65	
W-Wide Flange	W24X68	34	68.00	1021.25	34.72	W18X76	2676
W-Wide Flange	W24X76	65	76.00	1654.98	62.89	W18X76	
W-Wide Flange	W24X84	13	84.00	274.92	11.55	W18X86	
W-Wide Flange	W24X94	8	94.00	215.91	10.15	W18X106	
W-Wide Flange	W27X129	2	129.00	29.60	1.91	W30X132	116
W-Wide Flange	W27X146	1	146.00	42.83	3.13	W27X146	43
W-Wide Flange	W27X94	42	94.00	1154.57	54.26	W18X106	
W-Wide Flange	W30X108	1	108.00	30.29	1.64	W18X106	
W-Wide Flange	W30X124	2	124.00	60.58	3.76	W30X132	
W-Wide Flange	W30X132	1	132.00	26.00	1.72	W30X132	
W-Wide Flange	W30X90	18	90.00	459.32	20.67	W18X106	
W-Wide Flange	W30X99	5	99.00	108.00	5.35	W18X106	
W-Wide Flange	W33X118	5	118.00	151.00	8.91	W33X118	151
W-Wide Flange	W33X130	5	130.00	152.29	9.90	W33X130	152
W-Wide Flange	W33X141	1	141.00	30.29	2.14	W33X141	30
W-Wide Flange	W33X169	2	169.00	30.21	2.55	W33X169	30
W-Wide Flange	W36X135	2	135.00	27.54	1.86	W36X135	28
W-Wide Flange	W40X149	2	149.00	74.08	5.52	W36X150	74
W-Wide Flange	W40X183	3	183.00	81.75	7.48	W36X194	82
W-Wide Flange	W40X199	1	199.00	42.83	4.26	W33X201	43
W-Wide Flange	W6X16	5	16.00	52.20	0.42	W6X20	52
W-Wide Flange	W8X10	50	10.00	305.12	1.53	W8X10	305
W-Wide Flange	W8X18	20	18.00	110.77	1.00	W8X21	111
W-Wide Flange	W8X24	1	24.00	12.00	0.14	W8X24	12
W-Wide Flange	W8X31	4	31.00	53.51	0.83	W8X31	54
C-Channel	C10X20	33	20.00	569.28	5.69	C12X20.7	569
C-Channel	C5X6.7	15	6.70	54.35	0.18	C6X8.2	54
HSS	HSS14X6X3/8	3	47.80	38.50	0.92	12X8X1/2	327
HSS	HSS16X8X5/8	3	93.10	66.00	3.07	12X8X1/2	
HSS	HSS20X12X1/2	1	103.00	24.76	1.28	12X8X1/2	
HSS	HSS20X12X5/8	1	127.00	11.29	0.72	12X8X1/2	
HSS	HSS20X8X5/16	6	57.30	164.60	4.72	12X8X1/2	
HSS	HSS20X8X5/8	1	110.00	22.00	1.21	12X8X1/2	
HSS	HSS5X3X3/8	3	17.20	19.52	0.17	6X4X5/16	228
HSS	HSS6X6X3/8	9	27.40	208.31	2.85	6X4X5/16	
HSS	HSS8X6X1/4	30	22.40	369.93	4.14	8X4X3/8	370

APPENDIX B: EXISTING CONDITIONS SITE PLAN



APPENDIX B: EXISTING CONDITIONS SITE PLAN

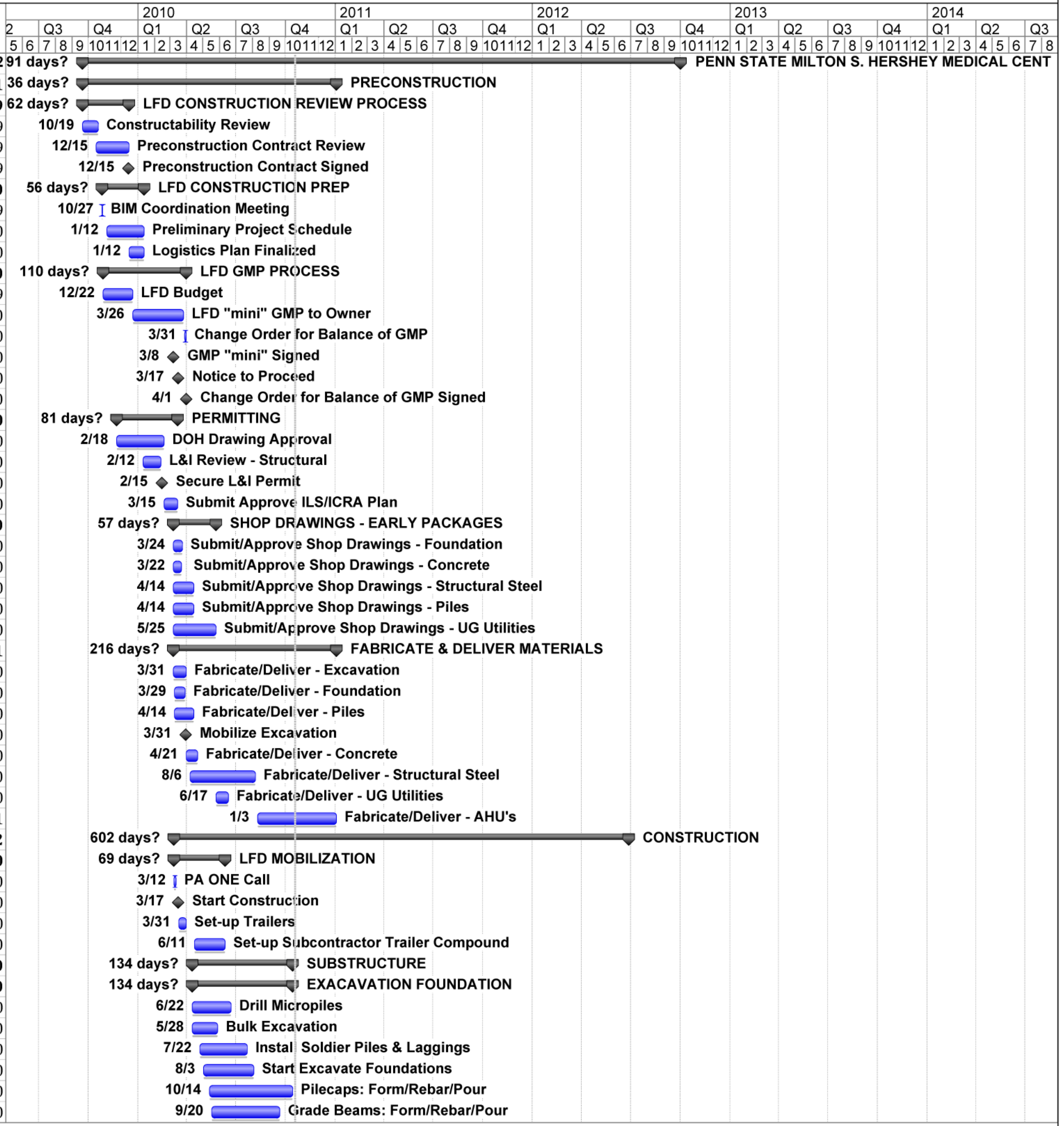
APPENDIX C: DETAILED PROJECT SCHEDULE

PENN STATE MILTON S. HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL
Dr. Chimay Anumba

ABDULWAHAB HASAN
CONSTRUCTION MANAGEMENT

SENIOR THESIS FINAL REPORT
APRIL 7, 2011

ID	ℹ	Task Name	Duration	Start	Finish
1		**PENN STATE MILTON S. HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL**	**791 days?**	**Mon 9/21/09**	**Tue 10/2/12**
2		**PRECONSTRUCTION**	**336 days?**	**Mon 9/21/09**	**Mon 1/3/11**
3		**LFD CONSTRUCTION REVIEW PROCESS**	**62 days?**	**Mon 9/21/09**	**Tue 12/15/09**
4	▦	Constructability Review	21 days?	Mon 9/21/09	Mon 10/19/09
5	▦	Preconstruction Contract Review	43 days?	Fri 10/16/09	Tue 12/15/09
6	▦	Preconstruction Contract Signed	0 days	Tue 12/15/09	Tue 12/15/09
7		**LFD CONSTRUCTION PREP**	**56 days?**	**Tue 10/27/09**	**Tue 1/12/10**
8	▦	BIM Coordination Meeting	1 day?	Tue 10/27/09	Tue 10/27/09
9	▦	Preliminary Project Schedule	49 days?	Thu 11/5/09	Tue 1/12/10
10	▦	Logistics Plan Finalized	20 days?	Wed 12/16/09	Tue 1/12/10
11		**LFD GMP PROCESS**	**110 days?**	**Thu 10/29/09**	**Thu 4/1/10**
12	▦	LFD Budget	39 days?	Thu 10/29/09	Tue 12/22/09
13	▦	LFD "mini" GMP to Owner	68 days?	Wed 12/23/09	Fri 3/26/10
14	▦	Change Order for Balance of GMP	3 days?	Mon 3/29/10	Wed 3/31/10
15	▦	GMP "mini" Signed	0 days	Mon 3/8/10	Mon 3/8/10
16	▦	Notice to Proceed	0 days	Wed 3/17/10	Wed 3/17/10
17	▦	Change Order for Balance of GMP Signed	0 days	Thu 4/1/10	Thu 4/1/10
18		**PERMITTING**	**81 days?**	**Mon 11/23/09**	**Mon 3/15/10**
19	▦	DOH Drawing Approval	64 days?	Mon 11/23/09	Thu 2/18/10
20	▦	L&I Review - Structural	25 days?	Mon 1/11/10	Fri 2/12/10
21	▦	Secure L&I Permit	0 days	Mon 2/15/10	Mon 2/15/10
22	▦	Submit Approve ILS/ICRA Plan	17 days?	Fri 2/19/10	Mon 3/15/10
23		**SHOP DRAWINGS - EARLY PACKAGES**	**57 days?**	**Mon 3/8/10**	**Tue 5/25/10**
24	▦	Submit/Approve Shop Drawings - Foundation	13 days?	Mon 3/8/10	Wed 3/24/10
25	▦	Submit/Approve Shop Drawings - Concrete	11 days?	Mon 3/8/10	Mon 3/22/10
26	▦	Submit/Approve Shop Drawings - Structural Steel	28 days?	Mon 3/8/10	Wed 4/14/10
27	▦	Submit/Approve Shop Drawings - Piles	28 days?	Mon 3/8/10	Wed 4/14/10
28	▦	Submit/Approve Shop Drawings - UG Utilities	57 days?	Mon 3/8/10	Tue 5/25/10
29		**FABRICATE & DELIVER MATERIALS**	**216 days?**	**Mon 3/8/10**	**Mon 1/3/11**
30	▦	Fabricate/Deliver - Excavation	18 days?	Mon 3/8/10	Wed 3/31/10
31	▦	Fabricate/Deliver - Foundation	14 days?	Wed 3/10/10	Mon 3/29/10
32	▦	Fabricate/Deliver - Piles	26 days?	Wed 3/10/10	Wed 4/14/10
33	▦	Mobilize Excavation	0 days	Wed 3/31/10	Wed 3/31/10
34	▦	Fabricate/Deliver - Concrete	15 days?	Thu 4/1/10	Wed 4/21/10
35	▦	Fabricate/Deliver - Structural Steel	87 days?	Thu 4/8/10	Fri 8/6/10
36	▦	Fabricate/Deliver - UG Utilities	17 days?	Wed 5/26/10	Thu 6/17/10
37	▦	Fabricate/Deliver - AHU's	104 days?	Wed 8/11/10	Mon 1/3/11
38		**CONSTRUCTION**	**602 days?**	**Tue 3/9/10**	**Wed 6/27/12**
39		**LFD MOBILIZATION**	**69 days?**	**Tue 3/9/10**	**Fri 6/11/10**
40	▦	PA ONE Call	4 days?	Tue 3/9/10	Fri 3/12/10
41	▦	Start Construction	0 days	Wed 3/17/10	Wed 3/17/10
42	▦	Set-up Trailers	10 days?	Thu 3/18/10	Wed 3/31/10
43	▦	Set-up Subcontractor Trailer Compound	41 days?	Fri 4/16/10	Fri 6/11/10
44		**SUBSTRUCTURE**	**134 days?**	**Mon 4/12/10**	**Thu 10/14/10**
45		**EXACAVATION FOUNDATION**	**134 days?**	**Mon 4/12/10**	**Thu 10/14/10**
46	▦	Drill Micropiles	52 days?	Mon 4/12/10	Tue 6/22/10
47	▦	Bulk Excavation	35 days?	Mon 4/12/10	Fri 5/28/10
48	▦	Install Soldier Piles & Laggings	64 days?	Mon 4/26/10	Thu 7/22/10
49	▦	Start Excavate Foundations	67 days?	Mon 5/3/10	Tue 8/3/10
50	▦	Pilecaps: Form/Rebar/Pour	110 days?	Fri 5/14/10	Thu 10/14/10
51	▦	Grade Beams: Form/Rebar/Pour	90 days?	Tue 5/18/10	Mon 9/20/10



