West Village Commons
Towson University
Towson, Maryland

SENIOR THESIS CAPSTONE REPORT
APRIL 7TH, 2010

Nicholas Umosella, LEED AP – Construction Management – Advisor: Jim Faust

West Village Commons
Towson University
Towson, Maryland

Project Team

Owner:	Towson Unversity
Architect:	GWWO, Inc./Architect
Constructors:	Barton Malow Company
MEP Engineers:	James Posey, Associates
Lighting Designer:	Bruce Dunlop Lighing
Civil Engineer:	Site Resources
Lanscape Architect:	Mahan Rykiel

Building Statistics

Size:	85,000 Square Feet
Occupancy:	Mixed Use Dining Services
Delivery Method:	Design-Bid-Build
Construction Cost:	$31,012,000
LEED Goal:	Silver
Construction Dates:	July 15, 2009 to February 28, 2011

Architecture

The West Village Commons Building was designed with the intent of becoming the gateway to the west side of campus. The first floor will house a grocery store, ATMs, and specialty take-out food shops. A dining hall is located on the second floor which will provide buffet style meals to the students. The third floor will contain an exercise room and support offices, while the fourth floor will mainly be used as large multi-purpose and gathering spaces. The third and fourth floor of the new facility span over the recently completed Emerson Drive. This bridge like structure provides an architectural focus for students and faculty when entering the West Village area.

Building Systems

Mechanical

-Two 10,000 lb Boilers Rated at 3,000 MBH
-One 3,535 MBH, 565 max gpm chiller
-One 16,000 lb, Draft Counter Flow Upblast Cooling Tower
-5 Custom and 2 Modular AHUs Feeding Over 90 Terminal Units

Sustainable Features

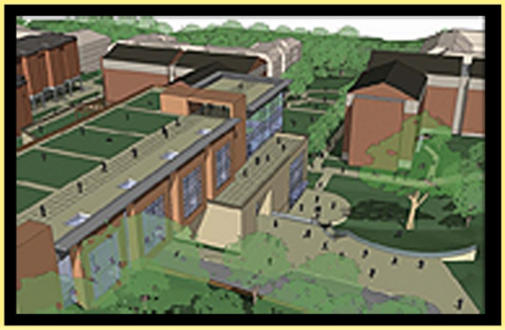
-Publicly Accessible Green Roof System
-Low Flow Plumbing Fixtures
-Large Curtain Wall Allows Daylighting
-Pre and Post Consumer Recycled Materials

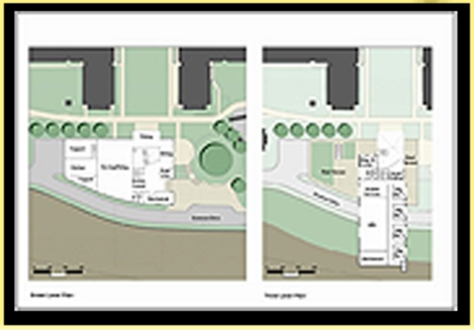
Structural

-Ram Aggregate Pier Substructure with Concrete Caps
-Floors 1 & 2: Concrete Columns and Beams with 9" Suspended Slabs
-Floors 3 & 4: Structural Steel Columns and Beams with Composite Metal Deck

Electrical

-1500 KVA Main Feed
-277/480 Volt, 3 phase/4 Wire Distribution
-150 KW Natural Gas Generator
-Ornamental Stair Accent Lighting





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-EXECUTIVE SUMMARY-

West Village Commons will serve as the center piece for Towson University's campus expansion to the west. The 85,000 square foot, $30,000,000 building will be home to student dining amenities, meeting rooms, and green space. This capstone thesis report wraps up a year of research on the building project, and a semester of technical analyses on the effects Integrated Project Delivery method would have on the project; cost and schedule impacts on a structural redesign to structural steel; the use of a prefabricated masonry panel system; and the exploration of using a central utility plant as opposed to separate building systems.

Integrated Project Delivery research helped create a West Village Commons IPD Execution Guide. Design and construction phasing was redefined, building system "design clusters" were organized, new contract language was highlighted, and an extensive report was written on what IPD entails. Extensive research into contract terms and project compensation shows the major difference to traditional delivery methods. This delivery option opens the doors to the three other analyses researched this semester.

Because IPD involves trade contractors early in the design phase, a steel structural system can be utilized for West Village Commons. Concrete was originally designed to allow construction to begin earlier, finishing the project in time for the 2011 – 2012 school year. Because of early involvement, procurement time for structural steel can be reduced and fabrication can begin earlier than in a traditional delivery method. A structural breadth studied the redesign of a typical roof and floor bay, which allowed for the sizing of beams, girders, and columns. A cost analysis found that the total system was estimated to be $505,000 (material and general conditions savings) and 2.5 months faster. Early trade involvement could also allow prefabricated masonry panels construction of the exterior façade. An analysis of panel sizes and design constraints helped lead to a cost and duration estimate taking transportation restrictions and panel layout into consideration. The masonry panels, though led to an increase in cost of $154,000, but a significant decrease in schedule.

The current heating and cooling loads for the commons building and the surrounding apartments were analyzed to approximate the size of a central utility plant. A comparison was made to a similar university to discuss areas of construction, and initial versus operating costs. A more detailed energy analysis of all of the buildings was not possible, but universities across the country are experiencing a much needed decrease in total operating costs. Because of the difference in peak capacities of the apartments and the commons, the utility plant can be designed with a lower total cooling load than a decentralized system.

This report aims to tie Integrated Project Delivery with all of the different analyses. Quantifying savings through a change in delivery method is difficult to undertake, but an attempt was made to show definitive improvements IPD would have in the conceptualization, design, constructions, and operation of West Village Commons.

-THE MASTER VISION FOR TOWSON UNIVERSITY-

In September of 2003, the facilities management department at Towson University of Maryland conducted a Master Plan laying out the framework for the future renovations, expansions, and growth of their 44 building campus. The president of the university, Dr. Robert L. Claret, made it clear that the university would be adding around 2,500 students to their population over the next 10 years. For a campus that already struggles with current spacing needs, "accepting additional students creates a significant challenge." The university at the time had a $52 million backlog in deferred maintenance issues for academic and support buildings; there has only been one significant building addition in the past 25 years; and there was been no "comprehensive renovation of over 90% of the academic facilities on campus in the past 30 years" (Towson University Facilities Management, September 2003). It was clear that a major issue was beginning to form in regards to facilities, and the university president was dedicating efforts and funds to solve those issues.

Figure 1: Towson University Renovations; West Village can be seen in the upper right-hand corner in orange (Towson University Facilities Management, 2009)

One major concern addressed in the 2003 Master Plan was the increase in the student body, especially of graduate students. Currently the majority of students move off campus after freshman year, and almost all graduate students reside in various apartments surrounding Towson, Maryland. The idea was to create a living environment geared to providing affordable living to graduate students coupled with parking, outdoor leisure areas, and student meeting space. The vision for the new "West Village" was created with those goals in mind. The area on the western end of campus known as Towson Run, where two apartments are currently operated by 3rd party companies, would be the home for 8 new apartments for 3,000 students, a parking garage, and an 85,000 square foot commons space. West Village Commons, this report's main focus, would be the marquee center piece to the entire area, providing dining amenities, meeting areas, and green space for West Village resident students. Figure

1 is an image of all renovations and additions that the 2003 Master Plan called for (it is an image from the updated 2009 Master Plan).

The construction West Village would take place in five phases. The apartments would be built over a period of ten years in five phases, highlighted in figure 2. West Village Commons will be built during Phase A, in between Phase I and II, and the parking garage will be built during Phase B, sometime before the completion of the apartments. Figure 2 is an aerial rendering of West Village, highlighting the different phases.

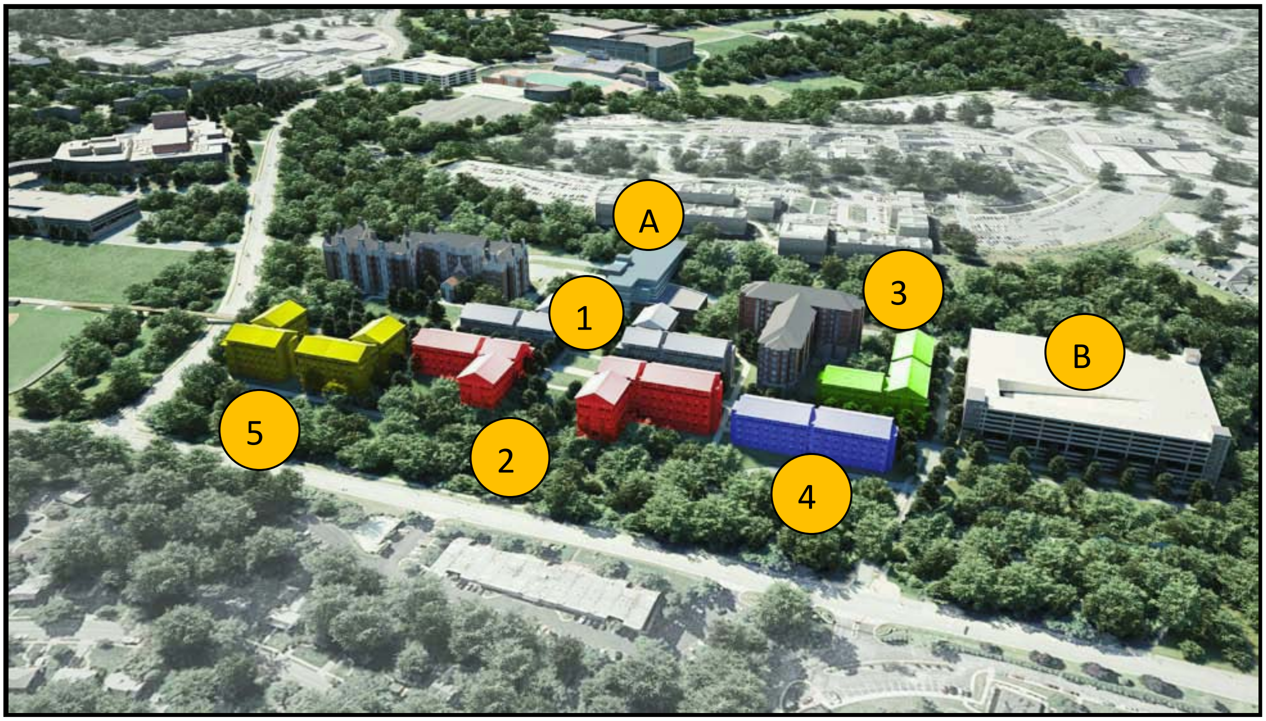

Figure 2: Aerial Rendering of West Village with proposed buildings highlighted (Towson University Facilities Management, 2009)

In August of 2007, President Caret announced his intention to pursue LEED certification for all new campus buildings. West Village Commons itself will be pursuing a LEED Silver certification, though it may have the point total to receive LEED Gold. The "smart growth" strategy in the Master Plan has always included green space initiatives. Part of the attraction of West Village will be its ample outdoor green areas for the students, including a green roof on the commons building. Almost all universities have to battle the rise in utility costs, and a major design consideration for all new buildings and renovations will be operating costs. The majority of the campus is served by a central utility plant, but West Village is too far away to be connected to the plant. Baltimore Gas and Electric will provide all of the utilities for the apartments and the commons.

It was important to note the entire plan for West Village for the studies conducted in this report. Any approach toward a construction project and expansion should aim to get behind the entire design intent. An integrated team utilizing Integrated Project Delivery needs to think like an owner, make decisions for the best of the project, and always work toward project goals. The only way to do that is really delve into the larger picture view. This report aimed to not only satisfy the design intent of West Village Commons, but also help enhance the product that Towson University was trying to provide for its students. That alone will define a successful project for any of the key members participating and will ultimately lead to a more efficient, higher quality product.

-WEST VILLAGE COMMONS PROJECT OVERVIEW-

West Village Commons may be relatively small in stature, but it is not without great architectural and engineering value. Below is a brief synopsis of the differing systems that make up the commons. More detailed explanations can be found in the various technical reports submitted during the fall semester, and the CPEP website.

Architecture

West Village Commons is an 85,000 square foot mixed-use occupational building that will serve the West Village area with dining amenities, meeting space, and outdoor green areas. The main architectural feature of the building is the south end's third and fourth floor "bridge" structure over Emerson Drive. This "bridge" structure will be a welcoming gate to students and faculty traveling through West Village. The exterior façade is a combination of a curtain wall system, zinc metal panel walls, and brick masonry cavity walls. Portions of the second floor roof will use green roof technology to minimize storm water run-off and as a visually pleasing lounge area of students. Some of the key interior areas is the open seating buffet area and kitchen, the large multipurpose room on the fourth floor (equipped with foldable partitions), and the space dedicated to 3rd party vendors located throughout the building. Figure 3 is the final design rendering by GWWO Inc. / Architects.

Figure 3: Exterior Design Rendering (GWWO Inc./Architect, 2009)

Foundation System

The building's foundation system consists of spread footings on natural soil for the basement and Ram Aggregate Piers® (R.A.P. or Geo Piers) for level 1. The piers have a bearing capacity of 6,000 ksf minimum and compacted fill with an allowable bearing capacity of 4,000 psf. To place the R.A.P.'s, first an auger is drilled to the geotechnically specified depth. Stone is placed in 12" lifts and pounded by an excavator equipped with a hydraulic break hammer. See Figure 4 for a cross-sectional view of the process. When properly placed, these piers not only allow direct structural support, but also strengthen the surrounding soil. With a foundation loads greater than 3,000 kips, the system will limit foundation settlement to 1 inch or less. (Geostructures, 2009 - 2010)The smallest footers have 6 piers each and the most have 16. All footers and grade beams shall have a compressive strength of 4000 psi and have dimensions ranging from 3' x 3' x 16" to 13' x 13' x 44". The south side of the building, where the bridge portion of the structure meets the hill, has a crawl space consisting of a 4" slab on grade and 12" thick concrete walls.

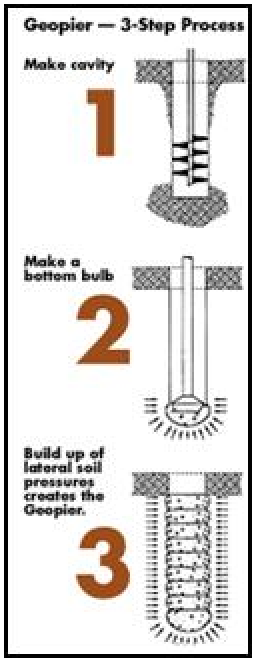

Figure 4: Geopier - 3 Step Process (Geostructures, 2009 - 2010)

Cast-In Place-Concrete

The north half of the building consists of cast-in-place concrete for all retaining walls, columns, beams, suspended slabs, and slabs on grade. This half of the building will have all of the dining commons and take-out restaurants. The abundance of mechanical piping and ductwork to support the kitchen equipment requires a larger plenum height, which cast in place concrete allows. Figure 5 shows where the building's structural systems split. Floor slab to floor slab height on level 2 (location of the largest kitchen) is 17' – 4" with a plenum height of 7' – 4", ample room to coordinate overhead systems.

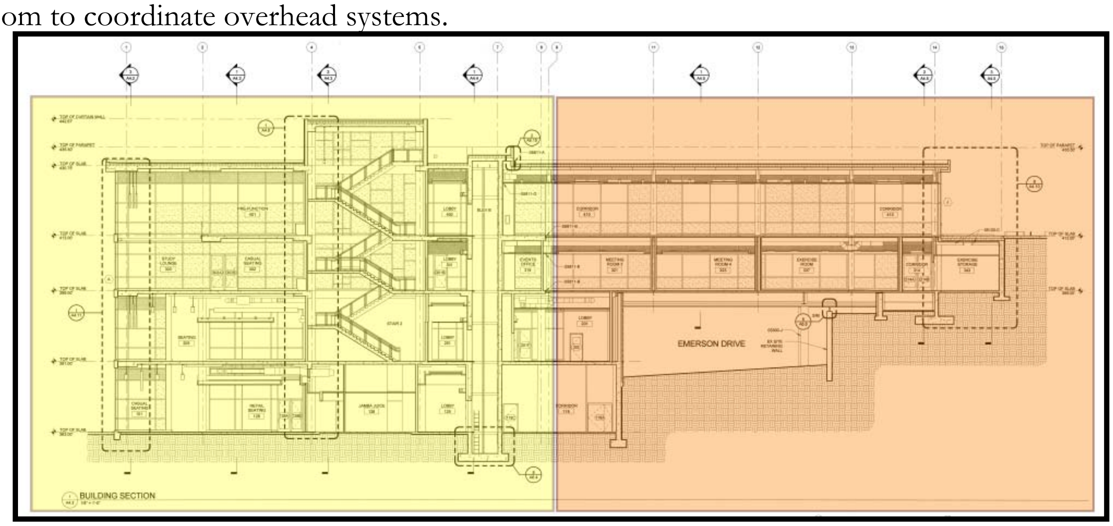

Figure 5: Divison of Structural Systems. The yellow shading is the north end structural concrete, and the red shading is the structural steel. (GWWO Inc./Architect, 2009)

The suspended slabs are 9" thick normal weight concrete with 7 1/4" drop panels. Most of the concrete columns are 24" x 24" with 12 #8 reinforcing bars. The elevator and stairwell walls act as 12" thick shear walls reinforced with #5 reinforcing bars at 12" o.c. The slab on grade is 5" thick reinforced with 6"x6" - W2.9 x W2.9 welded wire fabric (WWF). The roof structure for the third floor partial roof and on the fourth floor of the north end of the building is 9" thick normal weight concrete. Table 1 gives the typical concrete strengths. All formwork on the job will be reusable so as to expedite the process. They will also be made with Forest Stewardship Council certified wood to count for LEED credit MRc7: Certified Wood. Concrete will be placed with two different methods; either by a concrete pump placing concrete directly in the formwork or by a crane and bucket. The concrete pump will mainly be used for foundations, slabs on grade, and initial columns. When the tower crane is erected, concrete will pumped into a bucket and swung to locations.

Type	Strength (psi)
Footings, Grade Beams	4,000
Slab on Grade	3,500
Retaining Walls	4,000
Columns, Slabs, and Shear Walls	5,000
Curbs and Equipment Pads	4,000

Table 1: Concrete Strength Breakdown

Structural Steel

The south end of the building where the structure spans over Emerson Drive, is supported by structural steel. This system was chosen because overhead head mechanical support systems are less dense (no kitchen areas, just meeting rooms) and requires less plenum space. The steel also has the tensile strength to span across Emerson Drive without supports; at some points spanning between 40 and 50 feet. On the third floor (the first floor of the bridge) the beams are larger to support the load over the road. Some of the typical beams are W18x35, W21x24, W24x55, and W24x76.

The fourth floor beams are more consistent in type, only varying between bays. The four main beams are W10x12, W12x14, W12x19, and W14x22. The steel columns are mostly W12x40's with the occasional W12x45 or 50.The floors are a composite slab structure made up of 3-1/4" light weight concrete reinforced with 6"x6" - W2.1xW2.1 WWF, over a 2", 20 gauge composite steel deck. The roof structure for the south end utilizes 52DLH16 sloped joists with 1-1/2", 20 gauge steel decking. Structural bracing runs east to west along the north and south side of the bridge on the third and fourth floor. There is also two 17’ sections of cross bracing on east and west wall at the very south end of the bridged. This building was designed for Seismic Site Class C. All structural steel and metal decking will be set using a tower crane approximately 120' tall with a boom radius of 164'.

Mechanical

Heating Water System:

The hot water system for West Village Commons consists of two packaged cast iron sectional pressurized, wet-base, water boiler-burners. They run off natural gas and are rated for 3000 MBH. Each weighs approximately 10,000 lbs. The hot water is distributed throughout the building by two 465 gallon per minute pumps located in the basement.

Chilled Water System:

The cold water source is from a chiller located in the basement. The evaporator for the chiller is 3535 MBH with a 565 gpm max flow, and will require 193 kilowatts to power it. The cold water is distributed by two 565 gpm pumps located in the basement. It works together with a closed loop condenser water system which consists of a cooling tower located on the roof. The tower is rated as a 300 ton, induced draft counter flow, upblast system, with a 20 horsepower motor and a maximum flow rate of 900 gpm. The condensed water system is distributed by two 900 gpm pumps located in the basement.

HVAC:

The new commons building has an interesting heating, ventilating, and air conditioning system in that it has 7 separate air handling units (AHU) spread throughout the building. They provide hot or cold air to variable air terminal units, allowing greater control in each of the zones. The dining commons kitchen has its own dedicated AHU, and the 3rd and 4th floor are the largest areas supplied by one unit. Greater control means a greater expense in not only material, but also labor and coordination.

Exhaust System

The large kitchen and individual restaurants require multiple ventilation systems and exhaust hoods. There are 11 of these hoods throughout the building that are exhausted with 6 separate exhaust fans. They range from 800 cfm to 8300 cfm and are located on either Level 3 or Level 4 roof. In addition to the exhaust fans, a 2,000 gallon grease interceptor will be installed below grade and connected to all pieces of equipment with grease waste products.

Fire Suppression

West Village Commons has a water-based, wet automatic fire suppression system. It will connect with the domestic water piping to achieve a minimum static pressure of 99 psi. The two stair towers will house the sprinkler risers, where at each landing a sprinkler zone valve is installed. In areas of elevated temperatures, such as the kitchen, high temperature sprinkler heads will be used.

Electrical/Lighting

West Village Commons will tie into existing campus utilities and provide an outlet to future buildings on the west side of campus. Currently there are three main outdoor switch gears providing 15 kilovolts and 1200 amps each. A new switch gear with the same attributes will feed into a 1500KVA, medium voltage transformer and then into the main switchboard in the basement level. The lighting system is powered by 277/480 volts, 3-phase, 4-wire power and distributed through 7 different electrical panels throughout the building. Fixtures in the larger rooms are usually fluorescent down lights or 2x2 recessed fluorescent troffers. In other areas with more of an architectural element, there are pendent surfaced mounted lights, wall washers, and decorative pendent lighting.

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The vast amount of kitchen equipment requires a lot of energy and many electrical connections. The complicated electrical system needs to be closely coordinated with the kitchen equipment vendors. Equipment is constantly changing and the owner will want the most up to date appliances. Changes in locations of connections will have to be carefully tracked.

