Daniel Alexander | CM | Dr. Messner

Thesis Final Report

Doctors Community Hospital | Lanham, MD

April 7, 2009

Doctors Community Hospital

Lanham MD

Project Team

- Owner: Doctors Community Hospital
- CM: Gilbane Building Company
- Architect: CR Goodman Associates
- Structural: Mincin-Patel-Milano
- Mech & Electrical: Leach Wallace Associates

Structure

- Steel columns and beams built up on existing steel construction
- Concrete footers with grade beams (~50% existing, 50% new)
- Lightweight concrete on metal deck to form composite slab
- Non-load bearing brick on metal stud facade

Mechanical

- Roof mounted mechanical plant
- 90,000 CFM air handler feeding VAV boxes
- 425 Ton chiller
- Draw through 425 ton cooling tower
- (3) 2,678 MBH duel fuel boilers
- Medical Gas and Vacuum tubes feed each patient room

Project Overview

- Function: Medical Hospital
- Size: 270,000 SF expansion
- Cost: $42 Million
- Delivery: Design-Bid-Build with a GMP from a CM@Risk
- Occupant: Doctors Community Hospital
- Dates: Nov '07- March'10

Electrical/Lighting

- 1,200 Amp switchgear
- (2) 2,500 Amp switchboards
- 1,250 kVA Emergency Generator fed by 5,000 gal fuel tank
- Power fed vertically through stacked electrical rooms with multiple transformers in each
- Lighting typically consists of recessed 2x4 fluorescent lights

Special Considerations

- Construction is occuring directly above and adjacent to an operational hospital. Outages must be coordianted with owner, and special dust and debris control is needed in renovation portions

Architecture

- Patient rooms arranged on the outside with support areas in the center
- Brick facade with split-face CMU banding and cast stone window lintels
- Roof: Built up Styrene-Bitumen-Styrene system on 3" polystyrene foam

Daniel Alexander | Construction Mangement

http://www.engr.psu.edu/ae/thesis/portfolios/2009/dra5002/

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ACKNOWLEDGEMENTS

I would like to extend my deepest appreciation to the following people for their assistance, insight, and time throughout the past year:

- **Gilbane Building Company**
  - Benjamin Alexander, Assistant Project Manager
  - Ben Miller, Project Engineer
  - Brian Horn, 3D Design Coordinator, DSL

- **Doctors Community Hospital**
  - Jerry Dyer, Director of Plant Operations
  - Thomas Crowley, Executive Vice President
  - Lynn Woodell, Asst to Mr. Dyer
  - Regina Robinson, Asst to Mr. Crowley

- **DCH Construction Team**

- **Penn State Faculty**
  - Dr. John Messner
  - Professor Kevin Parfitt
  - Professor Robert Holland

- **Industry Professionals**
  - Jason Reece, Balfour Beatty
  - Kurt Maldovan, Jacobs

- **Fellow AE Students, especially**
  - Lindsay Hagemann
  - Craig Dubler
  - Shane Goodman
  - Chitwan Saluja

EXECUTIVE SUMMARY

This document is a comprehensive technical analysis of the construction of the Doctors Community Hospital (DCH) expansion currently underway in Lanham, MD. An overview of the project, including a look at the project team, the client, the current design and construction methods was performed. Other important information such as site plans, current schedules, and project costs were also outlined.

Three areas of analysis were performed and address different aspects of the construction industry. Value engineering, schedule reduction, constructability, and a critical industry issue were four items addressed in these analyses.

The first analysis focused on a critical industry issue: BIM Implementation. BIM is growing in popularity and has much of the industry interested in its capabilities. This analysis focused specifically on 3D MEP coordination and a generalized process for performing this task. The goal was to generate a process that could tie into ongoing research at Penn State with the Computer Integrated Construction group. A process map based on input from several experience industry members was developed. The application of this process to the DCH project was also analyzed and a plan for implementation was created.

Analysis Two focuses on using a precast façade in place of the current system, hand laid brick façade. Positive gains in the schedule, decreasing it 6 weeks, were realized by using the new system. Structural calculations were performed to ensure that the heavier system was still able to be supported without a redesign of the steel superstructure. Mechanical calculations showed that there was improved energy efficiency which translated into operations savings of roughly $2,700 per year. Initial costs were significantly higher, and as such, this alternative system was deemed unfeasible.

The final analysis looked at the current site logistics, specifically the site congestion, and how it affected the constructability of the project. Interviews with subcontractors were performed to assess the effects of the congested site on their respective trades. This information was synthesized and an overall cost and schedule impact was generated based on their input. Property adjacent to the site that DCH contemplated purchasing was looked at from a cost/benefit standpoint based on this new information. Had the owner moved to purchase the land 2-3 years ago at the original offer price of $500,000, it would have been a good investment. The current asking price of $2 million is too high for it to be a viable move at this time.

INTRODUCTION

Doctors Community Hospital (DCH) is located in Lanham, MD which is just outside of the Washington, DC, beltway in Prince George's County. Suburban Maryland is constantly growing and the hospital needs to improve its facility to continue to serve the area as a top-tier medical establishment.

The goal of the project is to provide a roughly 200,000 square foot expansion to an existing hospital and renovate about 70,000 square feet of existing space. All of the work will be completed while the hospital remains fully functional. Constructing a building that is attached to an existing, functional hospital, poses unique challenges for the project team, especially in terms of dust and debris control.

The expansion will consist of a 1st floor expansion to the existing Emergency Department, 2nd floor shell space (as of now, change order expected to fit-out space as administrative offices), and floors 3 through 5 will be patient rooms. Existing rooms on floors 3, 4 and 5 will be renovated as the last step in the project.

Gilbane Building Company is serving as the CM-at-risk for the DCH construction project. Design began in June of 2006 and the Notice to Proceed came forth on November 14, 2007. Three phased finish dates exist for the project: Emergency Department Expansion completed by February 2009, Patient Tower Expansion completed by June 2009, and Renovations finished by March 2010.

The original total cost for the project was $31,000,000 but the original scope did not include the 1st floor ED expansion. The total cost of the project as it currently stands is roughly $37,000,000.

PROJECT OVERVIEW

CLIENT INFORMATION

Doctors Community Hospital is a privately run, not-for-profit organization located in Prince Georges County, Maryland, which is adjacent to Washington, DC. Their goal is to serve the surrounding area of PG County and provide top notch medical service to those people in the region.

The expansion project was borne out of a need to create more space to adequately serve the needs of its patients. Currently, the hospital is very crowded, and many rooms that were originally designed to be private, individual rooms have been turned into semi-private, two person rooms. The vertical expansion is aimed to create enough new patient rooms that they can continue to serve the region, but offer private rooms for all individuals that require overnight stays at their facilities. Through this project, coupled with other construction underway on the campus as well, they also hope to expand their influence and reach into neighboring Anne Arundel County for patient care.

PROJECT DELIVERY METHOD

This project is being delivered with a Construction Manager at risk method. CR Goodman and Associates is serving as the architect for this project. As shown in Figure 1-Contractual Arrangements for the DCH Expansion, they are being compensated through a lump sum contract with the owner, DCH. CR Goodman has enlisted the services of consulting engineers for both structural and MEP work, and is using Lump Sum contracts for these arrangements. The majority of the design was completed before documents were sent out to bid.

Gilbane has been selected to perform the CM-at-risk responsibilities for the expansion and has entered into a Guaranteed Maximum Price contract with the owner. They have hired their subcontractors and entered into Lump Sum agreements for the major subs shown at right.

Traditional bonds are not required on this project by the owner or Gilbane, but instead, Contractors Default Insurance is being used to handle this risk. This insurance method is handled largely at the corporate level, not on the jobsite. The main advantage of this structure is that should a contractor go under, there is not an investigation by a bonding agency, therefore, the jobsite staff has better control over how to proceed, thus mitigating the impact on the project.

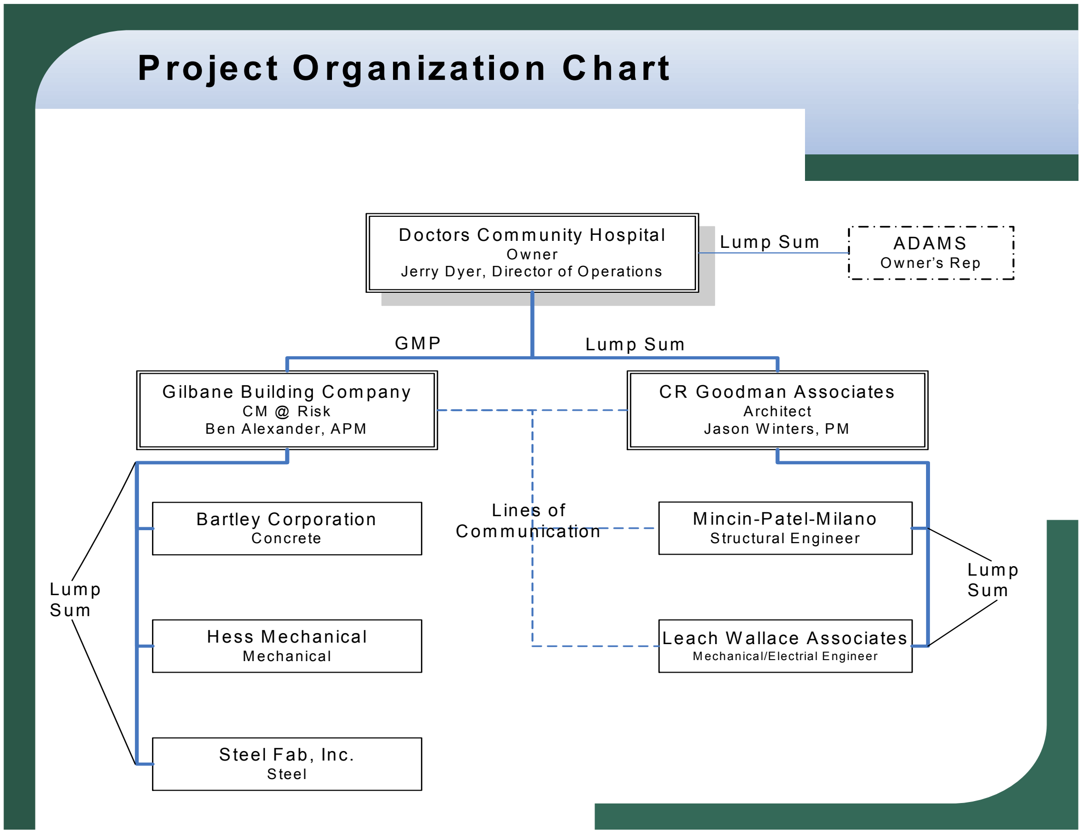


FIGURE 1-CONTRACTUAL ARRANGEMENTS FOR THE DCH EXPANSION

GILBANE PROJECT TEAM

Gilbane's staffing plan is relatively straight forward, without any complex relations or special positions and is laid out in Figure 2-Staffing Plan for Gilbane Building Company on DCH. The Project Executive oversees this project, along with a few other projects within the company. He is generally not on site, and makes appearances for roughly a day each week or less. Lisa Hancock, Project Manager, is the primary Gilbane employee in charge on site. She is supported in her management duties by her APM, Ben, and her project engineer, also named Ben. In the field, General Superintendent Ed is responsible for the construction activities and is supported by Tim.

It is curious to note that on such a MEP intensive project, systems which account for nearly half of the building cost, they do not employ at least a part time, if not full-time, MEP coordinator. Gilbane has specialized part of its company into Hospital construction, expansion, and renovations. Coordination is generally handled by the APM's and project engineers.

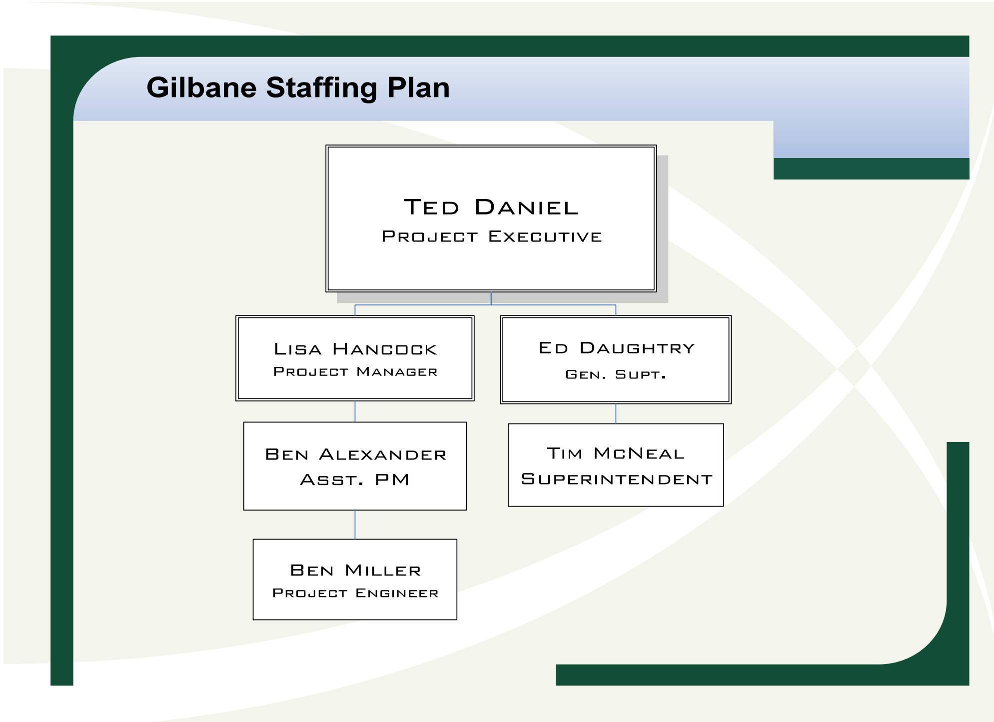


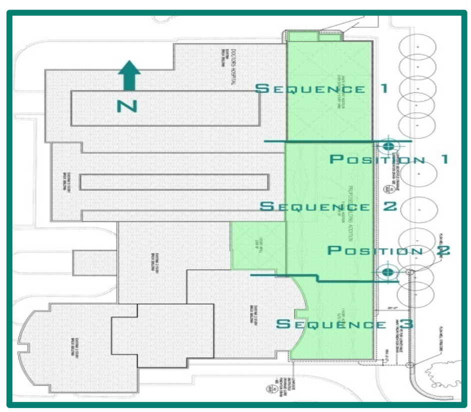
FIGURE 2-STAFFING PLAN FOR GILBANE BUILDING COMPANY ON DCH

DESIGN AND CONSTRUCTION OVERVIEW

TABLE 1-BUILDING SYSTEMS OVERVIEW

Scope of Work	Summary Features

Demolition	• Demolition occurs in two main phases
	  o **Exterior Prep**- To ready existing site and portions of existing façade for new structure (Brick and asphalt)
	  o **Interior Renovations**- as the 2nd through 5th floors in the existing structure are renovated (Drywall, casework, partitions, Limited concrete deck fill)
	• **Asbestos and lead paint** abatement is expected in the interior portion of renovations. As of yet, **quantity is undefined** for both. (Original construction in 1970's)
	  o Expecting to find asbestos in existing pipe insulation
	  o Expecting lead paint in most/all painted rooms
	  o Contractor is expected to remove any asbestos encountered, even if it is not friable
	• Contractor to **salvage existing** hospital items in renovation area as directed by owner. **Contractor is responsible** for all salvaged material until reinstalled.

Structural Steel	• **W-Shape** columns and beams placed on concrete footers
	  o Size range W8x30 to W12x170
	  o Placed from North to south via a 130 Ton truck crane
	  o The crane uses two locations as shown in Figure 3-Crane Location for Steel Erection.
	
	FIGURE 3-CRANE LOCATION FOR STEEL ERECTION
	
	• **Composite slab** on metal deck with shear studs
	  o **Lightweight concrete** 5" slab (3 ½" Topping slab on ½" metal deck)
	  o 6x6x8/8 WWM typical throughout for deck reinforcement
	• **Moment resistance: 6 K-frames** located at 6 different

<table>
<tr><th>Scope of Work</th><th>Summary Features</th></tr>
<tr><td></td><td>column lines down center of building
Full penetration moment welds at girders tying into these framing units</td></tr>
<tr><td>Cast in Place Concrete</td><td>
Caissons, column footers, foundation walls, slab on grade, concrete on metal deck
Drilled caissons being used down to a depth of 50’ at 11 locations
No formwork used; Drilled and placed direct into ground (ground is formwork)
Placed via Pump
4000 PSI
(14) #11 rebar reinforcing with #3 ring ties 12” O.C. for length of caisson
Foundation walls and Footers
Formwork
Footers- Occasional use of stick built form work. Often used ground as form work.
Foundation Wall- Reusable, prefabricated form work
Placement
Footers- Direct Chute
Foundation Wall- Pump
3000 PSI
Reinforcement ranges from #3-#12 depending on location
Slab on Grade
2x edge formwork
Placed Via Direct Chute
4000 PSI concrete on 4” crushed gravel fill and vapor barrier
6x6x8/8 WWM reinforcement
Concrete on Metal Deck
Pour stops incorporated in steel work
Placed via Pump
4000 PSI
</td></tr>
<tr><td>Mechanical Systems</td><td>
Mechanical plant for all air system located in penthouse
Chiller, Boilers, Cooling tower, AHU
All extremely large; must be craned in to place
AHU to be fabricated and delivered in 5 pieces
AHU fed by chilled and hot water loops
Two mechanical shafts used for distribution
One at north end, one at south end
Additional Isolation Exhaust air from selected rooms at ends of wings on North end.
High pressure exhaust ductwork
</td></tr>
</table>

Scope of Work	Summary Features
	o **VAV's (some with reheat)** are used throughout the facility o **Linear Radiant Heating Panels** are incorporated at all windows in the patient rooms • **Medical Gas, Vacuum** (fed from penthouse compressors) **& Oxygen** (fed from on site oxygen plant) lines feed each patient room • Each Patient room has **private restrooms** • Fire Suppression o Expanded sprinkler system into addition o Wet type, zone activated (4 zones per floor) o Standpipes at 4 locations (each stairwell) per floor- 2 existing
Electrical System	• System ties into **two existing 2500 A** Switch boards o Boards to be reconfigured; consolidating smaller breakers to feed a new distribution panel to allow larger 800 Amp breakers put in place to serve distribution panels in addition • **N+1** Redundancy o **1000 KW** Emergency generator o **5000 Gallon** fuel tank o Located outside away from building. **Requires underground duct bank** to feed into new electrical room o Sized for expansion only; existing structure still feed from existing generator back up plant
Masonry	• CMU, fire-rated stairwells o Self-supporting stair tower o Vertical #5 @ 16" O.C, wall grouted solid o Requires scaffolding whole height o Anchored at each slab on deck with ¾" anchor bolts welded to angle iron • Brick Façade o Veneer, non-load bearing cavity wall assembly o Erected "by face". Slower in opening areas up to begin interior trades, but requires less scaffolding. o Attached to CFMF with veneer anchors
Excavation Support	• **Underpinning** the existing structure was necessary during excavation near existing foundations • **Sheeting and Shoring** were support method of choice for excavation • Ground water was not an issue (above water table), therefore dewatering was not a consideration o Pumps were used if occasional rain or snow created standing water

LOCAL CONDITIONS

Doctors Community Hospital is being constructed in Lanham, Maryland, a suburb of Washington, DC, located just outside of the capital beltway on a 33 acre site. The majority of the site has already been developed by the hospital and consists either of parking lots or other buildings. The remainder of the site is dense trees, which cannot be removed or disturbed during construction due to zoning ordinances and buffer requirements.

Preferred construction methods in the DC area generally focus on Low floor-to-floor heights due to height restrictions within the district. Satisfying this restriction has typically led to an increased use of concrete structures. This project is not subject to these restrictions since it is just outside of city limits, and as such, has elected to use a steel superstructure.

This project is not seeking LEED certification, but Gilbane has set a company policy of achieving 75% recycling on all projects. Debris must be sorted on site between two dumpsters. One is designated for “heavy debris”, concrete, CMU, Brick, etc and the other dumpster has all other construction waste. Dumpsters are averaging being pulled between 1 and 2 times per week, at a cost of $400/pull. EAI, Inc, is responsible for taking them away, and they handle all the recycling needs of the project.