Project: DETAILED PROJECT SCHEI
Date: Mon 10/18/10

Task	▬	Milestone	◆	Rolled Up Task	▬
Progress	▬	Summary	▼▬▼	Rolled Up Milestone	◇
Rolled Up Progress	▬	External Tasks	▬	Group By Summary	▼▬▼
Split	⋯	Project Summary	▽▬▽	Deadline	⇩

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APPENDIX C: DETAILED PROJECT SCHEDULE

PENN STATE MILTON S. HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL
Dr. Chimay Anumba

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CONSTRUCTION MANAGEMENT

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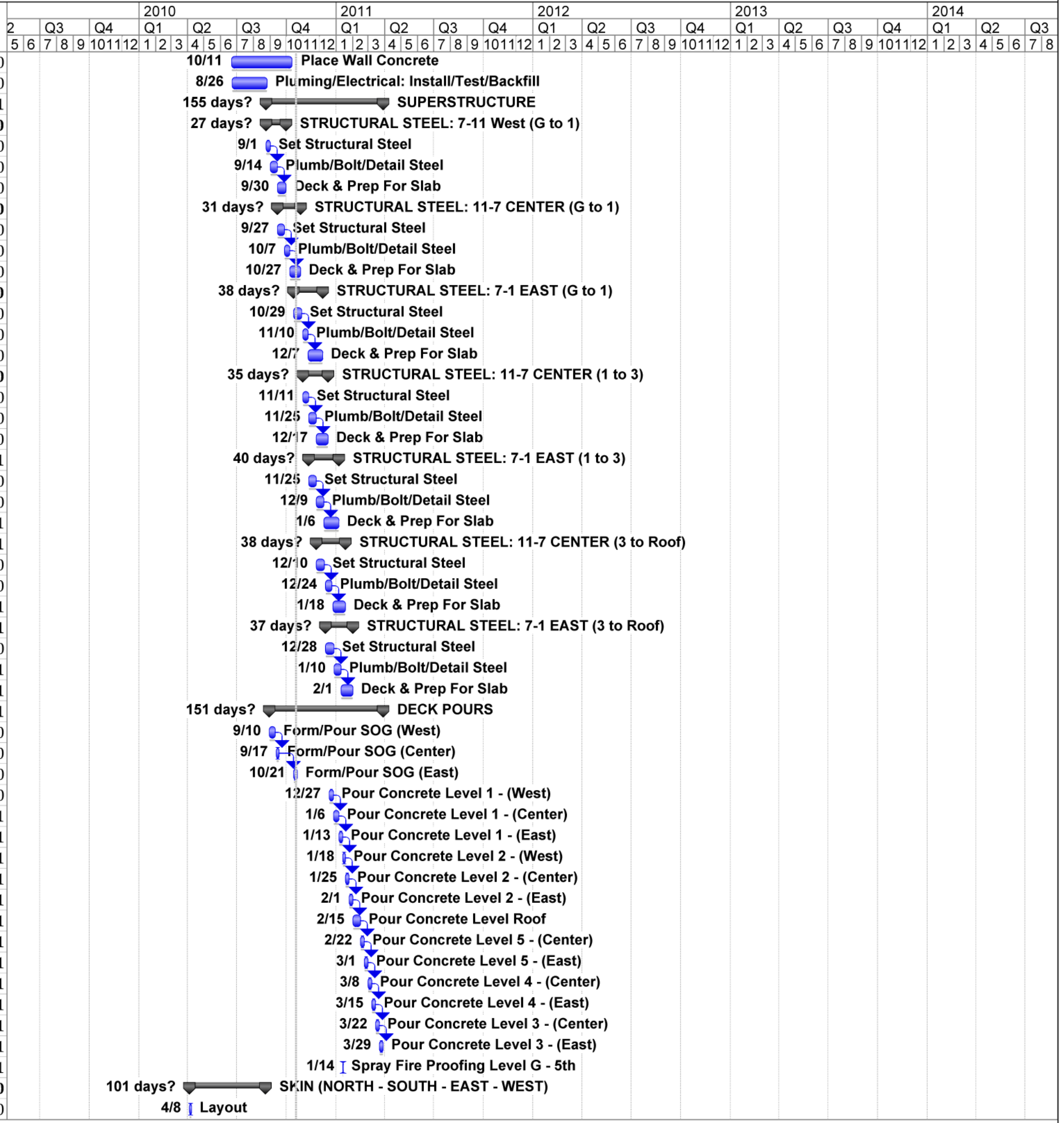
ID	Task Name	Duration	Start	Finish
52	Place Wall Concrete	80 days?	Tue 6/22/10	Mon 10/11/10
53	Pluming/Electrical: Install/Test/Backfill	47 days?	Wed 6/23/10	Thu 8/26/10
54	**SUPERSTRUCTURE**	**155 days?**	**Wed 8/25/10**	**Tue 3/29/11**
55	**STRUCTURAL STEEL: 7-11 West (G to 1)**	**27 days?**	**Wed 8/25/10**	**Thu 9/30/10**
56	Set Structural Steel	6 days?	Wed 8/25/10	Wed 9/1/10
57	Plumb/Bolt/Detail Steel	9 days?	Thu 9/2/10	Tue 9/14/10
58	Deck & Prep For Slab	12 days?	Wed 9/15/10	Thu 9/30/10
59	**STRUCTURAL STEEL: 11-7 CENTER (G to 1)**	**31 days?**	**Wed 9/15/10**	**Wed 10/27/10**
60	Set Structural Steel	9 days?	Wed 9/15/10	Mon 9/27/10
61	Plumb/Bolt/Detail Steel	8 days?	Tue 9/28/10	Thu 10/7/10
62	Deck & Prep For Slab	14 days?	Fri 10/8/10	Wed 10/27/10
63	**STRUCTURAL STEEL: 7-1 EAST (G to 1)**	**38 days?**	**Fri 10/15/10**	**Tue 12/7/10**
64	Set Structural Steel	11 days?	Fri 10/15/10	Fri 10/29/10
65	Plumb/Bolt/Detail Steel	8 days?	Mon 11/1/10	Wed 11/10/10
66	Deck & Prep For Slab	19 days?	Thu 11/11/10	Tue 12/7/10
67	**STRUCTURAL STEEL: 11-7 CENTER (1 to 3)**	**35 days?**	**Mon 11/1/10**	**Fri 12/17/10**
68	Set Structural Steel	9 days?	Mon 11/1/10	Thu 11/11/10
69	Plumb/Bolt/Detail Steel	10 days?	Fri 11/12/10	Thu 11/25/10
70	Deck & Prep For Slab	16 days?	Fri 11/26/10	Fri 12/17/10
71	**STRUCTURAL STEEL: 7-1 EAST (1 to 3)**	**40 days?**	**Fri 11/12/10**	**Thu 1/6/11**
72	Set Structural Steel	10 days?	Fri 11/12/10	Thu 11/25/10
73	Plumb/Bolt/Detail Steel	10 days?	Fri 11/26/10	Thu 12/9/10
74	Deck & Prep For Slab	20 days?	Fri 12/10/10	Thu 1/6/11
75	**STRUCTURAL STEEL: 11-7 CENTER (3 to Roof)**	**38 days?**	**Fri 11/26/10**	**Tue 1/18/11**
76	Set Structural Steel	11 days?	Fri 11/26/10	Fri 12/10/10
77	Plumb/Bolt/Detail Steel	10 days?	Mon 12/13/10	Fri 12/24/10
78	Deck & Prep For Slab	17 days?	Mon 12/27/10	Tue 1/18/11
79	**STRUCTURAL STEEL: 7-1 EAST (3 to Roof)**	**37 days?**	**Mon 12/13/10**	**Tue 2/1/11**
80	Set Structural Steel	12 days?	Mon 12/13/10	Tue 12/28/10
81	Plumb/Bolt/Detail Steel	9 days?	Wed 12/29/10	Mon 1/10/11
82	Deck & Prep For Slab	16 days?	Tue 1/11/11	Tue 2/1/11
83	**DECK POURS**	**151 days?**	**Tue 8/31/10**	**Tue 3/29/11**
84	Form/Pour SOG (West)	9 days?	Tue 8/31/10	Fri 9/10/10
85	Form/Pour SOG (Center)	5 days?	Mon 9/13/10	Fri 9/17/10
86	Form/Pour SOG (East)	5 days?	Fri 10/15/10	Thu 10/21/10
87	Pour Concrete Level 1 - (West)	6 days?	Mon 12/20/10	Mon 12/27/10
88	Pour Concrete Level 1 - (Center)	8 days?	Tue 12/28/10	Thu 1/6/11
89	Pour Concrete Level 1 - (East)	5 days?	Fri 1/7/11	Thu 1/13/11
90	Pour Concrete Level 2 - (West)	3 days?	Fri 1/14/11	Tue 1/18/11
91	Pour Concrete Level 2 - (Center)	5 days?	Wed 1/19/11	Tue 1/25/11
92	Pour Concrete Level 2 - (East)	5 days?	Wed 1/26/11	Tue 2/1/11
93	Pour Concrete Level Roof	10 days?	Wed 2/2/11	Tue 2/15/11
94	Pour Concrete Level 5 - (Center)	5 days?	Wed 2/16/11	Tue 2/22/11
95	Pour Concrete Level 5 - (East)	5 days?	Wed 2/23/11	Tue 3/1/11
96	Pour Concrete Level 4 - (Center)	5 days?	Wed 3/2/11	Tue 3/8/11
97	Pour Concrete Level 4 - (East)	5 days?	Wed 3/9/11	Tue 3/15/11
98	Pour Concrete Level 3 - (Center)	5 days?	Wed 3/16/11	Tue 3/22/11
99	Pour Concrete Level 3 - (East)	5 days?	Wed 3/23/11	Tue 3/29/11
100	Spray Fire Proofing Level G - 5th	1 day?	Fri 1/14/11	Fri 1/14/11
101	**SKIN (NORTH - SOUTH - EAST - WEST)**	**101 days?**	**Mon 4/5/10**	**Mon 8/23/10**
102	Layout	4 days?	Mon 4/5/10	Thu 4/8/10