The majority of the lighting is of generic standard and there is not much architectural value to highlight. The ornamental stair case has some architectural lighting, but will probably be cut from the project due to the high cost. There is mostly down lighting to provide adequate visual comfort for cafeteria dining. The large multipurpose room on the fourth level (Room #411) will have special dimming capabilities depending on what the room is being used for. Dimming switches will be installed capable of dimming standard and low-voltage incandescent and halogen fixtures, and fluorescent fixtures with dimming ballasts. The room has movable partitions to divide it into three sections, and will be equipped with partition lighting sensors. These will dim to the appropriate lumen level for smaller rooms. All audio-visual equipment will have lighting controls as well.

Exterior Masonry Veneer

The east and west side of the north end of the building has an exterior face brick veneer that encloses the 1st and 2nd floor. The exterior wall has a load bearing metal stud back up, followed by exterior gypsum board, rigid insulation, and an air cavity. Adjustable metal anchors tie the brick into the exterior wall studs and gypsum board. The metal brick relief angles supporting the brick at each floor are connected to concreted slabs by vertical channel brackets. As part of the LEED requirements, all brick needs to have been extracted, harvested, or recovered, as well as manufactured, within 500 miles of the project site. Due to site restrictions brick veneer installation must utilize hydraulic mast-climbing work platforms on all facades. All work platforms will have catch nets installed under them to protect workers and pedestrians.

The basement level, mechanical rooms, and all 2 hour fire-rated risers use a concrete masonry unit wall. They have a minimum compressive strength of 2,800 psi and are classified as lightweight. The walls are strengthened vertically with reinforcing bars and laterally with hot-tip galvanized ladders. Again, the material must be brought from within 500 miles of the project site.

Curtain Wall

The north end of the West Village Commons has a glass curtain wall on the north elevation for floors 1 through 4, and on the east and west elevations from floors 2 through 4. A variation of clear tempered glazing, low-e tempered spandrel panels, and spandrel panels make up the main composition. Thermally broken aluminum framing connects the glazing, and in between floors a continuous aluminum panel matching the curtain wall is placed to hide the floor slabs. The south end has a similar curtain wall on the east and west elevations of the bridge span over Emerson Drive. The curtain wall was architecturally designed by GWWO, Inc./Architects and is a unified system: it will be fabricated in sections and installed on site.

Support of Excavation

The excavation for West Village Commons will be supported with sheathing and shoring (soldier beams and lagging boards). They will remain permanent on site after excavation concludes. Figure 6 is a photo of the support system on site. The water table varies with times and location but there is a reliable indication of hydrostatic water at levels ranging from 18-33 feet below existing grade. A dewatering system will need to be used during construction activities.

Figure 6: Support of Excavation

-CONSTRUCTION OVERVIEW-

Schedule

The north side of the building made up of a concrete structure is the focus of construction for the beginning of the project. Foundations and structural concrete follow a west to east pattern, topping out on February 24th 2010. The second section of this project is the north building span over Emerson Drive, which is made of structural steel and rests on a concrete foundation/crawlspace built into a hill. Structural Steel erection begins right after concrete tops out on February 24th, and lasts approximately 30 days. During this time masonry veneer and curtain wall enclosures begin on the north end moving in both an east and west direction around the building. The interior completion of the building is a long process beginning with interior partitions in March 2010 and subcontractor substantial completion around 11 months later. Appendix A is a summary milestone schedule of the project, and Appendix B is the critical path schedule (please note that there may be a few discrepancies between the two, as they were given at different times. Educated assumptions may have been made on specific dates, but they will be noted).

Cost

West Village Commons was bid out to a private list of contractors on a best value basis. Contractors bid on fee, reputation, construction techniques, reputation, and job history. The Barton Malow Company won the project when bid package A was 100% Design Development and bid package B was around 25% Design Development. Barton Malow signed a contract with the owner as a Construction Manager at Risk. The following is a breakdown of bid package "A" and bid package "B." Table 2 is a breakdown of the project cost according to the different bid packages and table 3 is a breakdown of cost of the structural system.

Bid Package "A"

- Excavation, Earth Retention and Site Utilities
- Deep Foundations (Rammed Stone Piers)
- Arborist Services & Tree Preservation
- Cast-in-Place Concrete & Waterproofing
- Under-slab & Slab Penetrations for Mechanical, Plumbing & Fire Protection
- Under-slab & Slab Penetrations for Electrical

Bid Package "B"

- Finish Sitework
- Landscaping & Topsoil Placement
- Masonry
- Structural Steel
- Miscellaneous Metals
- Ornamental Stairs & Rails
- Millwork and Architectural Woodwork
- Roofing & Rheinzink Cladding
- Fireproofing
- Windows, Entrances, Curtain Wall, & Metal Wall Panels
- Interior Partitions and Ceilings
- Ceramic Tile and Stone Flooring
- Resilient Flooring and Carpet
- Painting and Wall Covering
- General Trades, Doors, Frames, & Hardware
- Signage
- Food Service Equipment
- Elevators
- Mechanical & Plumbing
- Fire Protection
- Electrical, Fire Alarm & Security

Total Project Cost

Package	Total Project Cost (TC)	TC/SF	MBE Participation**
CM Preconstruction	$300,000.00	$3.53	$0.00
Bid Package A	$7,120,965.00	$83.78	$1,432,510.00
Bid Package B	$22,961,029.00	$270.13	$5,885,843.00
Total	$30,381,994.00	$357.44†	$7,318,353.00

**Contract values of companies qualified as a Minority Business Enterprise, must be 25% of project
†Design fee information is unavailable

Table 2: Project Cost Breakdown

STRUCTURAL COST SUMMARY

	Total Cost
Structural Steel	$830,506.34
Structural Concrete	$2,404,891.36

Table 3: Structural Cost Estimate

A detailed general conditions estimate was calculated to determine cost savings from schedule acceleration. The cost was found to be $1,951,641.25 for the total project duration. A detailed breakdown can be found in Appendix C.

Site Conditions

Towson University West Village Campus is an extremely tight site. Figure 7 is a site plan of the existing conditions, utility lines, and project constraints that was recreated using civil drawings by Site Resources, Inc. All construction parking is located down Emerson Drive, approximately 1.5 miles away. Emerson Drive will be the only entrance to the construction area with trucks entering from the west and exiting to the east. This road must also remain functional during construction as it serves as the main avenue to the Towson Run Apartments and the Millennium Hall. The University has also emphasized the importance of not damaging the Great Elm located within the construction perimeter.

The Barton Malow Company has several different site plans for the various phases of construction, but the excavations and foundations site plan seen in figure 6 shows the main elements of the construction site. As it can be seen, there is very little space for shakeout material storage on site. Major construction deliveries will need to be made the day they are installed, and truck traffic must be meticulously coordinated. Strategies will mirror those typically seen on an urban construction site.

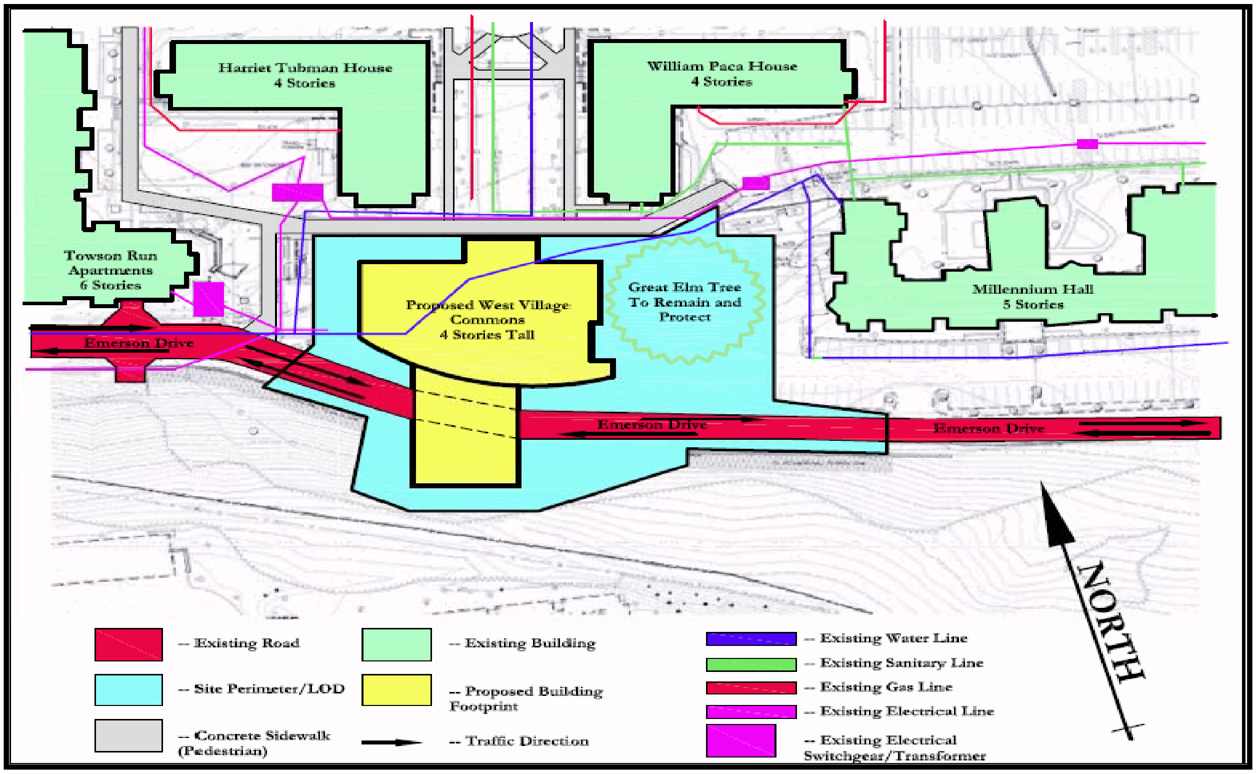


Figure 7: Site Plan of Existing Conditions

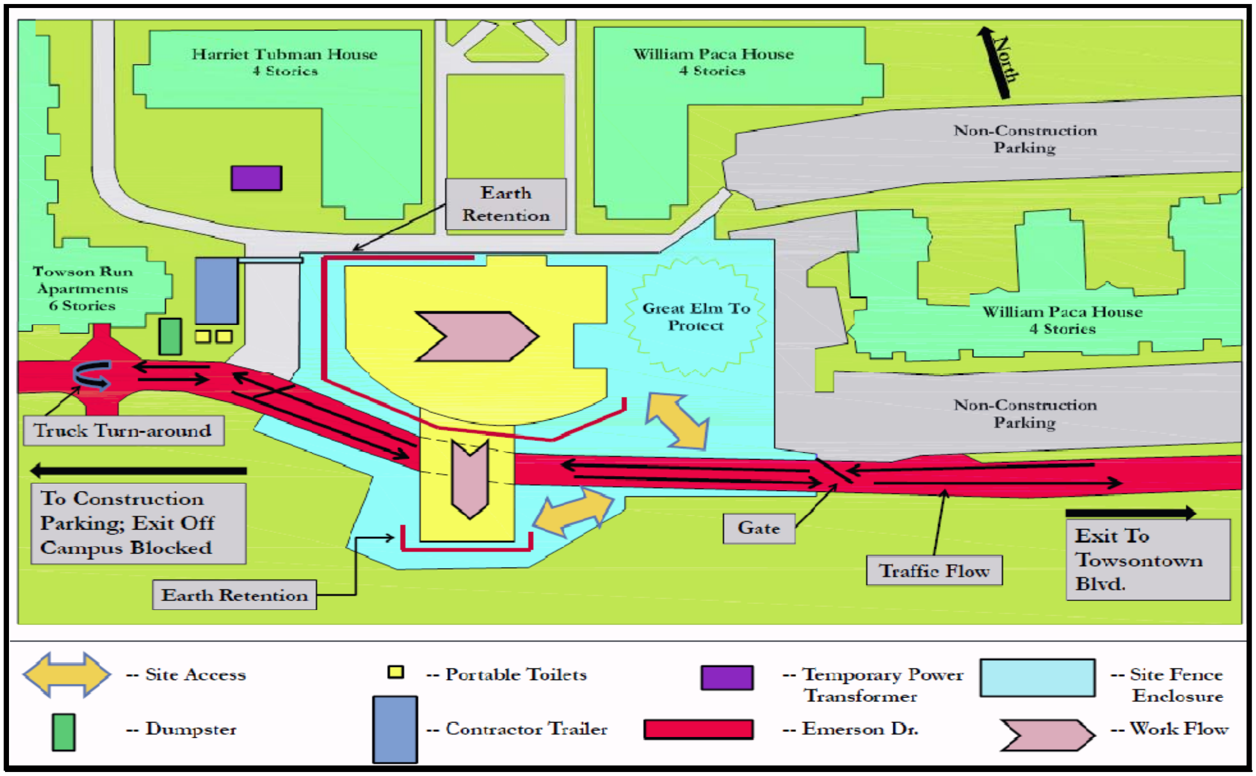


Figure 8: Excavation and Foundations Site Plan

Project Team Breakdown

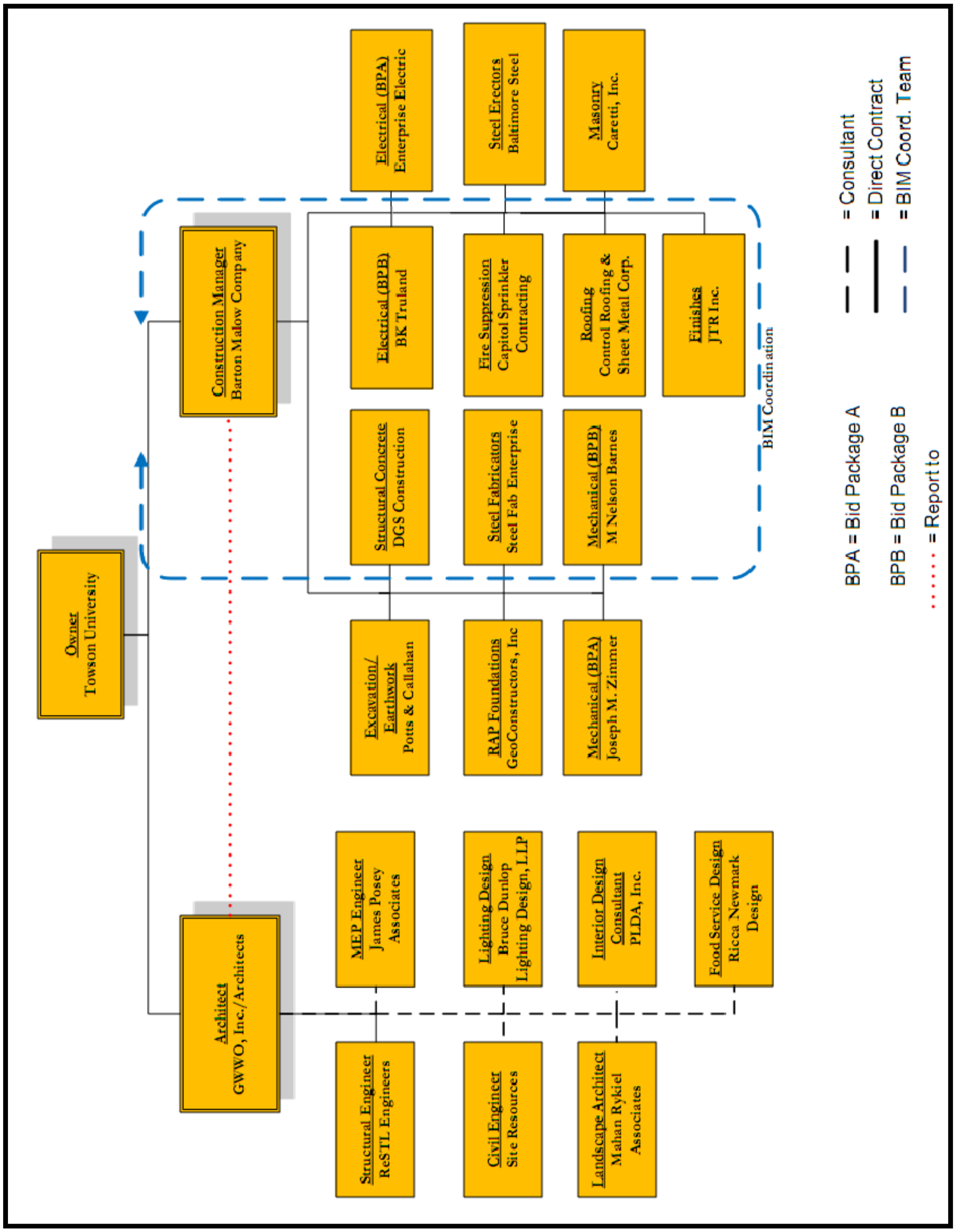


Figure 9: Project Team Breakdown

Barton Malow Staffing Plan

The Barton Malow Company has a presence in several regions throughout the country. Currently they are broken into three separate regions: The central region, where the main headquarters is located (Southfield, Michigan), the southern region, and the eastern region. The eastern region has shown a huge advancement in the past 10 to 15 years, and has become a major focus for Barton Malow. The Senior Vice President of the eastern region is Phil Kirby, and within that region are several office. The Mid-Atlantic area (Virginia, DC, and Maryland) is run from their office outside of Baltimore in Linthicum, Maryland. West Village Commons was bid from the Baltimore, Office, whose Vice President is Robert Grottenthaler (Penn State AE Alum). The staff is made up of a project director, who is responsible for this project and a few others, a project manager, a general superintendent, and two project engineers. Figure 10 is an organizational chart of the Barton Malow team.

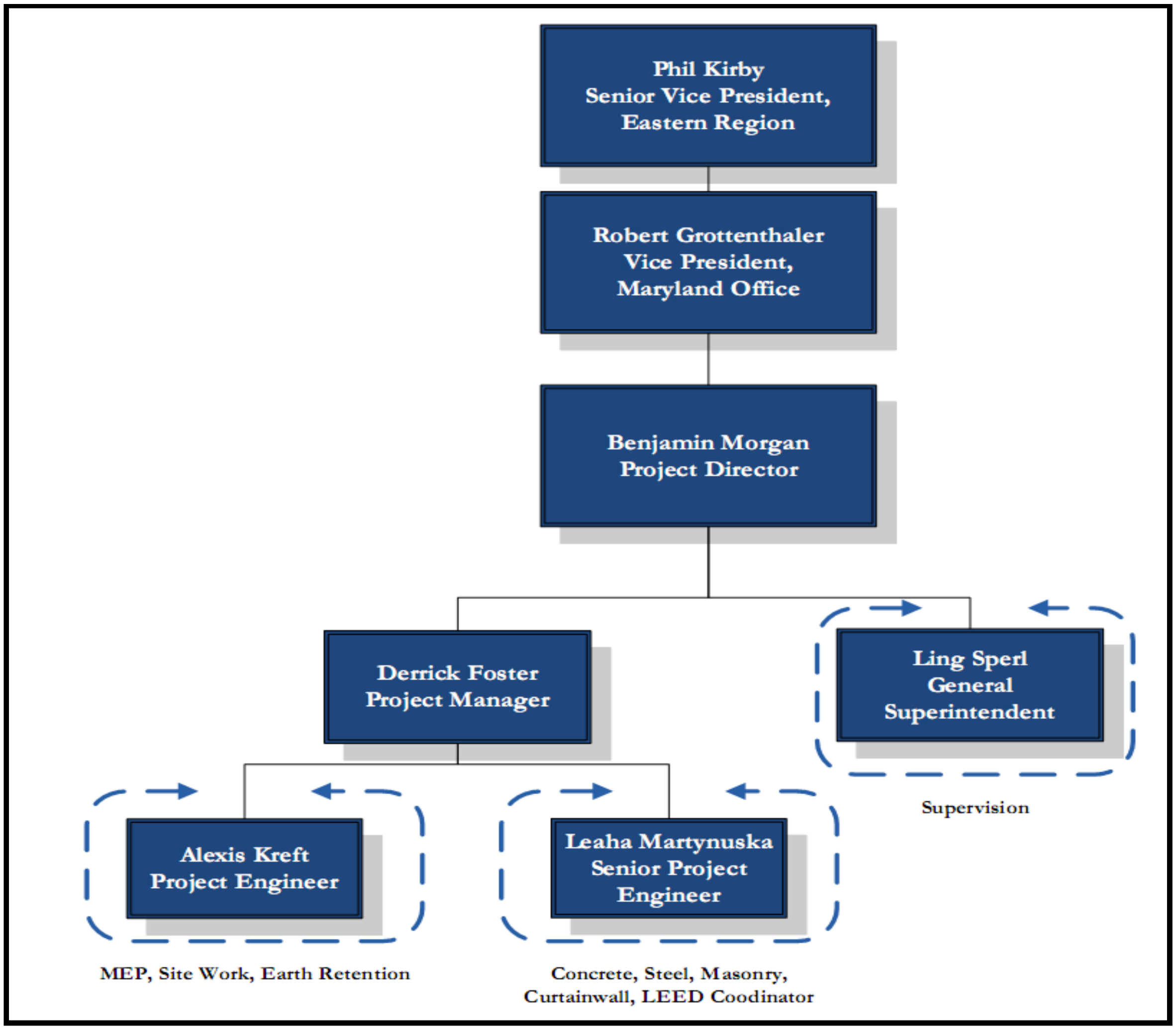


Figure 10: Barton Malow Project Team

Performance and Payment Bonds

All subcontractors are required to submit performance and payment bonds, as well as show evidence that their stored materials will be properly insured. At the sole discretion of Barton Malow, subcontractors may be allowed to participate in a controlled insurance and bond program, specifically SubGuard. This allows for a lower bid on all subcontractors because they will no longer mark up their performance and payment bonds. Instead the contractor has the ability to apply their own fee to the cost of SubGuard. The following is the contract language from the project manual contract:

2.01 PERFORMANCE BONDS AND PAYMENT BONDS

> *A. Barton Malow Company may, at its' sole determination, elect to enroll the Subcontractor into a Controlled Insurance Program – specifically Subguard. If so engaged, the costs of the Subcontractors' Performance and Payment Bonds shall be directed to the Subguard insurance program (the Subcontractor will not be required to submit P&P Bonds) and the initial value of the evaluated base contract price shall be adjusted accordingly.*

Local Conditions

Towson, Maryland medium size city located right outside of the larger metropolis, Baltimore City. The major contractors in the area usually work in and around Baltimore, central Maryland, and the eastern shore of Maryland. With the economic crash as of late, some have begun to branch out into new regions to search for more work. Even major construction managers are stretching the arms out a little further to keep their employees working. Barton Malow has begun bidding on projects on the eastern shore and is making a strong push to enter the Washington, DC market. The Baltimore area has developed some construction trends over the year. First off, Baltimore utilizes a lot of steel and brick masonry, as opposed to DC's projects which are almost exclusively concrete. Baltimore is also heavily weighted toward union workers. While non union members are not scrutinized as much as areas like New York City, there is a distinct loyalty to one's chapter, even

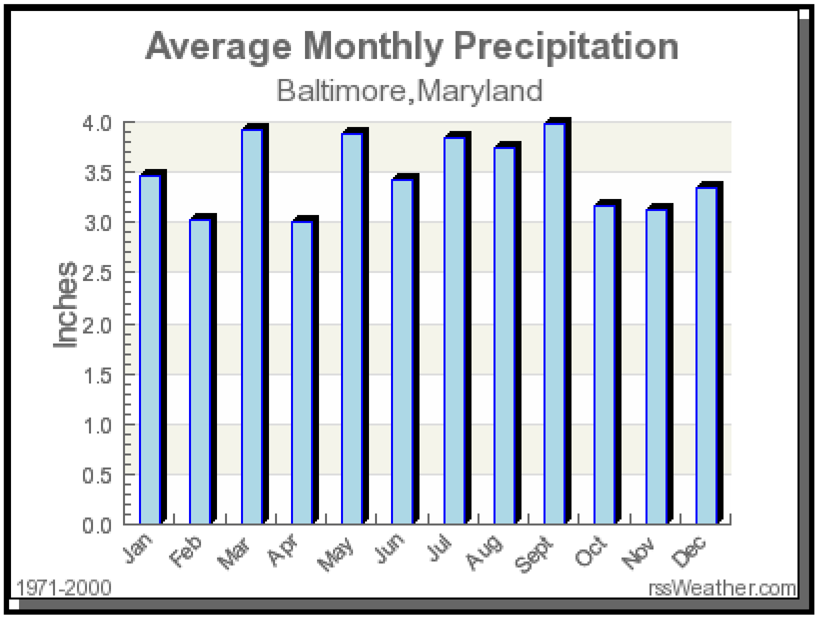


Figure 11: Baltimore Average Monthly Precipitation (HAMweather, 2003 - 2007)

during economic hardships. Baltimore's major construction projects are usually split between three contractors: Whiting-Turner, Barton Malow, and Gilbane. Occasionally Clark Construction, which holds a major share of the DC construction market, makes its way up to Baltimore for a project or two. Whiting-Turner is constructing the new Liberal Arts Building for Towson only a few hundred yards away from West Village Commons.