Several borings were taken around the site to establish a good thought pattern on what types of soil were likely to be discovered during excavation. Boring logs confirmed what was already suspected; no rock was to be encountered during excavation and the water table will not be a factor. Water levels were not hit generally until about the 30’ mark below grade. Almost all excavation would stay above this mark. As such, only dewatering due to rain/snow would be a consideration for DCH. The only structure that goes deeper are drilled caissons, for which water levels have minimal impact. Soil types ranged from Lean Clay to Sandy Silt. No rock was discovered via borings, which bodes well for a speedy excavation.

EXISTING SITE CONDITIONS

Space at the Doctors Community Hospital expansion is in very short supply. Four factors contribute to this reality.

1. They are not building on an open site. As seen in Figure 4-DCH Site Plan, there are 6 other structures, including the one they are expanding, already on site. Structures 7 and 8 are currently under way on the south end of the site. One is a new parking deck; the other is a new Medical Office Building. All of these structures take up space that could be used for lay down, but is clearly not available.
2. Construction is occurring on the east side of the current hospital, which abuts a private residence. They are unable to utilize any space beyond the property line, which limits

the path way on the east to a mere 25' from the footprint of the expansion. Between this limited road way, and the existing building they are expanding on the other side, access to the construction is extremely limited and creates an exorbitant amount of congestion.

3. Contractors are competing for space with the other construction site on campus. Both sites are in need of lay down and material storage space, which is a finite quantity. The apparent "green space" in Figure 4-DCH Site Plan is unfortunately not open field, but rather heavily forested areas that they cannot clear to create more space due to zoning regulations.
4. Much of the parking lot space must remain usable so that they hospital may continue functioning normally. Both medical staff and patients must be able to access the fully functional hospital throughout the duration of construction. This fact limits the amount of parking lot space that can be usurped for construction activities.

These factors cause a significant risk of impacting the construction of this project. The congestion can lead to productivity inefficiencies that cause schedule delays and cost overruns. Risk is an evil that must be managed effectively on any construction project, and this one is no different. Space limitation is by far, one of, if not the largest, areas of risk present at the DCH vertical expansion.

Another large area of risk related to site planning is non construction traffic (vehicular and pedestrian). The hospital will maintain full functionality throughout the project. Ambulances must be able to come and go freely and quickly. This need will make it imperative to have prominent and clear signage to direct staff, patients, and construction traffic in the right direction to: reduce congestion, keep people safe, and not impact hospital operations.

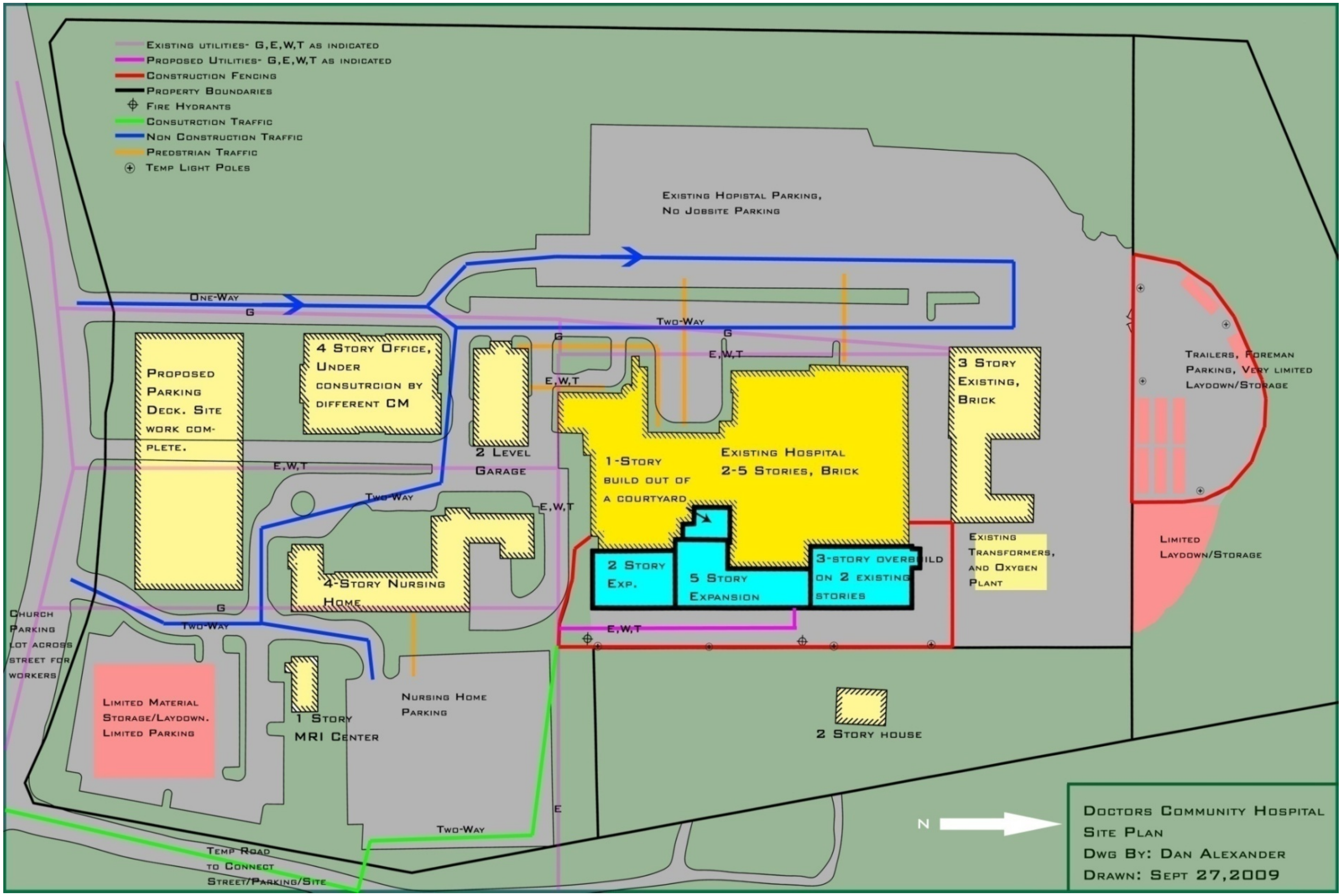


FIGURE 4-DCH SITE PLAN

SITE LAYOUT PLANNING

Site planning is a critical issue on the Doctors Community Hospital project. The site is extremely congested, and there are multiple construction projects going on simultaneously. Furthermore, the hospital is remaining in full operation during the construction. This fact means traffic management will be a critical issue so as not to interfere with emergency vehicles entering and leaving the campus.

If the north side of the site were able to be utilized for traffic flow, it would be a big advantage because one-way traffic could be implemented. However, as noted on the site plan in Appendix I, the area is too congested. Parking for hospital employees limits the traffic to typical pickup trucks and foreman vehicles only. Tractor trailers and other large delivery trucks have too large a turning radius to safely navigate that area. As a result, all larger deliveries (Concrete trucks, Flatbeds, large trucks) must all come in from, and exit at the south gate. This situation also makes communication of traffic patterns to delivery people crucial. If a tractor trailer were to take the west entrance road, they would get stuck and have to navigate out of the lot by backing the whole way back down to the main road. Traffic would be congested if this were too happen, which could impact emergency vehicles entering and exiting the hospital grounds.

EXCAVATION

Excavation was not very extensive on this project. Shallow excavation was all that had to occur at the south end of the building. The grade was already low enough, and the only excavation that occurred was for footings and underground MEP installation. The northern limit of excavation was deeper and also required underpinning along the existing building so as not to undercut existing foundations. (See Appendix I: Site Layout Planning for plan)

STEEL ERECTION

Steel Erection poses one very distinct challenge. With the crane on site, it becomes very difficult to have traffic move through the site. Fortunately, there was just enough room when having the truck crane on site, other vehicles were still able to get by if needed, though it was avoided if at all possible. One crane was used for steel erection, and though it was a truck crane, they only used two locations.

INTERIOR FIT-OUT

Throughout the façade installation and during interior fit out, a hoist will be used to move people and materials vertically. This situation will exist until the permanent elevators are fully functional and protected to be used for the duration of construction. Buggies and trash chutes will be used until the building is closed in. As the façade closes, the chute will be removed, and the buggies will go all the way to the dumpster.

PROJECT LOGISTICS

SCHEDULE

The Doctors Community Hospital (DCH) is a 3 piece addition to the existing building. The first piece is 1 story on the south end that will expand the Emergency Department (ED). Piece two is a five story tower being built alongside the existing patient room tower. The first floor of this tower will tie in with the Emergency Department expansion. The second floor is currently left as shell space, but allowances have been placed in the schedule to facilitate the build out when it is released. The hospital has not finalized what the space will be used for, but it is expected to be partially an MRI suite, with the remainder being used for administrative office space. The top three floors of piece two are all private patient rooms. The final piece is actually an extension of piece two. The north end of the patient tower is being built on top of an existing two story transition care portion of the building. All of these "pieces" are being constructed simultaneously.

When the addition is complete, renovations are to take place on floors three through five of the existing tower. This point will signify the complete of the project. A detailed Gantt chart showing durations and relations can be found in Appendix I | CPM Schedule.

PROJECT COST SUMMARY

Costs on any project are always an important metric to establish at the beginning, and to carefully track throughout construction. Several methods can be used to establish projected costs. These methods range from a very quick ROM estimates based on the cost of some definable unit (Number of beds for a hospital, cost per apartment in a complex, total seats for a theatre) to detailed take offs of each system in the project to develop a final budget.

Cost projections for this project shown below in Table 2-Cost Breakdown for DCH are provided courtesy of Gilbane Building Company. It looks at total project costs, including a breakdown of some major systems in the project. "Total project" includes all costs (Land, sitework, overhead, general conditions) and "Building costs" include only the cost of labor and material.

It is interesting to note that this original cost did not include the 1st floor Emergency Department Fit out, or any potential second story fit out. These spaces were originally designated as shell space only. One change order has been processed already to add the finish scope of the 1st floor emergency department. The total contract as based on this addition stands at roughly $37 Million.

TABLE 2-COST BREAKDOWN FOR DCH

Cost Breakdown		
	Cost	Cost/SF
Total Project (Original)	**$ 31,318,000**	**$ 157**
Total Building (Original)	$ 26,413,000	$ 132
Systems		
Mechanical	$ 9,203,000	$ 46
Structural Steel	$ 1,554,000	$ 8
Electrical	$ 3,084,000	$ 15
Masonry	$ 1,052,000	$ 5
Concrete	$ 1,035,000	$ 5
Sprinkler	$ 444,500	$ 2

GENERAL CONDITIONS ESTIMATE SUMMARY

General conditions at Doctors Community Hospital have been divided into 4 major categories: Personnel, Utilities/Facilities, Site Office Support, and General Requirements. Personnel includes all project management staff that are onsite and employed by the CM, Gilbane. Temporary utilities and the trailers they power are included in the Utilities/Facilities category. Products that are necessary for the proper functioning of an office are in the Site Office Support category. This includes travel, vehicles, office supplies, phones, and furniture. General requirements encompasses everything else that is required for a safe and productive site including but not limited to signage, barriers and fences, waste removal, and hoists. A summary breakdown is shown below in Table 3-Summary of General Conditions Estimate. The final cost is $1,717,335 which translates to %5.5 of the original bid price. A detailed breakdown can be found in Appendix II | Detailed Estimate Breakdowns.

TABLE 3-SUMMARY OF GENERAL CONDITIONS ESTIMATE

Summary of General Conditions Estimate	
Personnel	$ 1,104,915
Utilities/Facilities	$ 90,190
Site Office Support	$ 91,950
General Requirements	$ 430,280
Total	**$ 1,717,335**

DETAILED STRUCTURAL SYSTEM ESTIMATE SUMMARY

Take-offs for this estimate were prepared using a combination of Revit Architecture and Revit Structure. A detailed model of the steel and concrete systems was created based of the hard copy construction drawings. Quantities were generated automatically within Revit using the Schedule/Quantities function. These gross values were then imported into Excel to filter into useful numbers that could be estimated with RS Means. The total for the detailed estimate for the structural system at Doctors Community Hospital was $1,539,912 as illustrated below in Table 4-Summary of Detailed Estimate. A detailed breakdown of the estimate maybe found in Appendix II | Detailed Estimate Breakdowns.

TABLE 4-SUMMARY OF DETAILED ESTIMATE

Summary of Detailed Estimate	
Steel	
Columns	$ 291,324
Beams	$ 623,164
Metal Deck	$ 116,042
Concrete	
Foundations	$ 210,067
Slabs	$ 252,835
Slab Reinforcing	$ 46,480
Structural Total	**$ 1,539,912**

Methodology and Assumptions for Estimate

- Used RS Means online costworks for all cost values (2008 values)
- Adjusted to reflect Maryland's location factor of .97 (Automatically done online)
- Utilized "Concrete in place" category, which includes formwork, finishing, placement, and reinforcement in unit cost
- Overhead and Profit were not included
- Open shop labor was assumed

ANALYSIS 1| IMPLEMENTING BIM

BACKGROUND

Building Information Modeling (BIM) is fast becoming a more integral part of the construction industry. With several leaders pushing the envelope of BIM integration into the design and construction processes, the technology is continuing to gain momentum. With this gaining momentum, more companies are turning to BIM to help improve their projects and companies through its many uses: 3D MEP Coordination, Automated Quantity Take-offs and Cost Estimating, Phase Planning, 4D Modeling, and Energy Analyses to name a few. With all of these new tools and opportunities presenting themselves, the process in which to implement these new tools can become vague and unclear.

One research project that is currently underway to address this issue is the BIM Execution Planning Guide being headed up by the Computer Integrated Construction (CIC) Research Program at The Pennsylvania State University. The goal of the research is "to develop a method to create a BIM Execution Plan in the early stages of a project".

Defining expectations of the model and outlining the process to utilize these BIM uses are necessary steps in order to successfully implement BIM on a project with positive results. Not all uses are critical, or even useful, to a project; therefore, being able to understand the needs of the project and the processes that are to be used are important pieces of the puzzle. Understanding the process involved with implementation will allow owners and other early project team members to make informed selections on the BIM uses they wish to use on the project.

GOAL

Three main goals exist as part of this analysis:

1) Develop a generic process model that defines and illustrates best practices for the 3D MEP coordination process utilizing BIM
2) Compare methodologies from "traditional" 2D design coordination as used on DCH to 3D design coordination as defined in the generic process model
3) Define project specific process for implementing 3D MEP coordination at DCH

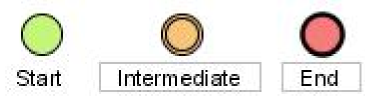
Analyzing BIM processes and their implementation is also demonstrating influence from a master's level class, AE 597G, BIM Execution Planning.

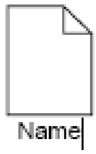
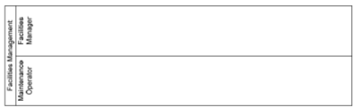
BUSINESS PROCESS MODELING NOTATION

The process model is illustrated in Business Process Modeling Notation (BPMN), which was developed by the Business Process Management Initiative. BPMN was selected as the notation for this research in order to closely correlate this work with the ongoing research that is being conducted by the CIC.

BPMN, like other process modeling notations, has a goal to graphically represent an abstract process in order to clearly articulate it to a given audience. BPMN attempts to be an intuitive format; hence, the audience does not necessarily have to be of a technical nature or be overly familiar with the process in order to understand it. Some understanding of the notation is helpful, and is laid out in Table 5-Explanation of BMPN Symbols.

TABLE 5-EXPLANATION OF BMPN SYMBOLS

Notation	Explanation
	**Events-** Something that "happens" during the process model. They can be start, intermediate, or end events. Different symbols can be inside the circle further indicating the type of event (an email, a timed event, multiple trigger events, etc.)
	**Activity-** Generic term for work that is performed by a single entity, or multiple entities, either companies or individuals
	**Gateway-** Represents convergence or divergence in the flow of activities. It may represent a choice that must be made or be dependent on the outcome of the preceding activity to determine which way the model will flow
	**Sequence Flow-** Shows the order in which activities and events move
	**Association-** Used to link information to Flow objects. Allows non-flow objects (such as a data object) to be associated to Flow Objects (Activities and Events) Associations can have arrows indicating directionality of the non-flow object

	**Data Object-** Demonstrate movement of information in or out of items, but do not impact the flow of the model. Can be used to show what information/resources are required for events or activities to be performed.
	**Lane-** Used to categorize and organize activities into areas of similar functionality
	**Annotation-** Used to add additional information to a graphic. In this particular model, they represent agents who will be executing the tasks which they are under.

3D MEP COORDINATION PROCESS MAP

While BIM is not commonplace yet in the construction industry, it is continuing to improve its foothold and there are several companies that have taken to the forefront with integrating it into their projects.

In order to develop best practices for the generic process of 3D MEP coordination, discussions have been held with representatives from these companies. Through phone discussions and email correspondences, industry members from Balfour Beatty, Jacobs, and Gilbane offered lessons learned and insight for successful 3D coordination processes. Additional information was gathered from academic resources, such as previous classes, graduate students who are familiar with and have run 3D coordination on industry projects, and journal papers. This information was then compiled and common traits examined to develop the 3D coordination process map.

TIBCO Business Studio is the software in which the process map is created. During original trials of developing the map, multiple swim lane configurations were examined. One such model was developed defining swim lanes as the participants on the project. Another model used swim lanes that looked at Resources, Tasks, and Results/Output as the defining categories. While each of these models had their own unique value, it was decided that the swim lanes of External Information, Enterprise Information, Process, and Building Information Model in order to keep the results of this work in close agreement with CIC research.

The first section of the 3D MEP coordination model,shown in Figure 5-Section 1 of the 3D MEP Coordination Process, represents the steps leading up to the involvement of the sub contractors. (Sections are arbitrary and used only to increase image fidelty for the purpose of discussions.) Full explanations of each event, task, and data object can be found in Table 22-

Explanation of Tasks as Defined in Process Model and Table 23-Explanation of Events as Defined in Process Model in Appendix IV | Process Model.

Once the model is completed to a specified level by the designers, the start event for this model, it must be transferred to the GC. This is the first time that external information enters the process in the form of exchange requirements. In order for the GC to successfully use the model, it must be understood what the file formats will be. While some level of interoperability does exist in the industry, many challenges can be avoided if these exchange requirements are defined early. While it is not necessary for the same exact platforms to be used, doing so would prove beneficial. The exact requirements for this exchange are outside of the scope of this research, but their definition is an aspect that warrants attention and is the focus of the National BIM Standards (NBIMS) which is currently under development.

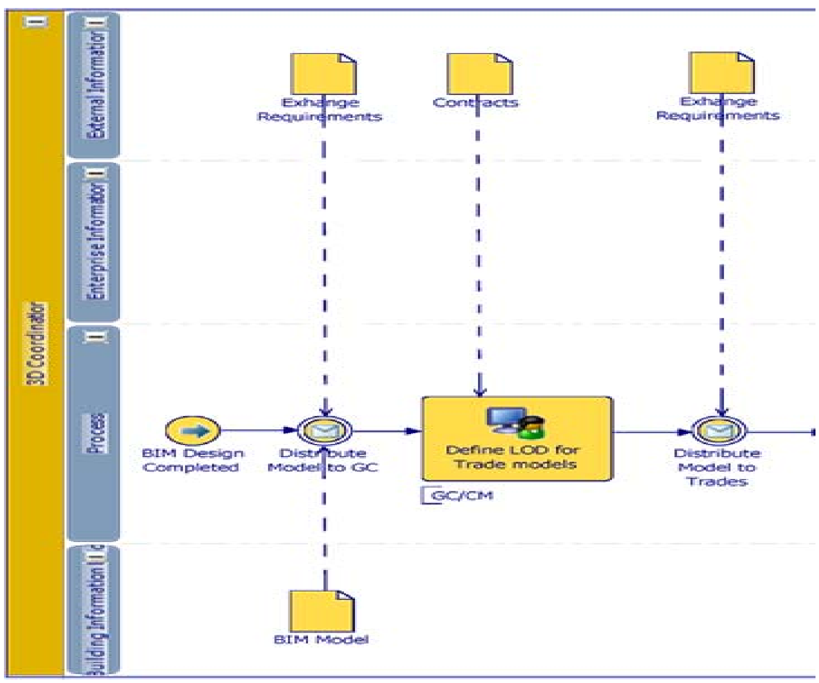


FIGURE 5-SECTION 1 OF THE 3D MEP COORDINATION PROCESS

Once the GC has the model, it is their responsibility to define the Level of Detail that will be expected from the subcontractors for their modeling tasks. These requirements should be written into the language of the subcontract. Several different organizations have developed addendums to standard contracts that attempt to address contractual issues arising from BIM. ConsensusDOCS, the AIA, and USACE have all written language to use in contracts, but none have been fully vetted through the courts, so no precedents exist. This external contract information will affect this event and is shown as information flow in, but the specifics of this impact will be unique to each project.