Project: DETAILED PROJECT SCHEI Date: Mon 10/18/10	Task	▬	Milestone	◆	Rolled Up Task	▬	Rolled Up Progress	▬	External Tasks	▬
	Progress	▬	Summary	▬	Rolled Up Milestone	◇	Split	┈	Project Summary	▬
									Group By Summary	▬
									Deadline	⇩

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PENN STATE MILTON S. HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL
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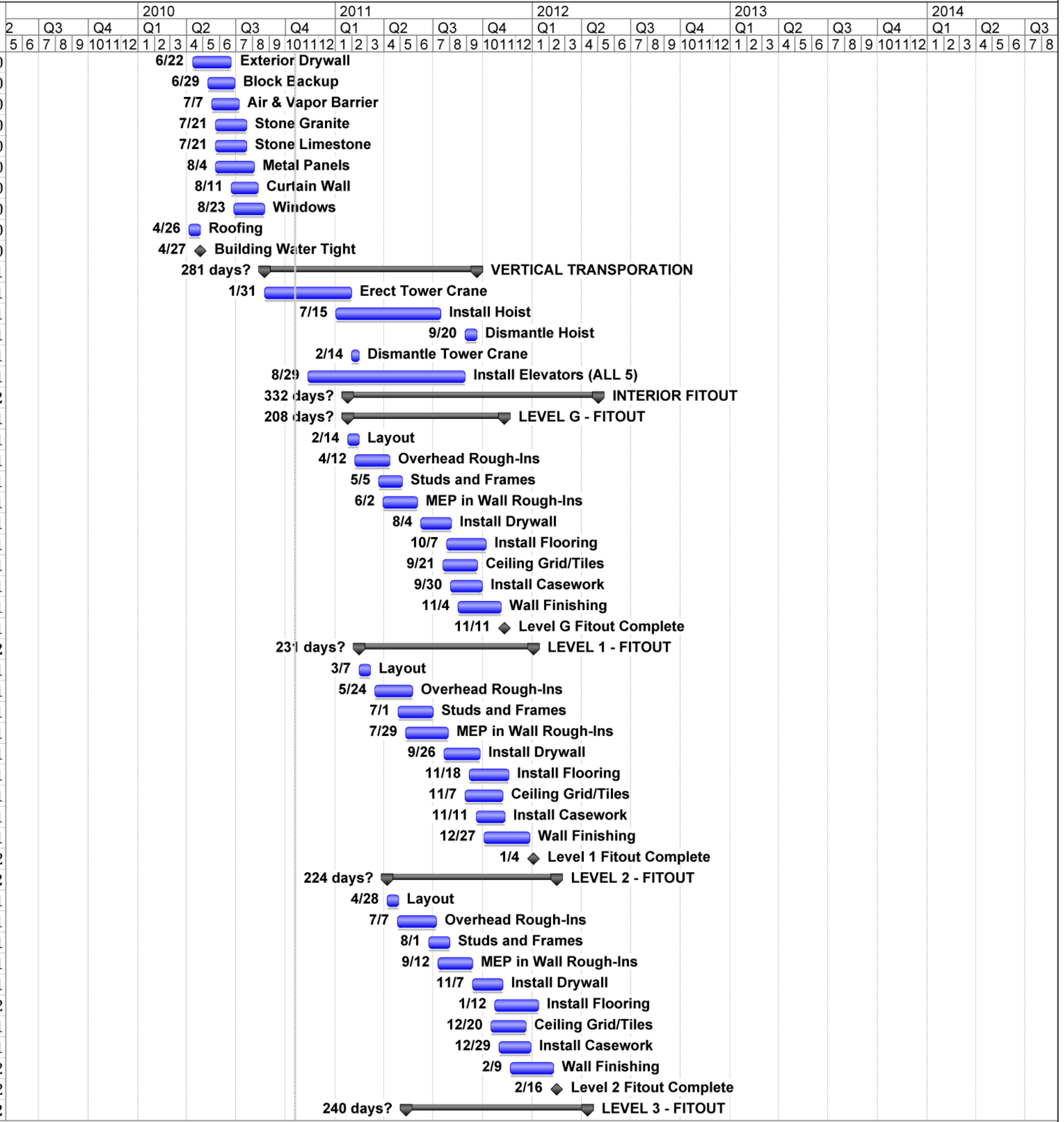
ID	ℹ	Task Name	Duration	Start	Finish
103	▦	Exterior Drywall	51 days?	Tue 4/13/10	Tue 6/22/10
104	▦	Block Backup	36 days?	Tue 5/11/10	Tue 6/29/10
105	▦	Air & Vapor Barrier	37 days?	Tue 5/18/10	Wed 7/7/10
106	▦	Stone Granite	42 days?	Tue 5/25/10	Wed 7/21/10
107	▦	Stone Limestone	42 days?	Tue 5/25/10	Wed 7/21/10
108	▦	Metal Panels	52 days?	Tue 5/25/10	Wed 8/4/10
109	▦	Curtain Wall	36 days?	Wed 6/23/10	Wed 8/11/10
110	▦	Windows	41 days?	Mon 6/28/10	Mon 8/23/10
111	▦	Roofing	15 days?	Tue 4/6/10	Mon 4/26/10
112	▦	Building Water Tight	0 days	Tue 4/27/10	Tue 4/27/10
113		**VERTICAL TRANSPORATION**	**281 days?**	**Tue 8/24/10**	**Tue 9/20/11**
114	▦	Erect Tower Crane	115 days?	Tue 8/24/10	Mon 1/31/11
115	▦	Install Hoist	140 days?	Mon 1/3/11	Fri 7/15/11
116	▦	Dismantle Hoist	16 days?	Tue 8/30/11	Tue 9/20/11
117	▦	Dismantle Tower Crane	10 days?	Tue 2/1/11	Mon 2/14/11
118	▦	Install Elevators (ALL 5)	207 days?	Fri 11/12/10	Mon 8/29/11
119		**INTERIOR FITOUT**	**332 days?**	**Tue 1/25/11**	**Thu 5/3/12**
120		**LEVEL G - FITOUT**	**208 days?**	**Tue 1/25/11**	**Fri 11/11/11**
121	▦	Layout	15 days?	Tue 1/25/11	Mon 2/14/11
122	▦	Overhead Rough-Ins	47 days?	Mon 2/7/11	Tue 4/12/11
123	▦	Studs and Frames	32 days?	Wed 3/23/11	Thu 5/5/11
124	▦	MEP in Wall Rough-Ins	46 days?	Thu 3/31/11	Thu 6/2/11
125	▦	Install Drywall	41 days?	Thu 6/9/11	Thu 8/4/11
126	▦	Install Flooring	53 days?	Wed 7/27/11	Fri 10/7/11
127	▦	Ceiling Grid/Tiles	46 days?	Wed 7/20/11	Wed 9/21/11
128	▦	Install Casework	43 days?	Wed 8/3/11	Fri 9/30/11
129	▦	Wall Finishing	58 days?	Wed 8/17/11	Fri 11/4/11
130	▦	Level G Fitout Complete	0 days	Fri 11/11/11	Fri 11/11/11
131		**LEVEL 1 - FITOUT**	**231 days?**	**Tue 2/15/11**	**Wed 1/4/12**
132	▦	Layout	15 days?	Tue 2/15/11	Mon 3/7/11
133	▦	Overhead Rough-Ins	50 days?	Wed 3/16/11	Tue 5/24/11
134	▦	Studs and Frames	47 days?	Thu 4/28/11	Fri 7/1/11
135	▦	MEP in Wall Rough-Ins	57 days?	Thu 5/12/11	Fri 7/29/11
136	▦	Install Drywall	47 days?	Fri 7/22/11	Mon 9/26/11
137	▦	Install Flooring	53 days?	Wed 9/7/11	Fri 11/18/11
138	▦	Ceiling Grid/Tiles	50 days?	Tue 8/30/11	Mon 11/7/11
139	▦	Install Casework	39 days?	Tue 9/20/11	Fri 11/11/11
140	▦	Wall Finishing	61 days?	Tue 10/4/11	Tue 12/27/11
141	▦	Level 1 Fitout Complete	0 days	Wed 1/4/12	Wed 1/4/12
142		**LEVEL 2 - FITOUT**	**224 days?**	**Fri 4/8/11**	**Thu 2/16/12**
143	▦	Layout	15 days?	Fri 4/8/11	Thu 4/28/11
144	▦	Overhead Rough-Ins	52 days?	Wed 4/27/11	Thu 7/7/11
145	▦	Studs and Frames	27 days?	Fri 6/24/11	Mon 8/1/11
146	▦	MEP in Wall Rough-Ins	46 days?	Mon 7/11/11	Mon 9/12/11
147	▦	Install Drywall	40 days?	Tue 9/13/11	Mon 11/7/11
148	▦	Install Flooring	59 days?	Mon 10/24/11	Thu 1/12/12
149	▦	Ceiling Grid/Tiles	47 days?	Mon 10/17/11	Tue 12/20/11
150	▦	Install Casework	43 days?	Tue 11/1/11	Thu 12/29/11
151	▦	Wall Finishing	58 days?	Tue 11/22/11	Thu 2/9/12
152	▦	Level 2 Fitout Complete	0 days	Thu 2/16/12	Thu 2/16/12
153		**LEVEL 3 - FITOUT**	**240 days?**	**Fri 5/13/11**	**Fri 4/13/12**