The Baltimore area's weather is much like typical mid-Atlantic patterns. At its coldest average in January, the temperature dips down to 23.5°F at night and its highest in July is 87.2°F during the day. The driest month is usually April with only 3" of precipitation and the wettest is September with 3.98", though the amount of precipitation throughout the year stays pretty even (see figure 11). Weather may play a factor during concrete construction; the schedule has concrete beginning in November and ending in March - the coldest time of the year.

-THESIS RESEARCH-

INTEGRATED PROJECT DELIVERY

Opportunity for Resolution

The construction world we live in currently embodies one of hostile and adverse relations, little collaboration, and finger-pointing mentalities. When issues of design and construction occur, they appear too late for pro-active solutions. Innovative efforts are hampered by wasted time defending liability resulting in a diminished quality of a finished product and on average of 5% increase in project budget (American General Contractors of America Project Delivery Committee, 2009). Designers might not consider some construction implications of design resulting in rework; Constructors are often not given the opportunity or hired in time to give input on design, cost, and schedule until it is too late in the project; and owners sometimes face a process whittled with unforeseen costs and a vague vision of their product. The architecture, engineering, and construction industry is a trying world that can strains business relationships and collaborative processes, but the world of Integrated Project Delivery (IPD) could offer a solution this industry has been searching for.

West Village Commons involved a contractor during the design development to help plan out the construction sequence and create an accurate estimate. But the relationship between the contractor and the architect is very strained. Victor Sanvido of Southland Industries explains that the Architect struggles to understand the financial risk a contractor takes on, and the contractor does not understand the professional liability the architect takes on (Sanvido, 2009). The goals of both are not aligned and until they are, project communication and efficiency will not reach full potential. There needs to be a delivery system that unites the key members involved, the architect, contractor, and owner, and creates common goals for the project team to strive for.

Research Goals

The goal of this research is to develop an IPD process that will harness the full potential of communication, the benefit of bringing on a contractor at project inception, signing a single contract based on project goals, and utilizing the full potential of BIM technologies. Research will focus on finding possible solutions to IPD issues such as bonding and insurance problems and quantifying profit based on project goals. A comparison of the AIA sample IPD contract and the AGC's Consensus contract will be made to find the commonalities and research solutions to the differences. This research will be put together to create an integrated project delivery execution guide (industry issue depth) for West Village Commons that will include everything from goals, constraints, and stakeholders to key member "design clusters" (American General Contractors of America Project Delivery Committee, 2009).

The use of integrated project delivery on West Village Commons will open the doors to several areas of research for this capstone project. First, a structural breadth study will be performed on the effects of using a complete structural steel system for the building. This was the original design of the system, but later was changed to structural concrete to begin construction earlier. IPD would allow a structural steel system to begin construction earlier because of early contractor involvement. A typical bay will be designed for the roof and the fourth floor directly below, and a construction depth study will evaluate constructability, costs, schedule, safety, and site issues.

A second construction depth will explore the use of a prefabricated masonry panels. Prefabricating materials requires a longer procurement time, making them tough to implement on the average project. Buyout of this contract is not done early enough to complete procurement and fabrication by the time the material is needed on site. IPD will allow a prefabricator to join the project team earlier, work with the structural engineers and shorten procurement time. Research on project constructability, costs, schedule, safety, and site issues will be conducted. A third and final energy breadth will be research the use of a central plant for West Village (The 8 apartments and the commons). Because IPD brings many key players to the table earlier (at the time the plan for West Village was incepted), a proper energy analysis could be completed that would take into consideration initial construction costs versus long term operating savings. The building loads for West Village can be compared to a similar university situation as a means of comparison.

-IPD EXECUTION GUIDE-

WEST VILLAGE COMMONS

West Village Mission Statement

The Campus Master Plan framework, principles, and recommendations were developed to embody, advance, and support the University's mission. However, the plan is more than that – it is an opportunity to create a better future for the students, faculty, staff, alumni, neighbors, and partners of Towson University (Towson University Facilities Management, 2009).

West Village Goals and Constraints

When completed, the West Village Precinct will contain 3,000-plus additional on-campus beds, almost 2,000 parking spaces, outdoor recreation and green space, and a new commons building providing dining services, meeting spaces, and study areas for the resident population.

a. Goals
   i. Add a marquee center piece to support the new West Village residence halls which will provide at least 85,000 square feet of dining amenities, meeting spaces, and study areas.
   ii. Add to the green campus movement by achieving at least a LEED Silver rating.
   iii. Explore alternative energy efficient power sources; explore construction of a West Village utility plant.
   iv. Create well-lit, ample green space built into and surrounding WVC for recreational space and campus safety.
   v. Deliver project before the 2011-2012 school year.
   vi. Use Integrated Project Delivery as a means of developing WVC in a timely manner with the upmost quality considerations and effective cost management.

b. Constraints
   i. Money – With the economic turndown, West Village is being built in phases. Responsible use of funds is vitally important. The Board of Regents will not only be looking into first costs but also long term energy costs.
   ii. Schedule – the project must be accelerated either by construction means or delivery method to be open in time for the 2011 - 2012 school year.
   iii. Integrated Project Delivery – because IPD is such a new concept, traditional design and construction means will be completely new. It is important we select key members who are forward thinking and motivated toward an improved building delivery process.
   iv. Infrastructure – The current central plant is too distant to support West Village. Either a central plant will need to be constructed or West Village will need to tie in

with Baltimore Gas & Electric for service needs. A cost benefit of running our own plant will need to occur, including possibly making connections to current residence halls.

v. Space – Towson University has made a commitment toward adding 3,000-plus beds, mostly in West Village. Available space is limited in the area, and a utility plant will further limit available space.

vi. Third party dining vendors – We need to work with vendors in designing space and mechanical properties to fit their needs. At the same time we need to keep spaces flexible for future changes.

Primary and Secondary Stakeholders, Concerns

a. Primary

i. Towson University Students and Faculty – Students and faculty will be the main occupants of WVC. Their main concerns will regard flexible meeting spaces, food quality, and outdoor space/environment. Surveys could be distributed to decide what types of food and type of technology needed for the commons.

ii. The University System of Maryland – This group will be concerned with the future impact the commons has on the campus, students, and budgeting for the university. They will also be concerned with the quality of the project.

iii. Board of Regents – The Board of Regents are responsible for approving the long term visions of all projects. They have a firm commitment in increasing on campus housing by 3,000 beds. They will be concerned with the quality of the project, the cost and funding, long term energy costs vs. first costs, opening the project on time, LEED, and exceeding the standards set by other universities.

iv. Vendors – The vendors will need a space that they feel is adequate for their needs. We will need to market the commons early so as to design the spaces with their input. Their main concerns will be in regards to mechanical connections, space, and lease costs.

v. Facilities Management – this group of people will be concerned with the operation and maintenance costs. The university has had issues with much needed back log of facilities maintenance and will not want to fall behind with West Village. Proactive monitoring technology (through BIM or other means) could be made available for the university.

vi. IPD Key Members – With IPD, the success of the project will determine the success of the key members involved in design and construction. Definitive, clear, and quantifiable goals will need to be set early. Their main concerns will be interrelationship and communication processes, project goal success, profit risks, schedule, duration, BIM technology, collaborative design, safety of pedestrians and construction crews, new contract type, budget, and LEED.

vii. IPD Key Members Legal – The legal department with all of the key members will be very concerned with the lack of precedent on multi-party contract types. Research into the few projects of have executed such a contract will help clear up any cloudy issues. The AIA C-191 2009 contract type, the ConsensusDoc300 contract type, or a combination of the two will be used. A true test of the innovative nature of the key members will be in the contract negotiation process.

b. Secondary Stakeholders
   i. Campus Traffic controllers (impact of construction and post construction)
   ii. Neighboring Residence (construction noise/impact)
   iii. Non-key member contractors/consultants
   iv. State and local governments
   v. Other food vendors on campus
   vi. Kitchen Staff

What is Integrated Project Delivery?

Integrated Project Delivery is a relatively new topic, and many industry professionals are still unclear on what exactly IPD is. This following synopsis contains research from many leaders in the building industry who have practical experience with IPD. This will serve as the baseline values for IPD on this project, and as educational material for the project team and other stakeholders unfamiliar with IPD.

A Needed Change

In 2007, the American Institute of Architects released a document called "Integrated Project Delivery: a Guide" that was highly criticized as an unrealistic dream. The ideas and principles behind the document though spawned industry leaders to think of ways the dream of IPD could come to fruition. The AIA's guide defines IPD as:

"…A project approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction." (American Institute of Architects, California Council, 2007)

The mentality behind IPD is total collaboration among the owner, designers, and constructors, which sounds like a perfect world. Many industry professionals are extremely skeptical of infusing such collaboration into the building industry. Architects have a hard time giving up ownership of design and realizing the financial risk the constructors take. The constructors struggle to realize the professional liability the architect faces (Tardiff, 2009). Owners cannot grasp the idea that the lowest bid does not always equal the best value and quality. In today's economy, lenders are more concerned with upfront costs as opposed to long term operating savings.

Jim Frey of Alberici Group opens up his presentations to owners regarding IPD with a statement: "Imagine actually getting the building you wanted, at the price you were promised, on the day you were promised" (American General Contractors of America Project Delivery Committee, 2009). Now this statement causes his audience to laugh, but when looking at the facts, the building industry is constructing less efficiently than 30 or 40 years ago, as seen in figure 12. This chart shows the productivity index decrease among the construction industry compared to non-farm production. In addition, research studies by the Construction Managers Association of America (CMAA) shows that 92% of owners feel architectural drawings are not suitable for construction (Construction Managers Association of America, 2005) and 30% of projects do not make budget or schedule requirements (Construction Managers Association of America, 2007). The economist magazine reports that 37% of building materials are wasted during construction, giving light to an unproductive industry (The Economist Magazine, 2002). At one time the United States building industry was the greatest in the world; it is time for an evolution in how we build so that we can reclaim that title back.

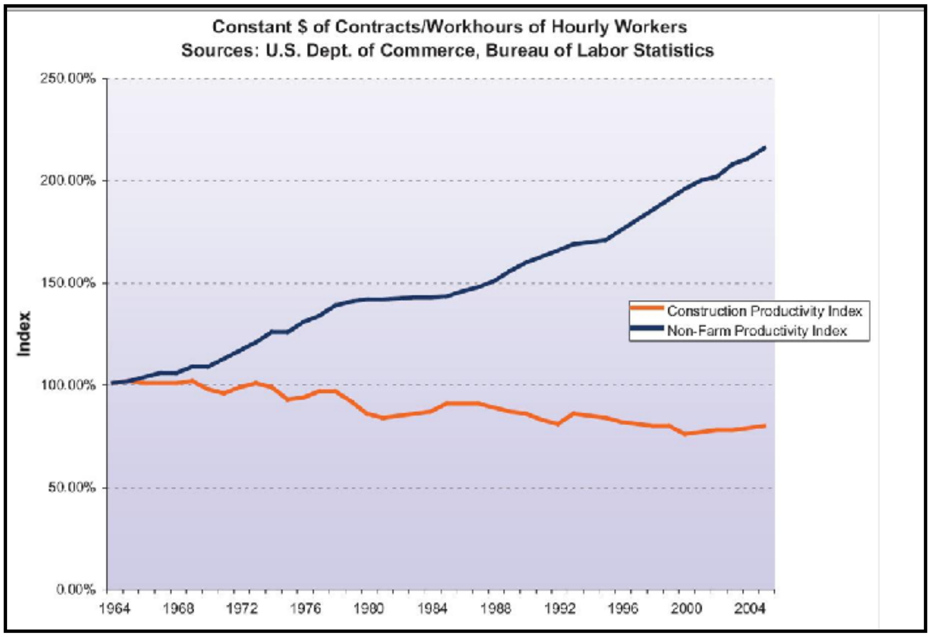


Figure 12: Constant $ of Contracts/Workhours of Hourly Workers (U.S. Department of Commerce, 2004)

Three Elements of Integrated Project Delivery (Sanvido, 2009)

i. Integrated Contract

A single contract tying all key members together is the first element of a true IPD approach. Depending on the project type, differing key members such as architect, engineers, contractors, mechanical subcontractors, etc. will all sign the same contract tying everyone together financially. One entity allows for transfer cost transparency minimizing risk to contractors and harboring a more team like environment. Incentive clauses linked to project goals are the basis for part of everyone's fee, strengthening reliance on one another. Integrated contracts require key members to focus on the quality of the project and not just selfish business interests. It creates a mentality of solution seeking not liability protection.

ii. Self-Selecting Key Members

IPD requires a sophisticated owner to make best value selections on key members at project inception. General contractors, mechanical, electrical, and plumbing subcontractors, architects, and/or engineers are selected at the same time. They are all needed to assist on creating a program, developing a building, engineering the systems, defining construction and lifecycle costs, and facilitating efficient construction activities. All members must work collaboratively forcing face to face meetings or co-location of office personnel. Owners find team members through quality selections based on expertise, job history, and presentation, giving them the difficult task of finding industry leaders who are dedicated, engaged, and excited about collaboration. Team selection may be single most important aspect of creating an IPD project (Duke, 2010). Not many owners can get past the idea best value equaling lowest bid, creating an obstacle IPD must hurdle.

KLMK Group, LLC, a "leading provider of comprehensive facility solutions to healthcare owners," uses an interesting approach to selecting their key members for IPD projects. After an initial Request for Proposal, they shortlist architect and contractors and in some cases engineers and MEP subcontractors. They then invite the companies to team up with each other (or with companies they are familiar with) and participate in a workshop where they provide them a hypothetical situation that will require plausible results. KLMK will observe and judge on teamwork, integrated thinking, engagement with the "owner," solutions to problems, and various other IPD like attributes. The teams would than present to KLMK and the owner group as a single entity. Some costs will be taken into account, such as typical fees and overhead, but teams will mainly be selected on best value and judgment during the workshop. Fee percentages, overhead, etc… are determined through collaborative negotiations. This unconventional approach is not for everyone, and Patrick Duke (Senior Vice President, KLMK Group, LLC, Mid-Atlantic Regional Manager) states that it takes an extremely trusting and forward thinking ownership to use IPD. This may be a great way to select a team for West Village Commons (Duke, 2010).

iii. Communication and Design Tools - "BIM is an IPD Enabler" (American General Contractors of America Project Delivery Committee, 2009)

The Building Information Modeling (BIM) initiative has skyrocketed in the last decade, changing the building industry for good. IPD needs BIM to have a similar take off. BIM benefits all project team members that use it, especially on the contractor side. BIM has helped provide extremely accurate take-offs, visual sequencing, and clash detection, all of which make the management of a construction process smoother and more cost effective. IPD allows BIM to reach further potential with contractors designing systems with the engineers. The model is created exactly how it will be fabricated, eliminating shop drawings. When the model is equipped with accurate information, it can be used for 3-dimensional layout, quality control, and material tracking. At the end of the job owners are provided with a more accurate tool to maintain their facilities. With IPD, BIM can be brought to a new level, and vice versa.

The Sutter Medical Center in Castro Valley, California used IPD for their $320 million hospital renovation and expansion. One of the tactics used was to bring their steel fabricators in with the design team so that the original structural drawings were designed exactly how they were to be fabricated. Mechanical, electrical, and plumbing trades were able to give input on the system as well. Not only did the steel construction process shorten from 15 months to 8, a better quality design was created that took every system designer and contractor into account (Khemlani, 5). A similar approach may be a definite possibility in shortening the construction schedule and overhead costs.

Clear and concise communication is key with IPD, and different BIM technologies give the whole project team the power to pass information along to different parties. There is a strong connection between IPD and BIM, and one will not reach their full potential without the other. The technical power of BIM coupled with the interpersonal and collaborative nature of IPD will create a cohesive environment with an efficient information exchange.

Target Value Cost Design (Architects, 2007)

At the 2008 AIA symposium on IPD (American Institute of Architects, California Council, 2007), building industry leaders gathered to hold small group discussions on the status of an IPD culture. One owner related IPD to the approach Apple Computers use toward their product development. When one entity has total control over "the design, the fabrications, the financing, and the marketing" success is inevitable. IPD grasps the concept of a single entity created to "mutually and collaboratively…manage the planning, design, fabrication, and construction process" (American Institute of Architects, California Council, 2007). A presentation given by the AGC calls this target value design (American Institute of Architects, California Council, 2007) where the quality of the project is constantly being fine tuned. This allows earlier design refinements, increased owner awareness of finances, and a more predictable budget for constructors. Jim Frey, a senior vice president of Alberici Group, Inc., spoke of the liberating experiencing of dropping the Guaranteed Maximum Price during the construction of the Cardinal Glennon Children's Hospital. It put a larger risk on the owner, but it allowed a clearer picture of cost of the building. When the target value was set in stone, it shared profit risk among the design team, constructor, and core subcontractors, in addition to the owner. (American General Contractors of America Project Delivery Committee, 2009)

Benefits of Integrated Project Delivery

i. Early Involvement

This idea of "team design" helps contractors and subcontractors give input to design, taking their experiences, lessons learned, and insight into account, creating an environment of open knowledge. Value engineering takes on a new meaning with IPD, for construction knowledge and trade knowledge is all integrated at the beginning of the project. Michael Tardiff of Grunley Construction believes that 20% of design determines 80% of the cost (Tardiff, 2009). Ideas that can have a huge effect on cost need to be streamlined at the beginning of design. Many times innovation is not realized until it is no longer cost effective to redesign because of the effects on other systems and the time to re-work drawings.

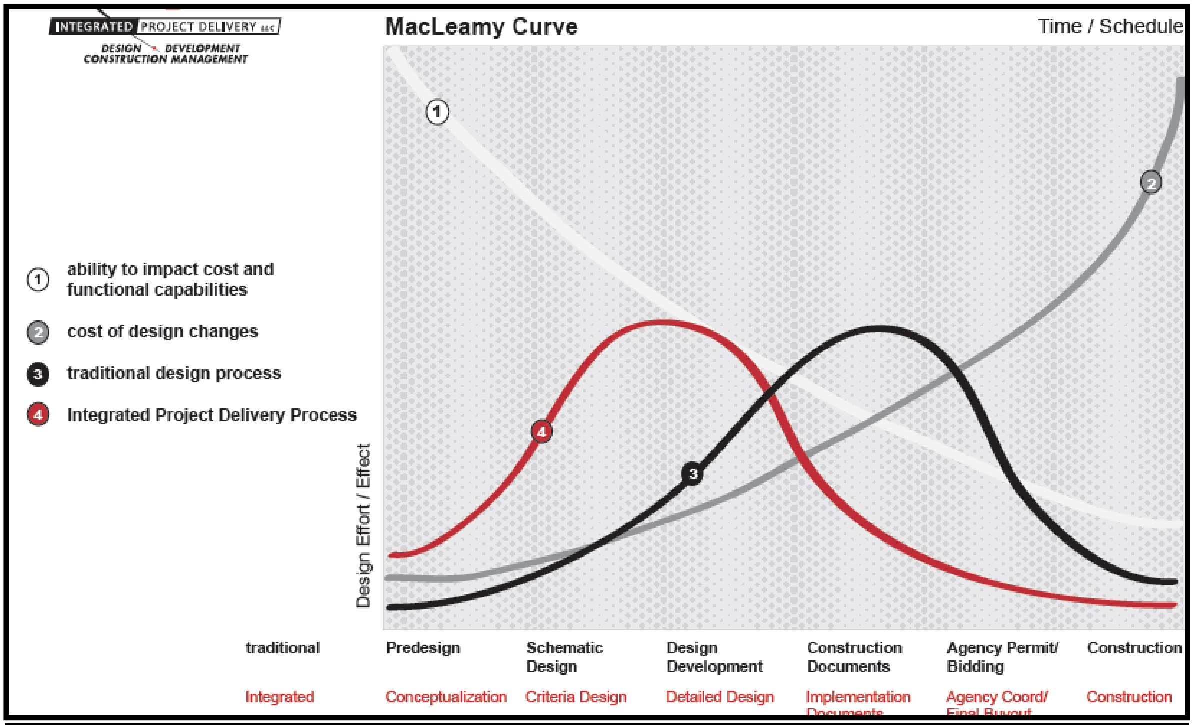


Figure 13: MacLeamy Curve (MacLeamy, 2009)

Early involvement will in most cases cost the owner more money in the beginning of the job, but early planning has proven to "effectively balance project options to meet [owner] enterprise goals" (American Institute of Architects, California Council, 2007). Figure 13, the famous MacLeamy Curve, shows how early decision making has the biggest effect on cost. When the design team has more insight at the beginning of a job in the IPD method, there is a more accurate budget estimate, more informed design decisions, and early design issue resolutions. Early planning cuts down on the cost of wasted time of infield rework and design omissions, allowing contingency budgets to shrink. This idea was reflected by one constructor from the AIA Symposium stating that a "day in preconstruction is as valuable as a day in construction" (American Institute of Architects, California Council, 2007).

ii. Shared Risk/Shared Reward

"Trust is the Foundation of Integrated Project Delivery" (American Institute of Architects, California Council, 2007)

Shared incentives and shared risk may be the driving force that will make IPD projects successful. Incentive agreements are based on project and team goals established at the beginning of the job, and they are incorporated into the contract. These goals can include cost, energy efficiency, sustainability, schedule, safety, collaboration or any other goals the team establishes. When these goals are reached everyone involved receives their share of the profits. These incentives can be part of left over contingency, general conditions, or part of the entities' fees. There is a lot of creativity in how incentives can be written into contracts, but it forces everyone to rely on each other as a single team and help your fellow teammates.