Once the contract language and expectations are delineated, the GC must distribute the model to the subs. While many parts of the model distributed will be reworked or retooled by the trades, a common "background" for all trades to use with defined coordinate systems is an important part. According to multiple interviewees, it is helpful to run through the entire process once at a very small scale to ensure that idiosyncratic behavior is worked out so that once large scale coordination begins these trouble spots can be avoided. A small area that is indicative of the project scope and involves all trades that will be participating in the coordination process is an ideal area for this first run through. It was noted by one interviewee that after this initial process, though the trade contractors had been initially hesitant, they became very engaged and excited about the coordination process.

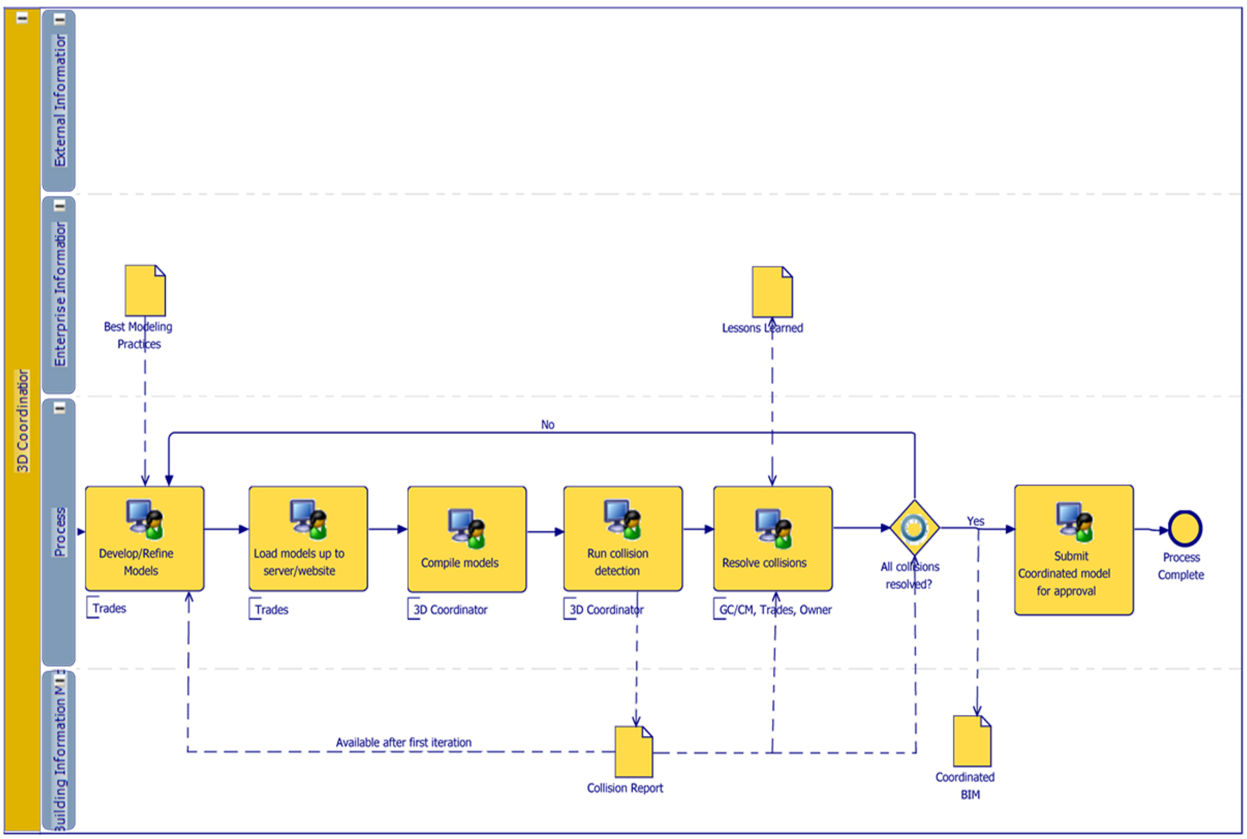


FIGURE 6-SECTION 2 OF THE 3D MEP COORDINATION PROCESS

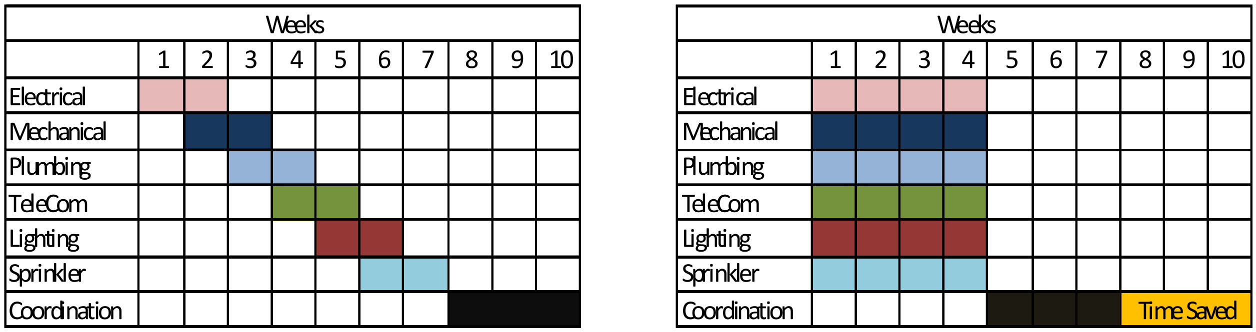
Figure 6-Section 2 of the 3D MEP Coordination Process illustrates the remainder of the 3D MEP coordination process. The first task of this section is executed by the trades, and it involved actually developing the model that will be used for the coordination. Enterprise information will affect this step in terms of best practices used for modeling. After the first iteration of this process, a collision report will be available in order to specify what modeling must be adjusted prior to the next detection being run.

Project specific processes will govern this task, but a common trait of successful projects as relayed by the interviewees is to proceed by area. It is unadvisable to coordinate the whole building at once since it could lead to thousands of clashes and could be too cumbersome to efficiently handle. Furthermore, due to hardware and software limitations, it is unadvisable to have an entire system modeled in one file. The file sizes will become extremely large and even with high end hardware will still be very slow to run.

Another general consideration that should be made at this point is the sequencing of who models first. Some industry members propose that it is still beneficial to follow a “2D process” in that HVAC modeling is done first, and then plumbing, followed by electrical, then sprinklers, etc. working down in size in order to help minimize collisions in the initial detection. This “linear model” was employed after the first coordination area was completed at DSL in order to help reduce conflicts. Clashes were reduced to almost half in the following iteration of the process for the next areas.

A contrasting view point to this method takes a more contractual stance and is employed on more time critical projects, especially design-build. Contractors are still contractually required to coordinate their work before the 3D coordination process begins. The work performed by the GC (if they are running the coordination) is in a facilitator role to aid the coordination, not just a passive observer role. The GC in this case expects that modeling work will be conducted simultaneously, “concurrent modeling”, by all trades and that the trades still perform their coordination. The 3D process is not a replacement to the original coordination, but an added level of verification to eliminate collisions.

Based on experience and anecdotal evidence, one interviewee took the time to respond with the following graphic, Figure 7-Comparison of Linear and Concurrent Modeling Practices, comparing the linear method and the concurrent method based on his perceptions and time spent implementing 3D coordination on projects. While the graphic does not represent concrete data, it is an interesting comparison to consider, especially since the linear method is being given a generous assumption in that the modeling would only take half as long.



Linear Concurrent

FIGURE 7-COMPARISON OF LINEAR AND CONCURRENT MODELING PRACTICES (COURTESTY OF BBC)

The next task, again executed by the trades, is to load the models to a server or website in order for the coordinator to retrieve them. E-mail is unadvisable due to the sheer size that these files can reach. FTP servers/websites allow for faster transfer of these large files. All the parties that were interviewed indicated that using a server or website is the preferred method for transfer of files.

Once all the files have been collected by the 3D coordinator, it is their job to compile the files into one master file/file set. Specific steps for this task will depend solely on the software being used by the project team. Collision detection is then run based on the compiled model. The report is generated automatically and then can be distributed to the trades in order to lead into the next step, resolving the collisions.

The task of resolving collisions can take on many forms depending on how the project team elects to define this process. Activities in this step can range from in person meetings at the jobsite trailers, to teleconferencing, to simply disseminating the report and allowing the trades to coordinate on their own outside of any coordinator intervention. The level of involvement of the 3D coordinator at this step will be a decision for the project team. Lessons learned by the companies will influence this task and generally dictate which specific method of collision resolution will be implemented.

According to a case study at Dickinson School of Law performed by Leicht and Messner, the collisions can fall into three categories. First, there are clashes that arrive from insufficient level of detail. Examples of this could be piping penetrating a slab where sleeves were not required to be modeled. It is understood that a sleeve will be present, so this clash can be approved. The next category is a Coordination Issue. This could be conduit conflicting with a pipe, and issue that warrants attention and discussion by the trades involved to establish a resolution.

The final possibility is a design issue, such as inadequate clearance for ductwork as designed. This collision will result in an RFI being issues out to the design team.

The next point in the process is a gateway decision premised on the question, “Are all collisions resolved?” If, for the given coordination area, clashes are still present, the process of refining the model will begin anew and proceed though another iteration of the collision detection process. If all clashes have been resolved for the area, the model may be signed off on by the trades and the coordinated model maybe submitted for approval. The submission of the coordinated model represents the final task in the 3D MEP Coordination Process Model.

DCH (2D) COORDINATION PROCESS AND COMPARISON TO 3D

The coordination process at DCH did not utilize any 3D modeling for the project, and as such, did not implement a 3D MEP coordination process, but rather moved forward with a more traditional 2D process.

Coordination relied on the overlay of 2D drawings in order to identify conflicts. This task was handled in two ways. The majority of the coordination was done using AutoCAD files and the overlay was done in a computer based environment. In some select cases, hard copy drawings were used on a light table. While the tools used for the coordination on the DCH project differ from the tools used in a 3D coordination, the actual process bears several similarities and overlaps in tasks.

The steps for 3D coordination shown previously in Figure 5-Section 1 of the 3D MEP Coordination Process, closely correlate in terms of general intent, but not in terms of specific data transfers. Electronic drawings are commonly exchanged throughout the duration of construction projects, and due to the relatively universal language of currently used CAD formats, exchange requirements are not as critical to define. However, the general steps of distributing the “model”, in this case the AutoCAD files to the GC and to the trades, still has the same intent, the dissemination of information that is critical to the success of the process. The only difference is in the actual information itself that is being passed along. The BIM Model shown as an information input is represented by the CAD files in the process at DCH. Contracts are also much more well-defined in the 2D process than the 3D process, so this consideration is not nearly as important, although it does still exist.

Figure 6-Section 2 of the 3D MEP Coordination Process, shown previously, has many of the same intentions as the 2D method, but there is a difference in tools and end products. Trades at DCH are still responsible for developing the “model” and uploading it to a central server, except the “model” in this case is actually 2D coordination drawings, so the objective of the process remains intact, just the actual deliverables are modified. In order to help limit the

number of conflicts, as mentioned for the 3D process, the project team allowed dry HVAC to layout their system first, and then followed this with plumbing, chilled water/hot water, medical gas, electrical, and finally, sprinklers. By allowing the largest space needs first, ductwork, it ensured they had the space the ducts needed and allows the other trades to work around them.

The task of compiling the models also changes, but only in execution, not in its goal. In a 2D world, the software allows quick overlays of layers that all CAD users are familiar with and can quickly complete on their own. No external software or processes are needed in order to put the 2D drawings together into a coordinated drawing file, unlike a 3D process which requires outside software and significant steps in order to compile all of the separate files.

The step of running the collision detection is not automated in the 2D process. Instead of relying on algorithms to detect when two objects are in the same space, 2D relies on the eyes, intuition, and experience of the project team. This change in execution does not mean that this task does not occur. This task still takes place, but it is in phone calls, emails, and jobsite meetings, not done automatically by software. The task can also not be as easily divided, but instead occurs almost simultaneously with the next task in the process. The resolution of the collisions is this next step, and it too does not differ greatly from 3D into 2D. After discussions and meetings to address conflicts, the teams go back to their files and revise them as necessary based on the agreed upon solutions, and try again at the next meeting. While again lacking some of the automated assistance (clash reports) and clarity (3D views showing the collision), the conflicts will still be resolved and taken back to the "model" (2D drawings) to be changed. Both of these steps differ in their actual execution and tools used, but again the intent of the process is the same when comparing 2D and 3D coordination.

The gateway is the first major difference in the process because there is no automated output from the 2D coordination process that will inform the team members if there are still collisions to be resolved. It is left up to the experience of the participants to determine when the coordination process has ended and all clashes have been rectified. There are still multiple iterations of the process in 2D to ensure that collisions are identified and corrected ahead of time, but the lack of an automated report is a significant deviation from the 3D process.

The final task of submitting the coordinated information, much like the rest of the process, has the same objective in each process, but the methodology is not the same. The end goal of all of this work is to submit final coordinated drawings or models to the designers for approval. While the form of the information varies (2D drawings vs. a 3D coordinated model), the content of that information remains relatively unchanged. The end goal of gaining designer approval for the drawings or model is identical regardless of the medium in which the information is sent.

IMPLEMENTING 3D COORDINATION AT DCH

Currently, as outlined previously, the Doctors Community Hospital project is only utilizing 2D methods to meet the coordination needs. Using common successful traits from the interviews and research, an implementation plan for the use of 3D MEP coordination is outlined in the following section.

First and foremost, 3D MEP coordination is often spoken about as the "low hanging fruit" of the BIM world. This statement holds true because it is one that can be implemented relatively late in the game. Owners do not need to specify its implementation in early phases in order for it to be utilized. In fact, a BIM model does not even have to be created in the design phase for this use to be taken advantage of. While it is easier if at least an architectural model exists so that the trades do not need to create one for a background, this fact is not a prerequisite. The process outlined for the implementation will be based on the assumption that the entire project is not BIM oriented, and that no design models are available for use by the GC or trades in order to keep it as closely applicable to the project in its current form as possible.

In order to successfully implement 3D coordination, the first task is to assess the abilities and needs of the project team. In this case, the project team at DCH from Gilbane Building Company does not have experience running a 3D MEP coordination process. That does not mean that Gilbane as a company does not have experience with 3D MEP coordination. Both Hershey Medical Center in Hershey, PA, and Dickinson School of Law at University Park were projects run by Gilbane and used 3D MEP coordination. In order to address the shortcoming of the projects team knowledge pertaining to 3D coordination, they would have to turn to others in the company to supplement their knowledge base.

Next, the team must define the trades that should be involved. Any trades that will need space in the plenum area of the building are the ideal participants to have involved. For the DCH project, these trades are outlined in Table 6-Participants Important to 3D Coordination.

TABLE 6-PARTICIPANTS IMPORTANT TO 3D COORDINATION

Trades for 3D Coordination	
• Steel	• HVAC
• Plumbing	• Electrical
• Medical Gas	• Sprinkler
• Pneumatic Tubing	• Cable trays

The steel provider for this project, Steel Fab, Inc., uses Tekla for 3D modeling and creates these models independent of contract requirements as part of their fabrication process. This fact lends itself well to incorporating 3D coordination since the structure would already be created in a 3D format. Hess Mechanical has had some exposure to the 3D coordination process, but it is not extensive. They do however, recognize it as a valuable tool and are capable of performing the 3D modeling necessary either in house or by subcontracting it out. VarcoMac Electrical and Pevco (Pneumatic Tubes and Cable Trays) have not had previous exposure to a 3D coordination process. Fireguard Corporation, the sprinkler contractor, has done some 3D modeling for its fabrication process, but has not been involved in a 3D MEP coordination process. Given the lack of exposure and experience with a 3D process for these subcontractors, a well-crafted and clearly articulated execution plan will be critical to the successes of this BIM use.

Before modeling can take place, Limits of Detail must be defined for each of the trades as well as areas of separation. Currently, software and hardware have a hard time handling large files without lagging and becoming hard to navigate. Based on successful coordination conducted at Hershey Medical Center, for this project the boundary separation will be by floor. This project is not large enough to warrant further separation. The level to which each of these areas will be modeled will be determined by the project team. For the purposes of this project in order to clearly articulate expectations, levels of detail will be derived from the "Model Progression Specification (MPS)" that has been developed by Vico Software and been incorporated into the new E202 document from AIA. Figure 8-Definition of Levels of Detail for MPS shows the breakdown of these levels and what the general requirements are for each level as they specifically pertain to 3D coordination. Figure 9-Examples of LOD based on the MPS goes into further detail and uses specific details and modeled items to further illustrate the levels.

Level of Detail ->	100	200	300	400	500
Model Content					
Design & Coordination (function / form / behavior)	Non-geometric data or line work, areas, volumes zones, etc.	Generic elements shown in three dimensions - maximum size - purpose	Specific elements Confirmed 3D Object Geometry - dimensions - capacities - connections	Shop drawing/ fabrication - purchase - manufacture - install - specified	As-built - actual

FIGURE 8-DEFINITION OF LEVELS OF DETAIL FOR MPS

Level of Detail ->	100	200	300	400	500
Element					
Interior wall	Not modeled. Cost and other information can be included as an amount per s.f. of floor area.	A generic interior wall, modeled with an assumed nominal thickness. Properties such as cost, STC rating, or U-value may be included as a range.	A specific wall type, modeled with the actual thickness of the assembly. Properties such as cost, STC rating, or U-value can be specified.	Fabrication details are modeled where needed.	The actual installed wall is modeled.
Duct run	Not modeled. Cost and other information can be included as an amount per s.f. of floor area.	A 3-dimensional duct with approximate dimensions.	A 3-dimensional duct with precise engineered dimensions.	A 3-dimensional duct with precise engineered dimensions and fabrication details.	A 3-dimensional representation of the installed duct.

FIGURE 9-EXAMPLES OF LOD BASED ON THE MPS

It is advisable that for coordination purposes, at least a 300 level of detail be maintained for all systems in the plenum space.

The sequence in which modeling will occur must also be defined by the project team. In order to keep a fast paced schedule, it is recommended that a concurrent modeling approach be utilized. Each floor will be modeled simultaneously by all trades participating, and then 3D coordination sessions will begin. Since modeling is occurring simultaneously, contractors will still have to be responsible for coordination outside of the 3D sessions since it is still their contractual obligation.

File format exchange requirements must also be defined for a successful implementation of 3D coordination. These requirements will be dependent upon the software that is utilized for the collision detection. File formats do not necessarily have to open natively in the clash program, as long as they can be exported from the subcontractors software and read by the collision program being implemented.

Once the modeling is completed for each area, the subcontractors must post the file to a central server for the coordinator to retrieve. The coordinator can then compile the models to prepare for the first 3D coordination session. Due to the lack of exposure that the majority of the team has, this project should have in-person meetings held at the jobsite using a projector. Prior to the meeting, in order to minimize live navigation of the model which can be difficult and slow depending on the model size, the coordinator should set viewpoints for the clashes so that they can be readily pulled up. Also, any false positives should be filtered out. The GC and the subcontractors will discuss each clash and either resolve them, or issue and RFI depending on what the options are for the collision. A report from each meeting will be generated and the changes made to the models. The process will repeat the following week until the model can be signed off. The cycle should be clearly illustrated for the contractors so that they understand. Figure 10-Weekly Process Model for Coordination Cycle, shows the time frame that should be expected on a weekly basis.