Project: DETAILED PROJECT SCHEI
Date: Mon 10/18/10

Task	▬	Milestone	◆	Rolled Up Task	▬	Rolled Up Progress	▬	External Tasks	▬	Group By Summary	▬
Progress	▬	Summary	▬	Rolled Up Milestone	◇	Split	┈	Project Summary	▬	Deadline	⇩

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PENN STATE MILTON S. HERSHEY MEDICAL CENTER CHILDREN'S HOSPITAL
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CONSTRUCTION MANAGEMENT

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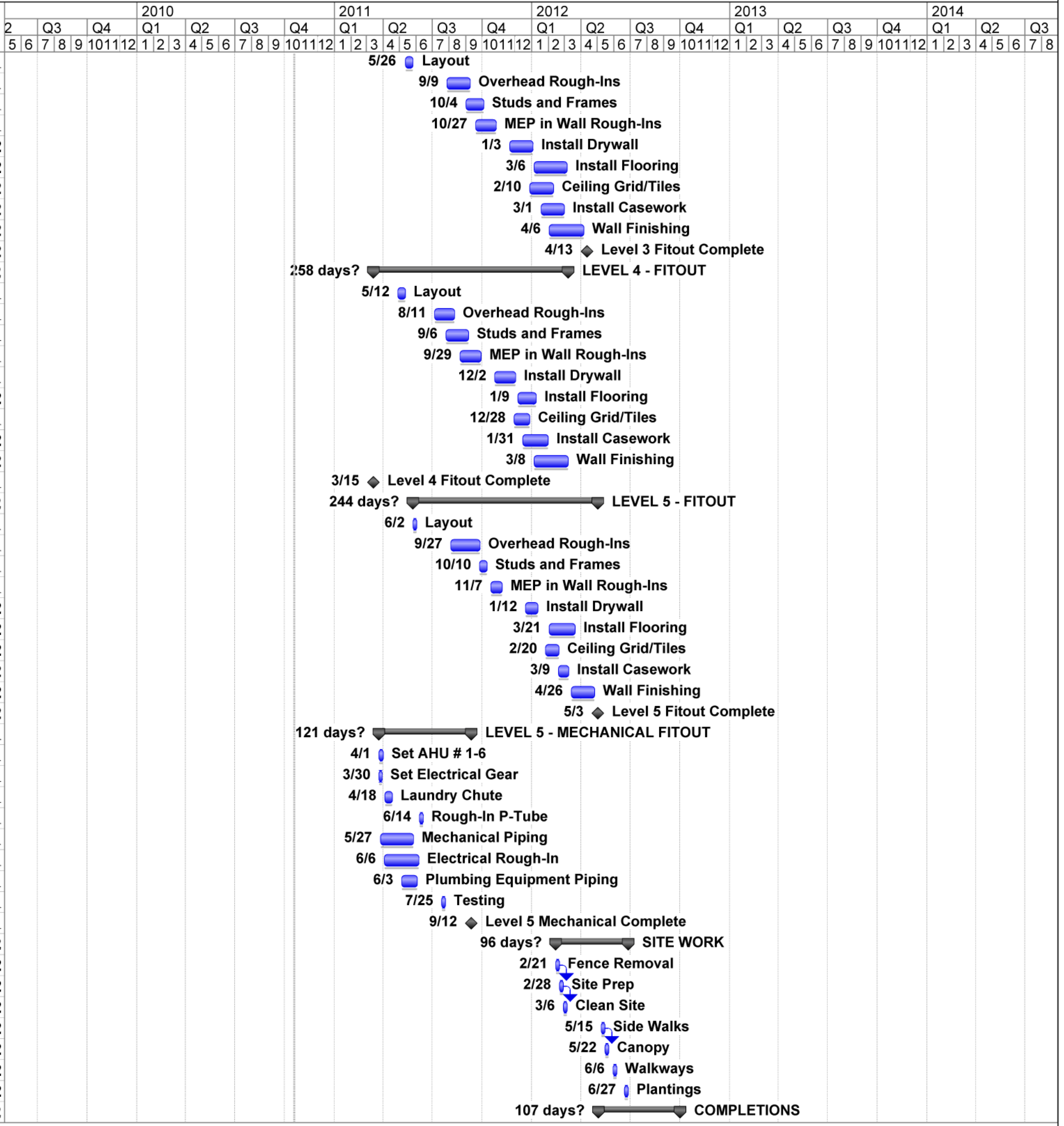
ID	ℹ	Task Name	Duration	Start	Finish
154	▦	Layout	10 days?	Fri 5/13/11	Thu 5/26/11
155	▦	Overhead Rough-Ins	31 days?	Fri 7/29/11	Fri 9/9/11
156	▦	Studs and Frames	23 days?	Fri 9/2/11	Tue 10/4/11
157	▦	MEP in Wall Rough-Ins	28 days?	Tue 9/20/11	Thu 10/27/11
158	▦	Install Drywall	31 days?	Tue 11/22/11	Tue 1/3/12
159	▦	Install Flooring	43 days?	Fri 1/6/12	Tue 3/6/12
160	▦	Ceiling Grid/Tiles	32 days?	Thu 12/29/11	Fri 2/10/12
161	▦	Install Casework	31 days?	Thu 1/19/12	Thu 3/1/12
162	▦	Wall Finishing	46 days?	Fri 2/3/12	Fri 4/6/12
163	▦	Level 3 Fitout Complete	0 days	Fri 4/13/12	Fri 4/13/12
164		**LEVEL 4 - FITOUT**	**258 days?**	**Tue 3/15/11**	**Thu 3/8/12**
165	▦	Layout	10 days?	Fri 4/29/11	Thu 5/12/11
166	▦	Overhead Rough-Ins	27 days?	Wed 7/6/11	Thu 8/11/11
167	▦	Studs and Frames	30 days?	Wed 7/27/11	Tue 9/6/11
168	▦	MEP in Wall Rough-Ins	29 days?	Mon 8/22/11	Thu 9/29/11
169	▦	Install Drywall	29 days?	Tue 10/25/11	Fri 12/2/11
170	▦	Install Flooring	24 days?	Wed 12/7/11	Mon 1/9/12
171	▦	Ceiling Grid/Tiles	21 days?	Wed 11/30/11	Wed 12/28/11
172	▦	Install Casework	33 days?	Fri 12/16/11	Tue 1/31/12
173	▦	Wall Finishing	45 days?	Fri 1/6/12	Thu 3/8/12
174	▦	Level 4 Fitout Complete	0 days	Tue 3/15/11	Tue 3/15/11
175		**LEVEL 5 - FITOUT**	**244 days?**	**Fri 5/27/11**	**Thu 5/3/12**
176	▦	Layout	5 days?	Fri 5/27/11	Thu 6/2/11
177	▦	Overhead Rough-Ins	38 days?	Fri 8/5/11	Tue 9/27/11
178	▦	Studs and Frames	10 days?	Tue 9/27/11	Mon 10/10/11
179	▦	MEP in Wall Rough-Ins	15 days?	Tue 10/18/11	Mon 11/7/11
180	▦	Install Drywall	17 days?	Wed 12/21/11	Thu 1/12/12
181	▦	Install Flooring	34 days?	Fri 2/3/12	Wed 3/21/12
182	▦	Ceiling Grid/Tiles	17 days?	Fri 1/27/12	Mon 2/20/12
183	▦	Install Casework	15 days?	Mon 2/20/12	Fri 3/9/12
184	▦	Wall Finishing	31 days?	Thu 3/15/12	Thu 4/26/12
185	▦	Level 5 Fitout Complete	0 days	Thu 5/3/12	Thu 5/3/12
186		**LEVEL 5 - MECHANICAL FITOUT**	**121 days?**	**Fri 3/25/11**	**Mon 9/12/11**
187	▦	Set AHU # 1-6	6 days?	Fri 3/25/11	Fri 4/1/11
188	▦	Set Electrical Gear	4 days?	Fri 3/25/11	Wed 3/30/11
189	▦	Laundry Chute	10 days?	Tue 4/5/11	Mon 4/18/11
190	▦	Rough-In P-Tube	5 days?	Wed 6/8/11	Tue 6/14/11
191	▦	Mechanical Piping	45 days?	Mon 3/28/11	Fri 5/27/11
192	▦	Electrical Rough-In	46 days?	Mon 4/4/11	Mon 6/6/11
193	▦	Plumbing Equipment Piping	21 days?	Fri 5/6/11	Fri 6/3/11
194	▦	Testing	5 days?	Tue 7/19/11	Mon 7/25/11
195	▦	Level 5 Mechanical Complete	0 days	Mon 9/12/11	Mon 9/12/11
196		**SITE WORK**	**96 days?**	**Wed 2/15/12**	**Wed 6/27/12**
197	▦	Fence Removal	5 days?	Wed 2/15/12	Tue 2/21/12
198	▦	Site Prep	5 days?	Wed 2/22/12	Tue 2/28/12
199	▦	Clean Site	5 days?	Wed 2/29/12	Tue 3/6/12
200	▦	Side Walks	5 days?	Wed 5/9/12	Tue 5/15/12
201	▦	Canopy	5 days?	Wed 5/16/12	Tue 5/22/12
202	▦	Walkways	5 days?	Thu 5/31/12	Wed 6/6/12
203	▦	Plantings	5 days?	Thu 6/21/12	Wed 6/27/12
204		**COMPLETIONS**	**107 days?**	**Fri 5/4/12**	**Tue 10/2/12**