Obstacles Facing Integrated Project Delivery

i. Lack of Legal Precedence

Slow evolution of business practices has plagued the building industry from adopting lean construction values. Legal and financial risk can account for a huge amount of the snail like pace in developing new techniques. IPD contractual arrangements have no legal precedence, making it hard to convince owners and contractors to use a true IPD method. The risk of expensive legal complications outweighs IPD benefits in their eyes.

ii. Procurement

Different industry leaders have varying opinions of what markets IPD would best benefit and where it is likely to appear first. Bruce Rysztak of Barton Malow believes IPD will emerge in the energy and automotive industries (Rysztak, 2009). Both have complex systems and are funded by sophisticated owners/entities. Others see IPD benefiting healthcare projects more than other. State or federally funded projects would also make worthy candidates. All of these markets would excel in an integrated and collaborative arrangement, but a few obstacles lay in procurement.

Procurement of state funded projects in most regions must be competitively bid, where contracts are rewarded to lowest possible qualified bidder. This makes IPD structure impossible for these projects. This includes many healthcare and university projects that are partially funded by the state. IPD legislation is non-existent to allow such an approach. We now face a larger issue than just trying to convince our own industry of IPD potential. The markets most viable for an integrated delivery method cannot be considered due to a political misconception that lowest price equals best value.

iii. Fear of Cultural Change

The building industry has always had an air of volatility and lack of trust. As stated earlier, trust is the basis of IPD, and the only way IPD projects will be successful is if key members can rely on each other. If members of the team only look out for their own business interests, the project as a whole will fail. One member needs to trust that other members will raise red flags on issues, even if it is not their responsibility. Changing this mentality across the industry will be a daunting task, requiring strong leaders to give complete commitment toward their IPD team. "If you have individuals who are so immersed in the old approach they can't reach the point of trusting…it's not going to work," (American Institute of Architects, California Council, 2007) stated a designer at the AIA symposium.

IPD calls for a value and qualification type proposal for key members to be selected. Owners must select based on reputation, project history, technical expertise, and fee percentage. Most owners do not have the confidence to hire contractors without some idea of what their project is going to cost. Establishing trust at the onset of the project will require clear communication of goals and establishment of reward. Imagine a system of profit based not only on individual performance, but also the performance of other companies…a scary thought in a time of financial insecurity. This fear keeps viable designers and contractors from exploring IPD opportunities.

Summary Theme

If IPD is determined to be the delivery method for West Village Commons, success will be dictated by three things: People, Processes, Promises (American General Contractors of America Project Delivery Committee, 2009). A positive trustworthy team must be selected, including the most cost effective entities; a well defined process needs to be created early with buy in from all the key members (including the Towson team); and the promises made to be kept among all key members and back up with a well thought out contract.

Key Members of West Village Commons

Key member participants for West Village Commons will include the owner, architect, constructor, and lean core subcontractors/consults. Lean Core (LC) subcontractors/consults (AGC of America Project Delivery Committee, 2009) will be brought on early to assist with the design (see Integrated Project Phasing). Each design cluster will be eligible for savings and profit incentives. Budgets and durations will be set at a certain date (Target Value Design). The list below shows those members vital to successful design (Primary) and those that could be included for the right price (Secondary). For a cost effective and successful integrated project, the primary LC members will be needed. Secondary members could be brought on later in the process to help define systems, costs, materials, etc…

Lean Core Subcontractors/Consultants – Primary

1. Steel Fabricator/Erector
2. Structural Engineer
3. Civil Engineer
4. Kitchen Consultant
5. Kitchen Vendor
6. MEP Engineer*
7. MEP Contractor(s)*
    a. Mechanical
    b. Electrical Contractor
    c. Plumbing contractor
8. Architectural Precast Subcontractor
9. Curtain Wall Contractor

Lean Core Subcontractors/Consultants - Secondary

1. Fire suppression engineer*
2. Fire suppression contractor*
3. Drywall Contractor
4. Lighting Consultant
5. Sustainability Consultant
6. Commissioning agent

** These members could be sufficed by a Design/Build entity.*

Contract Design

Please note that from here on, actual company names that are currently participating on West Village Commons will be used. If a contact is left blank, it is because the opted not to participate. Effort was made to include all relative names. This portion of my research is the second stage of the execution guide, after selection of Key Members and Primary Lean Core Subcontractors/Consultants. This was done to make the report relevant, allow actual estimates to be compared to new, and to create a less confusing explanation. Also note that because of copy right laws, I will not be able to include a copy of either contract types, but I can quote from sections.

Two contract types were considered for Towson West Village Commons IPD Execution Guide: ConsensusDOCS 300 and AIA Document C191 – 2009. Both Contracts have similarities and difference; ConsensusDOCS spells out the entire process from design intent to closeout in great detail, while the AIA contract focus on the big picture and is not as specific. Both have similarities in team make up, target value design, incentives, and risk sharing. For the interest of this project, the AIA C191 – 2009 document will be followed for several reasons.

First of all, because this is a new type of delivery method, the AIA contract re-spells out a new order and naming of the delivery phasing of a project: "Conceptualization, Criteria Design, Detailed Design, Implementation Documents, Agency Review, Buyout, Construction, and Closeout" (American Institute of Architects, 2009). This is important because IPD is a people, process, and motivation delivery method; with a larger design team it is important that the management of people is kept organized. There needs to be well spelled out responsibilities, deadlines, and goals. Within these periods is significant freedom of design methods, meeting times, co-location, etc.

Another reason for choosing the AIA C191 – 2009 is the amendment process. C191 allows for the parties to agree to the project, team members, risk sharing, and other typical terms of IPD, without defining a cost quite yet. There are amendments to be added to the contract later in the design process called "Target Criteria Amendment." The AIA contract evolves as during the first two project phases, just as the project team grows. For instance the "Exhibit AA: Target Cost Breakdown" allows for an amendment to be placed when the Project Executive Team has decided on a target value for the project. It takes a risk off of all three parties: The Constructor is not stuck to a price when the contract is signed, the architect can get updates and stay on a budget track much more effectively, and the owner can see how his project is developing cost-wise earlier in design (as opposed to later). Value engineering now emphasizes cost savings or goal achieving innovation, as opposed to cost cutting to reach a fixed budget.

This amendment process also allows the whole team to define the project, establish project goals, define scopes of services, define a project schedule, and establish protocol for Building Information Modeling. They can act as milestones during the pre-design and design schedule, and must be agreed unanimously by the Project Executive Team.

One major difference between the AIA contract, the ConsensusDOCS, and traditional building contracts is in regards to exceeding the target value cost. "Article 4.2.4, Compensation for Labor Costs When Actual Costs Exceed the Target Cost" of the AIA document gives the option that the owner will either pay the labor costs of all parties or that he is not responsible - it is open to negotiation. The document later states (Article 4.5.4) that "if Actual Costs for the Project exceed the Target Cost, as adjusted under the Contract Documents, the Owner shall not be relieved of its obligation to pay the other Parties any Goal Achievement Compensation earned on the Project" (American Institute of Architects, 2009). The ConsensusDOCS loss allocation "either shift[s] all risk of loss to the owner or share the costs in excess of the targeted amount capped at the fees of the designer and constructor" (Victor O. Schrinnerer & Company, Inc., 2009).

This part of the contract will be a tough concept to grasp for most owners. They are used to when the budget exceeds the guaranteed maximum price, the contractor consumes the loss. It will also be a new position for the designer; there may be a risk to his profit based on the final costs of the project. This places both the owner and designer into the shoes of the contractor and puts them in the circle of cost responsibility. But with this risk, both the designer and owner can gain a new vision for the project. First, the owner receives a much clearer picture for financing options, and s/he has more control on what is being designed. In conjunction with project quality goals, the architect now has a contractor that can give definitive costs to certain aspects of the design. The key members can now make decisions on what aspects may be important to pay for (ie energy efficiency, aesthetics, etc…) and what aspects are not. The overall theme with this key idea is to promote collaboration; all three parties can gain much if they work together in delivering the project.

While the ConsensusDOCS 300 focuses on overall process and has many good qualities, the AIA C191 – 2009 has made vast improvements to it. It also looks much more familiar to many contractors, designers, and owners, diminishing some fear of the unknown. I think aspects of the ConsensusDOCS 300 are important to include, such as the joining agreement additional consultants and trade contractors or the much more spelled out dispute resolution clauses. The following sections will define different aspects of the AIA C191 – 2009 contract in accordance to Towson West Village Commons. Sections will also explain the overall concept trying to be achieved with the certain contract clauses.

Project Executive Team Members

The Project Executive Team is responsible for the planning and managing of the overall project in "such a manner as to allow the parties to achieve project goals and successfully complete the project." Basically this team has a representative from the owner, designer, contractor, and additional parties if agreed upon, to help steer the project. The Project Management team, on the other hand, is responsible for the day to day design/construction aspects, but the executive team exercises authority on the best interest of the project. All decisions must be unanimous, and if an agreement cannot be reached, the issue moves onto "dispute resolution" (which is described earlier). This team delegates responsibilities onto the Project Management Team, but is not responsible for supervising other party employees. Figure 14 is the Project Executive Team for West Village Commons.

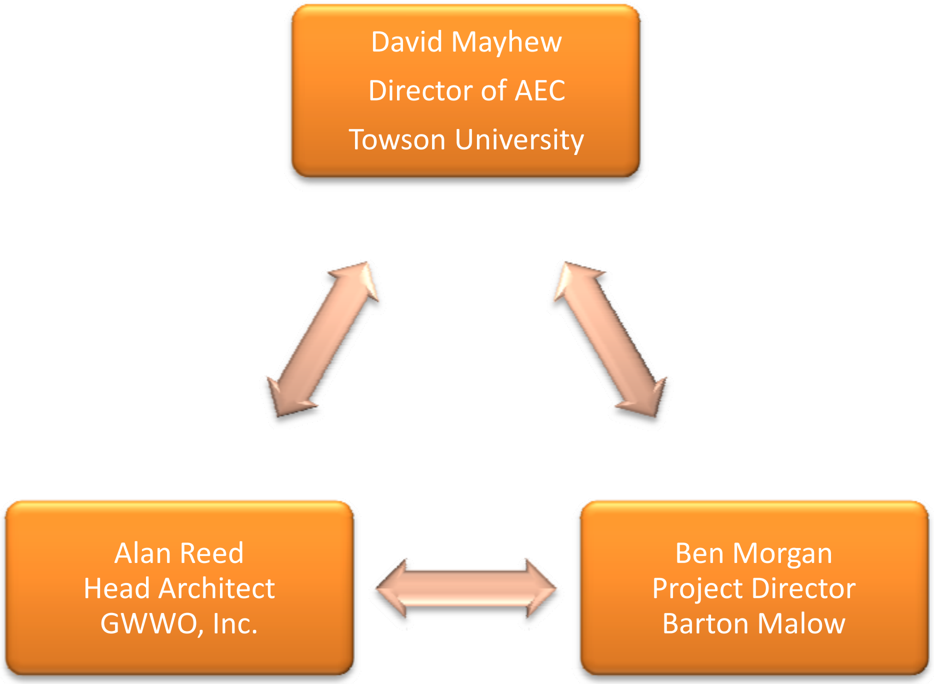


Figure 14: Project Executive Team

Note that the MEP engineer and subcontractors are not key members; they will be a LC subcontractor consultant.

The Project Management Team

The Project Management Team is directly responsible for executing the plans, decisions, and directives set by the Project Executive Team. Their responsibility is similar to the traditional project managers on typical building projects. The differing team members have employees underneath of them that they are responsible for. The Project Management Team will need to plan and implement programs to improve the project performance and keep the project striving toward project goals, budget, and schedule. It is important for the Project Management Team to communicate the important principles of IPD and provide training if necessary. West Village Commons Project Management Team will be made up of the Individuals indicated in figure 15.

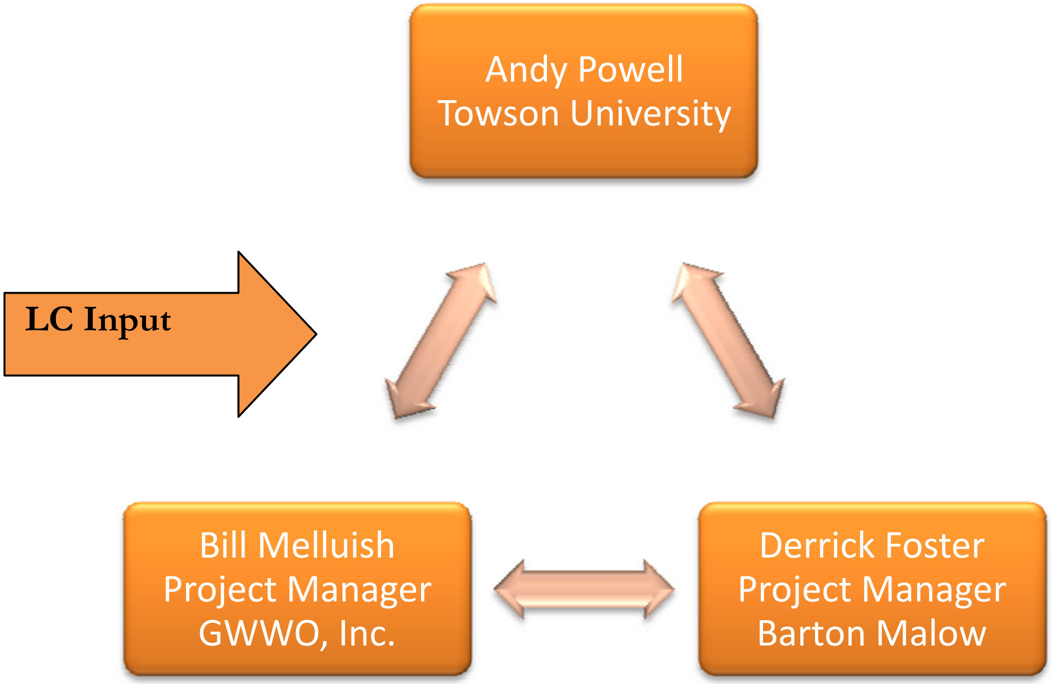


Figure 15: Project Management Team

The project management team may choose to include LC members in project management decisions depending on scenarios. These members have agreed to similar IPD terms – including target value design, project goal compensation, etc. They have been selected on best qualifications for preconstruction design and on their openness to collaborative teamwork. Lean Core subcontractors may be selected to perform trade work during construction if the Project Executive Team approves of them based on merit and cost. The LC's are basically a key participant with the IPD contract and will follow the same guidelines. Their "Design Cluster" (AGC of America Project Delivery Committee, 2009), which is explained in a later section, will have a part of the target value cost budget and certain project goals that will decide their compensation above direct costs.

Integrate Project Delivery Phasing

The phasing of the entire project will be broken up into 8 phases: Conceptualization, Criteria Design, Detailed Design, Implementation Documents, Agency Review, Buyout, Construction, and Closeout. Figure 16 (Architects, 2007) shows an approximate design time distribution of the phases.

Figure 16: The 8 IPD Phases (Architects, 2007)

- **Conceptualization**
    - Questions about the idea surrounding the project are answered:
        - What will WVC be used for?
        - Where will WVC be located?
        - When should WVC be operational?
        - Sustainable goals?
        - Etc…
    - The Executive Team will be involved exclusively during this phase
    - Close attention will be paid to the owner's intent
    - The owner will need to work with the project team to communicate spacing requirements
    - The Executive Team will select the Project Management Team and involve them in process
    - Project cost scope must be communicated from by the owner to other executive team members
    - The possibility of a West Campus Utility Plant will be evaluated for WVC, future residence halls, and possible retrofit of current buildings. This will include:
        - Approximate energy and electrical use of typical planned buildings
        - Location

        - Possible fuel sources
        - Sustainable techniques, mechanical equipment possibilities
        - Incentive programs for energy efficiency
        - Buy back period
        - Advantages/disadvantages
        - Comparative Campuses
        - Go/No-Go
    - BIM technology use and any training
    - LC candidates will be contacted and interviewed.
    - Broad project schedule is developed
    - All Pre-Target Criteria Proposal activities begin: Develop Project Goals, Definition, Target Cost, and Schedule.
    - Drivers: GWWO and Towson University
    - Key Milestones: IPD Contract Execution, Project Management Team selected, Concept criteria documented, spacing requirements set, Owner Go/No Go Decision
- **Criteria Design** *(Note that this is the time frame from which this Execution Guide is relevant to)*
    - The overall size of the building, space requirements, possible energy sources, etc will begin to be decided on.
    - LC candidates will be selected and introduced to IPD and West Village Commons.
    - The Project Executive Team will hand down responsibilities and begin to form possible design cluster for detailed design.
    - Geotechnical, solar angle, and yearly energy analysis (including costs of different systems) reports will need to be conducted.
    - Initial cost estimate/Sq. Ft. estimates made based on historical data will be created by constructor.
    - Phased construction schedule is defined by major activities (substructure, superstructure, etc…).

  - Information flow processes for the universal BIM model will be explained to all entities involved..
  - Initial building sketches, floor plans, room spacing will be created by Architect.
  - GWWO and Barton Malow will begin to develop the final Target Criteria Proposal (including Project Goals, Target Cost, Project Definition, and Project Schedule) and present to the owner for acceptance. This price will be the final value of whether there is project savings or extra costs at the end of the project. The Key Members will share savings according to compensation agreements. The Target Criteria Proposal will be finalized during the detailed design.
  - Drivers: GWWO, Barton Malow, Towson University
  - Key Milestones: Project specific goals selected (including metrics for determining performance), LC Members selected, Broad system design (type of structure, façade, mechanical, etc…), project goals and schedule set.

- **Detailed Design**
  - The overall Architectural design is finalized
  - All major building systems are defined and finalized including fixtures, furniture, etc…
  - Building elements will be fully engineered and a universal Building Information Model will nearly be completed. The universal BIM model is discussed later in this report.
  - Estimation will be based on exact quantities derived from the BIM model quantities. Major changes to the Target Value Criteria must be approved by the Project Executive Team and changed within the contract.
  - It is important for Barton Malow and the LC to periodically update the entire Project Management team on the state of the Target Value Cost.
  - LC members will be used in design clusters to help with design, cost estimating, scheduling, and tolerances. They will include information traditionally on shop drawings in the universal BIM model.
  - Specifications are developed on systems
  - Drivers: GWWO, Barton Malow, LC members, and Towson University
  - Key Milestones: Quantity estimate complete, major systems designed, Target Value Cost set

- **Implementation**
    - All Construction engineering complete including procurement, assembly, layout, detailed schedule, site plans for activity phasing, testing and commissioning requirements, closeout requirements.
    - Information traditionally checked through submittals will have already been implemented through the Detailed Design phase and Implementation Phase. The Submittal Process will be greatly reduced.
    - Construction BIM plan implemented
    - Prefabrication of LC materials may begin, as they were involved in design, shop drawing phase may be eliminated.
    - Major systems constructed virtually with 4D model
    - Scope of works will be written for all trades, including those trades not by LC members.
    - LC Subcontractors will finalize their pricing according to their scope of work
    - Cost information can be added to model to assist owner with acquiring financing
    - Drivers: Barton Malow, LC subcontractors, Towson University
    - Key Milestones:
- **Agency Review**
    - Because the BIM is used, Barton Malow is involved early, and LC members are involved early, the permitting process may be on going throughout the design phases.
    - Barton Malow must communicate to the appropriate design clusters, GWWO project architects, and Towson University project managers, comments from permitting agencies.
    - BIM code analysis software could be utilized.
    - Team needs to begin pursuing building permits
    - Drivers: Barton Malow, LC members
- **Buy out**
    - Trades not involved with the LC will be bid out to subcontractors and suppliers.

  - LC participants will have had some guarantee to perform their scope of work and will be responsible for fulfilling their scope of work to the cost estimate they provided.
  - All subcontractors, including LC subcontractors will be managed by Barton Malow, but selected by the Project Management Team.
  - Drivers: Barton Malow, Project Management Team

- **Construction**
  - Construction of the project commences.
  - Because submittal information, collaborative system design, and virtual construction occurred earlier in the project, significantly less RFI's will be needed, field issues will be greatly reduced, and more prefabricated systems can be used.
  - GWWO and subsequent engineers (those part of the LC and those contracted under architect) will be responsible for quality control checks along with Towson University project managers
  - WVC will begin the prefabrication of steel earlier to begin the substructure and superstructure construction phases earlier (see structural strategy section).
  - WVC will implement a prefabricated brick façade strategy to accelerate the enclosure construction phase. This will allow for a safer construction environment, a shortened construction schedule, and earlier commencement of interior work (see building façade strategy section)
  - Drivers: Barton Malow, LC, additional subcontractors Towson
- **Closeout**
  - A comprehensive, intelligent 3D model may be turned over to Towson University for future expansions, renovations, and additions.
  - A facilities management program may be incorporated for Towson University
  - Traditional commissioning and close-out tasks will be completed
  - After project completion, project goals will be evaluated for key member compensation.