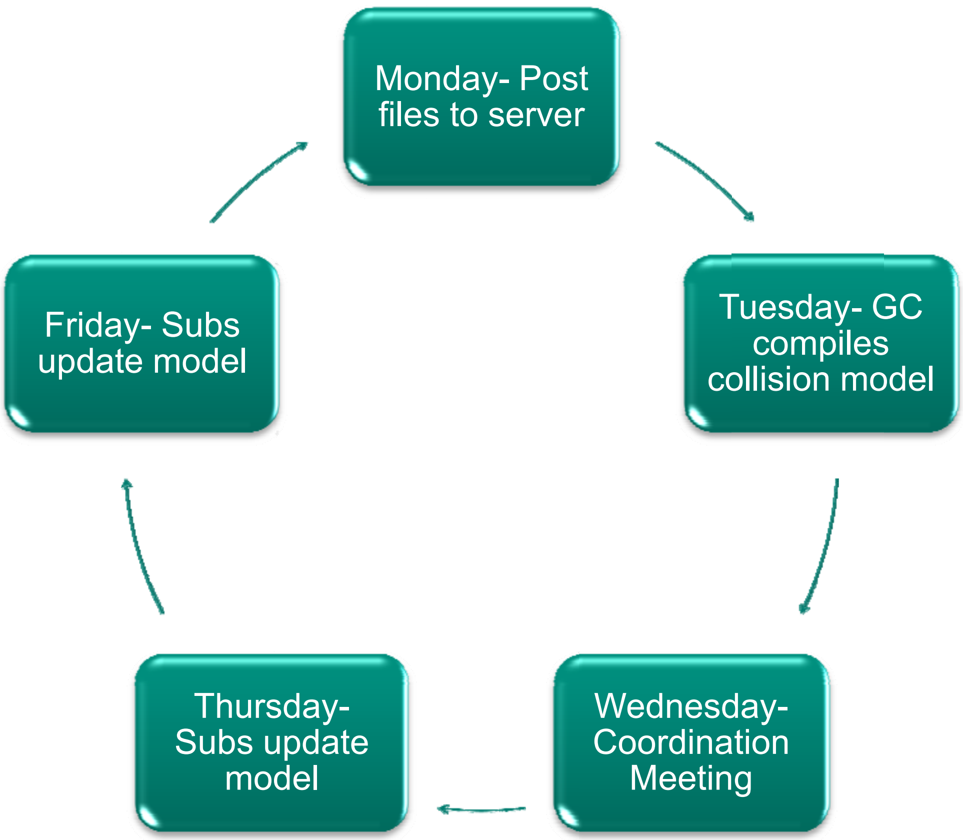


FIGURE 10-WEEKLY PROCESS MODEL FOR COORDINATION CYCLE (COURTESY OF BBC)

Due the contractual arrangement currently in place, the shop drawings will have to be submitted in a 2D format for approval. However, these drawings should be taken from the model and annotated as necessary to avoid too much duplication of work, and also avoid user error when recreating the drawings which would negate the gains of the 3D coordination.

IMPLEMENTATION SUMMARY

A detailed implementation as outlined above can be derived by analyzing the questions that it strives to answer. Focusing on the questions listed below, which have been gleaned from this process mapping and development of a project specific plan, should help to address the issues around implementing 3D MEP Coordination.

Critical Questions to Address:

- What assets does the project team have related to 3D MEP coordination and how can weaknesses be overcome?
- What trades will be involved in the process and what is their previous 3D coordination experience?
- To what level of detail will the systems be modeled?
- What file formats will be required as outputs from the models?
- Where and how will the coordination meetings be run?
- What will the weekly cycle for coordination look like?

ANALYSIS 2|PREFABRICATED FAÇADE

BACKGROUND

The concept of building components to be assembled off site, and shipped onto the project ready for final placement is known as "Prefabrication". This concept can be applied to different systems in the building including structural, mechanical, plumbing, and the envelope. Concrete buildings can have structural components poured in a controlled environment and then trucked onto the site when they are needed. Plumbers can have pipe ordered, cut, and threaded in the shop and then delivered to site ready for installation. Envelopes can be completely fabricated in a warehouse, safe from the elements, and then dropped off at the site just in time to be put in place. While this practice is gaining in popularity, especially as BIM takes hold and fabricators are seeing the returns on digital fabrication, it is not used widely. Precast facades are one of the more prevalent uses of prefabrication.

Prefabricated facades are an alternative to other traditional envelopes such as hand-laid brick, EIFS, and curtain wall systems. The ability to have higher quality control standards in a more controlled setting during fabrication, allow work to take place offsite thus reducing site congestion, and the fast pace of installation are all factors that make prefab systems desirable for construction projects. The vast finishes for prefab systems increases its appeal to architects for new structures, and this same flexibility also allows it to match existing facades which makes it a good candidate for expansions.

The advantages previously mentioned would be an asset on any construction site. At DCH, three traits factored into the decision to analyze a precast system as an alternate façade: increased installation rate compared to hand laid brick, the ability to match existing facades, and the reduced site congestion.

GOAL

There are three goals for this prefabricated façade section:

1. Analyze impacts of the envelope change on the site logistics, schedule, and cost of the DCH project.
2. Assess impact on structure due to building envelope.
3. Increase envelope insulation properties to aid mechanical system performance.

SYSTEM SELECTION CRITERIA

The project at DCH is an expansion that boasts roughly 37,000 square feet of exterior wall area and it is immediately adjacent to the current hospital. Therefore, the ability of a system to match the brick façade on the existing structure is not only an important issue, but it is in fact the critical issue.

Other factors that will be considered:

- Cost of system
- Weight of the system
- Insulation properties of the system

Two alternative systems are being compared against these criteria as shown in Table 7-CarbonCast vs. Nitterhouse vs. Brick. The best suited alternative will be further investigated looking at its impacts on the previously stated goals.

TABLE 7-CARBONCAST VS. NITTERHOUSE VS. BRICK

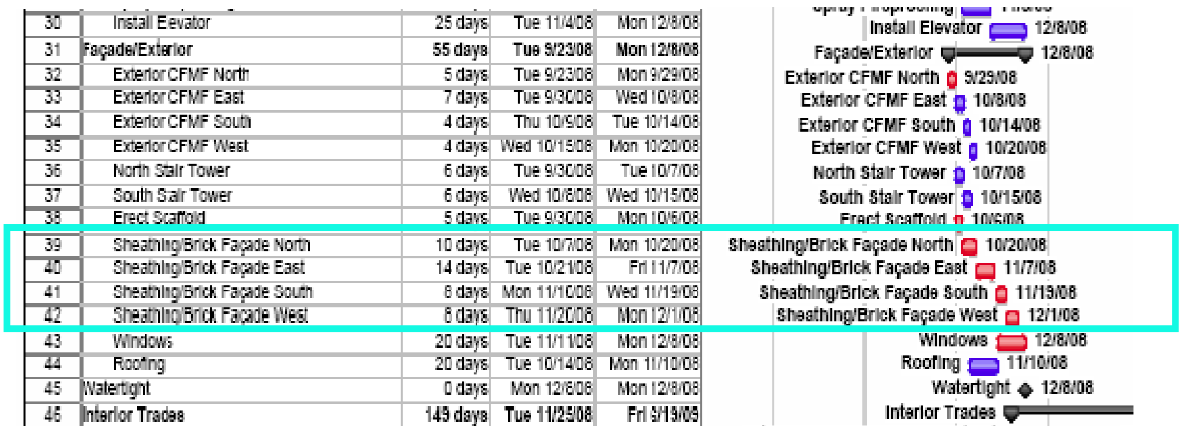
Criteria	CarbonCast	Nitterhouse	Brick Facade
Ability to Match Existing?	A variety of brick finishes can be matched through the use of Thin Brick inlays[1]to the system	Also, using ThinBricks, this product can match a variety of finishes.	Existing building is hand laid brick, so matching is easy
Cost of System?	$37/SF delivered and installed	$35/SF delivered and installed	$28/SF installed
Weight of System?	65 lbs/SF	75 lbs/SF	42 lbs/SF
Insulation properties?	R-Value: 5.4	R-Value: 0.48	R-Value: 0.44

Based on the selection criteria above, even though the cost of the CarbonCast system is $2/SF more than the product from Nitterhouse, the slightly reduced weight, and significantly higher, more than 10 times higher, R-value will hopefully make up this price difference. Therefore, the CarbonCast system will be selected and analyzed more in depth for its impact on the project.

[1] Thin Brick inlays- the practice of using 5/8" thick bricks in cast concrete to recreate a hand-laid brick appearance

SCHEDULE ANALYSIS

One factor for selecting the CarbonCast system was its speed of erection. The current hand-laid brick façade lies on the critical path. Delays early in the project have made getting the building dried in an even more important item. . An excerpt from the CPM schedule, below in Figure 11-Exceprt from CPM Showing Façade Construction on Critical Path, shows that the construction of the envelope lies on the critical path of the project and is the key to getting the project watertight.



30	Install Eevator	25 days	Tue 11/4/08	Mon 12/8/08
31	Façade/Exterior	55 days	Tue 9/23/08	Mon 12/8/08
32	Exterior CFMF North	5 days	Tue 9/23/08	Mon 9/29/08
33	Exterior CFMF East	7 days	Tue 9/30/08	Wed 10/8/08
34	Exterior CFMF South	4 days	Thu 10/9/08	Tue 10/14/08
35	Exterior CFMF West	4 days	Wed 10/15/08	Mon 10/20/08
36	North Stair Tower	6 days	Tue 9/30/08	Tue 10/7/08
37	South Sair Tower	6 days	Wed 10/8/08	Wed 10/15/08
38	Erect Scaffold	5 days	Tue 9/30/08	Mon 10/6/08
39	Sheathing/Brick Façade North	10 days	Tue 10/7/08	Mon 10/20/08
40	Sheathing/Brick Façade East	14 days	Tue 10/21/08	Fri 11/7/08
41	Sheathing/Brick Façade South	8 days	Mon 11/10/08	Wed 11/19/08
42	Sheathing/Brick Façade West	8 days	Thu 11/20/08	Mon 12/1/08
43	Windows	20 days	Tue 11/11/08	Mon 12/8/08
44	Roofing	20 days	Tue 10/14/08	Mon 11/10/08
45	Watertight	0 days	Mon 12/8/08	Mon 12/8/08
46	Interior Trades	149 days	Tue 11/25/08	Fri 3/19/09

FIGURE 11-EXCERPT FROM CPM SHOWING FACADE CONSTRUCTION ON CRITCAL PATH

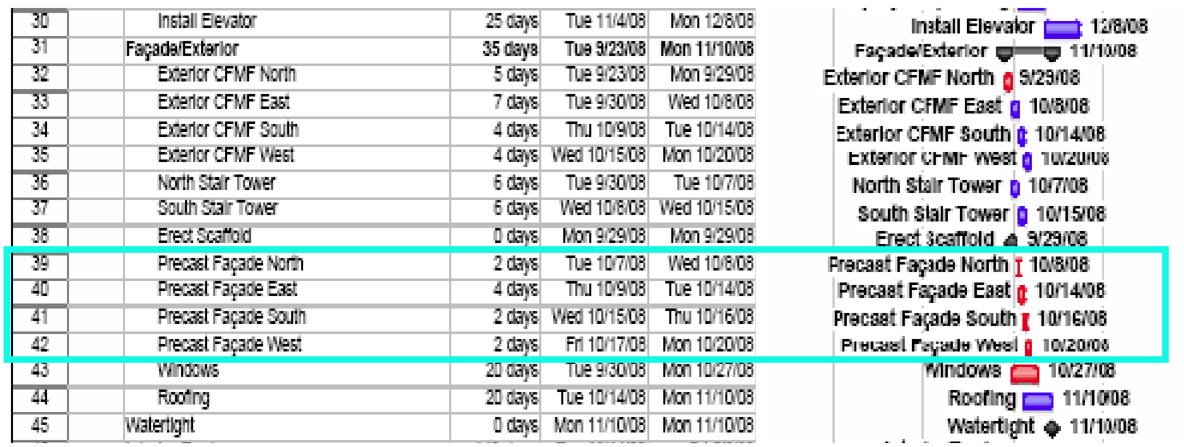
Shortening the duration of critical path activities will generally shorten the overall duration of the project, provided it doesn't move other tasks onto the path. Shown below in Table 8-Comparison of Durations, is a side by side analysis of the durations it would take to complete the façade construction. Making the change from the hand-laid façade to a precast system can shorten the envelope construction time to 25% of its original duration.

TABLE 8-COMPARISON OF DURATIONS

Façade System	Duration (In working days)
Hand-laid Brick Façade	40
Precast	10
Net Difference	Save 40 Days

The duration of the precast system is based on three independent interviews with suppliers of the precast façade. They indicated a typical production rate of erecting 10-30 panels per day. To err on the side of caution, a production rate of 15 panels per day was used for schedule calculations. Maximum panel sizes for shipment without special permitting requirements is 12' x 28'. This yields a maximum square footage of 336 square feet per panel. Not all panels will cover this theoretical maximum, therefore to again err on the side of caution, we will assume

75% effective coverage, or 252 SF per panel. Using the gross building envelope area of 37,127 SF, calculated from the Revit Take off shown in Table 24-Revit Take Off of Exterior Wall Area shown in Appendix V | Take-off Data, 148 panels will be used to cover the building. Based on the previously mentioned production rate of 15 panels per day, the duration shown in Table 8, 10 Days, is reached.



30	Install Elevator	25 days	Tue 11/4/08	Mon 12/8/08
31	Façade/Exterior	35 days	Tue 9/23/08	Mon 11/10/08
32	Exterior CFMF North	5 days	Tue 9/23/08	Mon 9/29/08
33	Exterior CFMF East	7 days	Tue 9/30/08	Wed 10/8/08
34	Exterior CFMF South	4 days	Thu 10/9/08	Tue 10/14/08
35	Exterior CFMF West	4 days	Wed 10/15/08	Mon 10/20/08
36	North Stair Tower	6 days	Tue 9/30/08	Tue 10/7/08
37	South Stair Tower	6 days	Wed 10/8/08	Wed 10/15/08
38	Erect Scaffold	0 days	Mon 9/29/08	Mon 9/29/08
39	Precast Façade North	2 days	Tue 10/7/08	Wed 10/8/08
40	Precast Façade East	4 days	Thu 10/9/08	Tue 10/14/08
41	Precast Façade South	2 days	Wed 10/15/08	Thu 10/16/08
42	Precast Façade West	2 days	Fri 10/17/08	Mon 10/20/08
43	Windows	20 days	Tue 9/30/08	Mon 10/27/08
44	Roofing	20 days	Tue 10/14/08	Mon 11/10/08
45	Watertight	0 days	Mon 11/10/08	Mon 11/10/08

FIGURE 12-CPM EXCERPT SHOWING NEW DATES WITH PRECAST FACADE

Comparing Figure 12-CPM Excerpt Showing New Dates with Precast Facade to the previous dates in Figure 11 illustrates how much time can be saved. The completion date for the façade moves from December 1, 2009, back all the way to October 20, 2009. This six week savings also translates directly to the finish dates of the entire project. The project originally moved off site February 12, 2010, but can now demobilize January 1, 2010. This six week shortening of duration in the facade directly translates into the demobilization date and allows the owner to occupy and begin its revenue flow six weeks sooner.

COST ANALYSIS

Changing out a façade system will not only impact the schedule on a project, but can also have an impact on the financial aspect as well. The overall cost to procure and install the system will be analyzed, as will savings associated with the decreased overhead and possible extra costs due to impacts on other trades.

The initial costs of the system delivered and installed are compared below to the original cost of the masonry façade in Table 9-Cost Comparison of Brick and CarbonCast.

TABLE 9-COST COMPARISON OF BRICK AND CARBONCAST

System	Unit Cost	Total Cost
Hand Laid Brick	From Contract	$ 1,052,419
CarbonCast	$37 per SF	$ 1,373,699
$ Difference		$ 321,280
% Difference of Façade Cost		% 30.5
% Difference of Total Project Cost		%0.94

It is true that CarbonCast is the more expensive system to produce and install. The dollar value per SF used above was provided courtesy of HighConcrete, Inc. A 30% increase in the cost of a particular system is a large increase, but this corresponds to only a %0.94 increase in the overall building cost, which is not incredibly large. .Table 9 only considers the cost of material, delivery, and installation. It does not consider the savings that are outlined below in Table 10-General Conditions Savings.

TABLE 10-GENERAL CONDITIONS SAVINGS

GC Savings	
GC Costs per Week	$ 14,430
Total Weeks Saved	6
Total Saved	$ 86,588,

Scaffolding is no longer needed to install the façade of the DCH project, however, this poses another problem for the sheathing installation. Anning-Johnson, the drywall contractor, was also under contract to install the exterior sheathing. One of the agreements of the deal was that they would be able to utilize the scaffolding provided by the masonry contractor to install the bricks. Since the brick façade is not being used, clearly there will be no mason's scaffolding for them to use. In order to install the sheathing, a boom lift must be rented. This will add to the cost on the order of $3,100 for a four week period, which should be sufficient enough time to complete this sheathing.

Several costs and savings must be considered to determine the final impact of switching to a new system. Table 11-Summary of Financial Impact looks at all the costs and savings associated with the new precast system that have been previously outlined.

TABLE 11-SUMMARY OF FINANCIAL IMPACT

Summary	
Total Added Cost of System	$ 321,280
Total Overhead Savings	$ 86,588
Added Cost for Lift	$ 3,100
Net Cost	$ 237,792
Net Cost as % of Façade	% 22.5
Net Cost as % of Total Project	% 0.69

STRUCTURAL IMPACT

A new façade has the potential to greatly affect the structural system in a building. Significant reductions in dead load can help to reduce member sizes and in turn will decrease the cost of the building. Conversely, a substantial increase in the façade weight will result in an increase in member sizes which will raise the total cost of the project.

CONNECTION DETAILS

First, in order to determine how the load will affect the structure, it must be determined how the gravity load will be transferred to the superstructure. The CarbonCast system, as provided by High Concrete, uses a column connection detail as shown in Figure 13-Typical Panel to Column Connection Detail.

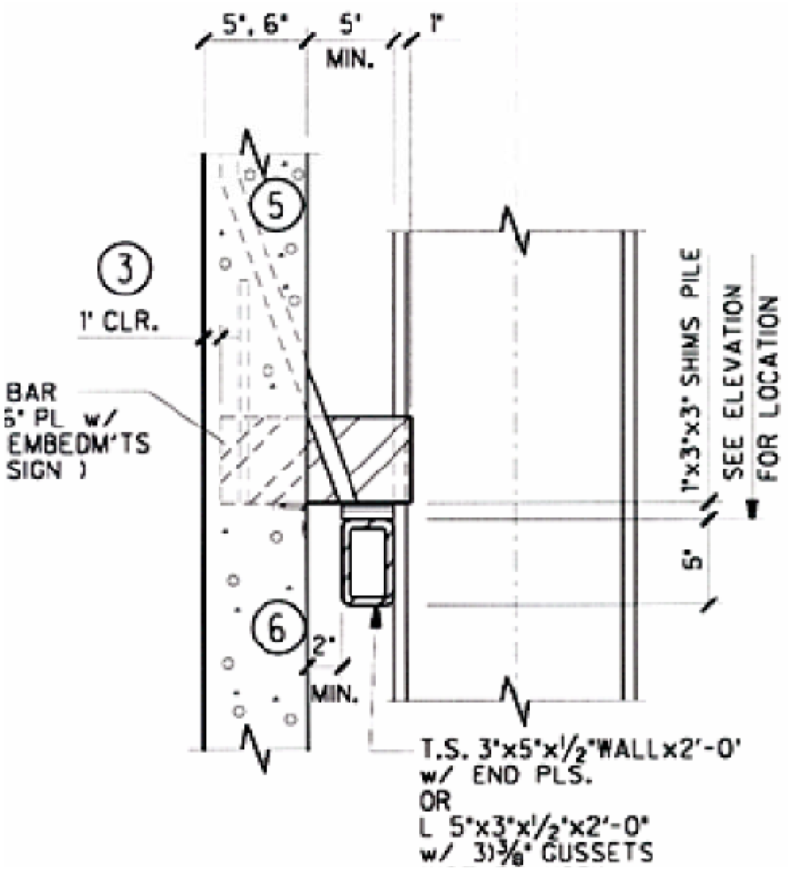


FIGURE 13-TYPICAL PANEL TO COLUMN CONNECTION DETAIL (COURTESY OF HIGHCONCRETE.COM)

This detail shows that the load will transfer directly into the columns and down to the foundation. Hand-laid brick façade would have to transfer to the exterior beam by way of a steel angle before being transferred into the columns. Hopefully, by eliminating this load transfer, the exterior beams can be downsized.

STRUCTURAL CALCULATIONS

Given Parameters and Assumptions (See Appendix VI | Detailed Structural Calculations for complete calculations):

- From IBC 2003, Live Load design weight: 100 PSF for typical floors
- From ASCE 7-05 Table 4-2: Live Load Element Factor, K_{LL}= 2 for Edge Beams and 4 for Exterior Columns
- Allow 15 PSF dead load for suspended HVAC/Electrical/Plumbing
- From Vulcraft Composite Deck Catalog: 43 PSF for 5" LW Concrete deck on 1.5", 20 Ga. Steel deck

Exterior Beam Calculation:

The typical exterior edge beam for the DCH project must support the loads from its tributary floor area, illustrated in Figure 14-Tributary Area for Typical Edge Beam, as well as the exterior brick façade. The current beam size of W16x36 is typical for the edge beams and has a maximum LRFD moment capacity of 240 kip-ft.