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Task	▬	Milestone	◆	Rolled Up Task	▬	Rolled Up Progress	▬	External Tasks	▬	Group By Summary	▬
Progress	▬	Summary	▬	Rolled Up Milestone	◇	Split	┈	Project Summary	▬	Deadline	⇩

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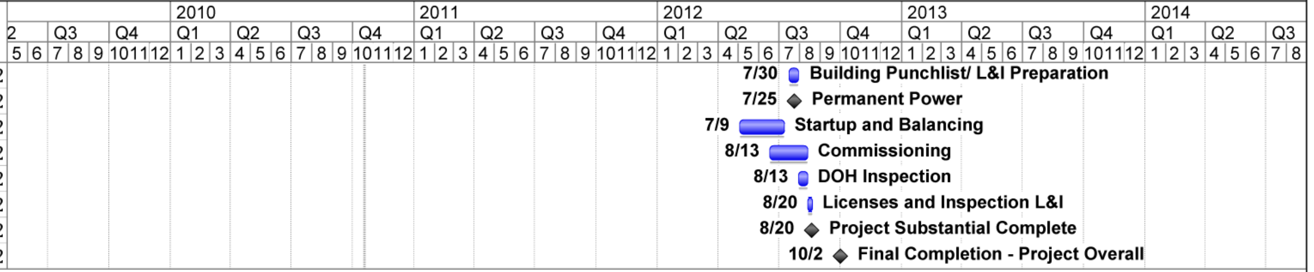
ID	ℹ	Task Name	Duration	Start	Finish
205	▦	Building Punchlist/ L&I Preparation	10 days?	Tue 7/17/12	Mon 7/30/12
206	▦	Permanent Power	0 days	Wed 7/25/12	Wed 7/25/12
207	▦	Startup and Balancing	47 days?	Fri 5/4/12	Mon 7/9/12
208	▦	Commissioning	41 days?	Mon 6/18/12	Mon 8/13/12
209	▦	DOH Inspection	10 days?	Tue 7/31/12	Mon 8/13/12
210	▦	Licenses and Inspection L&I	5 days?	Tue 8/14/12	Mon 8/20/12
211	▦	Project Substantial Complete	0 days	Mon 8/20/12	Mon 8/20/12
212	▦	Final Completion - Project Overall	0 days	Tue 10/2/12	Tue 10/2/12



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Task	▬	Milestone	◆	Rolled Up Task	▬	Rolled Up Progress	▬	External Tasks	▬	Group By Summary	▬
Progress	▬	Summary	▬	Rolled Up Milestone	◇	Split	┈	Project Summary	▬	Deadline	⇩

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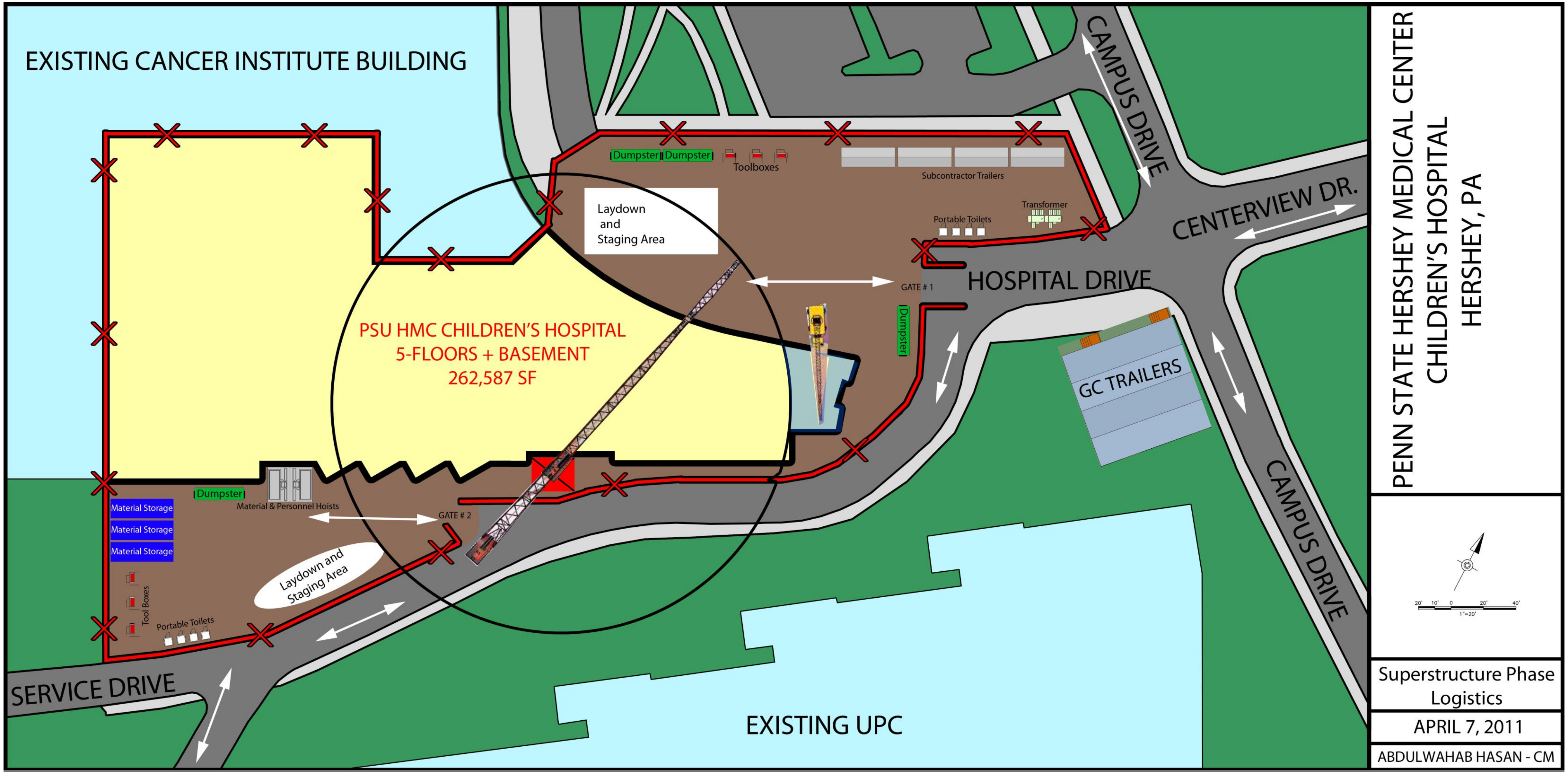
APPENDIX D: SUPERSTRUCTURE PHASE – SITE LOGISTICS PLAN



PENN STATE HERSHEY MEDICAL CENTER
CHILDREN'S HOSPITAL
HERSHEY, PA

Superstructure Phase
Logistics

APRIL 7, 2011

ABDULWAHAB HASAN - CM

APPENDIX D: SUPERSTRUCTURE PHASE – SITE LOGISTICS PLAN

APPENDIX E: GENERAL CONDITIONS ESTIMATES

TABLE D-1: GENERAL CONDITIONS : SUPERVISION AND PERSONNEL

ITEM	QUANTITY	UNIT	Hrs/Week	UNIT RATE	COST
Project Executive	135	WKS	8	$ 140.95	$ 152,226.00
Sr. Project Manager	135	WKS	40	$ 121.56	$ 656,424.00
General Superintendent	135	WKS	40	$ 107.75	$ 581,850.00
Superintendent	122	WKS	40	$ 100.95	$ 492,636.00
Assistant Superintendent	132	WKS	40	$ 91.25	$ 481,800.00
Project Manager	135	WKS	40	$ 88.95	$ 480,330.00
Project Manager	129	WKS	40	$ 88.95	$ 458,982.00
Project Manager	135	WKS	40	$ 88.95	$ 480,330.00
MEP Coordinator	139	WKS	40	$ 88.95	$ 494,562.00
Assistant Project Manager	141	WKS	40	$ 55.65	$ 313,866.00
Cost Engineer	116	WKS	16	$ 88.00	$ 163,328.00
Project Scheduler	131	WKS	24	$ 100.97	$ 317,449.68
Project Accountant	135	WKS	24	$ 67.95	$ 220,158.00
	TOTAL				**$ 5,293,941.68**

TABLE D-2: GENERAL CONDITIONS : FIELD OFFICE EXPENSE

ITEM	QUANTITY		UNIT	UNIT RATE	COST
Office Trailers - Set-Up	1	LS	1	$ 12,500.00	$ 12,500.00
Office Trailers - Rental	31	MOS	1	$ 2,400.00	$ 74,400.00
Electric - Consumption	31	MOS	1	$ 600.00	$ 18,600.00
Water & Sanitary Consum.	31	MOS	1	$ 250.00	$ 7,750.00
Alarm - Set-up	1	LS	1	$ 1,500.00	$ 1,500.00
Alarm - Monthly	31	MOS	1	$ 200.00	$ 6,200.00
Telephones - Monthly	31	MOS	1	$ 1,125.00	$ 34,875.00
Mobile/Cellular	31	MOS	19	$ 100.00	$ 58,900.00
Furniture	1	LS	1	$ 20,000.00	$ 20,000.00
Stationary & Supplies	31	MOS	1	$ 1,150.00	$ 35,650.00
Copier - (Purchase)	1	LS	1	$ 52,500.00	$ 52,500.00
Fax Machine - Purchase	1	LS	1	$ 2,500.00	$ 2,500.00
Business Machine Maint.	31	MOS	1	$ 250.00	$ 7,750.00
Computer Equipment	31	MOS	1	$ 3,108.00	$ 96,348.00
Progress Photos	30	MOS	1	$ 625.00	$ 18,750.00
Personal Protective Equip.	1	LS	1	$ 11,250.00	$ 11,250.00
Safety Supplies	31	MOS	1	$ 235.00	$ 7,285.00
	TOTAL				**$ 466,758.00**