Actual costs will be compared to the Target Cost for savings evaluation (including direct costs such as overhead, etc.) Savings will be distributed to key members according to the contract terms.

Lean Core Subcontractors/Consultant Selection Process

As mentioned before the selection of teams is the most important aspect of any IPD project. Selection of those subcontractors and consultants will be just as vitally important to a successful project as was the key members. Selection of LC members will be much more than a fee and experience evaluation, adding the key values of IPD to the criteria. After the Request for Qualifications for preconstruction/design services has gone out, the Project Executive Team will shortlist and interview possible candidates to the primary LC members. The criteria shown in Appendix D will be used to score the subcontractor candidates.

The possible points for each criterion will indicate the importance of the topic, and a possible score out of a **250** will be used to assess the candidates. Interview questions will be based upon these criteria. The final score will be used only as a tool, as only a unanimous decision by the Project Executive Team will determine selection (Some selection criteria was drawn from the webinar by the AGC, "IPD: Lessons from the Trenches" and in an interview with Patrick Duke of KLMK, Group (AGC of America Project Delivery Committee, 2009) (Duke, 2010).

Design Clusters

The purpose of design clusters is to effectively design the systems of West Village Commons in accordance to the target value design and specific project goals. The design clusters will be made up of different key members and LC members. All design clusters will report to the Project Management Team on a weekly or bi-weekly basis to be sure they are staying on the design schedule, are striving for project goals, and collaborating with IPD principles.

The design clusters begin meeting to discuss architectural impacts of their systems during the "Criteria Design Phase." This is to help the architecture team with possible design implications. Their systems designs will primarily take place during the "Detailed Design process." Note that members in orange bubbles will absolutely be need (i.e. LC Primary members). Those in blue bubbles may or may not be added, depending on preconstruction fees, and whether they may have a substantial impact according to project executives.

Structural Design Cluster

- Goals
    - Design and develop economical and efficient structural system
    - Criteria for design will be based on project loads, initial costs, schedule impacts, coordination, safety, and impact on other building systems.
    - Designed in universal BIM Model to minimize submittal process, coordination process, and fabrication time.

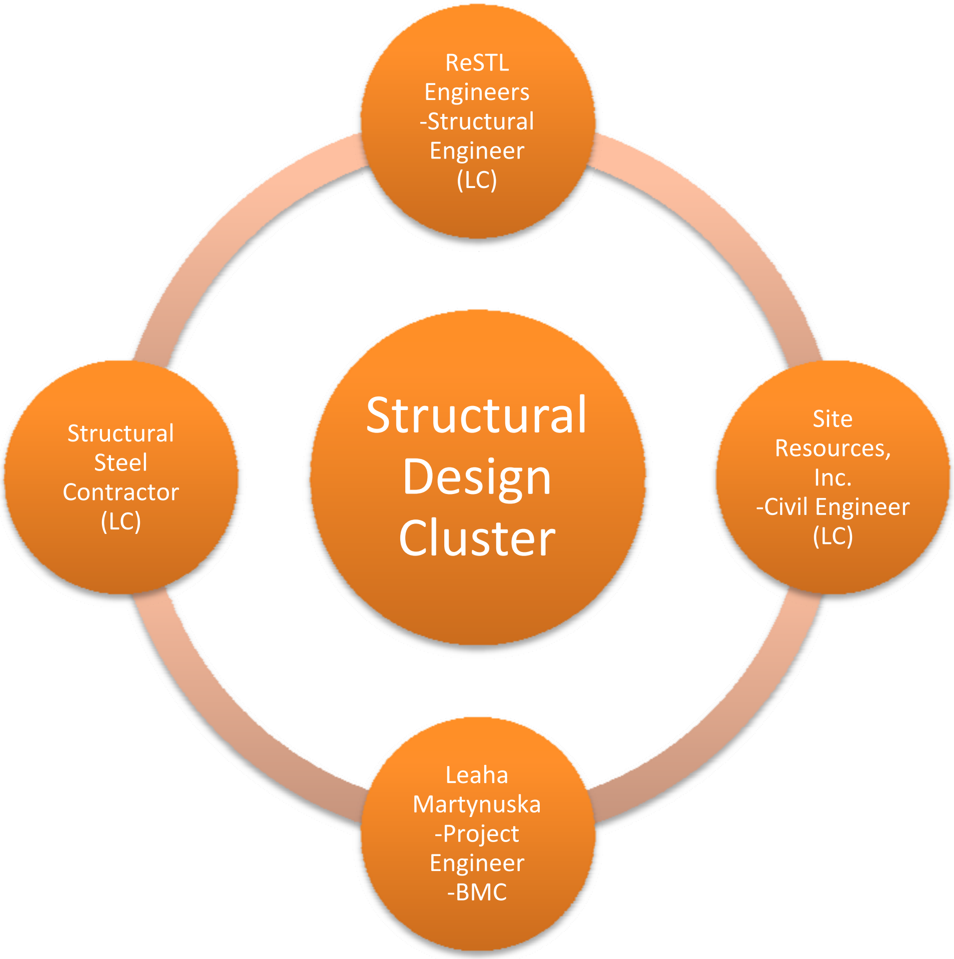


Figure 17: Structural Design Cluster

Mechanical, Electrical, and Plumbing Design Cluster

- Goals
    - Design and develop an economical mechanical, electrical, and plumbing systems
    - Criteria (order of importance) based on long term operating costs, energy efficiency, LEED point goals (LEED objectives set by Project Executive team and included in contract), initial costs, constructability, schedule, and commissioning.
    - Systems designed in the universal BIM model to minimize submittal and coordination process.

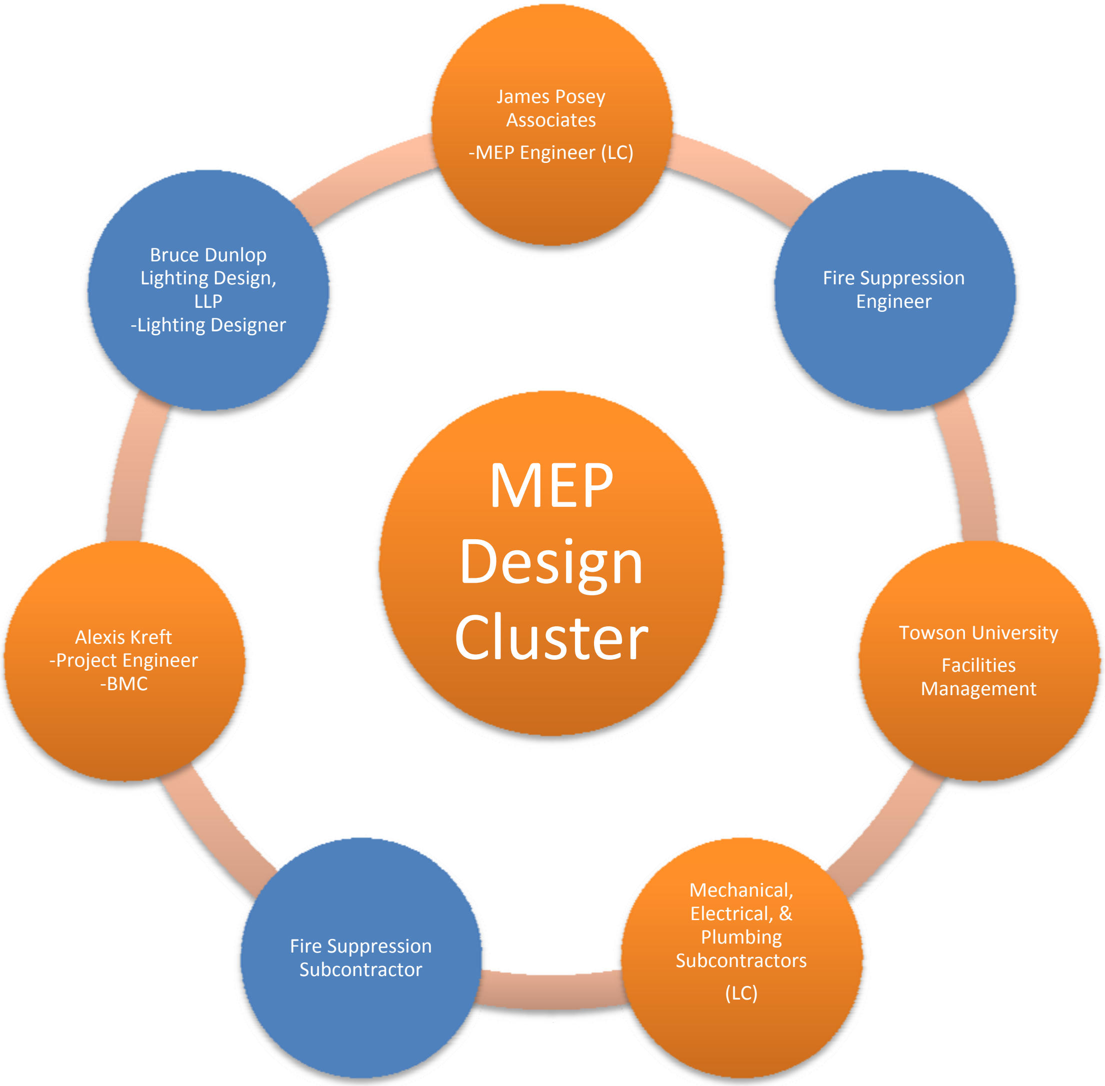


Figure 18: MEP Design Cluster

Façade Design Cluster

- Goals
    - Design and Develop an economical façade system in coordination with the architecture team's design intent.
    - Criteria based on architectural appeal (approved by Executive Team), energy efficiency and LEED Requirements, initial costs, schedule impact, structural impact, and construction coordination.
    - Because of early involvement, submittal and procurement length should be aimed as minimal. Prefabricated masonry and unitized curtain systems wall must be utilized to accelerate schedule and lower overhead.
    - All systems will be designed in the universal BIM model so as to minimize submittals and procurement time.

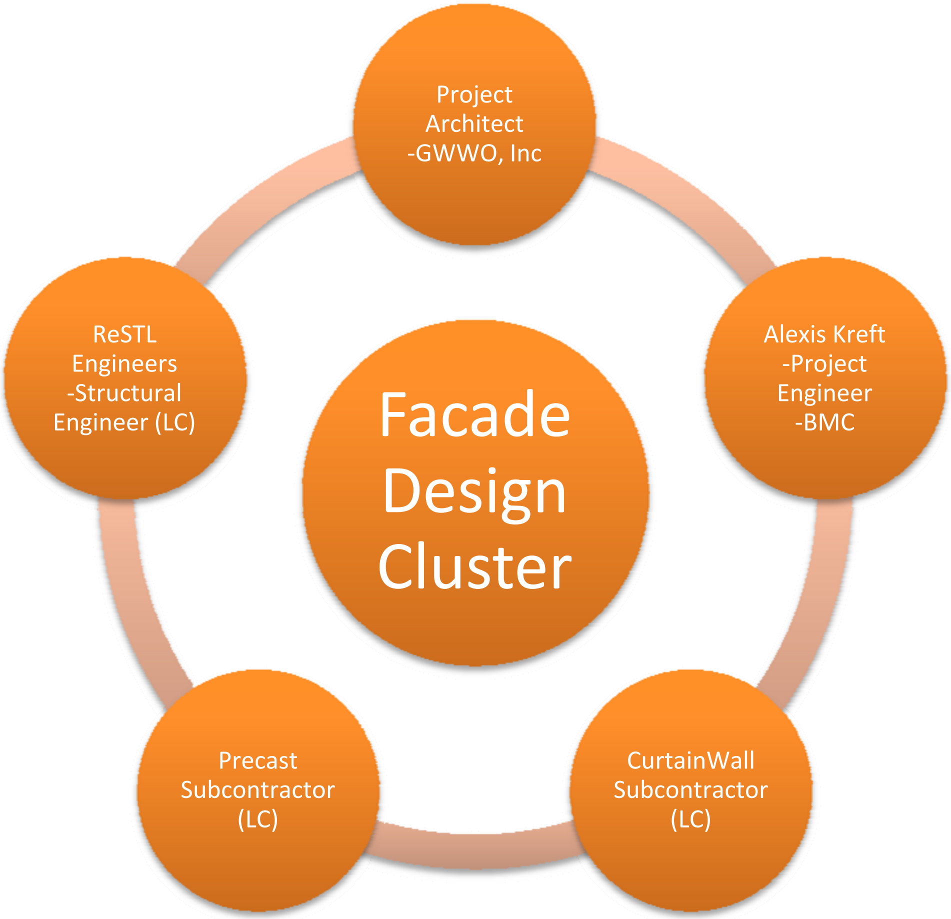


Figure 19: Facade Design Cluster

Kitchen/Food Services Design Cluster

- Goals
  - One main use of this commons is food services. It is a major project goal to create a food service design that will efficiently provide the needs to serve a major portion of West Village occupants.
  - Criteria will be based on owner space requirements, owner food service plans, operating costs/energy efficiency (will consider LEED), 3rd party vendor requirements (from owner), MEP impacts, initial costs, schedule, and coordination.
  - Design should aim to be implemented into universal BIM model so as to coordinate connection locations and needs, vent locations, drainage locations, etc.

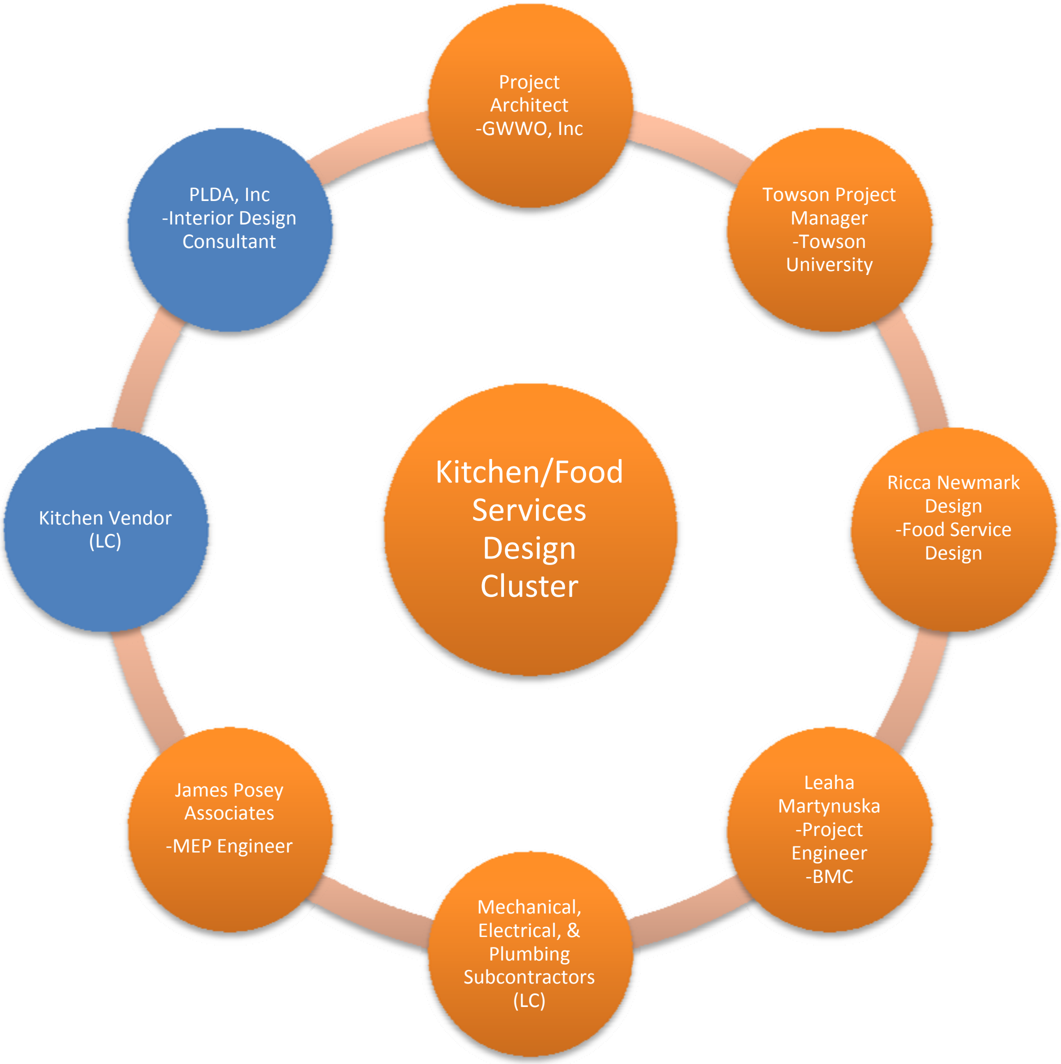


Figure 20: Kitchen/Food Services Design Cluster

Utility Plant Design Cluster

- Goals
    - Conduct a study to decide whether or not to construct a West Campus Utility Plant to serve the 8 new apartments and West Village Commons
    - Initial costs versus long term operating costs should be analyzed as a basis of decision.

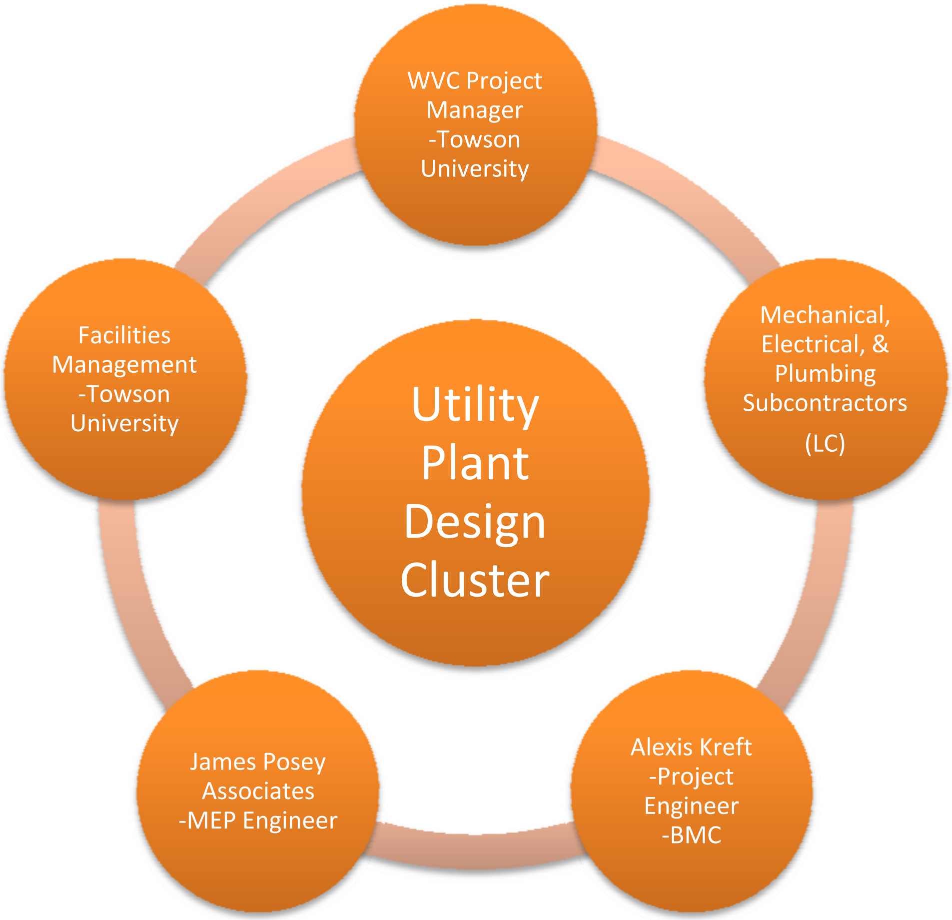


Figure 21: Utility Plant Design Cluster

Site Plan and Safety Design Cluster

- Goals
    - Zero loss time injuries and zero pedestrian incidents
    - Coordinate with the campus layout and project limits of disturbance to create effective construction site plans for different building phases.
    - This cluster will coordinate with design clusters and project management team to effectively develop site plans coinciding with the construction schedule
    - Safety hazard analyses will need to be conducted for separate phases. A site safety plan will need to be developed with consideration to OSHA, Maryland OSHA, campus precautions, and disruption of campus activities.

Figure 22: Site Plan and Safety Design Cluster

Universal BIM Model

> *"It is understood that integrated project delivery and building information modeling (BIM) are different concepts – the first is a process and the second a tool. Certainly integrated projects are done without BIM and BIM is used in non-integrated processes. However, the full potential benefits of both IPD and BIM are achieved only when they are used together."* (American Institute of Architects, California Council, 2007)

- Goals
    - Create one model for all design processes; architectural, structural, mechanical, electrical, plumbing, façade, 4-D scheduling, costs, coordination, closeout, and commissioning.
    - The model should be complete with operation and maintenance data, so at the end of the project, it can be turned over to the owner. It will be a great asset to facilities management.
- Process
    - The model will be used by the key members and LC subcontractors/consultants.
    - Ownership will be shared between the Key Members until turned over to the owner at the end of the project.
    - All information typically found on shop drawings will be inserted into the model. Effort to collaborate with fabrication software may be made. Engineers will work hand in hand with contractors so as to create this universal BIM model.
    - It is the responsibility of the project management team each week to meet with the design clusters to discuss possible implications on design. Meetings between separate design clusters will need to be schedule to discuss implications of designs.

It is vitally important that a process management procedure be established so that the entire team knows what systems are currently being designed, the impacts of the changes they make, and how to best suit each others' needs. Design cluster leaders need to be sure they are speaking to one another in weekly meetings so problems can be prevented as opposed to reacted to.

Dispute Resolution

The AIA C191 – 2009 plainly writes out how to handle disputes brought up during the project. Disputes can be brought up only if:

- Referral from the Project Executive Team
- If the Project Executive Team fails to come to a unanimous decision, any Party may initiate a dispute
- Issues on final payment, made by any member.

The beginning of the project, each key member will select someone from their company to act as a member of the "Dispute Resolution" committee. The Project Executive Team will also select a Project Neutral to mediate dispute measures. The Project Neutral will be responsible for all procedures, scheduling, and execution of the settlement. All costs will be shared equally among the parties.

Though disputes should be minimal, there is a distinct process that allows everyone equal say into how to precede. It is also a quick and relatively inexpensive process, and requires the key members to continue working on the project as if there was not a dispute.