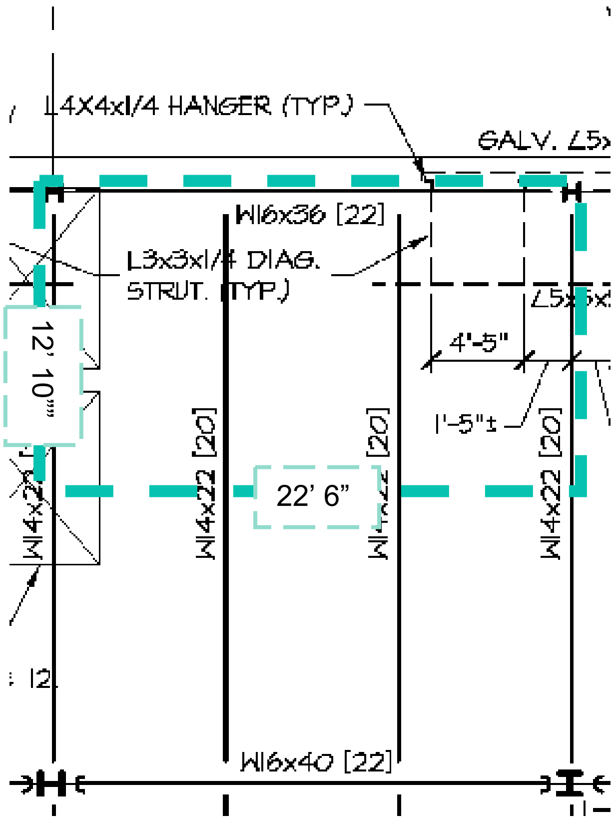


FIGURE 14-TRIBUTARY AREA FOR TYPICAL EDGE BEAM

Using the LRFD method, the beam will be designed to:

$$\Phi M_n > M_u$$

The reduced live load based on the tributary area equals 87.5 PSF. The total deal load used for the calculations is equal to 58 PSF. Using the equation for load combination 2 from ASCE, the total design load is:

$$1.2D + 1.6L = 1.2(58) + 1.6(87.5) = 209.6 \text{ psf}$$

Based on the calculations put forth in Appendix IV, this design load translates into

$$M_u = 151.2 \text{ kip ft}$$

for the live loads and structure self-weight. This does not include the weight of the brick façade, which based on detailed calculations in the appendix, adds an additional 41.2 kip-ft to the design moment. The final equality for the LRFD design:

$$\Phi M_n = 240 \text{ kip ft} > 192.4 \text{ kip ft} = M_u$$

Based on the above equality, it is clear that even with the design load of the brick façade included, that the beam is sized to a much larger capacity, indicating that loads other than gravity loads are controlling the design of the typical exterior beam. This fact also means that reducing the load on the beam from the brick façade by transferring it directly to the columns with the precast system does not impact the size of the typical edge beam.

Column Calculation:

In order to assess the impact on the columns of the structure, the new loads imposed by the change in façade will be analyzed along the entirety of one typical exterior column tower.

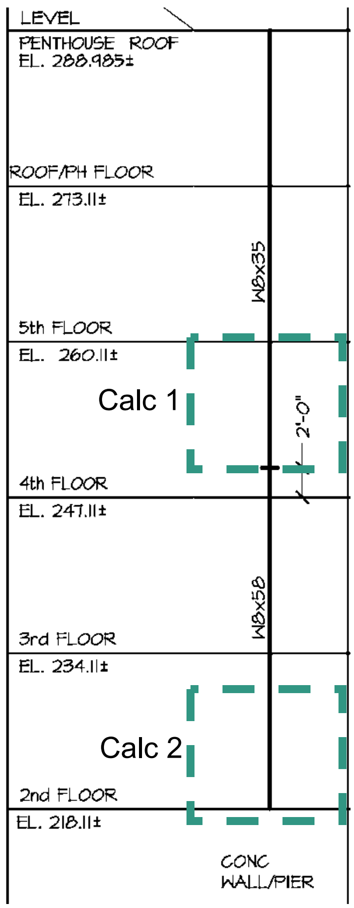


FIGURE 16-TYPICAL EXTERIOR COLUMN TOWER

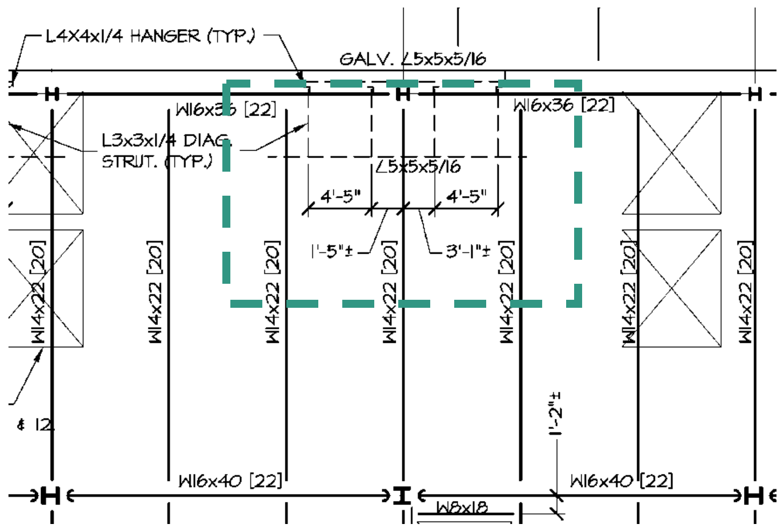


FIGURE 15-TRIBUTARY AREA FOR EXTERIOR COLUMN

Two critical areas will be evaluated for the new loading conditions. These areas, boxed out in Figure 16-Typical Exterior Column Tower, are the areas that carry the most load for each column size, and thus must be checked to ensure that they can withstand the imposed loads

As with the beam calculations, the same parameters and assumptions will be followed that are established at the beginning of this subsection.

Using the LRFD method, this column will be designed to:

$$\Phi_c P_n > P_u$$

The reduced live load based on the tributary area equals 50 PSF. The total deal load used for the calculations is equal to 58 PSF. Using the equation for load combination 2 from ASCE, the total design load is:

$$1.2D + 1.6L = 1.2(58) + 1.6(50) = 149.6 \text{ PSF}$$

Based on the calculations put forth in Appendix VI, this design load translates into

$$P_u = 186.2 \text{ kips}$$

for the live loads and structure self-weight. The P_u value above also includes the 57 kips that is added from the CarbonCast façade system. The final equality for the LRFD design:

$$\text{For W8x35:} \quad \Phi_c P_n = 300 \text{ kips} > 186.2 \text{ kips} = P_u$$

Similar, calculations were conducted to analyze the second highlighted area from Figure 16. The detailed calculations can be found in the appendix. The final equality for the LRFD for the second set of calculations:

$$\text{For W8x58:} \quad \Phi_c P_n = 514 \text{ kips} > 296.7 \text{ kips} = P_u$$

Based on the above equalities, the current column design will be able to support the change in the façade system. Therefore, even with the additional dead loads from the heavier system, no redesign must occur in order to facilitate the change.

MECHANICAL IMPACT

A new façade does not only affect the structure, but it can also impact the mechanical system of a building as well. If the R-Value is increased, the spaces will not gain as much heat from the exterior during the summer and will not lose as much heat to the outside during the winter. This change can impact both the boiler and the chiller size needed for the project.

The first step is to determine the R-value for each façade system. Tables 12 and 13 show the component break down of each wall system and the corresponding R-values attributed to that material.

TABLE 12-R-VALUE CALCULATION FOR BRICK FAÇADE (OLD SYSTEM)

Brick Façade			
Component	**R-Value**	**Thickness (in.)**	**Total R-Value**
Outside Air Film	0.17	-	0.17
Brick	0.11	4	0.44
Air Gap	0.94	1	0.94
Ext. Gyp Board	0.63	0.63	0.40
Batt Insulation	3.14	6	18.84
Int. Gyp Board	0.63	0.63	0.40
Inside Air Film	0.68	-	0.68
		Total	**21.86**
		U-Value	**0.0457**

TABLE 13-R-VALUE CALCULATION FOR CARBONCAST (NEW SYSTEM)

CarbonCast			
Component	**R-Value**	**Thickness (in.)**	**Total R-Value**
Outside Air Film	0.17	-	0.17
Concrete	0.08	3	0.24
XPS (Extruded Polystyrene)	5.00	1	5.00
Concrete	0.08	2	.16
Ext. Gyp Board	0.63	0.63	0.40
Batt Insulation	3.14	6	18.84
Int. Gyp Board	0.63	0.63	0.40
Inside Air Film	0.68	-	0.68
		Total	**25.88**
		U-Value	**0.0386**

In each of the tables, the U-value, or heat flow through an assembly, is calculated by the formula: $U = 1/R_{total}$. This U-value will be the basis for the comparison of the systems performance in insulating the building. Table 14-Temperature Design Considerations, shows the temperature for summer and winter design conditions in Washington, DC, and these calculations will assume 72 degree inside air at all times.

TABLE 14-TEMPERATURE DESIGN CONSIDERATIONS

Design Temperatures (F)		
	Summer	**Winter**
Outside Air (T_o)	95	0
Inside Air (T_i)	72	72
Temp. Difference (ΔT)	23	72

Using the equation for heat transfer, $h = A * U * \Delta T$, the affects of the new system compared to the existing system. Since windows are not being changed for either system, their effect on the heat transfer calculations has been omitted. Tables 15 and 16 show the impacts of the assemblies on the heat gain and heat loss of the DCH building and this impact on energy costs of operation. Table 17-Analysis of Savings and Payback Period analyzes the total savings and determines the payback period for the costs of this system that is not covered by the overhead savings. The cooling season and heating for Maryland area were both assumed to be 4 months.

TABLE 15-SUMMER HEAT GAIN CALCULATIONS

Summer Heat Gain					
System	Area (SF)	U-Value	ΔT (F)	Heat Gain (MBTU's)	Heat Gain (Tons)
Brick Façade	37,127	0.0457	23	114,263	9,522
CarbonCast	37,127	0.0386	23	96,511	8,043
				Difference (Tons)	**1,479**
				Difference (kWh)	**5,198**
				Savings @ $.128 per kWh	**$ 665.32**

TABLE 16-WINTER HEAT LOSS CALCULATIONS

Winter Heat Loss				
System	Area (SF)	U-Value	ΔT (F)	Heat loss (MBTU/Season)
Brick Façade	37,127	0.0457	72	357,692
CarbonCast	37,127	0.0386	72	302,121
			Difference (MBTU)	**55,571**
			Difference (kWh)	**16,271**
			Savings @ $.128 per kWh	**$ 2,082.73**

TABLE 17-ANALYSIS OF SAVINGS AND PAYBACK PERIOD

Savings Analysis	
Cooling Savings	$ 665.32
Heating Savings	$ 2,082.73
Total Annual Savings	$ 2,748.05
Payback Period	86.24 years

While the savings from the improved insulation in the façade are not substantial, they are a move in the positive direction. Ideally, a payback period would not be 86 years, but rather only a few years to make it a worthwhile investment. This payback period is based on the time it would take for the annual savings to recoup the additional $237,000 from Table 11. However, the mechanical gains are a nice incentive considering the already proven schedule gains.

CONCLUSIONS AND RECOMMENDATIONS

Changing the envelope of a building has wide reaching effects on a project. In this specific case, the construction duration was shortened by six weeks, resulting in savings on overhead and allowing the revenue stream to start sooner for the hospital. Structural systems and mechanical systems can also be impacted by a new façade. In this case, while there were no significant gains in these systems, the new façade did not adversely impact them either. In fact, there even proved to be a cost benefit in the operations cost of the facility through energy savings.

Considering all the effects on the project, the switch to precast does not seem to be advisable. Even though the positives of a reduced schedule and the slight mechanical benefits are encouraging, the upfront initial costs are too high to make this a worthwhile investment.

ANALYSIS 3| SITE LOGISTICS

BACKGROUND

The ability for a construction manager to effectively plan and utilize a site can impact how efficiently a project progresses and, ultimately, how successful the project will be with its schedule and overall costs. If a contractor is brought onboard very early in a project, they may be given the opportunity to impact the site selection based on site logistics, but this is seldom the case. For the vast majority of projects, the contractor is not able to affect site selection, but must be able to make the best of the site they are given.

Site logistics can have a large impact on any construction project. If contractors are forced to double handle materials due to the location of storage areas, have long hauls to retrieve materials, or do not have enough space to perform their tasks, the trades will work inefficiently and this can push out the schedule and add to the total cost of the project.

For many construction projects, DCH included, the constraints imposed by the site are generally known when the projects are bid by the contractors. One of the largest constraints at DCH is the access on the east side of the expansion, which is highlighted in Figure 17- DCH Site Plan Excerpt. It is only 25' wide and immediately adjacent to the construction.

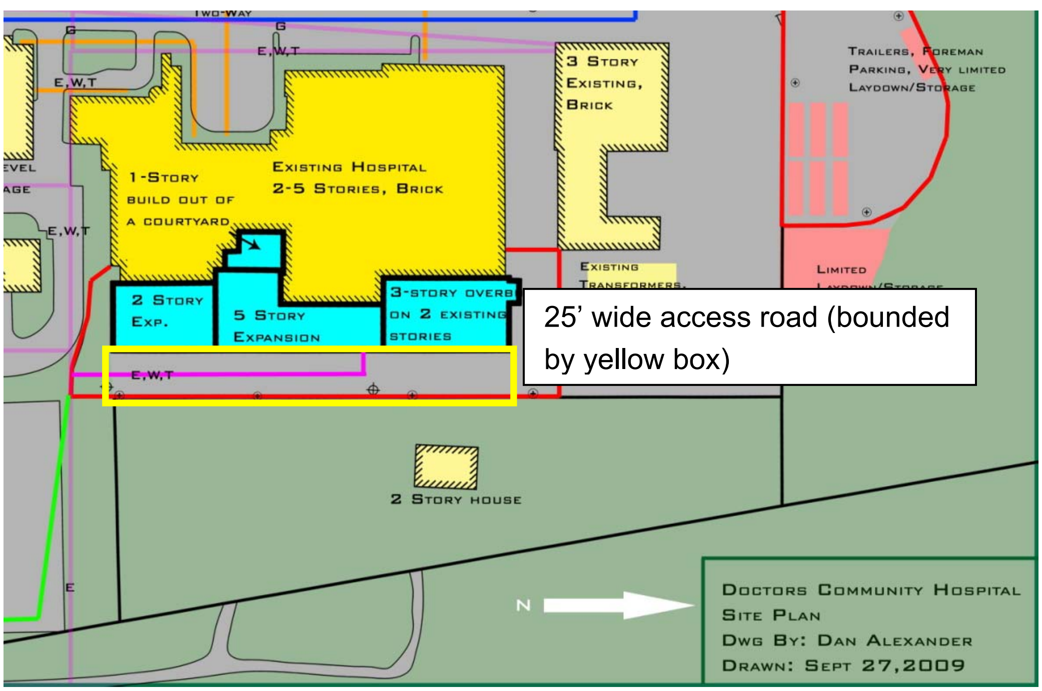


FIGURE 17-DCH SITE PLAN EXCERPT

Additionally, the narrow road was the location of the new ductbank that needed to be installed to feed the expansion. The location is shown above in Figure 17 by the purple line directly below the expansion footprint. Figure 18-Ground Perspective of Ductbank Location, shows another view of the location and illustrates how its installation would occupy almost all of this lone access road to the site.

FIGURE 18-GROUND LEVEL PERSPECTIVE OF DUCTBANK LOCATION

The owner of the hospital passed on the opportunity to purchase the adjoining property, outlined in Figure 6 by the black line around the 2 story structure to the east (bottom) of the picture. It is also shown in Figure 7 at the left side. Purchasing this property would have expanded the site and would have increased the site size which would help to ease the congestion. The effects of this purchase, and if the purchase would have been a sound investment, will be an area of focus for this analysis.

Assessing impacts from a hypothetical situation is not easy. In order to identify affects on the trades, interviews were conducted with the trades that were most affected by this site access issue : MEP, Masonry, Steel, and Concrete. Conversations were held with project managers and based on their intimate knowledge of the project and years of real world experience, they made assessments of possible impacts from additional site space.

GOAL

The goal of this analysis is to:

1. Assess if there is any impact from the congested site on the trades
2. Quantify this impact, if it exists, in terms of affect on the schedule and cost
3. Determine if purchasing adjacent property would have been a sound investment

EFFECTS OF SITE CONGESTION

Construction projects are usually driven by two main factors, schedule and cost. Project managers and superintendents often spend countless hours figuring out how to keep a project on schedule while managing their costs and cash flow. A congested site can sometimes be the culprit behind an expanding schedule, and in turn, added costs.

Conveniently located space is in short supply on the DCH project. During the steel erection, the crane was placed in locations one and two as marked in Figure 19-Crane Placement. These spots are on the sole access road for the site and there is not significant space for laydown adjacent to the crane locations. Steel was delivered directly to the crane by backing the tractor trailers up down the access road and placing steel directly from the trucks when possible, but the narrow road was impassible by other trades when this was the case.

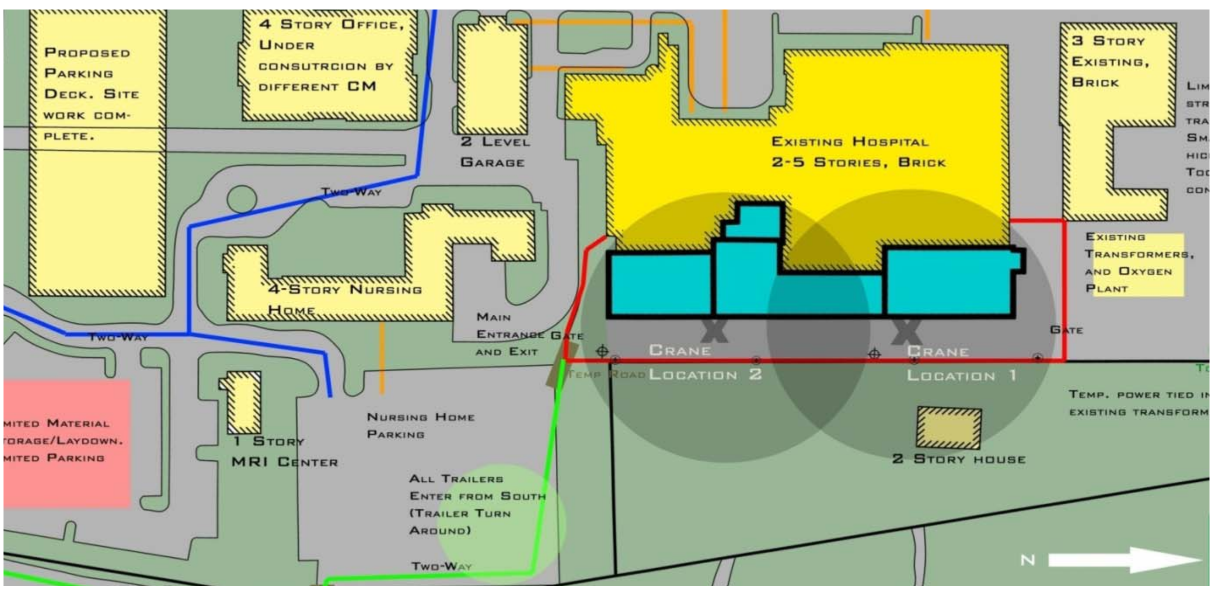


FIGURE 19-CRANE PLACEMENT

The already narrow access road was being restricted by a 130 ton mobile crane for the erection process. Furthermore, when trucks had to be unloaded, but could not be placed directly, the sides of the road were used as storage, further constricting the already narrow passage. There were times when steel erection had to be suspended to allow other trades use of the access road, again impeding progress

The steel trade was not the only one affected by the lack of space. Underground MEP was also impacted by the lack of space on the east side of the project. Since DCH did not own the property, the only location for the new ductbank that did not interfere with the building footprint forced it to run right down the middle of the access road as shown previously in Figures 17 and 18. Since there was not enough room for both the ductbank to be installed and the crane to occupy the space it needed, one task had to be bumped. The ductbank installation was scheduled later and this required the electrical trade to end up having multiple mobilizations. If there had been enough space (the adjacent property had been purchased), the ductbank could have been run 20' further to the east, allowing simultaneous installation of the bank and the steel.

A problem that plagues all trades is manpower inefficiency due to the location of storage areas. While storage areas are not always in the best location, at DCH they are a considerable distance away, depending on where you start and where you go, almost 4 football fields, further if you need to get to the parking areas. This affected two items: retrieval of needed materials, and amount of time taken on breaks.