TABLE D-3: GENERAL CONDITIONS : TEMPORARY FACILITIES

ITEM	QUANTITY	UNIT	UNIT RATE	COST
Porta-Potties - On Grade	30 MOS	1	$ 1,450.00	$ 43,500.00
Office Trailer Removal	1 LS	1	$ 23,257.00	$ 23,257.00
Temp. Storage Trailers	30 MOS	1	$ 500.00	$ 15,000.00
Temp. Fire Extinguishers	30 MOS	1	$ 150.00	$ 4,500.00
	TOTAL			**$ 86,257.00**

TABLE D-4: GENERAL CONDITIONS : MISCELLANEOUS COSTS

ITEM	QUANTITY	UNIT	UNIT RATE	COST
Project Signs	30 MOS	1	$ 1,200.00	$ 36,000.00
Tool Rentals	31 MOS	1	$ 500.00	$ 15,500.00
Housing Expenses	31 MOS	1	$ 6,647.00	$ 206,057.00
Travel Expenses	31 MOS	1	$ 5,996.00	$ 185,876.00
Automobile Mileage	31 MOS	1	$ 10,125.00	$ 313,875.00
Meeting Expenses	31 MOS	1	$ 525.00	$ 16,275.00
	TOTAL			**$ 773,583.00**

TABLE D-5: GENERAL CONDITIONS SUMMARY

ITEM	QUANTITY	UNIT	UNIT RATE	COST
SUPERVISION AND PERSONNEL	31 MOS	1	$ 170,772.31	$ 5,293,941.68
FIELD OFFICE EXPENSE	31 MOS	1	$ 15,056.71	$ 466,758.00
TEMPORARY FACILITIES	31 MOS	1	$ 2,782.48	$ 86,257.00
MISCELLANEOUS COSTS	31 MOS	1	$ 24,954.29	$ 773,583.00
TOTAL	**31 MOS**	**1**	**$ 213,565.79**	**$ 6,620,539.68**

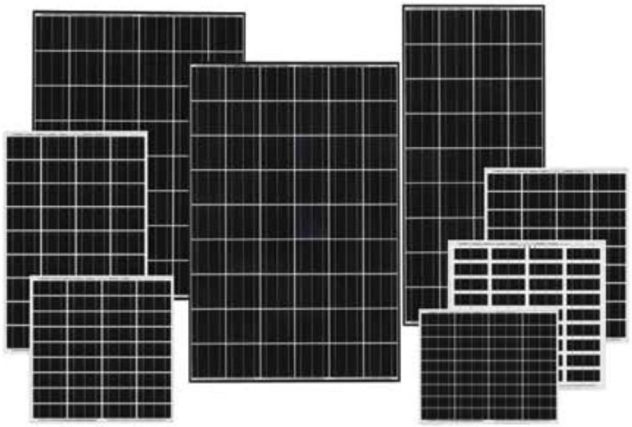
APPENDIX F: PV- PANEL PRODUCT DETAILS

KYOCERA

KD MODULES | P SERIES

Kyocera KD Modules

Kyocera KD Modules utilize a larger, more powerful, high efficiency 156mm x 156mm solar cell and produce higher output per module.



LOCKING PLUG-IN CONNECTORS
HEAVY DUTY ANODIZED ALUMINUM FRAME
LARGER, MORE POWERFUL 156MM SOLAR CELLS

Kyocera Empowers Your Future

Kyocera began research and development of solar energy back in 1975. Since then, we have been leading the solar industry with the development of the most efficient and cost effective systems available. With over 35 years of experience in solar, Kyocera is a natural industry leader. Our modules are ideal for a wide range of applications from off-grid industrial to on-grid commercial and residential, providing superior field performance among the competition. Kyocera stands behind its products and has a proven reputation within the solar industry for quality and reliability.

SOLAR by KYOCERA

KYOCERA

KD MODULES / P SERIES SPECIFICATIONS

	KD235GX-LPB	KD230GX-LPB	KD215GX-LPU	KD210GX-LPU	KD205GX-LPU	KD185GX-LPU	KD135GX-LPU
Maximum Power	235W	230W	215W	210W	205W	185W	135W
Number of Cells	60	60	54	54	54	48	36
Tolerance	+5% / -3%	+5% / -3%	+5% / -0%	+5% / -0%	+5% / -0%	+5% / -5%	+5% / -5%
Maximum System Voltage	600V	600V	600V	600V	600V	600V	600V
Maximum Power Voltage	29.8V	29.8V	26.6V	26.6V	26.6V	23.6V	17.7V
Maximum Power Current	7.89A	7.72A	8.09A	7.90A	7.71A	7.84A	7.63A
Open Circuit Voltage	36.9V	36.9V	33.2V	33.2V	33.2V	29.5V	22.1V
Short Circuit Current	8.55A	8.36A	8.78A	8.58A	8.36A	8.58A	8.37A
Series Fuse Rating	15A	15A	15A	15A	15A	15A	15A
Length	65.4″	65.4″	59.1″	59.1″	59.1″	52.7″	59.1″
Width	39.0″	39.0″	39.0″	39.0″	39.0″	39.0″	26.3″
Depth	1.8″	1.8″	1.8″	1.8″	1.8″	1.8″	1.8″
Weight	46.3 lbs	46.3 lbs	39.7 lbs	39.7 lbs	39.7 lbs	35.3 lbs	27.5 lbs
Termination Method	Locking Plug-in Connectors	Locking Plug-in Connectors	Locking Plug-in Connectors	Locking Plug-in Connectors	Locking Plug-in Connectors	Locking Plug-in Connectors	Locking Plug-in Connectors

Warranty

- Kyocera standard 20 year power output warranty and 5 year workmanship warranty applies in USA.
- Extended warranties available per project requirements.
- Kyocera standard 20 year power output warranty and 2 year workmanship warranty applies outside of USA.
- Refer to Kyocera warranty policy for details.

NEC 2008 Compliant
UL 1703 Listed, Class C
IEC 61215

Registered to ISO9001-2000

Kyocera reserves the right to modify these specifications without notice.

All specification at 25°C. cell temperature, 1.5 AM and 1000W/m^2.

KYOCERA SOLAR, INC.
800-223-9580 toll-free
800-523-2329 fax
www.kyocerasolar.com

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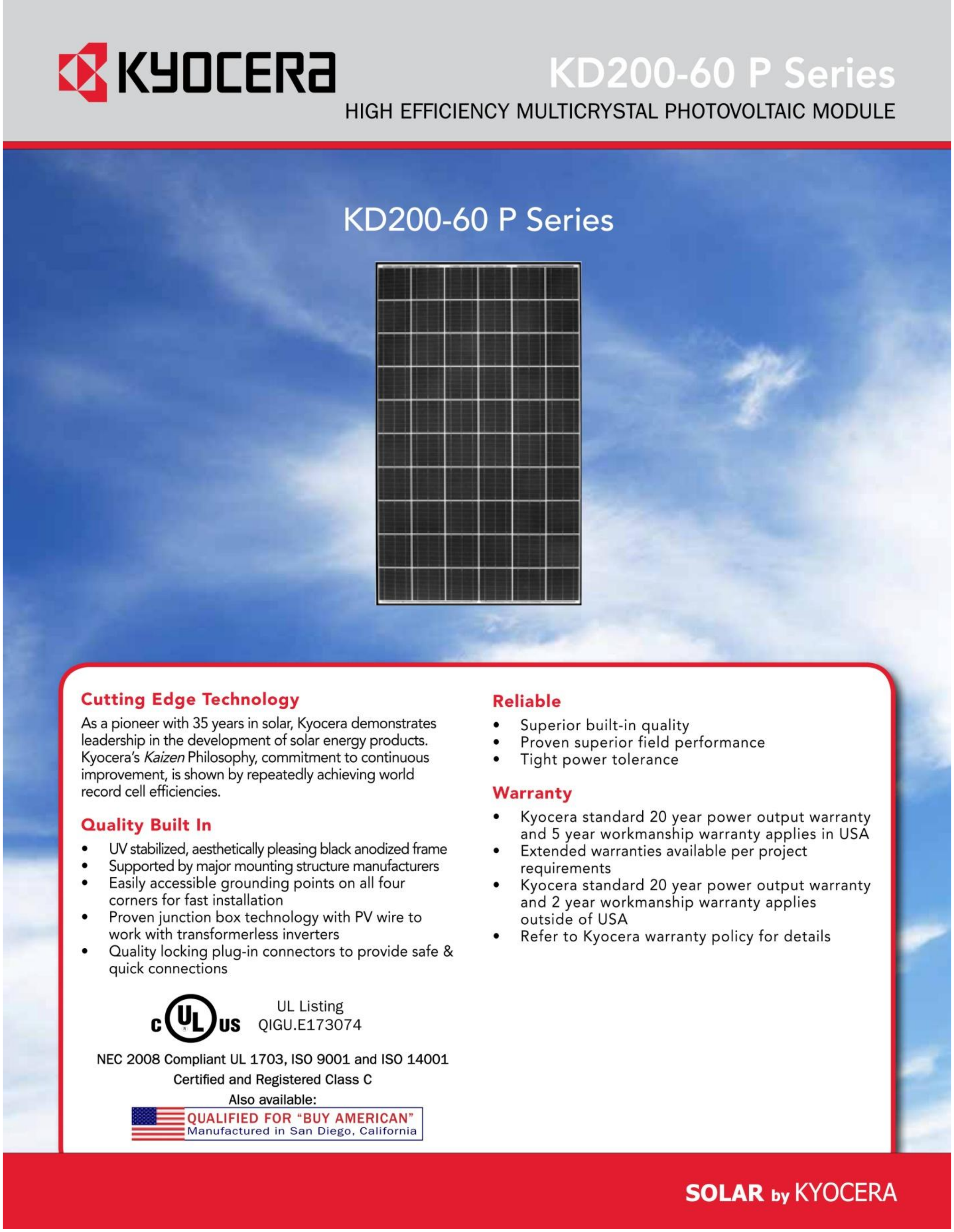


KYOCERA

KD200-60 P Series

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

KD200-60 P Series

Cutting Edge Technology

As a pioneer with 35 years in solar, Kyocera demonstrates leadership in the development of solar energy products. Kyocera's *Kaizen* Philosophy, commitment to continuous improvement, is shown by repeatedly achieving world record cell efficiencies.