Project Compensation & Project Goals

Project compensation offers a chance for great innovation in contract design and negotiation. Bob Grottenthaler of Barton Malow stated in an interview that this process could be a huge indicator of how a team will integrate with one another. If negotiations are a tough, battle ground process, it may be in indication of the relationships that the key members will have. Negotiations that are creative in regards to compensation (are they challenging, inspiring, innovative, constructive, etc…) will be a major indication of the type of company and individuals working on the project.

In regards to West Village Commons, there are two categories of shared risk/incentive goals that have been chosen to include in this contract. The first are goals that will be shared between the contractor and architect, and the other could be shared with varying proportions or individual incentives. Some or all of the secondary incentives can be chosen, as this just lists potential project goals.

- Primary
  - LEED Silver Rating
  - Completion with Certificate of Occupancy by the first day of the 2011 – 2012 school year
  - Building space requirements defined by owner
  - 10% decrease in operating cost compared to Glenn Dining Halls
  - Achieve the Target Value Design Cost (to be determined)
  - Less than 3% increase due to non owner initiated change orders
- Secondary
  - Zero loss time injuries on the job site (Contractor only)
  - Less than fifty RFI's (shared or shared with varying percentage)
  - Facilities Management Integrated Model (possibility of bonus)
  - Less than 15 errors and omissions changes (architect only or shared with varying percentage)

Most of the current IPD projects do not base the entire compensation wage for the architect and contractor on project goals. The trend has been to use about half of a normal profit percentage margin on a typical project. For example, assuming the contractor is making 3% profit, 1.5% of the profit would guaranteed and the other 1.5% would be based on the accomplishment of the definitive goals made in the beginning of the project. The profit margin of both the architect and contractor could be depleted by cost overruns up to a certain dollar amount (in which the owner would absorb costs). Traditionally this risk is merely on the contractor, but with the AIA C191 – 2009 contract, the architect and owner now share in this risk. It is to serve as an incentive for all three members to work together in solving cost overruns and schedule extensions. In addition, percentages of cost savings from the Target Value Cost can be negotiatiing terms.

All of the percentages, cost overrun caps, and project goals percentages are negotiated. Some goals will be worth more than others, and some goals will have varying percentages for the architect or contractor depending on level of responsibility. All negotiations will involve all three members, so a fair assessment of risk and profit can be made. The same process can be made between the Lean Core subcontractors and consultants, so as to provide incentives for them as well. They could have their own set of project goals linked to other members of their design clusters.

Project Goals and compensation are the heart of an IPD contract, and they provide for great innovation. If the owner and has done his job and sought out a creative and integrated team, this process can also be enjoyable. The purpose is to motivate and inspire true engineering ideas for a building project, and promote collaboration. If everyone is tied to the same project goals, there will be efforts made to help each other out.

Summary and Recommendation

Integrated Project Delivery opens possibilities that would not otherwise be possible. The over arching idea that IPD promotes is collaboration; the building design and construction process could truly become one of enjoyment and excitement between the key members if an environment of collaboration is created. While many of the IPD elements have not been tested enough to truly prove its quantitative benefits, the ideas behind it have true potential. The depths and breadths explored through this report stem from those potentials.

While Integrated Project Delivery will truly benefit projects with larger budgets and more complicated systems, cost savings can be seen even in average size projects such as West Village Commons. Process changes have been discussed and now this report will attempt to quantify system cost savings through a structural and façade redesign, and the possibility of using a Central Utility Plant.

-STRUCTURAL STRATEGY-

STRUCTURAL SYSTEM REDESIGN (BREADTH)

Opportunity for Resolution

Barton Malow Company became the construction manager at risk while the design for West Village Commons was still in development. At that time the structural system was a braced frame, structural steel system. They discovered that this type of construction may not start in time to be completed by indicated end date. They would have to have the entire building at 100% design to begin construction. They submitted the idea of using structural concrete for the north end of the building and structural steel in the south (please reference figure 5 on page 10). This allowed construction to begin earlier and allow the building to be open by the 2011 - 2012 school year.

Structural concrete has some advantages and disadvantages. First off it is a longer process with much more complicated coordination during construction. The project team spent many hours coordinating imbeds, sleeves, and MEP penetration, a strenuous and tedious process. The cost of structural concrete is slightly more expensive when taking into consideration the overhead of a longer duration. Due to schedule constraints in order to complete the project on time, the project team had to pour concrete between the months of October and March, the harshest weather conditions of the year. Almost all of the weather dates were used during the worst winter Baltimore experienced in years.

Integrated Solution

For this structural breadth and construction depth study, an attempt was made to recreate the structural system utilizing steel. The model made in the fall semester was re-designed to incorporate a steel layout that could be used to determine durations and costs for the new system. Because Integrated Project Delivery is being utilized, it is safe to assume the original design during the "Design Detailing" phase will include all connection and beam details. The universal BIM model will be used (if possible) for fabrication drawings. The steel fabricator will be brought on early as a LC member, eliminating the submittal phase and substantially shortening the procurement phase. Fabrication can begin earlier than a tradition design-bid-build delivery method. For the sake of this study, and because the fabricator is brought on so early, the procurement process will not have an effect on lengthening the schedule. This has been the case on several other, more complicated steel projects.

To design the system, a typical bay in the roof and a typical bay on the fourth floor was analyzed. Because the beams could be spliced every two floors, this would allow a design for the two bays' girders and beams, and the columns supporting them. This report does not consider the changes in the foundation that would occur, or the exterior beam change changes due to the prefabricated masonry panel changes (which is described later in the "façade strategy".

A construction analysis will then be conducted to analyze cost, duration, phasing, effect on the critical path, and safety on site. A recommendation will then be made on whether or not to use the steel system or stay with structural concrete.

Structural Redesign

Complete design calculations were conducted by hand and can be found as scanned copies in Appendix E

The bay used for calculations is on the column lines G to K (west to east) and 5 to 4 (south to north). It is 27 feet in the east-west direction and 33 feet in the north-south direction. The girders will run along the north-south direction as to run with the main lines of the mechanical ductwork. The layout can be seen in figure 23. All steel used will be Fy = 50 ksi.

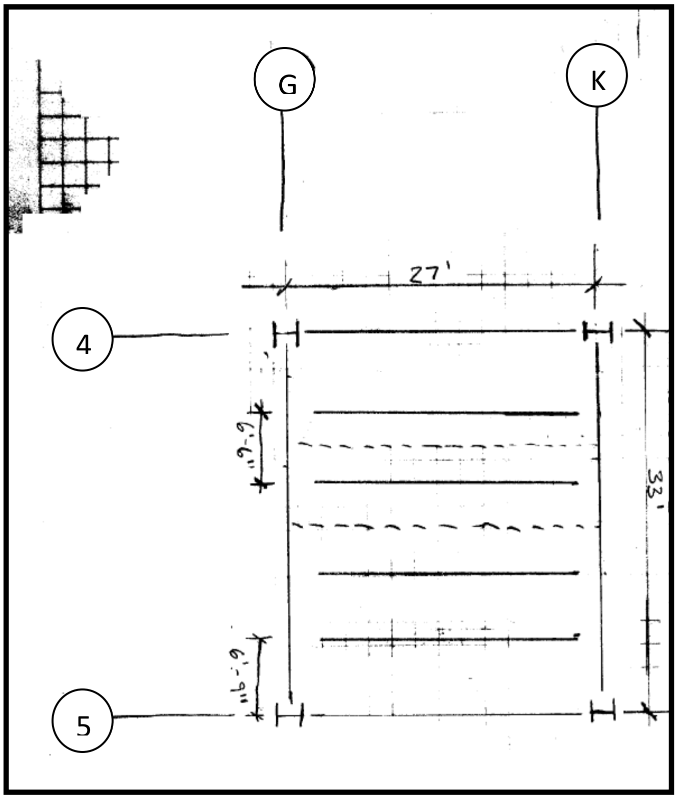


Figure 23: Typical Bay Dimensions

Roof Design

The following criteria/loads were used to determine the roof steel sizes.

- Snow Load
  - ASCE 7 – 1998 Sec. 7.3 for flat roof
  - Pg = 30 psf
  - Ce = 1.0
  - I = 1.0
  - Ct = 1.0
  - Pf = 0.7(Ce)*(Ct)*(I)*Pg
  - Pf = 21 psf
- Roof Live load
  - Original structural drawings for the south end state that a 30 psf was used for Live Load which includes the Snow load.
- Roof Dead Load (according to original structural drawings for the south end)
  - 2" deck with 3-1/4" light weight concrete (LWC) + ponding effect = 50 psf
  - Roofing membrane + insulation = 15 psf
  - Hung MEP Allowance = 10psf

  - Steel self weight = 10 psf
  - Total Dead Load = 85 psf

- According to inspection, the load combination that will be used according to ASCE will be:
  - $w = 1.2(D_L * A_t) + 0.5(L_L * A_t)$
- Loadings
  - Beams
    - w = 760.5 lbs/ft
    - $M_U = wl^2/8 = 69.3$ Kips – ft
    - $V_U = wl/2 = 10.27$ Kips
  - Girders
    - w = 2.49 kips/ft
    - $M_U = wl^2/8 = 340.3$ Kips – ft
    - $V_U = wl/2 = 41.91$ Kips

The beams and girders were analyzed to check internal moment, deflection, and shear. Self weight calculations and check was not needed, as an allowance was included in the Dead Load calculation. Selection of steel beams and girders was done so as to choose the most economical beam, and to try and be consistent with those already selected for the south end. W14 x 22 was selected to be used for the beams, and W24 x 55 was used for the girders.

Fourth Floor Design

- Live Load (typical room, non-mechanical)
  - 100 psf
- Dead Load
  - 2" deck with 3-1/4" LWC + "ponding" = 50 psf
  - Hung MEP Allowance = 10 psf
  - Steel Self Weight = 10 psf
- According to inspection, the load combination that will be used according to ASCE will be:
  - $w = 1.2(D_l * A_t) + 1.6 (L_L * A_t)$
- Loadings
  - Beams
    - w = 1.59 kips/ft
    - $M_U = wl^2/8 = 144.9$ Kips – ft
    - $V_U = wl/2 = 21.47$ Kips
  - Girders
    - w = 5.2 kips/ft
    - $M_U = wl^2/8 = 707.85$ Kips – ft
    - $V_U = wl/2 = 85.8$ Kips

The beams and girders were analyzed to check internal moment, deflection, and shear. Self weight calculations and check was not needed, as an allowance was included in the Dead Load calculation. Selection of steel beams and girders was done so as to choose the most economical beam, and to try and be consistent with those already selected for the south end. W14 x 34 was selected to be used for the beams, and W24 x 84 was used for the girders.

Column Design

- Load from fourth floor bay
    - 214.5 Kips
- Load from roof bay
    - 104.36 Kips
- Total load on Column
    - P_U = 318.86 Kips
- Typical length is 31 feet
- $r_X/r_Y = 2.64$
- $KL_{eff} = 11.74$

The column used will be a W12 x 40.

Building Information Model Images

The model creating during the first semester project served as a basis for the redesign of the structural system (reference Technical Assignment 2 for screen shots of the concrete and steel structure). The south side of the building remains the same as the original design. Figures 24 to 30 are screen shots of the new design.