Materials are generally not stored immediately adjacent to the place where they will be installed, but rather at some central location for the trade to farm out as needed. Unfortunately, at the DCH project, these locations are not very close to the building because the west side is blocked off by the existing structure and the east side has only 25 feet which is the only access road for the site. During the interviews, several trades noted that they are losing time having to haul materials much further than usual. Steel had to be double handled. Masons were waiting for mortar and brick that has to be hauled twice as far as usual. These impacts are on necessary work, and doesn't even account for when tools, materials, or drawings are forgotten and more time is spent walking long distances to retrieve the items. A person can lose up to 15 minutes in travel time from their location on site, to the trailer/material storage area and back when they are located as far away as they are at DCH. While this is not significant by itself, sum this up over the course of a project, and it can become quite an appreciable number

Secondly, break times get extended, much to the dismay of foreman and superintendents everywhere. Workers will start their break when they reach their truck, not when they start walking from the site, which can add almost 20 minutes of lost labor per man. On a 6 man crew, this works out to be 10 man hours lost per week. When trades are in full swing, and upwards of 60+ workers are taking these breaks, 100 man hours per week are being lost.

SCHEDULE AND COST IMPACT

As previously mentioned, hypothetical situations are hard to quantify on a construction site. In this case, the expertise of the project participants is the basis for the durations and costs used in this subsection. Table 18-Response to Schedule and Cost Impacts is a consolidation of the responses to a series of questions posed that pertains to the site and its congested nature and how this has impacted the respondents' trade. Project managers were the target group for the interviews. Based on these conversations, a common theme that emerged was that schedule improvements were driven by improved efficiency, and the cost savings stemmed from this and resulted in savings in labor costs.

TABLE 18-RESPONSES TO SCHEDULE AND COST IMPACTS

Trade	Schedule Impact	Impact in Days on CPM	Cost Impact
Steel	Shorten 15-20%	9	Save 5-10%
Mechanical/Plumbing	Shorten 25% (Underground)	15	Save $150,000
Electrical	Shorten 15%	4	Save 5%
Masonry	Shorten 10-15%	5	Save 10%
Concrete	Shorten 5-10%	7	Save $15,000

.

While not all activities of all of the trades listed above lie on the critical path, a schedule savings can be realized on the overall project. By looking at the activities in the CPM schedule in Appendix I that lie one the critical path, and accounting for the percentages indicated above, roughly totaled, about 40 days, can be shaved off of the schedule. The bulk of this comes early on in the project when the site has the most effect on the trades, especially in underground MEP and the sub and superstructure of the building.

The savings indicated above are only looking at items that are on the critical path, and will thus directly impact the over head costs of the project in a positive manner. Additional costs savings can be attributed to the improved efficiency of the trades. The total savings attributed to more space are outlined in Table 19-Overall Cost Savings Possible from improved Site Logistics, and include the savings in reduced overhead.

TABLE 19-OVERALL COST SAVINGS POSSIBLE FROM IMPROVED SITE LOGISTICS

Source of Savings	Approx. Contract	Savings %	Savings $
Steel	$1,550,000	5%	$ 77,500.00
Mech/Plumbing	$9,200,000	-	$ 150,000.00
Electrical	$3,000,000	5%	$ 150,000.00
Masonry	$1,000,000	10%	$ 100,000.00
Concrete	$1,000,000	-	$ 15,000.00
GC's	$14,430/wk	8 wks	$ 115,440.00
		Total Savings	**$607,940**

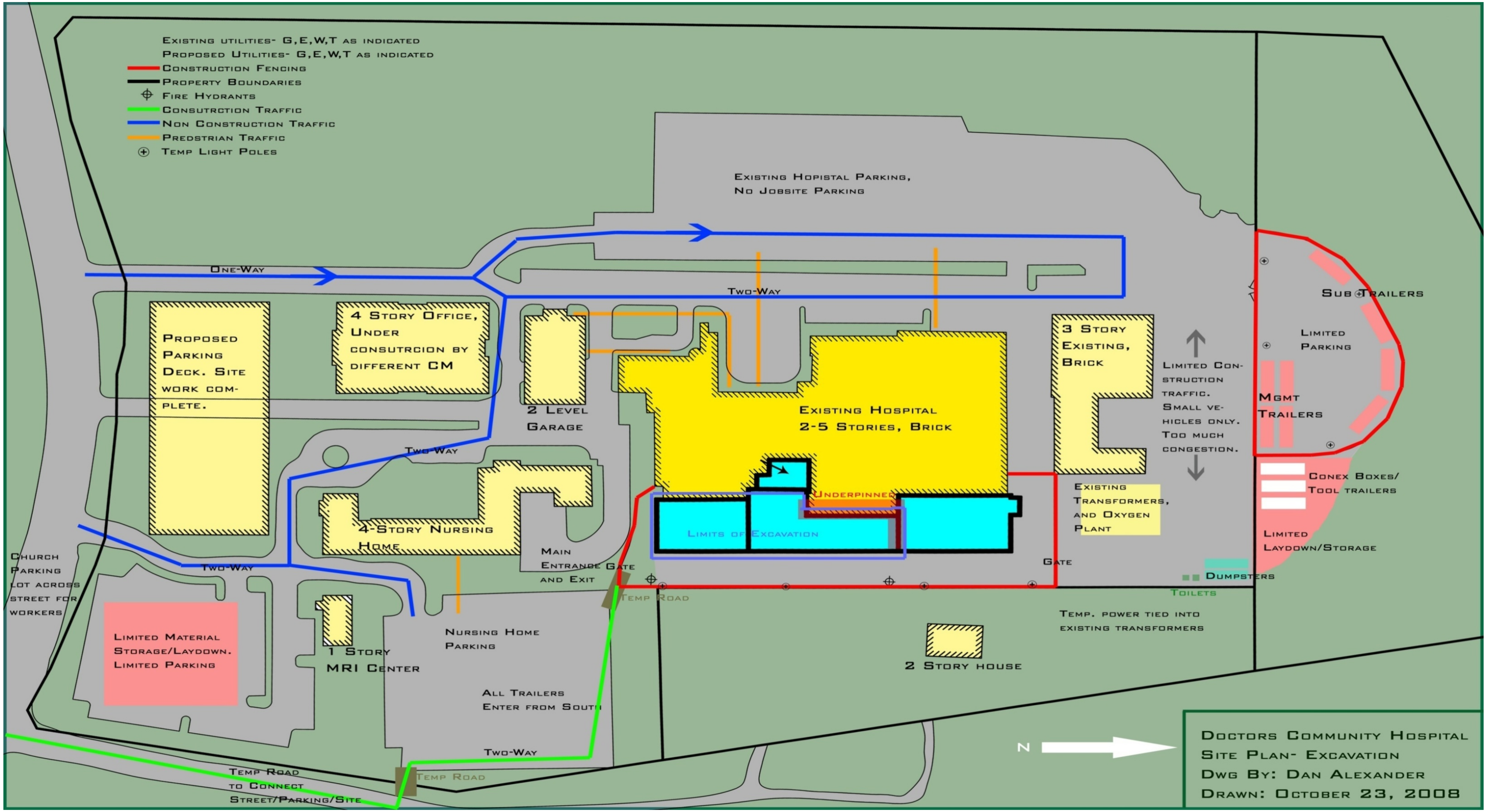
Based on the above information, Doctors Community Hospital would have to make the final decision on whether the purchase of the adjacent land is indeed worth it. DCH has passed on several opportunities to purchase the land in the past. Two to three years ago, they passed on the chance to buy the property from the owner for roughly $500,000, which would have ended up benefiting them in the long run with a more than $100,000 return. Most recently however, the owner, seeing the value of his land and based on input from his family, has upped his price to roughly $2.0 million when DCH approached him again at the onset of this expansion project.

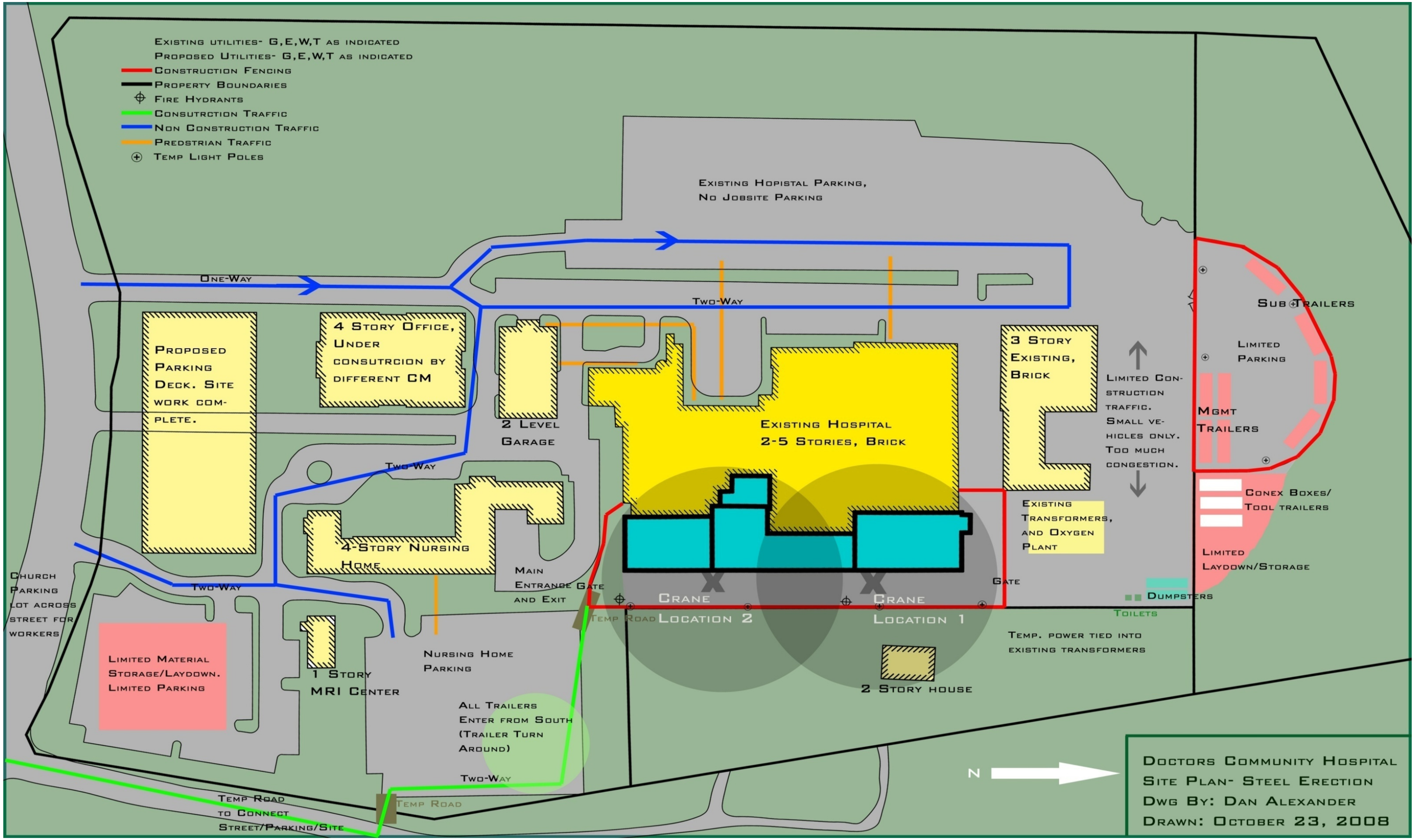
A point of consideration is how would the added land impacted the design of the building had the land been available at the start of the project. The architects could have used a more stand-alone structure that tied in with pedestrian bridges. This design would have eliminated much of the demolition work and would have reduced many of the construction problems that have arisen from building next to, and on top of, an operating hospital.

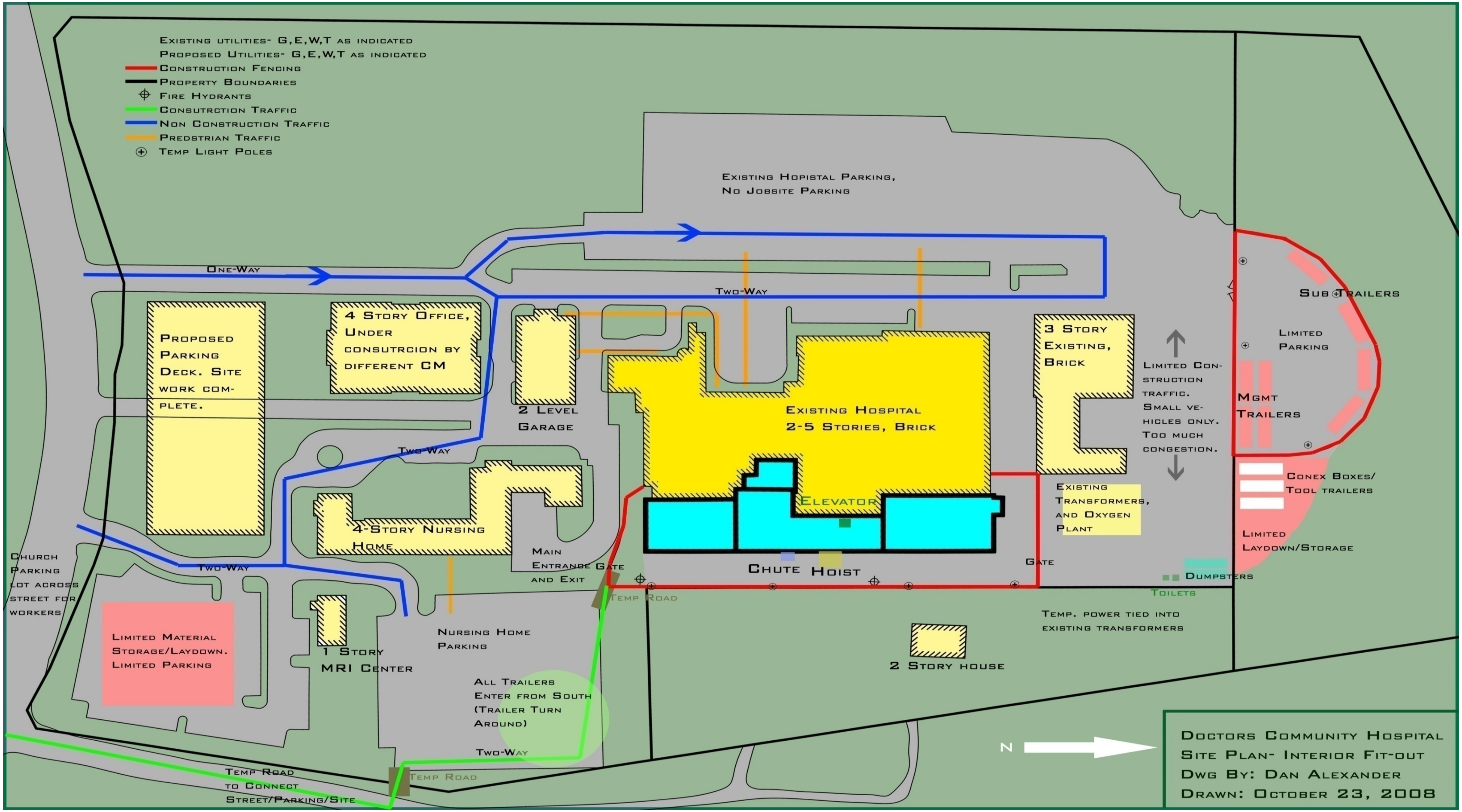
CONCLUSIONS AND RECOMMENDATIONS

Any contractor would be appreciative to have more space for site planning and to have additional room for storage and laydown, especially in a convenient location. The adjacent property at DCH can give exactly that. However, it would appear as though the cost/benefit analysis does not represent a solid investment opportunity at this time. If DCH had moved on the purchase 2-3 years ago, it would have been a sound investment. Based on the current situation, with the current asking price, it would not have been a worthwhile business venture.

APPENDIX I | SITE LAYOUT PLANS




Existing utilities- G,E,W,T as indicated
Proposed Utilities- G,E,W,T as indicated
Construction Fencing
Property Boundaries
Fire Hydrants
Consutrction Traffic
Non Construction Traffic
Predstrian Traffic
Temp Light Poles
Existing Hopistal Parking, No Jobsite Parking
One-Way
Two-Way
Proposed Parking Deck. Site work com- plete.
4 Story Office, Under consutrcion by different CM
2 Level Garage
Existing Hospital 2-5 Stories, Brick
3 Story Existing, Brick
Limited Con- struction traffic. Small ve- hicles only. Too much congestion.
Sub Trailers
Limited Parking
Mgmt Trailers
Conex Boxes/ Tool trailers
Limited Laydown/Storage
Existing Transformers, and Oxygen Plant
Gate
Dumpsters
Toilets
4-Story Nursing Home
Main Entrance Gate and Exit
Temp Road
Crane Location 2
Crane Location 1
Temp. power tied into existing transformers
2 Story house
Church Parking lot across street for workers
Limited Material Storage/Laydown. Limited Parking
1 Story MRI Center
Nursing Home Parking
All Trailers Enter from South (Trailer Turn Around)
Temp Road to Connect Street/Parking/Site
N
Doctors Community Hospital
Site Plan- Steel Erection
Dwg By: Dan Alexander
Drawn: October 23, 2008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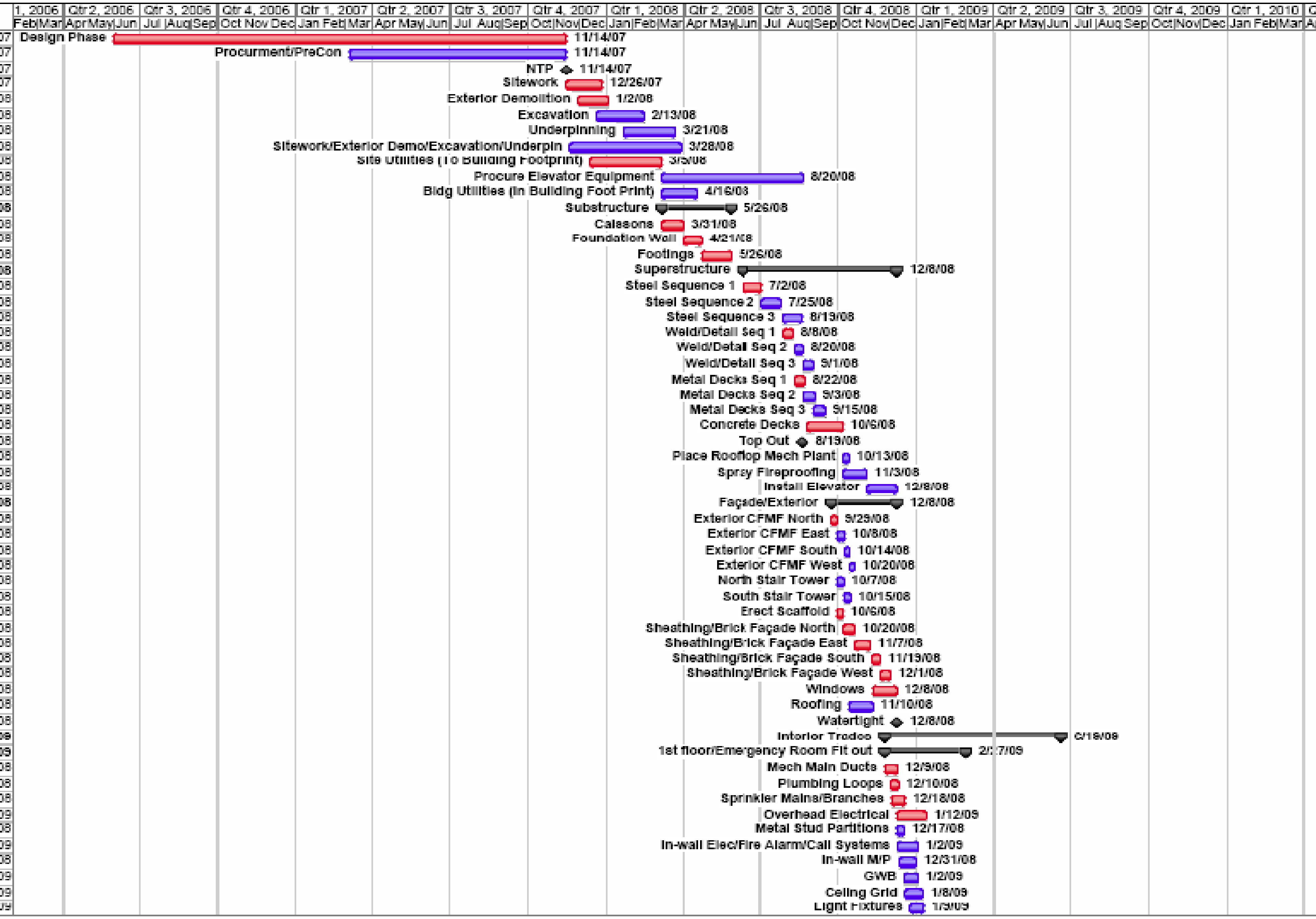
Limited Laydown/Storage
Existing Transformers, and Oxygen Plant
Elevator
Chute
Hoist
Gate
Dumpsters
Toilets
4-Story Nursing Home
Main Entrance Gate and Exit
Temp Road
Church Parking lot across street for workers
Limited Material Storage/Laydown. Limited Parking
1 Story MRI Center
Nursing Home Parking
All Trailers Enter from South (Trailer Turn Around)
Temp Road to Connect Street/Parking/Site
Temp. power tied into existing transformers
2 Story house
N
Doctors Community Hospital
Site Plan- Interior Fit-out
Dwg By: Dan Alexander
Drawn: October 23, 2008