Quality Built In

- UV stabilized, aesthetically pleasing black anodized frame
- Supported by major mounting structure manufacturers
- Easily accessible grounding points on all four corners for fast installation
- Proven junction box technology with PV wire to work with transformerless inverters
- Quality locking plug-in connectors to provide safe & quick connections

c UL us

UL Listing
QIGU.E173074

NEC 2008 Compliant UL 1703, ISO 9001 and ISO 14001
Certified and Registered Class C
Also available:
QUALIFIED FOR "BUY AMERICAN"
Manufactured in San Diego, California

Reliable

- Superior built-in quality
- Proven superior field performance
- Tight power tolerance

Warranty

- Kyocera standard 20 year power output warranty and 5 year workmanship warranty applies in USA
- Extended warranties available per project requirements
- Kyocera standard 20 year power output warranty and 2 year workmanship warranty applies outside of USA
- Refer to Kyocera warranty policy for details

SOLAR by KYOCERA

KD200-60 P Series

ELECTRICAL SPECIFICATIONS

Standard Test Conditions

	KD230GX-LPB	KD235GX-LPB	
P_{max}	230	235	W
V_{mp}	29.8	29.8	V
I_{mp}	7.72	7.89	A
V_{oc}	36.9	36.9	V
I_{sc}	8.36	8.55	A
$P_{tolerance*}$	+5/-3	+5/-3	%

Nominal Operating Cell Temperature Conditions (NOCT)

T_{NOCT}	47.9	47.9	°C
P_{max}	163	166	W
V_{mp}	26.4	26.4	V
I_{mp}	6.18	6.31	A
V_{oc}	33.3	33.3	V
I_{sc}	6.78	6.93	A

Temperature Coefficients

P_{max}	-1.04	-1.07	W/°C
V_{oc}	-0.133	-0.133	V/°C
I_{sc}	0.00502	0.00513	A/°C
Operating Temp	-40~90	-40~90	°C

System Design

Series Fuse Rating	15 A
Maximum DC System Voltage (UL)	600 V

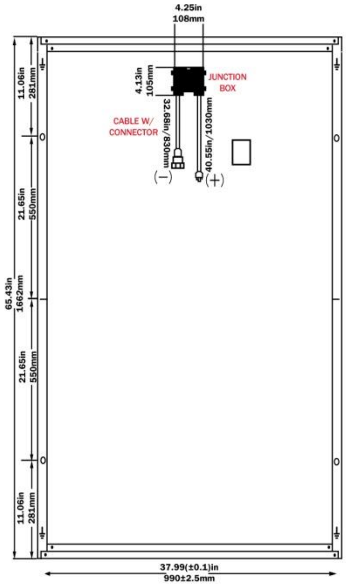
NEC 2008 Compliant
UL 1703 Listed

Registered to ISO9001-2000

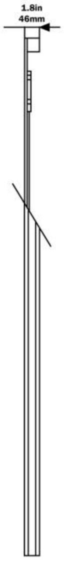
Kyocera reserves the right to modify these specifications without notice.

All specification at 25°C. cell temperature, 1.5 AM and 1000W/m².

MECHANICAL SPECIFICATIONS



Weight: 46.3lbs (21.0kg)



Legend
○ MOUNTING HOLES ● DRAINAGE HOLES ⏚ GROUNDING HOLES

AUTHORIZED DISTRIBUTOR

KYOCERA SOLAR, INC. 800-223-9580 toll-free 800-523-2329 fax www.kyocerasolar.com

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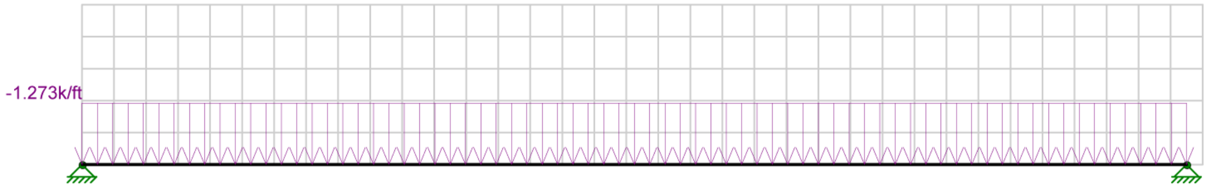
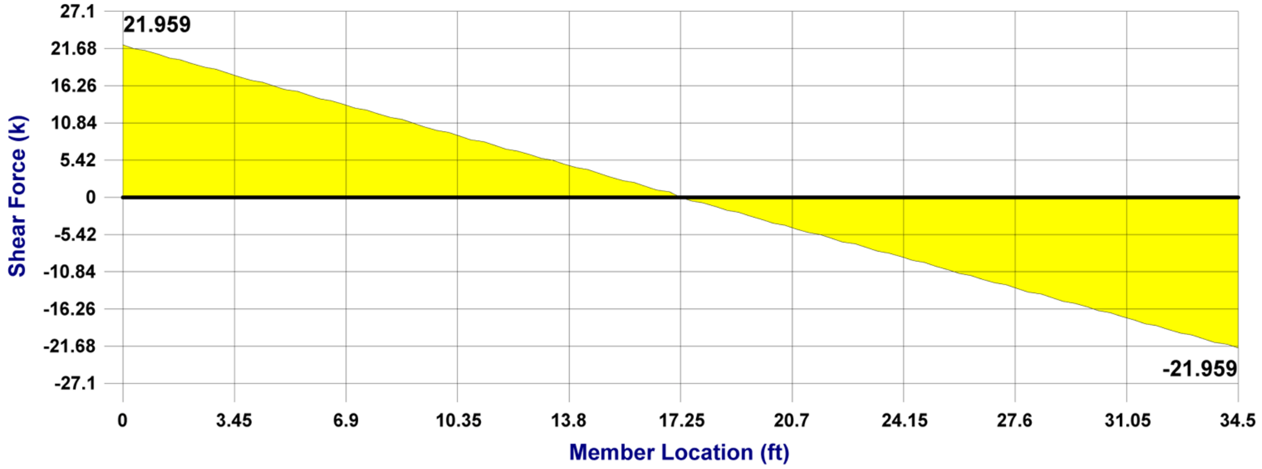
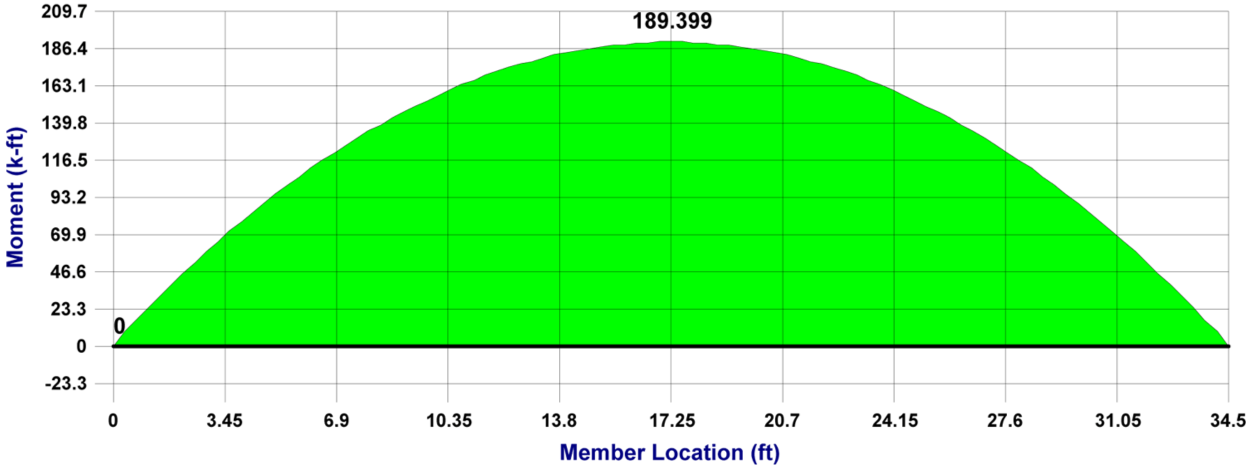
APPENDIX G: STRUCTURAL CALCULATIONS