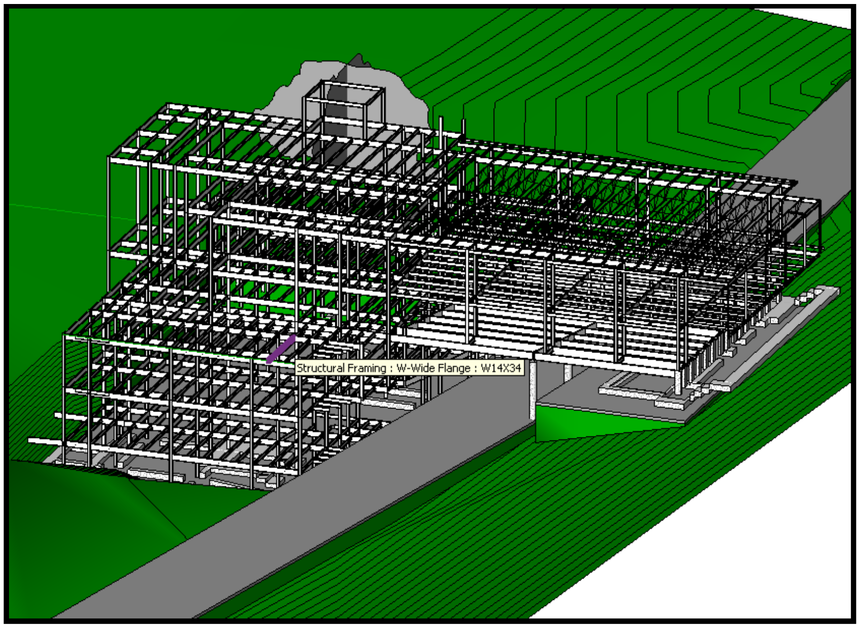


Figure 24: 3D view of structural steel from the southwest

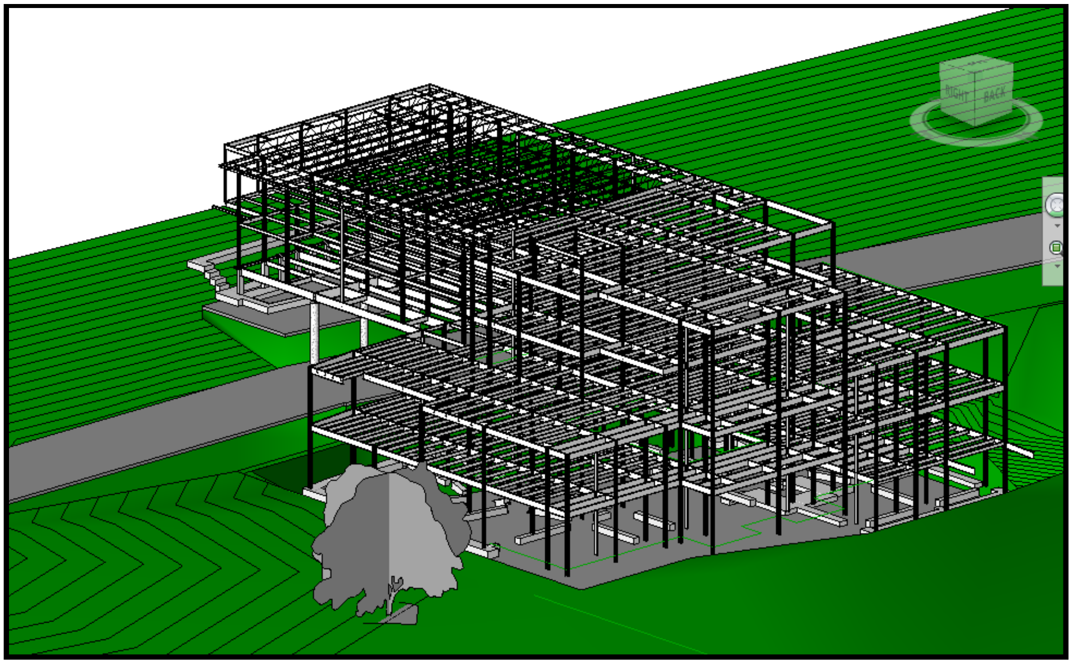


Figure 25: 3D view of the structural steel from the northeast

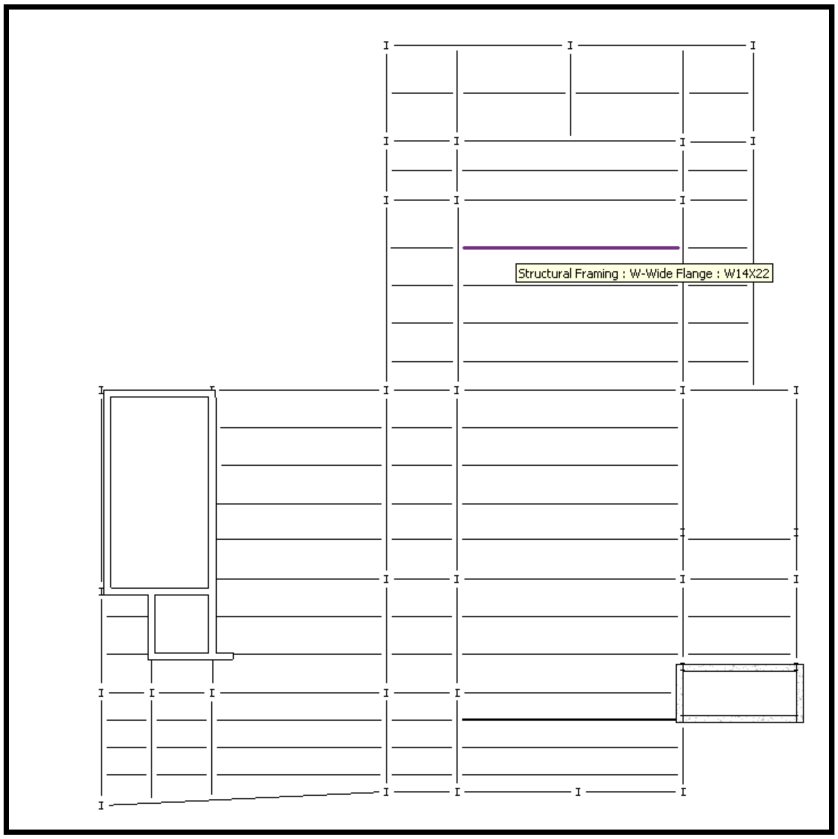


Figure 26: 2D Layout of the north roof structural steel

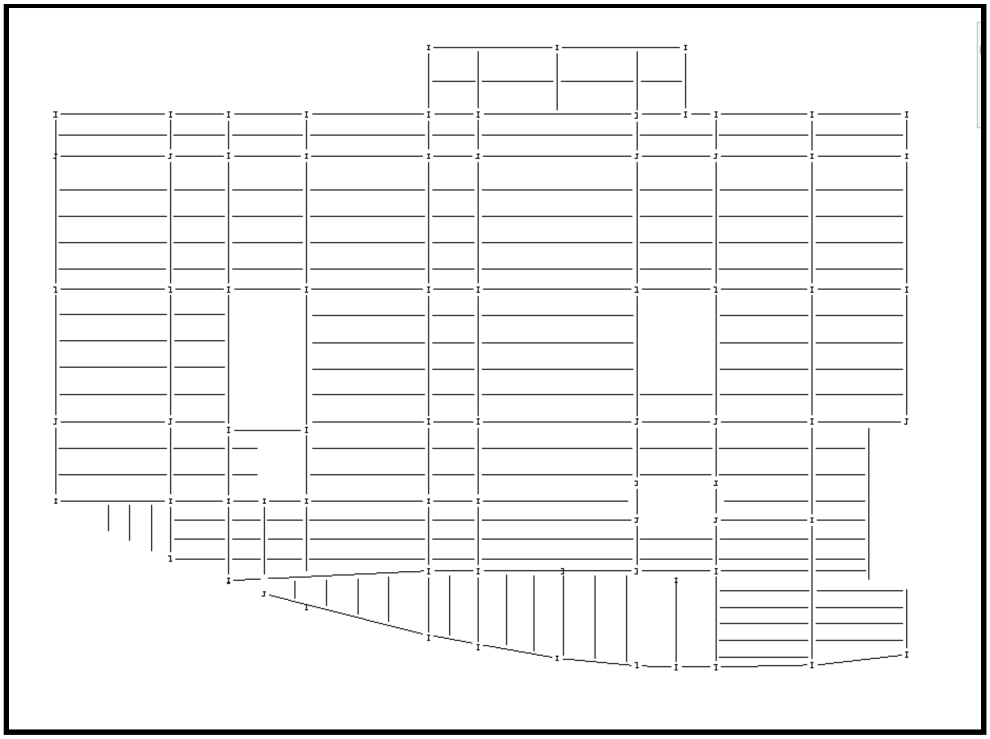


Figure 27: 2D Layout of the 3rd floor north structural steel

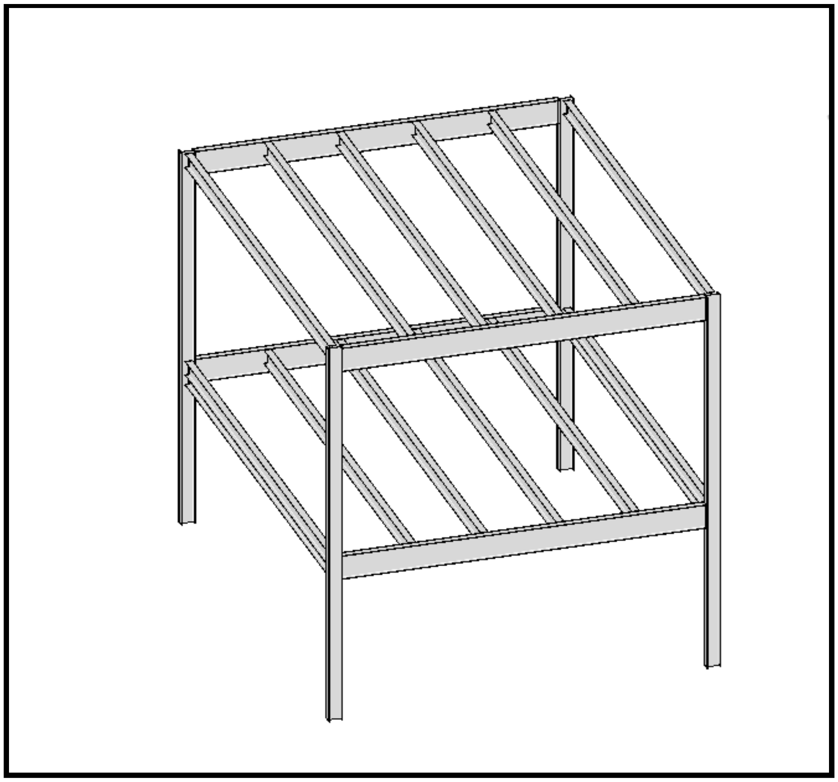


Figure 28: Original bay used for structural design

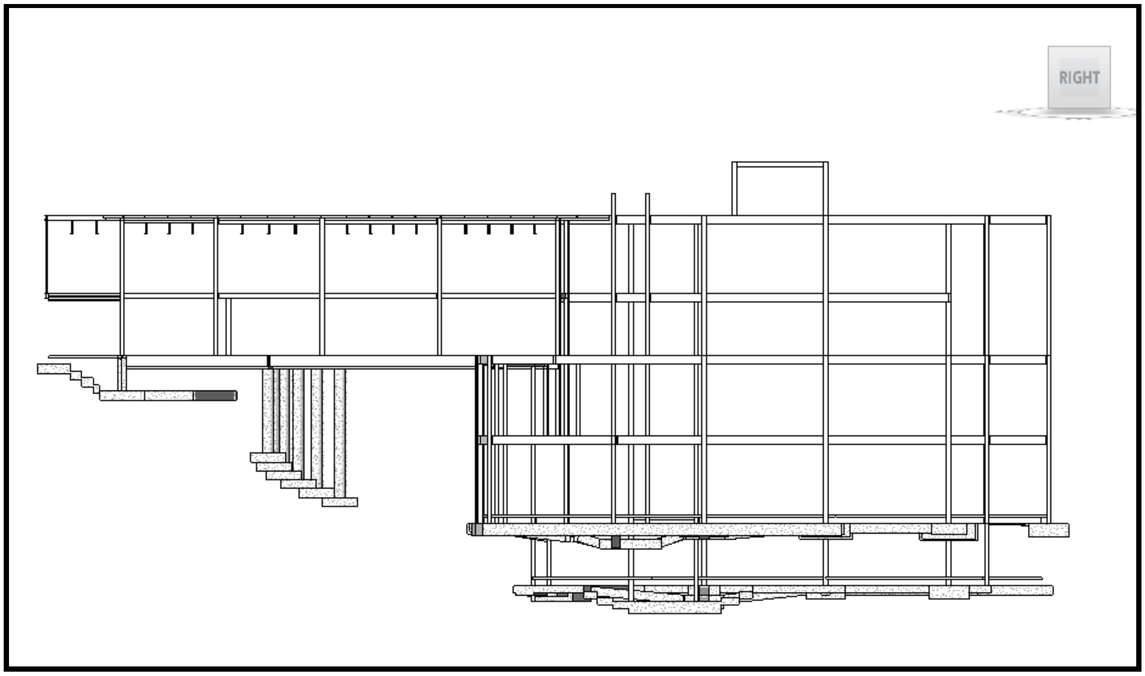


Figure 29: Structural steel east elevation

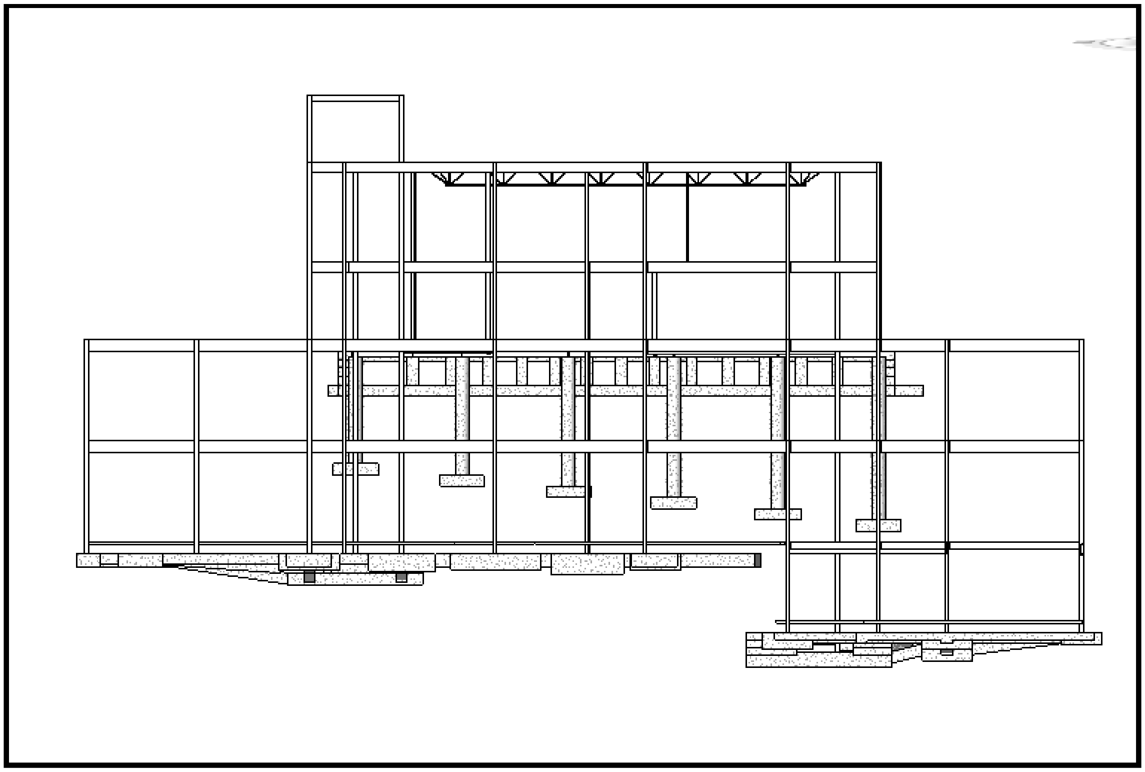


Figure 30: Structural steel north elevation

Cost Analysis

The model was used to analyze costs of the new system. Schedules were created of the columns, beams, girders, and floors, and then exported to excel. Cost information from Barton Malow Company estimating department or from the original estimation conducted in the fall semester. This was done to create a consistent comparison and is indicated as either BMC (Barton Malow Company) or ORG (original cost data). When given an estimation range, the conservative side was used. A complete take-off and cost estimate by phasing zone can be located in Appendix F. Phasing zones can be seen in Figure 31, and Figure 32 to Figure 62 are 4-dimensional snap shots of the model according to zone.

Below is a summary of the construction costs. Both include the original estimate for the spread footers and grade beams (but not the deep foundation "Ram Aggregate Piers, as cost data was not available).

Estimation Data

- Foundation cost will remain the same from Technical Assignment 2
- Cost of Steel = $2,600 per ton (BMC)
- LWC on Metal Deck = $184/CY (ORG)
- Welded Wire Mesh (6x6 W2.9 x W2.9) = $57/CSF (ORG)
- Metal Decking = $3.15/SF
- Roof Decking = $2.80/SF
- Crane = $30,030 per month (ORG)

Structural Cost Summary

- Total Foundation Cost (ORG from Technical Assignment 2)
    - $745,166 (includes foundation wall, slab on grade, grade beams, footings, reinforcement, and formwork)
- Structural Steel Columns
    - 5,781 tons
    - $301,038.34
- Structural Framing
    - 504.76 tons
    - $1,312,369.33
- Structural Flooring
    - 66,394.68 SF of LWC on Metal Deck
    - $209,143.24
- Roof Deck
    - 19,907.82 SF of Roof Deck

  - $55,741.90
- Crane Duration
  - 13.6 weeks (if steel and floor are exactly linear, conservative approach)
  - = 3.5 months
  - $105,105
- Subtotal Structural Steel Cost
  - $2,728,563
- Subcontractor Overhead and fee
  - Total cost * 10%
  - $272,856
- Total Structural Steel Cost
  - $3,001,419
- Original Structural Estimate
  - $3,235,397.70
- Savings
  - $233,978.70

Accuracies and Inaccuracies

The accuracy of this estimate is believed to be pretty strong due to the relative comparison to the estimate made in Technical Assignment 2. A major savings can be accredited to the decrease time that the crane will be utilized on site (approximately a difference of five months). The use of the model will also add to the accuracy of the estimate, as there is a decrease in double counting members, human error in measuring, and an increase in efficiency. While the time to create the model took many more hours, exporting the take offs was an extremely simple process.

Some of the inaccuracies in this estimate are the member types and foundation sizes. An analysis on the effect on the foundation due to the change in structural type was not conducted. The foundation will change in size and possible number. The deep foundation system may have been affected as well. This will all have an effect on the estimation. Because the typical bay is only an approximation of the other member types, a complete system was not estimated. It is assumed some beams, columns, and girders would be smaller, and others will be larger. An effort was made to find the most average of bays but this will fluctuate the estimate up or down.

Schedule and Phasing Analysis

The phasing of this project was broken up into different zones, completing the foundations and structural system in a west to east direction, from north to south. The site is extremely tight and therefore only crane crew and one steel erection crew was used to determine the schedule and duration. If possible, concrete pours on the metal deck can occur while steel is erected in a different zone. The foot print was broken up into eight distinct zones, six in the north and two in the south. Some floors will require all 8 zones, while others will not.

The phasing images shown were taken from the structural model created in Revit and exported to Navisworks. Figure 31 shows the zone layout, and Figure 32 to Figure 62 show the construction sequence. Please note that the concrete pours are assumed to be completed after steel erection has moved on to another floor, after the metal deck on the above floor has been placed. The erection will be completed by a crane, and the concrete poured by a truck pump. Zones are noted by Zx with "x" representing one of the eight zones (i.e. Z1 is equivalent to zone 1).