APPENDIX II | CPM SCHEDULE

Summary Schedule for Doctors Community Hospital

ID	Task Name	Duration	Start	Finish
1	Design Phase	380 days	Thu 6/1/06	Wed 11/14/07
2	Procurment/PreCon	183 days	Mon 3/5/07	Wed 11/14/07
3	NTP	0 days	Wed 11/14/07	Wed 11/14/07
4	Sitework	30 days	Thu 11/15/07	Wed 12/26/07
5	Exterior Demolition	25 days	Thu 11/29/07	Wed 1/2/08
6	Excavation	40 days	Thu 12/20/07	Wed 2/13/08
7	Underpinning	45 days	Mon 1/21/08	Fri 3/21/08
8	Sitework/Exterior Demo/Excavation/Underpin	95 days	Mon 11/19/07	Fri 3/28/08
9	Site Utilities (To Building Footprint)	60 days	Thu 12/13/07	Wed 3/5/08
10	Procure Elevator Equipment	120 days	Thu 3/6/08	Wed 8/20/08
11	Bldg Utilities (In Building Foot Print)	30 days	Thu 3/6/08	Wed 4/16/08
12	**Substructure**	**58 days**	**Thu 3/6/08**	**Mon 5/26/08**
13	Caissons	18 days	Thu 3/6/08	Mon 3/31/08
14	Foundation Wall	15 days	Tue 4/1/08	Mon 4/21/08
15	Footings	25 days	Tue 4/22/08	Mon 5/26/08
16	**Superstructure**	**130 days**	**Tue 6/10/08**	**Mon 12/8/08**
17	Steel Sequence 1	17 days	Tue 6/10/08	Wed 7/2/08
18	Steel Sequence 2	17 days	Thu 7/3/08	Fri 7/25/08
19	Steel Sequence 3	17 days	Mon 7/28/08	Tue 8/19/08
20	Weld/Detail Seq 1	9 days	Tue 7/29/08	Fri 8/8/08
21	Weld/Detail Seq 2	8 days	Mon 8/11/08	Wed 8/20/08
22	Weld/Detail Seq 3	8 days	Thu 8/21/08	Mon 9/1/08
23	Metal Decks Seq 1	10 days	Mon 8/11/08	Fri 8/22/08
24	Metal Decks Seq 2	10 days	Thu 8/21/08	Wed 9/3/08
25	Metal Decks Seq 3	10 days	Tue 9/2/08	Mon 9/15/08
26	Concrete Decks	30 days	Tue 8/26/08	Mon 10/6/08
27	Top Out	0 days	Tue 8/19/08	Tue 8/19/08
28	Place Rooftop Mech Plant	5 days	Tue 10/7/08	Mon 10/13/08
29	Spray Fireproofing	20 days	Tue 10/7/08	Mon 11/3/08
30	Install Elevator	25 days	Tue 11/4/08	Mon 12/8/08
31	**Façade/Exterior**	**55 days**	**Tue 9/23/08**	**Mon 12/8/08**
32	Exterior CFMF North	5 days	Tue 9/23/08	Mon 9/29/08
33	Exterior CFMF East	7 days	Tue 9/30/08	Wed 10/8/08
34	Exterior CFMF South	4 days	Thu 10/9/08	Tue 10/14/08
35	Exterior CFMF West	4 days	Wed 10/15/08	Mon 10/20/08
36	North Stair Tower	6 days	Tue 9/30/08	Tue 10/7/08
37	South Stair Tower	6 days	Wed 10/8/08	Wed 10/15/08
38	Erect Scaffold	5 days	Tue 9/30/08	Mon 10/6/08
39	Sheathing/Brick Façade North	10 days	Tue 10/7/08	Mon 10/20/08
40	Sheathing/Brick Façade East	14 days	Tue 10/21/08	Fri 11/7/08
41	Sheathing/Brick Façade South	8 days	Mon 11/10/08	Wed 11/19/08
42	Sheathing/Brick Façade West	8 days	Thu 11/20/08	Mon 12/1/08
43	Windows	20 days	Tue 11/11/08	Mon 12/8/08
44	Roofing	20 days	Tue 10/14/08	Mon 11/10/08
45	Watertight	0 days	Mon 12/8/08	Mon 12/8/08
46	**Interior Trades**	**149 days**	**Tue 11/25/08**	**Fri 6/19/09**
47	**1st floor/Emergency Room Fit out**	**69 days**	**Tue 11/25/08**	**Fri 2/27/09**
48	Mech Main Ducts	11 days	Tue 11/25/08	Tue 12/9/08
49	Plumbing Loops	7 days	Tue 12/2/08	Wed 12/10/08
50	Sprinkler Mains/Branches	12 days	Wed 12/3/08	Thu 12/18/08
51	Overhead Electrical	25 days	Tue 12/9/08	Mon 1/12/09
52	Metal Stud Partitions	7 days	Tue 12/9/08	Wed 12/17/08
53	In-wall Elec/Fire Alarm/Call Systems	18 days	Wed 12/10/08	Fri 1/2/09
54	In-wall M/P	14 days	Fri 12/12/08	Wed 12/31/08
55	GWB	12 days	Thu 12/18/08	Fri 1/2/09
56	Ceiling Grid	15 days	Fri 12/19/08	Thu 1/8/09
57	Light Fixtures	12 days	Thu 12/25/08	Fri 1/9/09



Project: DetailSched(New)
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Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

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Summary Schedule for Doctors Community Hospital

ID	Task Name	Duration	Start	Finish
58	Paint Prime and 1st Coat	10 days	Tue 1/6/09	Mon 1/19/09
59	Cabinetry	14 days	Wed 1/7/09	Mon 1/26/09
60	Floor Finish	15 days	Thu 1/8/09	Wed 1/28/09
61	Final Coat	6 days	Thu 1/22/09	Thu 1/29/09
62	MP Fitout	6 days	Tue 1/20/09	Tue 1/27/09
63	Doors and Hardware	10 days	Fri 1/30/09	Thu 2/12/09
64	Equipment and Accessories	15 days	Fri 1/30/09	Thu 2/19/09
65	Activate ED Expansion	6 days	Fri 2/20/09	Fri 2/27/09
66	Occupy ED	0 days	Fri 2/27/09	Fri 2/27/09
67	**2nd Floor Fit out**	**77 days**	**Wed 12/10/08**	**Thu 3/26/09**
68	Mech Main Ducts	11 days	Wed 12/10/08	Wed 12/24/08
69	Plumbing Loops	7 days	Wed 12/17/08	Thu 12/25/08
70	Sprinkler Mains/Branches	12 days	Fri 12/19/08	Mon 1/5/09
71	Overhead Electrical	25 days	Tue 1/13/09	Mon 2/16/09
72	Metal Stud Partitions	7 days	Tue 1/13/09	Wed 1/21/09
73	In-wall Elec/Fire Alarm/Call Systems	18 days	Wed 1/14/09	Fri 2/6/09
74	In-wall M/P	14 days	Fri 1/16/09	Wed 2/4/09
75	GWB	12 days	Thu 1/22/09	Fri 2/6/09
76	Ceiling Grid	15 days	Fri 1/23/09	Thu 2/12/09
77	Light Fixtures	12 days	Thu 1/29/09	Fri 2/13/09
78	Paint Prime and 1st Coat	10 days	Tue 2/10/09	Mon 2/23/09
79	Cabinetry	14 days	Wed 2/11/09	Mon 3/2/09
80	Floor Finish	15 days	Thu 2/12/09	Wed 3/4/09
81	Final Coat	6 days	Thu 2/26/09	Thu 3/5/09
82	MP Fitout	6 days	Tue 2/24/09	Tue 3/3/09
83	Doors and Hardware	10 days	Fri 3/6/09	Thu 3/19/09
84	Equipment and Accessories	15 days	Fri 3/6/09	Thu 3/26/09
85	**3rd Floor Fit-out**	**91 days**	**Thu 12/25/08**	**Thu 4/30/09**
86	Mech Main Ducts	11 days	Thu 12/25/08	Thu 1/8/09
87	Plumbing Loops	7 days	Thu 1/1/09	Fri 1/9/09
88	Sprinkler Mains/Branches	12 days	Tue 1/6/09	Wed 1/21/09
89	Overhead Electrical	25 days	Tue 2/17/09	Mon 3/23/09
90	Metal Stud Partitions	7 days	Tue 2/17/09	Wed 2/25/09
91	In-wall Elec/Fire Alarm/Call Systems	18 days	Wed 2/18/09	Fri 3/13/09
92	In-wall M/P	14 days	Fri 2/20/09	Wed 3/11/09
93	GWB	12 days	Thu 2/26/09	Fri 3/13/09
94	Ceiling Grid	15 days	Fri 2/27/09	Thu 3/19/09
95	Light Fixtures	12 days	Thu 3/5/09	Fri 3/20/09
96	Paint Prime and 1st Coat	10 days	Tue 3/17/09	Mon 3/30/09
97	Cabinetry	14 days	Wed 3/18/09	Mon 4/6/09
98	Floor Finish	15 days	Thu 3/19/09	Wed 4/8/09
99	Final Coat	6 days	Thu 4/2/09	Thu 4/9/09
100	MP Fitout	6 days	Tue 3/31/09	Tue 4/7/09
101	Doors and Hardware	10 days	Fri 4/10/09	Thu 4/23/09
102	Equipment and Accessories	15 days	Fri 4/10/09	Thu 4/30/09
103	**4th Floor Fit out**	**98 days**	**Fri 1/9/09**	**Tue 5/26/09**
104	Mech Main Ducts	11 days	Fri 1/9/09	Fri 1/23/09
105	Plumbing Loops	7 days	Fri 1/16/09	Mon 1/26/09
106	Sprinkler Mains/Branches	12 days	Thu 1/22/09	Fri 2/6/09
107	Overhead Electrical	25 days	Wed 1/28/09	Tue 3/3/09
108	Metal Stud Partitions	7 days	Wed 1/28/09	Thu 2/5/09
109	In-wall Elec/Fire Alarm/Call Systems	18 days	Mon 3/16/09	Wed 4/8/09
110	In-wall M/P	14 days	Wed 3/18/09	Mon 4/6/09
111	GWB	12 days	Tue 3/24/09	Wed 4/8/09
112	Ceiling Grid	15 days	Wed 3/25/09	Tue 4/14/09
113	Light Fixtures	12 days	Tue 3/31/09	Wed 4/15/09
114	Paint Prime and 1st Coat	10 days	Fri 4/10/09	Thu 4/23/09

Project: DetailSched(New)
Date: Wed 4/1/09

Task | Critical Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Critical Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | Group By Summary | Deadline

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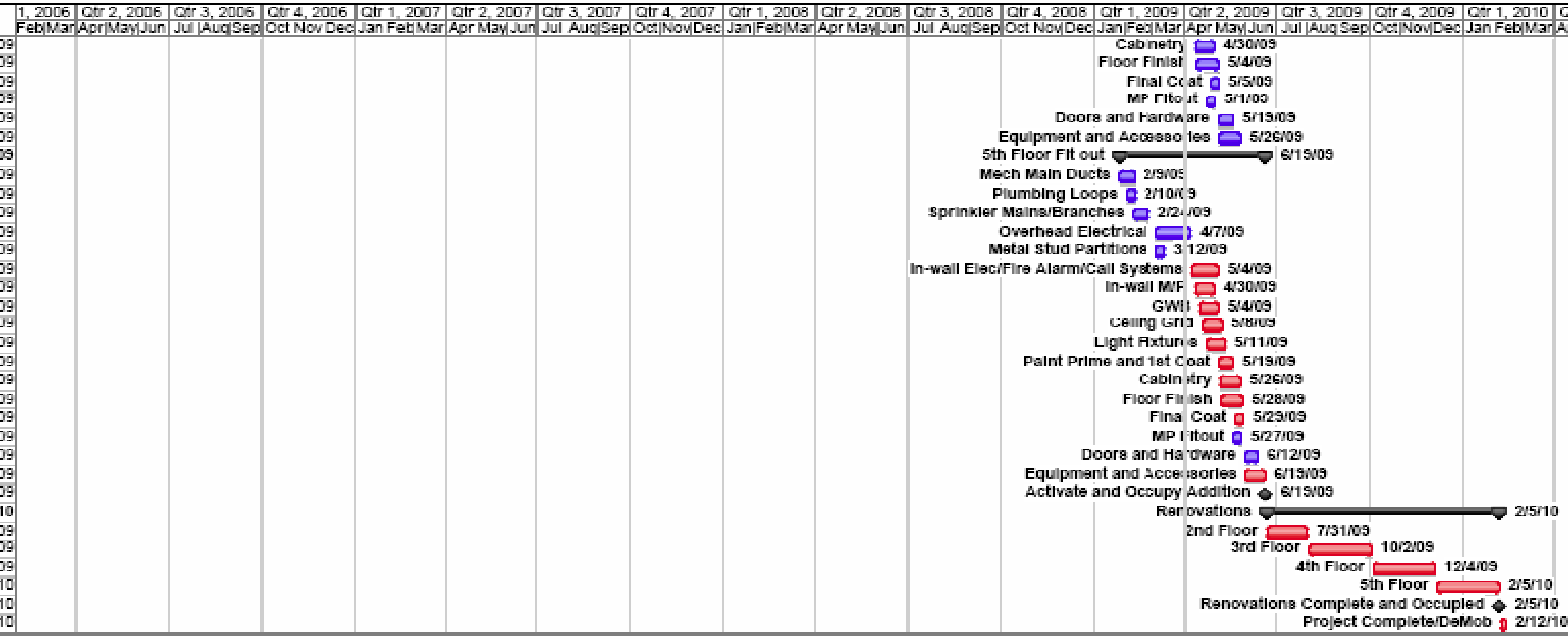
Summary Schedule for Doctors Community Hospital

ID	Task Name	Duration	Start	Finish
115	Cabinetry	14 days	Mon 4/13/09	Thu 4/30/09
116	Floor Finish	15 days	Tue 4/14/09	Mon 5/4/09
117	Final Coat	6 days	Tue 4/28/09	Tue 5/5/09
118	MP Fitout	6 days	Fri 4/24/09	Fri 5/1/09
119	Doors and Hardware	10 days	Wed 5/6/09	Tue 5/19/09
120	Equipment and Accessories	15 days	Wed 5/6/09	Tue 5/26/09
121	**5th Floor Fit out**	**105 days**	**Mon 1/26/09**	**Fri 6/19/09**
122	Mech Main Ducts	11 days	Mon 1/26/09	Mon 2/9/09
123	Plumbing Loops	7 days	Mon 2/2/09	Tue 2/10/09
124	Sprinkler Mains/Branches	12 days	Mon 2/9/09	Tue 2/24/09
125	Overhead Electrical	25 days	Wed 3/4/09	Tue 4/7/09
126	Metal Stud Partitions	7 days	Wed 3/4/09	Thu 3/12/09
127	In-wall Elec/Fire Alarm/Call Systems	18 days	Thu 4/9/09	Mon 5/4/09
128	In-wall M/P	14 days	Mon 4/13/09	Thu 4/30/09
129	GWB	12 days	Fri 4/17/09	Mon 5/4/09
130	Ceiling Grid	15 days	Mon 4/20/09	Fri 5/8/09
131	Light Fixtures	12 days	Fri 4/24/09	Mon 5/11/09
132	Paint Prime and 1st Coat	10 days	Wed 5/6/09	Tue 5/19/09
133	Cabinetry	14 days	Thu 5/7/09	Tue 5/26/09
134	Floor Finish	15 days	Fri 5/8/09	Thu 5/28/09
135	Final Coat	6 days	Fri 5/22/09	Fri 5/29/09
136	MP Fitout	6 days	Wed 5/20/09	Wed 5/27/09
137	Doors and Hardware	10 days	Mon 6/1/09	Fri 6/12/09
138	Equipment and Accessories	15 days	Mon 6/1/09	Fri 6/19/09
139	Activate and Occupy Addition	0 days	Fri 6/19/09	Fri 6/19/09
140	**Renovations**	**165 days**	**Mon 6/22/09**	**Fri 2/5/10**
141	2nd Floor	30 days	Mon 6/22/09	Fri 7/31/09
142	3rd Floor	45 days	Mon 8/3/09	Fri 10/2/09
143	4th Floor	45 days	Mon 10/5/09	Fri 12/4/09
144	5th Floor	45 days	Mon 12/7/09	Fri 2/5/10
145	Renovations Complete and Occupied	0 days	Fri 2/5/10	Fri 2/5/10
146	Project Complete/DeMob	5 days	Mon 2/8/10	Fri 2/12/10



Project: DetailSched(New)
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Task · Critical Task · Progress · Milestone · Summary · Rolled Up Task · Rolled Up Critical Task · Rolled Up Milestone · Rolled Up Progress · Split · External Tasks · Project Summary · Group By Summary · Deadline

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APPENDIX III | DETAILED ESTIMATE BREAKDOWNS

TABLE 20-DETAILED BREAKDOWN OF GENERAL CONDITIONS ESTIMATE

General Conditions Estimate

Total Project Weeks	119
Total Project Months	27

Personnel	% of time on Project	Total Billable Weeks	Cost per Week	Total Cost
Project Executive	50%	59.5	$ 2,100	$ 124,950
Project Manager	100%	119	$ 1,850	$ 220,150
Assistant Project Manager	100%	119	$ 1,600	$ 190,400
Field Engineer	100%	119	$ 1,125	$ 133,875
General Superintendent	70%	83.3	$ 1,800	$ 149,940
Assistant Superintendent	100%	119	$ 1,600	$ 190,400
Office Manager	100%	119	$ 800	$ 95,200
Category Total				**$ 1,104,915**

Utilities/Facilities	Frequency	Duration	Cost/Unit Time	Total Cost
Electric/Water	Monthly	27	500	$ 13,500
Internet	Monthy	27	$ 300	$ 8,100
Porta Johns	Weekly	119	$ 60	$ 7,140
Telephone	Monthly	27	$ 600	$ 16,200
Trailer Set up	Lump Sum	-	-	$ 10,000
Trailers	Monthly	27	$ 750	$ 20,250
Utilities Hook Up	Lump Sum	-	-	$ 15,000
Category Total				**$ 90,190**

Site Office Support	Frequency	Duration	Cost/Unit Time	Total Cost
Cell phone and Nextel	Monthly	27	$ 300	$ 8,100
Computers	Lump Sum	-	-	$ 10,000
Janitorial service for trailer	Monthly	27	$ 200	$ 5,400
Job Travel	Monthly	27	$ 250	$ 6,750
Job vehicle fuel/maintenance	Monthly	27	$ 400	$ 10,800
Job Vehicle/Auto Allowance	Monthly	27	$ 1,000	$ 27,000
Office Furniture	Lump Sum	-	-	$ 5,000
Office Supplies	Monthly	27	$ 400	$ 10,800
Postage and Shipping	Monthly	27	$ 300	$ 8,100
Category Total				**$ 91,950**

General Conditions Estimate (Cont)