F.1 ANALYSIS OF BEAM W16X36



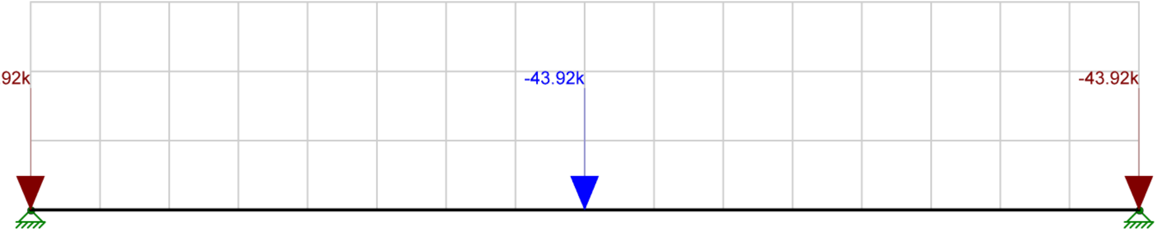


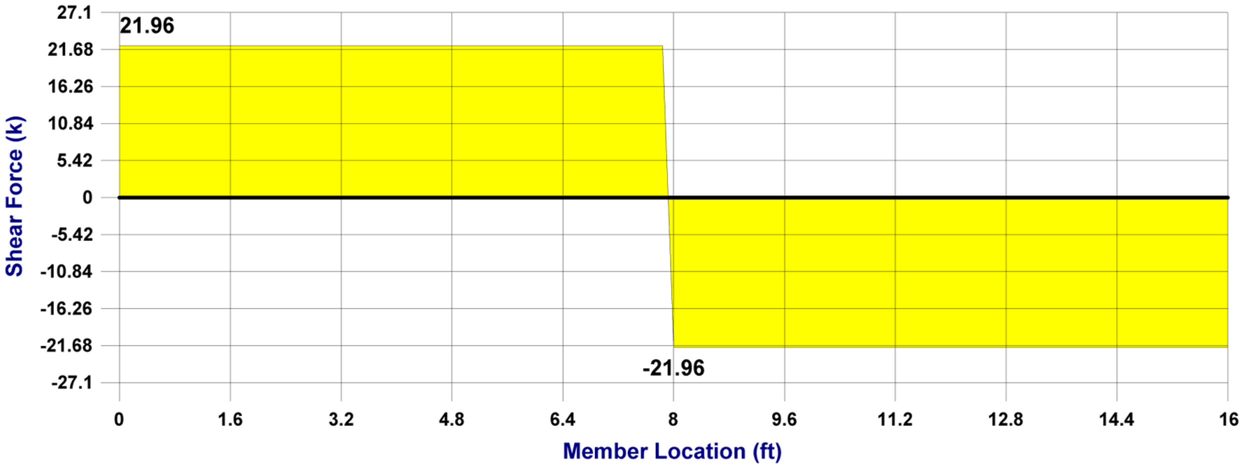


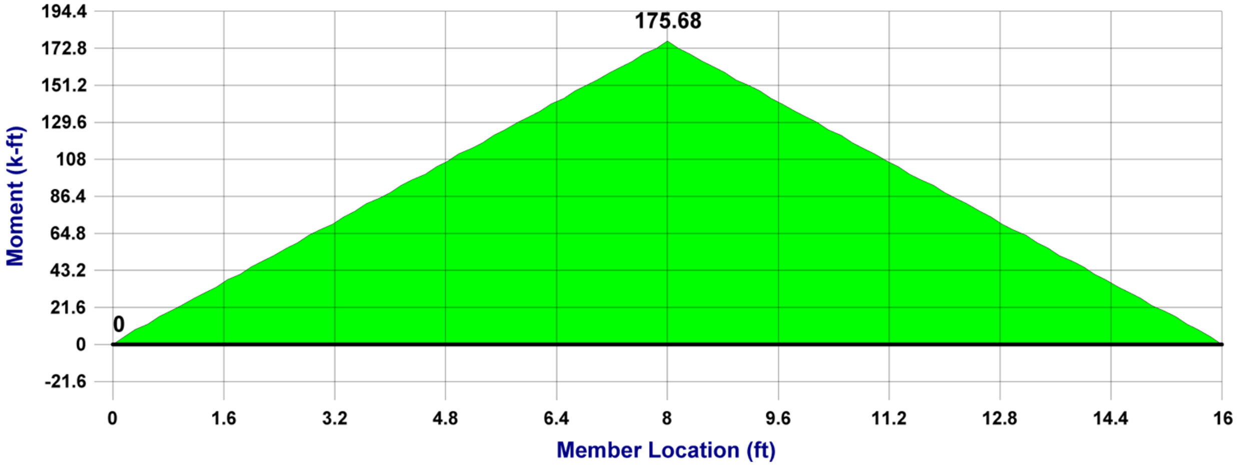
Consulting AISC Manual of Steel Construction, the W16X36 Beam is able to support the maximum moment reaction.

$$M_{max} = 189.399\ k\cdot ft < 240\ k\cdot ft = \emptyset_b M_{px}\ \therefore\ \boldsymbol{ok}$$

F.2 ANALYSIS OF GIRDER W16X36



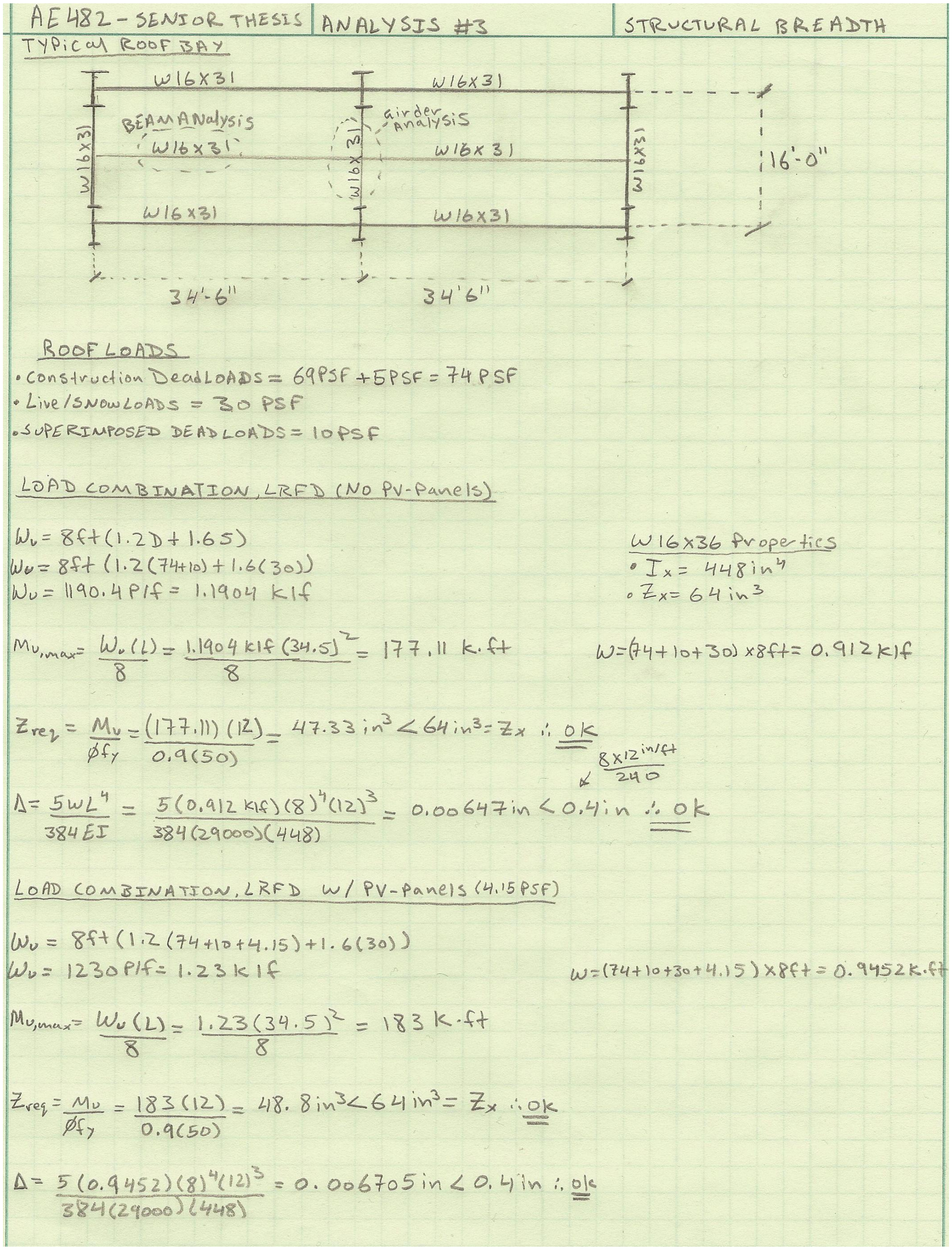




Consulting AISC Manual of Steel Construction, the W16X36 Girder is able to support the maximum moment reaction.

$$M_{max} = 175.68\, k \cdot ft < 240\, k \cdot ft = \emptyset_b M_{px} \; \therefore \; \boldsymbol{ok}$$

F.3 STRUCTURAL HAND CALCULATIONS



AE 482 - SENIOR THESIS | ANALYSIS #3 | STRUCTURAL BREADTH

TYPICAL ROOF BAY

ROOF LOADS

- Construction Dead LOADS = 69PSF + 5PSF = 74 PSF
- Live/SNOW LOADS = 30 PSF
- SUPERIMPOSED DEAD LOADS = 10 PSF

LOAD COMBINATION, LRFD (No PV-Panels)

$W_u = 8ft(1.2D + 1.6S)$

$W_u = 8ft(1.2(74+10) + 1.6(30))$

$W_u = 1190.4$ Plf $= 1.1904$ klf

W16x36 Properties

- $I_x = 448 in^4$
- $Z_x = 64 in^3$

$M_{u,max} = \frac{W_u(L)}{8} = \frac{1.1904 klf (34.5)^2}{8} = 177.11$ k.ft

$W = (74+10+30) \times 8ft = 0.912 klf$

$Z_{req} = \frac{M_u}{\phi f_y} = \frac{(177.11)(12)}{0.9(50)} = 47.33 in^3 < 64 in^3 = Z_x$ ∴ OK

$\frac{8 \times 12 in/ft}{240}$

$\Delta = \frac{5wL^4}{384EI} = \frac{5(0.912 klf)(8)^4(12)^3}{384(29000)(448)} = 0.00647 in < 0.4 in$ ∴ ok

LOAD COMBINATION, LRFD w/ PV-Panels (4.15 PSF)

$W_u = 8ft(1.2(74+10+4.15)+1.6(30))$

$W_u = 1230$ Plf $= 1.23$ klf

$W = (74+10+30+4.15) \times 8ft = 0.9452 k.ft$

$M_{u,max} = \frac{W_u(L)}{8} = \frac{1.23(34.5)^2}{8} = 183$ k.ft

$Z_{req} = \frac{M_u}{\phi f_y} = \frac{183(12)}{0.9(50)} = 48.8 in^3 < 64 in^3 = Z_x$ ∴ ok

$\Delta = \frac{5(0.9452)(8)^4(12)^3}{384(29000)(448)} = 0.006705 in < 0.4 in$ ∴ ok

M_u, Including BEAM SELFWEIGHT

$w = (74+10+4.5+4.15+30) \times 8ft = 0.9812 k \cdot f$

$M_{u,rw} = 1.2\left(\frac{0.036(34.5)^2}{8}\right) = 6.427\ k.ft$

$M_u = 183 + 6.427\ k.ft = 189.42\ k.ft$

$Z_{req} = \frac{189.42\ k.ft\ (12)}{0.9(50)} = 50.51\ in^3 < 64\ in^3\ \therefore \underline{\underline{OK}}$

$\Delta = \frac{5(0.9812)(8)^4(12)^3}{384(29000)(448)} = 0.00696\ in < 0.4\ in\ \therefore \underline{\underline{ok}}$

$\therefore$ BEAM W16X36 can sustain the additional PV-Array LoadS

Analysis of Girder W16X36

Wt. of W16X36 in Trib Area $= \frac{36\ plf \times 34.5 \times 2}{34.5 \times 16} = 4.5\ PSF$

$W_u = 34.5\ (1.2(74+10+4.15+4.5)+1.6(30))$

$W_u = 5491.71 = 5.491\ klf$

$W = (74+10+4.5+4.15+30) \times 34.5 = 4.231\ k.ft$

$M_u = \frac{5.491\ (16)^2}{8} = 175.712\ k.ft$

$Z_{req} = \frac{175.712\ (12)}{0.9\ (50)} = 46.857\ in^3 < 64 in^3\ \therefore \underline{\underline{ok}}$

$L/240 = \frac{34.5(12)}{240} = 1.725$

$\Delta = \frac{5(4.231)(16)^4(12)^3}{348(29000)(448)} = 0.5298 in < 1.725 in\ \therefore \underline{\underline{ok}}$

$\therefore$ Girder W16X36 can sustain the additional PV-Arrayloads