General Requirements	Frequency	Duration	Cost/Unit Time	Total Cost
Bid Set Repro Costs/Distribution	Lump Sum	-	-	$ 25,000
Copiers and Supplies	Monthly	27	$ 600	$ 16,200
Dumpsters	Weekly	119	$ 650	$ 77,350
Final Clean	Lump Sum	-	-	$ 20,000
Material Hoist	Weekly	21	$ 1,780	$ 37,380
Mock-up (Patient Room)	Lump Sum	-	-	$ 45,000
Safety and First Aid	Monthly	27	$ 1,200	$ 32,400
Signage	Lump Sum	-	-	$ 10,000
Snow Removal	Lump Sum	-	-	$ 25,000
Survey and Layout	Lump Sum	-	-	$ 35,000
Temp Fence	Monthly	27	$ 550	$ 14,850
Temp Ladders/Stairs/Ramps	Lump Sum	-	-	$ 30,000
Temp Roads	Lump Sum	-	-	$ 50,000
Trash Chute	Weekly	22	$ 550	$ 12,100
Category Total				**$ 430,280**
General Conditions Total				**$ 1,717,335**

TABLE 21-DETAILED STRUCTURAL ESTIMATE

Detailed Structural Estimate								
Steel								
		Quantity	**Unit**	**Material**	**Labor**	**Equipment**	**Total Unit Cost**	**Total**
Columns								
	HSS6X6X5/16	13	EA	$ 297.00	$ 43.50	$ 29.00	$ 369.50	$ 4,803.50
	W10X49	39	LF	$ 54.50	$ 2.27	$ 1.52	$ 58.29	$ 2,273.31
	W12X106	52	LF	$ 140.00	$ 2.55	$ 1.68	$ 144.23	$ 7,499.96
	W12X136	84	LF	$ 150.00	$ 2.55	$ 1.68	$ 154.23	$ 12,955.32
	W12X170	68	LF	$ 230.00	$ 2.57	$ 1.72	$ 234.29	$ 15,931.72
	W12X40	135	LF	$ 57.00	$ 2.27	$ 1.52	$ 60.79	$ 8,206.65
	W12X53	239	LF	$ 63.00	$ 2.27	$ 1.52	$ 66.79	$ 15,962.81
	W12X58	26	LF	$ 68.00	$ 2.30	$ 1.52	$ 71.82	$ 1,867.32
	W12X65	660	LF	$ 77.00	$ 2.32	$ 1.54	$ 80.86	$ 53,367.60
	W12X72	68	LF	$ 84.00	$ 2.35	$ 1.56	$ 87.91	$ 5,977.88
	W12X79	106	LF	$ 93.00	$ 2.35	$ 1.57	$ 96.92	$ 10,273.52
	W12X87	262	LF	$ 105.00	$ 2.38	$ 1.59	$ 108.97	$ 28,550.14
	W8X31	1480	LF	$ 37.50	$ 2.17	$ 1.45	$ 41.12	$ 60,857.60
	W8X35	226	LF	$ 42.00	$ 2.19	$ 1.47	$ 45.66	$ 10,319.16
	W8X40	216	LF	$ 49.00	$ 2.24	$ 1.49	$ 52.73	$ 11,389.68
	W8X48	169	LF	$ 58.00	$ 2.27	$ 1.52	$ 61.79	$ 10,442.51
	W8X58	93	LF	$ 68.00	$ 2.32	$ 1.55	$ 71.87	$ 6,683.91
	W8X67	282	LF	$ 81.00	$ 2.38	$ 1.59	$ 84.97	$ 23,961.54
Beams								
	W10X12	335.07	LF	$ 14.50	$ 3.91	$ 2.61	$ 21.02	$ 7,043.17
	W12X14	718.6	LF	$ 16.95	$ 2.66	$ 1.78	$ 21.39	$ 15,370.85
	W12X19	2361.84	LF	$ 24.00	$ 2.66	$ 1.87	$ 28.53	$ 67,383.30
	W12X22	159.1	LF	$ 26.50	$ 2.66	$ 1.87	$ 31.03	$ 4,936.87
	W12X30	180.22	LF	$ 35.00	$ 2.76	$ 1.90	$ 39.66	$ 7,147.53
	W12X35	709.25	LF	$ 42.50	$ 2.89	$ 1.93	$ 47.32	$ 33,561.71
	W12X40	280.05	LF	$ 48.00	$ 2.93	$ 1.97	$ 52.90	$ 14,814.65
	W14X22	6816.6	LF	$ 28.50	$ 2.35	$ 1.55	$ 32.40	$ 220,857.84
	W14X26	126.82	LF	$ 31.50	$ 2.37	$ 1.58	$ 35.45	$ 4,495.77
	W16X26	2097.62	LF	$ 31.50	$ 2.37	$ 1.58	$ 35.45	$ 74,360.63
	W16X31	97.76	LF	$ 37.50	$ 2.60	$ 1.74	$ 41.84	$ 4,090.28
	W16X36	1273.93	LF	$ 44.50	$ 2.87	$ 1.90	$ 49.27	$ 62,766.53
	W16X40	516.18	LF	$ 48.50	$ 2.93	$ 1.96	$ 53.39	$ 27,558.85
	W18X35	44.76	LF	$ 42.50	$ 3.53	$ 1.77	$ 47.80	$ 2,139.53
	W18X40	130.67	LF	$ 48.50	$ 3.53	$ 1.77	$ 53.80	$ 7,030.05
	W18X50	195	LF	$ 60.50	$ 3.72	$ 1.86	$ 66.08	$ 12,885.60
	W21X44	52	LF	$ 53.00	$ 3.19	$ 1.60	$ 57.79	$ 3,005.08
	W21X50	26	LF	$ 60.50	$ 3.19	$ 1.60	$ 65.29	$ 1,697.54
	W21X57	168	LF	$ 69.00	$ 3.24	$ 1.62	$ 73.86	$ 12,408.48
	W21X68	281.5	LF	$ 82.50	$ 3.27	$ 1.64	$ 87.41	$ 24,605.92
	W24X68	56	LF	$ 82.50	$ 3.06	$ 1.53	$ 87.09	$ 4,877.04
	W24X76	55.5	LF	$ 92.00	$ 3.06	$ 1.53	$ 96.59	$ 5,360.75
	W24X94	29.5	LF	$ 114.00	$ 3.14	$ 1.57	$ 118.71	$ 3,501.95
	W8X15	34.68	LF	$ 18.15	$ 3.81	$ 2.61	$ 24.57	$ 852.09
	W8X18	15	LF	$ 21.00	$ 3.84	$ 2.63	$ 27.47	$ 412.05
Metal Deck								
	1 1/2" 18 Gauge	67861	SF	$ 1.36	$ 0.32	$ 0.03	$ 1.71	$ 116,042.31
						Steel Total		**$ 1,030,530.47**

Detailed Structural Estimate (Cont)								
Concrete								
		Quantity	**Unit**	**Material**	**Labor**	**Equipment**	**Total Unit Cost**	**Total**
Foundations								
	Spread Footings (1-5 CY)	367	CY	$ 192.00	$ 95.50	$ 0.57	$ 288.07	$ 105,721.69
	Caissons	550	VLF	$ 56.50	$ 57.50	$ 66.00	$ 180.00	$ 99,000.00
	Grade Wall	10	CY	$ 228.00	$ 279.00	$ 27.50	$ 534.50	$ 5,345.00
Floors								
	Slab on Grade (6")	17423	SF	$ 1.95	$ 0.75	$ 0.01	$ 2.71	$ 47,216.33
	Concrete on Metal Deck (6")	67861	SF	$ 2.02	$ 0.73	$ 0.28	$ 3.03	$ 205,618.83
	6x6 WWF Reinforcing	852.84	CSF	$ 29.00	$ 25.50	$ -	$ 54.50	$ 46,479.78
						Concrete Total		**$ 509,381.63**

STRUCTURAL TOTAL:	**$**	**1,539,912.10**

APPENDIX IV | PROCESS MODEL

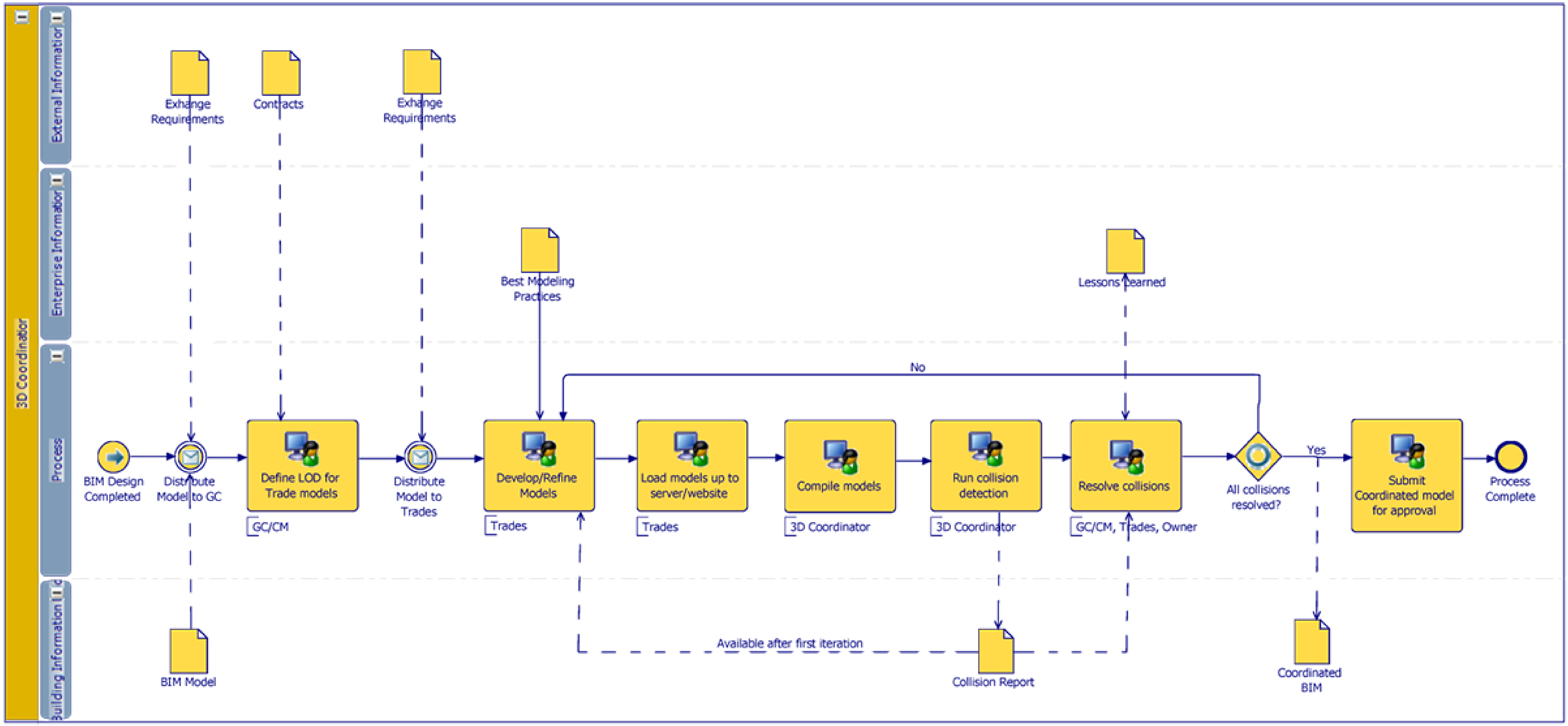


TABLE 22-EXPLANATION OF TASKS AS DEFINED IN PROCESS MODEL

Task Name	Explanation of Task and Related Data Objects
Define LOD for Trade Models	A level of detail must be defined in order for trades to accurately model the systems in order for 3D coordination to be effective. This stage will define what must be modeled. Some items that are typical question marks on whether to be included are: • Hangers, pipe supports, sleeves? • Conduits? • Pipe/Duct insulation? • Metal deck detail? According to Leicht and Messner, four main factors weigh into the determination for the level of detail: • Interaction with other systems • Sequence of Installation • Prefabrication Components • Layout considerations and density of systems Contracts- External information that will impact the contract language in the trades agreement (risk allocation, intellectual property licensure, etc.) and definitions for the LOD necessary for each trade.
Develop/Refine Models	This task consists of the actual work done to create the model. Time will be spent here by the trades or their consultants actually developing the 3D models to be used for coordination. Typically, this will consist of developing the model for one area of the building at a time. Best Modeling Practices- This data object represents enterprise information in the form of lessons learned and best ways to represent information in the 3D model. It will impact how trades/consultants will model the necessary information.
Load Models up to server/website	An FTP server or website should be maintained by the coordination leader in order to facilitate the transfer of the model files which can become quite large. Typically, e-mail will not have sufficient space for these files to be sent as attachments. Each trade will be responsible to upload their model for a given area by a specific date as determined by the coordinator. Files should be uploaded in a compatible format with the software that will be used for collision detection.

Compile Models	The leader for the 3D coordination will assemble the models into one file/file set in order to run the collision detection.
Run Collision Detection	The 3D coordinator will run the collision detection to find all conflicts between the models. At this point, the 3D coordinator can remove false positives depending on LODs that were previously determined. At the conclusion of this activity, a collision report will be outputted and distributed to the trades.
Resolve Collisions	Decisions will be made by the necessary participants to resolve each clash. Coordination issues will be resolved based on trade inputs. Design issues will result in RFI's. Clashes resulting from LOD (Leicht and Messner, 2008) The steps to resolve the collisions will be determined on a project or company level.
Submit Coordinated Model for Approval	The coordinated model is submitted back to designers for final approval.

TABLE 23-EXPLANATION OF EVENTS AS DEFINED IN PROCESS MODEL

Event Name	Explanation of Event and Related Data Objects
BIM Design Complete	This is the start to the 3D coordination process. The designers have completed the overall design intent for the project.
Distribute Model to GC	A transfer based event, in which the model is sent to the GC or CM on the project. Exchange Requirements- These must be defined by the project team and will determine what file formats will be used on the project to complete the 3D coordination. This is information that can be defined from an external resource that is not taken from either the model or internal enterprise information. BIM Model-Data taken from the BIM model (in this case the model itself) is an information input for this task.
Distribute Model to Trades	Another transfer based event, in which the model is sent to the trades in order for them to begin their work with actually creating the model for their specific trade. Trades to be included will be defined at the project specific level. Exchange Requirements- Requirements for transfer will be determined in order to define the necessary file formats to be distributed to the trades, and also the formats that they will return to the coordination leader.

APPENDIX V | TAKE-OFF DATA

TABLE 24-REVIT TAKE OFF OF EXTERIOR WALL AREA

Family	Family and Type	Area	Unit
Basic Wall	Basic Wall: For SF Take-Off	1064	SF
Basic Wall	Basic Wall: For SF Take-Off	205	SF
Basic Wall	Basic Wall: For SF Take-Off	9072	SF
Basic Wall	Basic Wall: For SF Take-Off	3817	SF
Basic Wall	Basic Wall: For SF Take-Off	3807	SF
Basic Wall	Basic Wall: For SF Take-Off	4680	SF
Basic Wall	Basic Wall: For SF Take-Off	1725	SF
Basic Wall	Basic Wall: For SF Take-Off	560	SF
Basic Wall	Basic Wall: For SF Take-Off	1040	SF
Basic Wall	Basic Wall: For SF Take-Off	5207	SF
Basic Wall	Basic Wall: For SF Take-Off	600	SF
Basic Wall	Basic Wall: For SF Take-Off	2335	SF
Basic Wall	Basic Wall: For SF Take-Off	1015	SF
Basic Wall	Basic Wall: For SF Take-Off	1015	SF
Basic Wall	Basic Wall: For SF Take-Off	420	SF
Basic Wall	Basic Wall: For SF Take-Off	1315	SF
	Total	**37877**	**SF**
	Non Precast Façade Area	**750**	**SF**
	Net Total Precast Area	**37127**	**SF**

APPENDIX VI | DETAILED STRUCTURAL CALCULATIONS

Exterior Beam:

Live Load Reduction:

$$LL_r = LL(.25 + \frac{15}{\sqrt{K_{LL} * A_t}})$$

$$LL_r = 100 \text{ psf} (.25 + \frac{15}{\sqrt{2 * 288\, sf}})$$

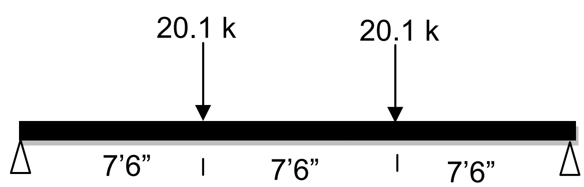
$$LL_r = 100 \text{ psf} (.875) \quad (.875 > .4 \therefore OK)$$

$$\boldsymbol{LL_r = 87.5 \text{ psf}}$$

Beam Shear and Moment Calculations:

$$1.2D + 1.6L = 1.2(58) + 1.6(87.5) = 209.6 \text{ psf}$$

$$209.6 \text{ psf} * 7'6"*12'10" = 20.1 \text{ kips as point loads on Edge beam}$$



$$Support\ Reactions = 20.1 \text{ k by symmetry inspection}$$

$$\therefore V_{max} = 20.1 \text{ k}$$

$$M_u = V_{max} * Spacing \text{ (for simply supported beam and point loads)}$$

$$M_u = (20.16 \text{ k}) * 7'6"$$

$$\boldsymbol{M_u = 151.2 \text{ kip ft}}$$

Load due to Exterior Brick Façade:

Brick weight: 42 psf Story Height: 13'

$$Distributed\ load = DL\ Saftey\ factor * Sq.Ft.Unit\ Weight * Story\ Height$$

$$Distributed\ load = 1.2 * 42 \text{ psf} * 13'$$

$$Distributed\ load = .655 \text{ klf}$$

For simply supported beam with distributed load :

$$M_{max} = \frac{(Dist. Load * Beam\ Length^2)}{8}$$

$$M_{max} = \frac{(.65 * 22.5^2)}{8}$$

$$\boldsymbol{M_{max} = 41.2\ \textbf{kip ft}}$$

Exterior Column:

$$KL = 1 * 13 = 13\ for\ column\ sizing\ from\ AISC\ steel\ manual$$

Live Load Reduction for Calc 1:

$$LL_r = LL\left(.25 + \frac{15}{\sqrt{K_{LL} * A_t}}\right)$$

$$LL_r = 100\left(.25 + \frac{15}{\sqrt{4 * (288 * 3)}}\right)$$

$$LL_r = 100(.5)\ \ .5 > .4\ \therefore OK$$

$$\boldsymbol{LL_r = 50\ \textbf{psf}}$$

Axial Loading Calculations for W8x35:

$$1.2D + 1.6L = 1.2(58) + 1.6(50) = 149.6\ \text{psf}$$

$$Axial\ Load = Tributary\ Area * Load\ per\ sq.ft.$$

$$Axial\ Load = \left(288\frac{\text{sf}}{\text{floor}} * 3\ \text{floors}\right) * 149.6\ \text{psf}$$

$$\boldsymbol{Axial\ Load = 129.2\ \textbf{kips (excluding facade)}}$$

$$Axial\ Load_{facade} = \left(292.5\frac{\text{sf}}{\text{story}} * 3\ \text{stories}\right) * 65\ \text{psf}$$

$$\boldsymbol{Axial\ Load_{facade} = 57\ \textbf{kips}}$$

$$\boldsymbol{Total\ Axial\ Load = P_u = 186.2\ \textbf{kips}}$$

$$\boldsymbol{\Phi_c P_n = 300\ \textbf{kips} > 186.2\ \textbf{kips} = P_u}$$

Live Load Reduction for Calc 2:

$$LL_r = LL\left(.25 + \frac{15}{\sqrt{K_{LL} * A_t}}\right)$$

$$LL_r = 100\left(.25 + \frac{15}{\sqrt{4 * (288 * 5)}}\right)$$

$$LL_r = 100(.44) \quad .44 > .4 \ \therefore OK$$

$$\boldsymbol{LL_r = 44\ \mathbf{psf}}$$

Axial Loading Calculations for W8x58:

$$1.2D + 1.6L = 1.2(58) + 1.6(44) = 140\ \text{psf}$$

$$Axial\ Load = Tributary\ Area * Load\ per\ sq.ft.$$

$$Axial\ Load = \left(288\frac{\text{sf}}{\text{floor}} * 5\ \text{floors}\right) * 140\ \text{psf}$$

$$\boldsymbol{Axial\ Load = 201.6\ \mathbf{kips}\ (\mathbf{excluding\ facade})}$$

$$Axial\ Load_{facade} = \left(292.5\frac{\text{sf}}{\text{story}} * 5\ \text{stories}\right) * 65\ \text{psf}$$

$$\boldsymbol{Axial\ Load_{facade} = 95.1\ \mathbf{kips}}$$

$$\boldsymbol{Total\ Axial\ Load = P_u = 296.7\ \mathbf{kips}}$$

$$\boldsymbol{\Phi_c P_n = 514\ \mathbf{kips}} > 296.7\ \mathbf{kips} = \boldsymbol{P_u}$$