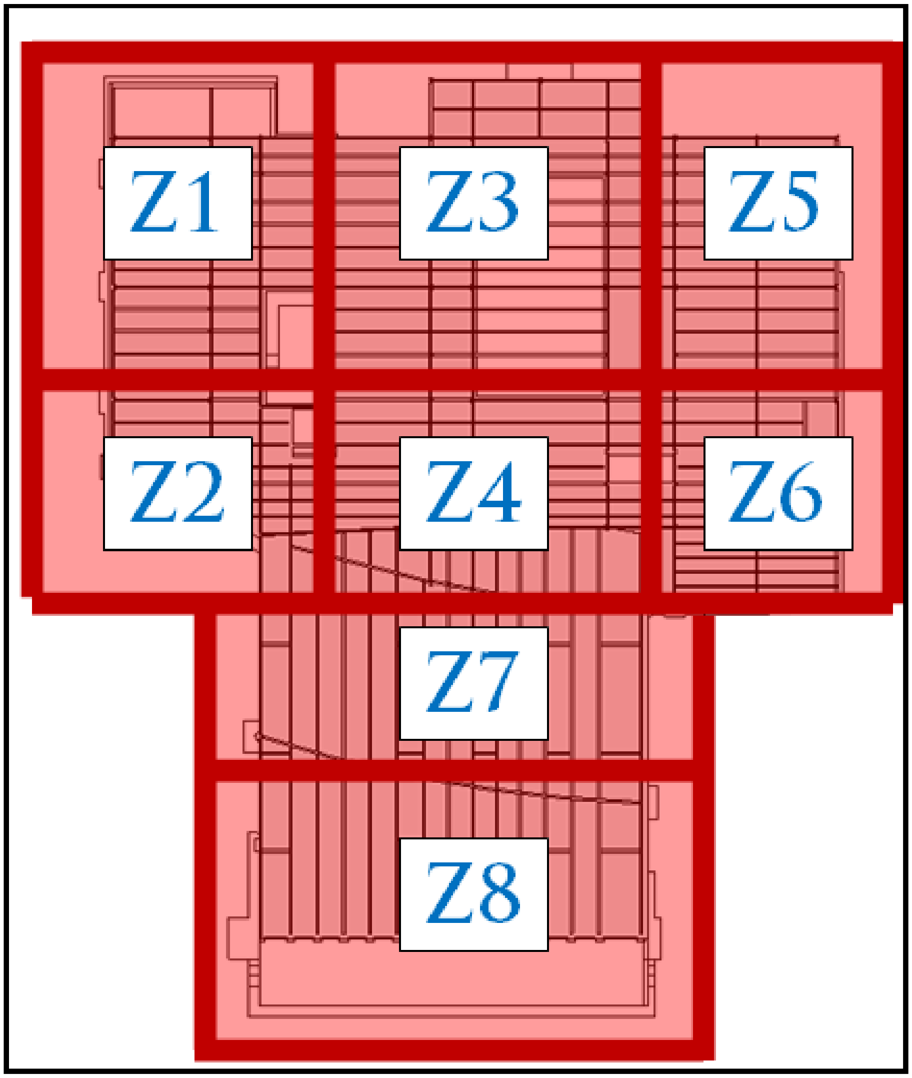


Figure 31: Zone Layout

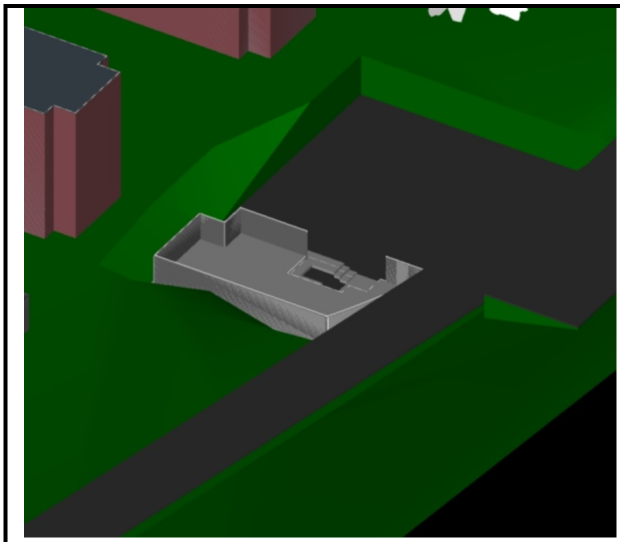


Figure 32: Basement Foundation

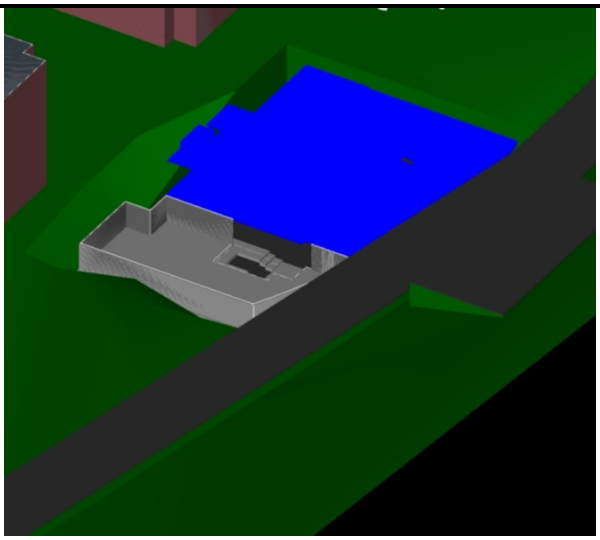


Figure 33: 1st Floor Foundation

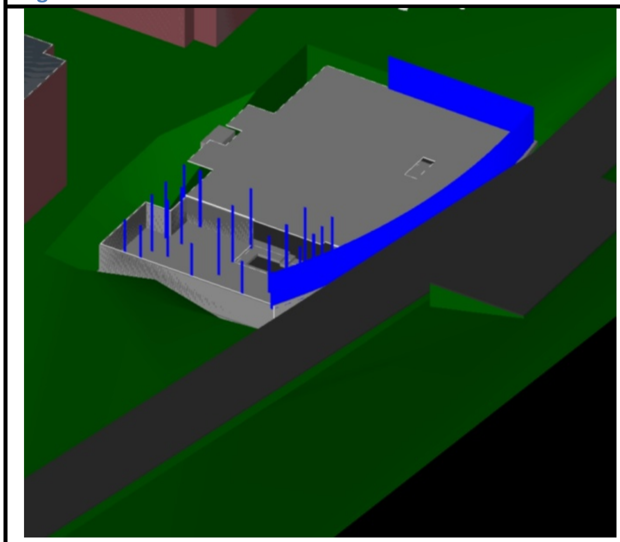


Figure 34: 1st floor columns, Z1 & Z2, and foundation wall

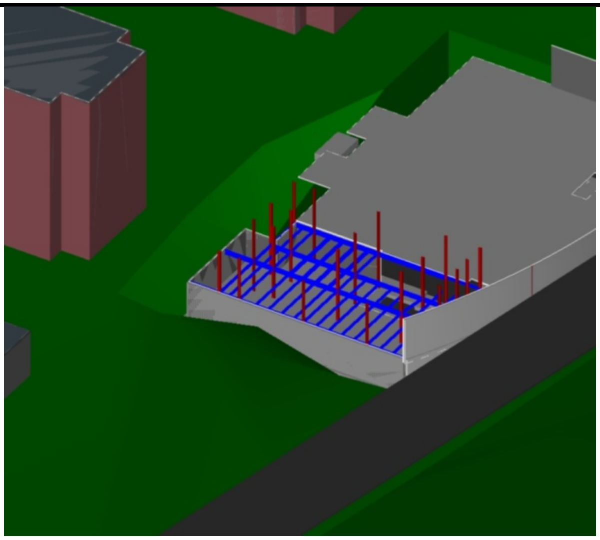


Figure 35: 1st Floor beams, Z1 & Z2

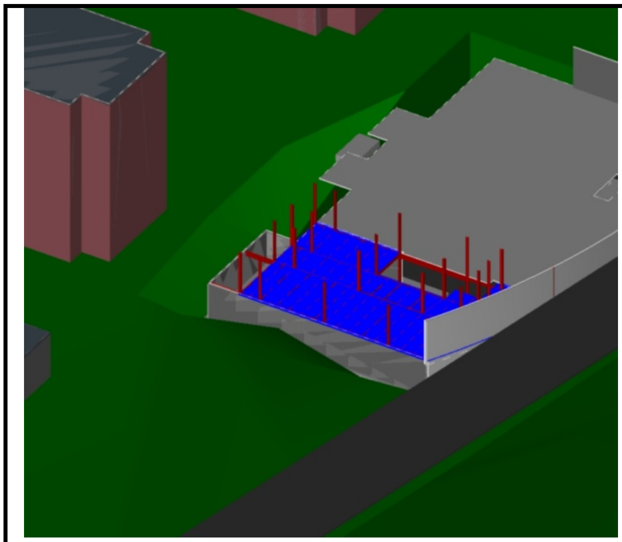


Figure 36: First Floor Metal Deck

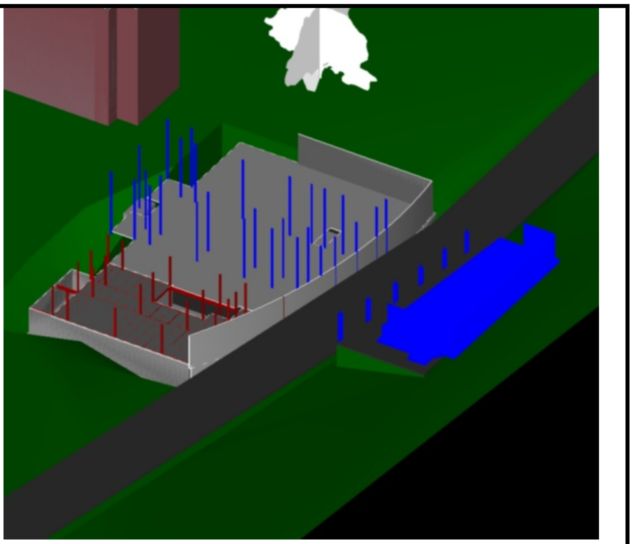


Figure 37: Columns 1st to 3rd, Z3 & Z4, South Foundation

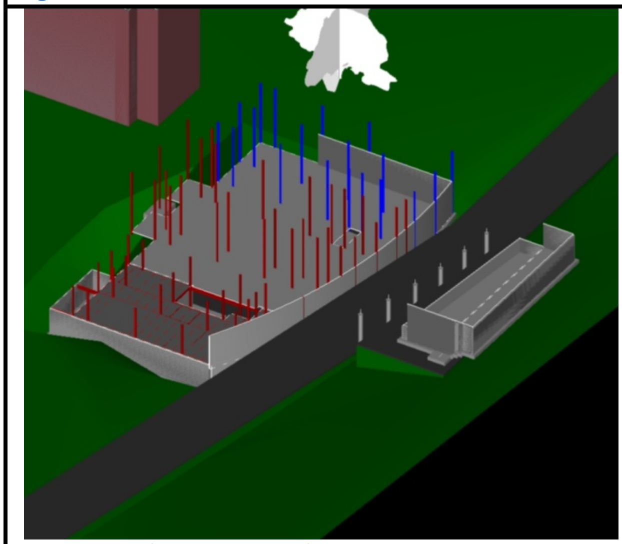


Figure 38: Columns 1st to 3rd, Z5 & Z6

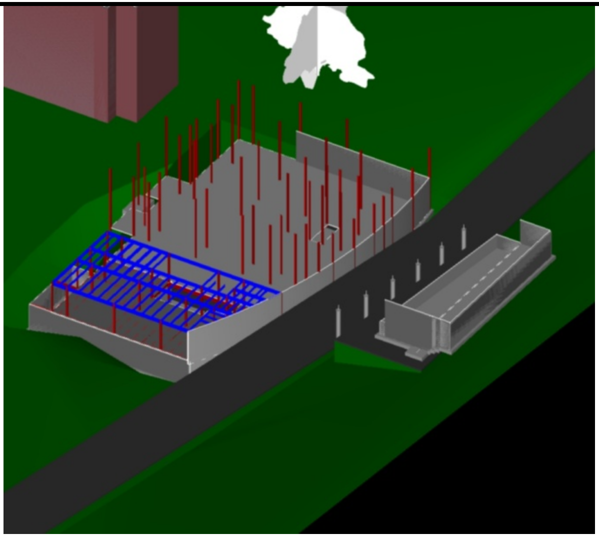


Figure 39: 2nd Floor Beams, Z1 & Z2

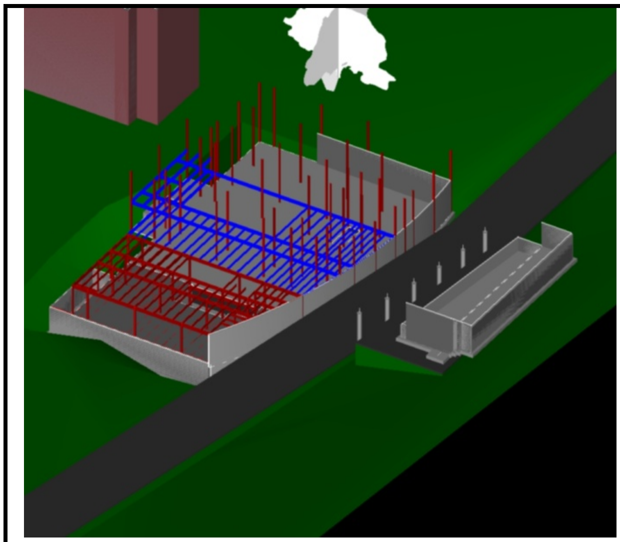


Figure 40: 2nd Floor beams, Z3 & Z4

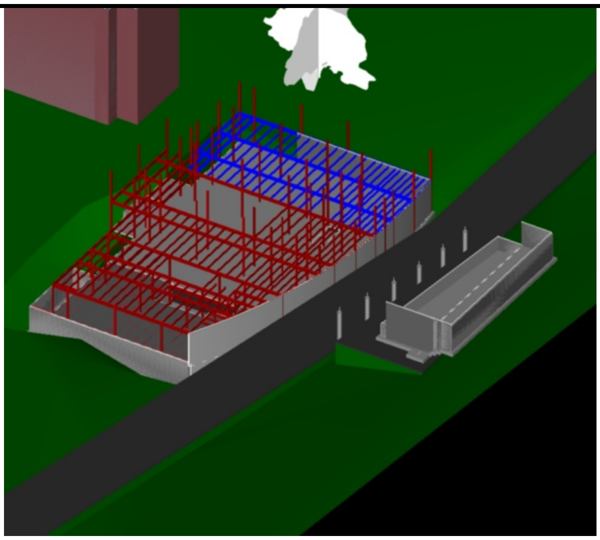


Figure 41: 2nd Floor beams, Z5 & Z6

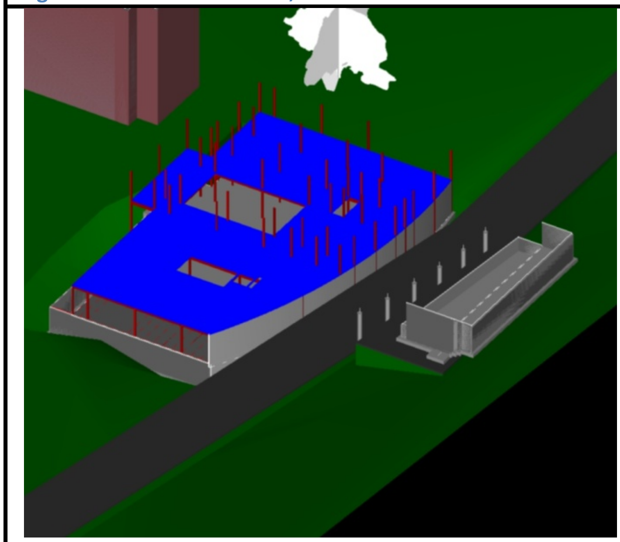


Figure 42: 2nd Floor Metal deck

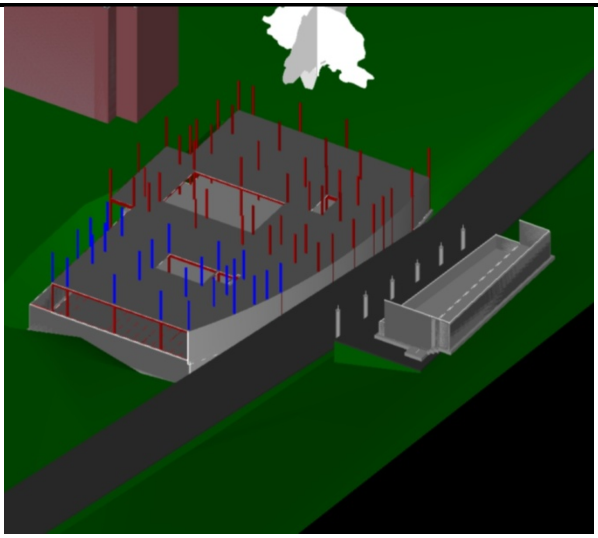


Figure 43: Columns 2nd to 3rd, Z1 & Z2

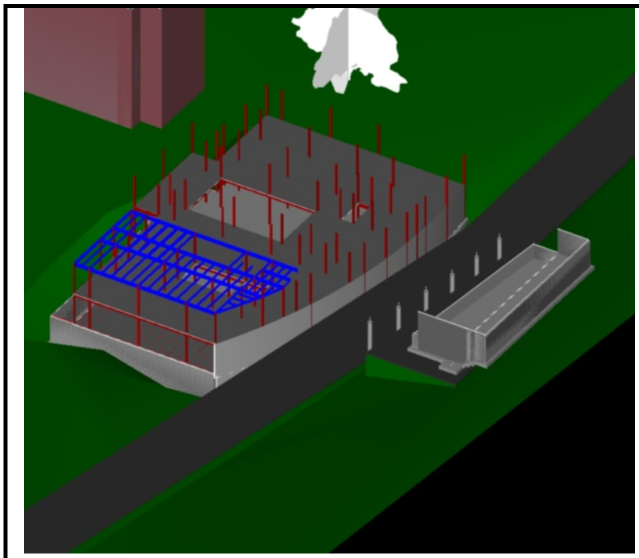


Figure 44: 3rd Floor Beams, Z1 & Z2

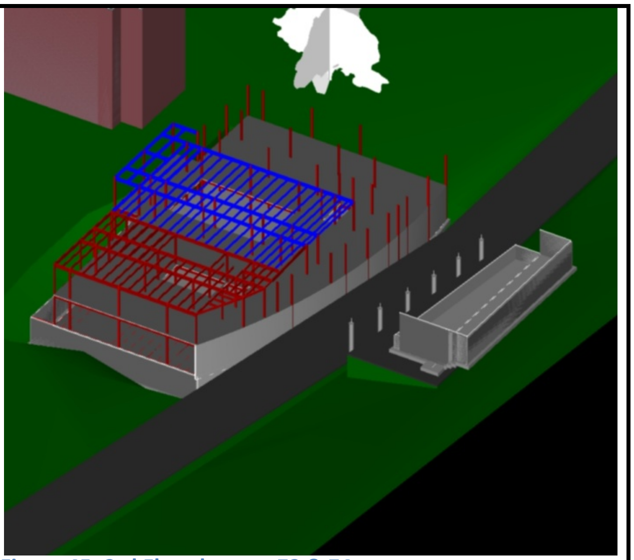


Figure 45: 3rd Floor beams, Z3 & Z4

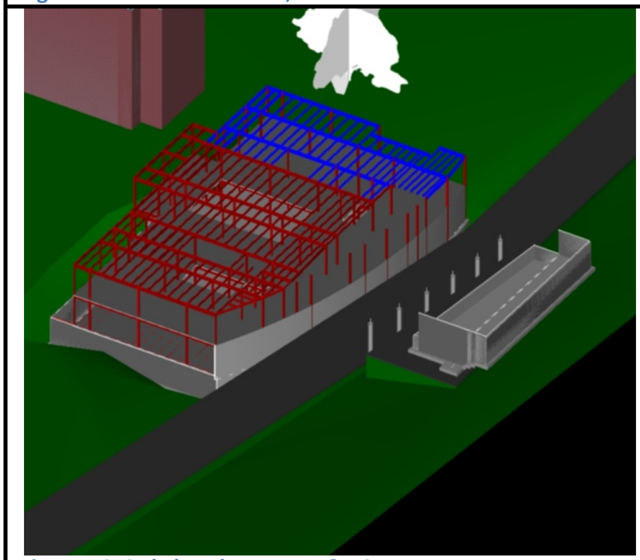


Figure 46: 3rd Floor beams, Z5 & Z6

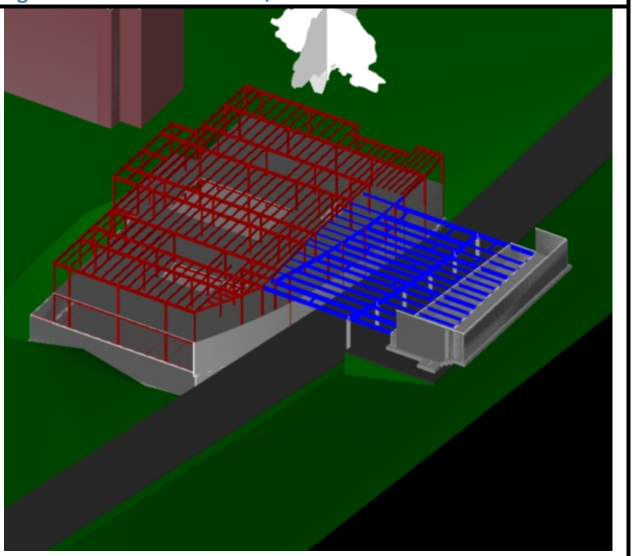


Figure 47: 3rd Floor beams, Z7 & Z8

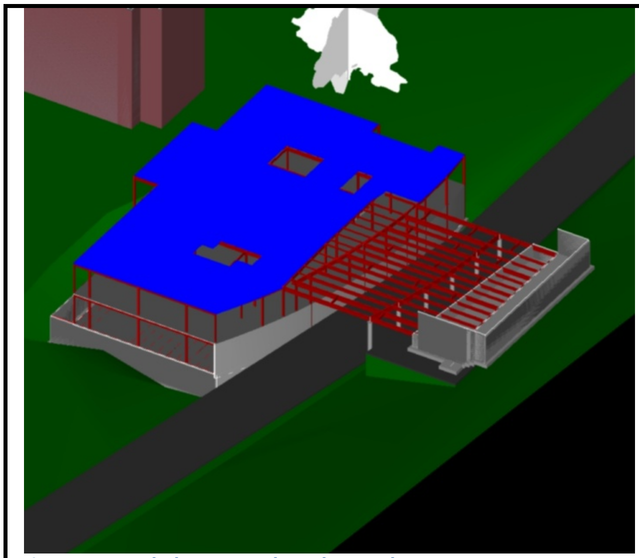


Figure 48: 3rd Floor Metal Deck, North

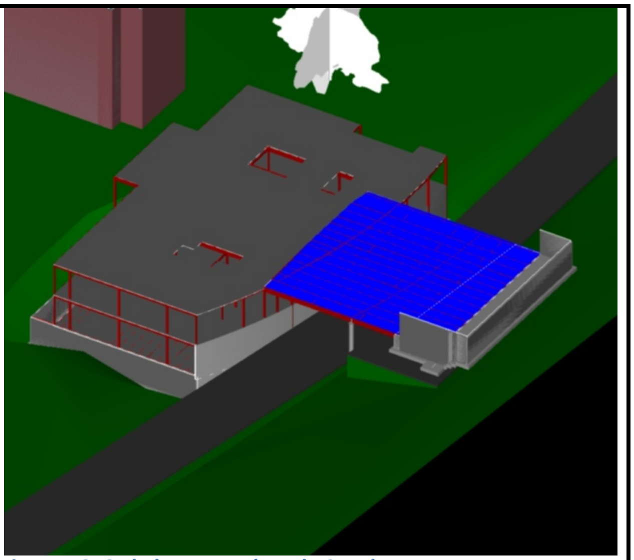


Figure 49: 3rd Floor Metal Deck, South

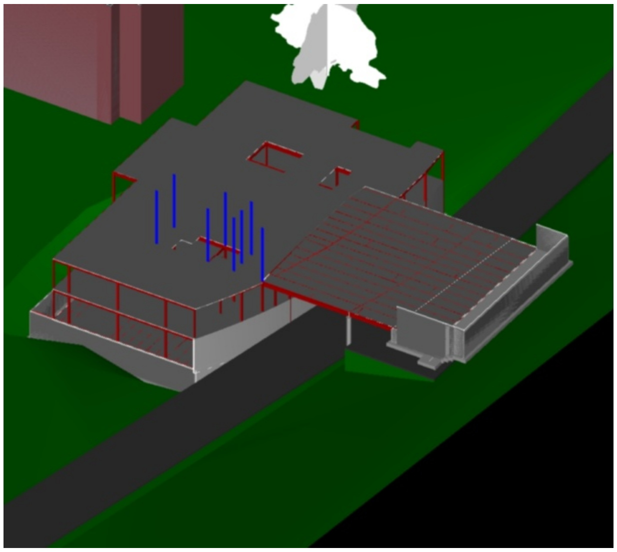


Figure 50: Columns 3rd to Roof, Z1 & Z2

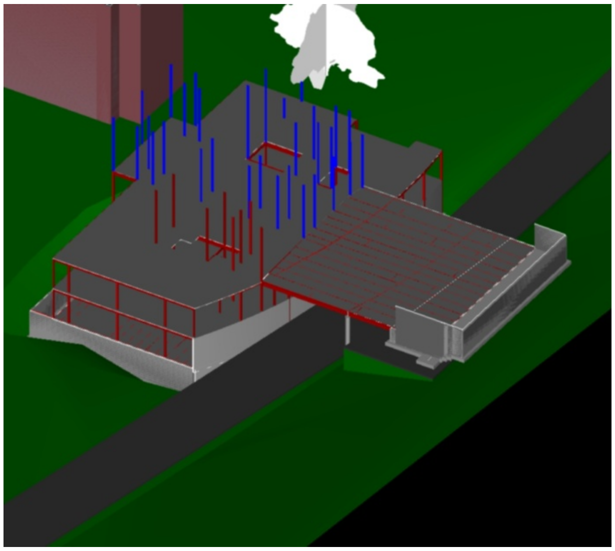


Figure 51: Columns 3rd to Roof, Z3 & Z4

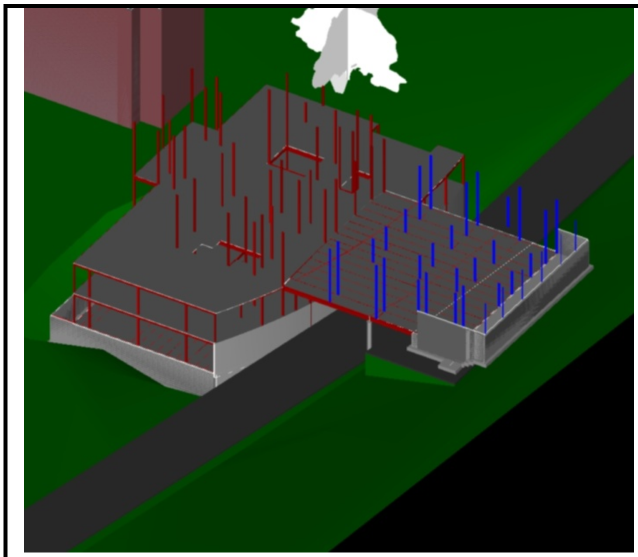


Figure 52: Columns 3rd to Roof, Z7 & Z8

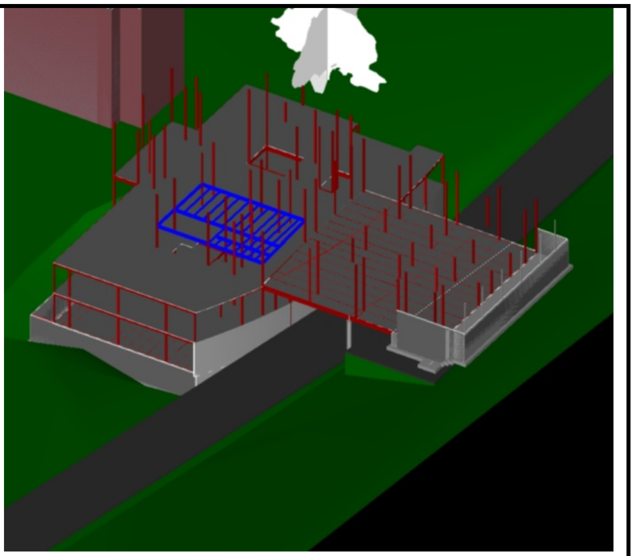


Figure 53: 4th Floor Beams, Z1 & Z8

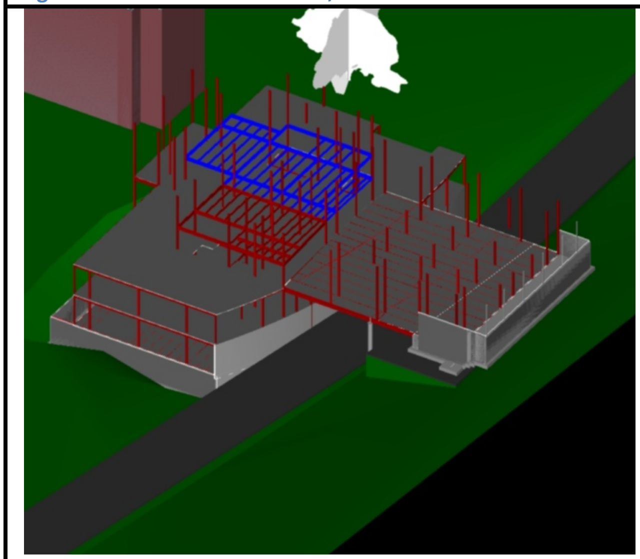


Figure 54: 4th Floor Beams, Z3 & Z4

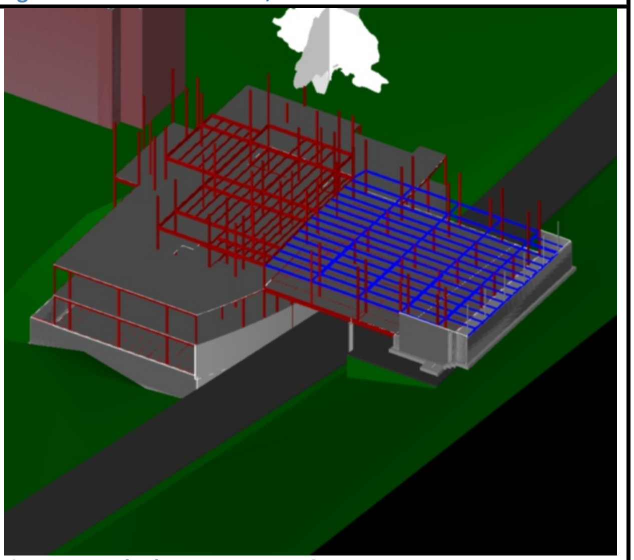


Figure 55: 4th Floor Beams, Z7 & Z8

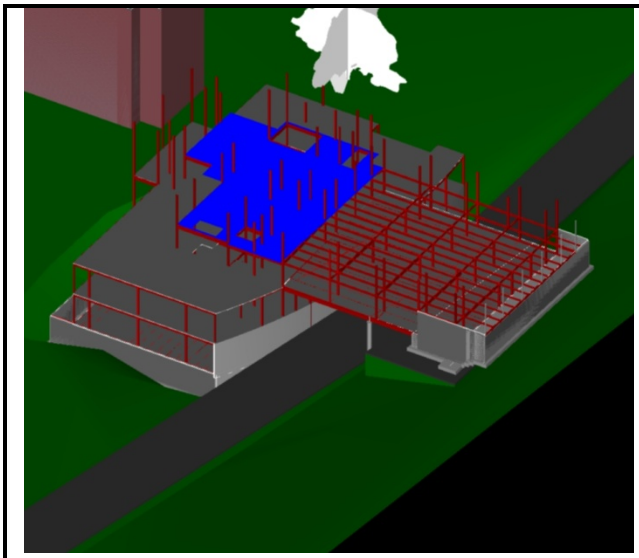


Figure 56: 4th Floor Metal Deck, North

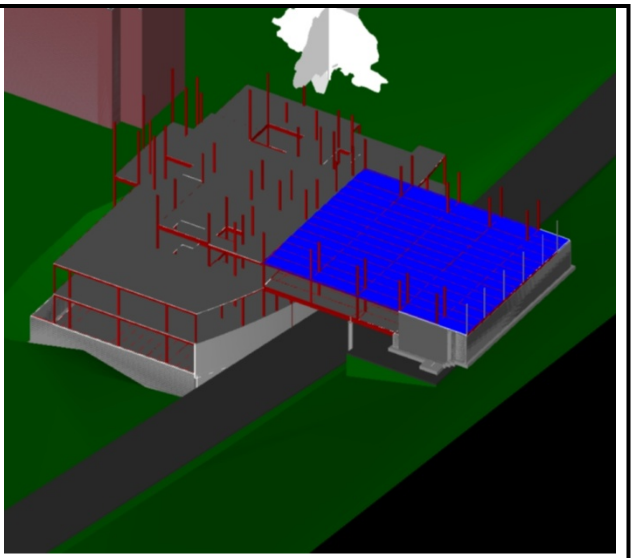


Figure 57: 4th Floor Metal Deck, South

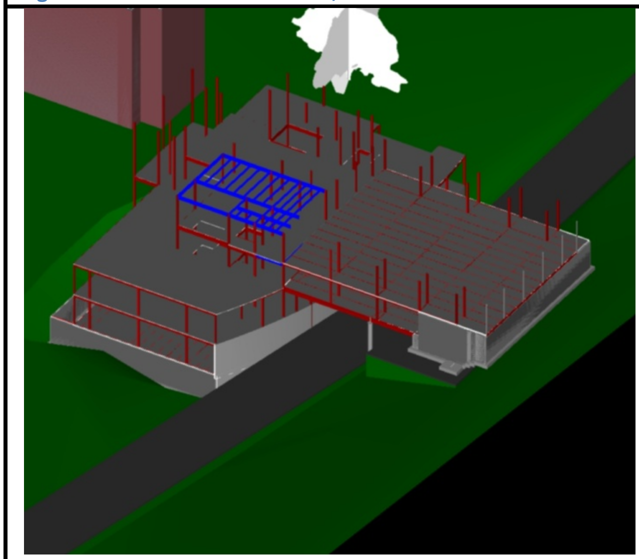


Figure 58: Roof Beams, Z1 & Z2

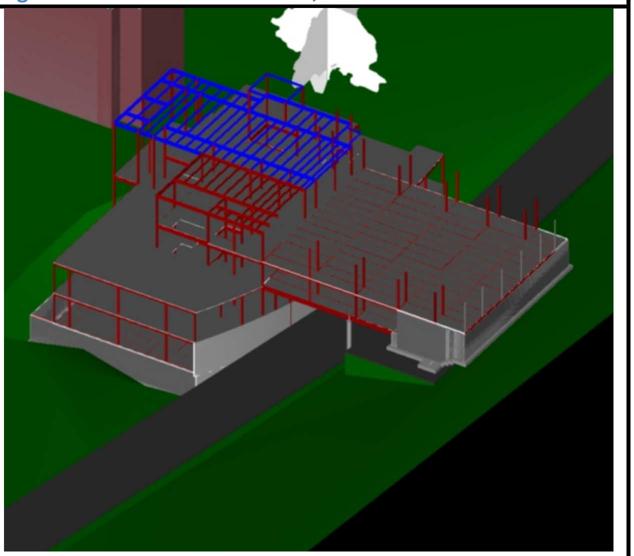


Figure 59: Roof beams, Z3 & Z4

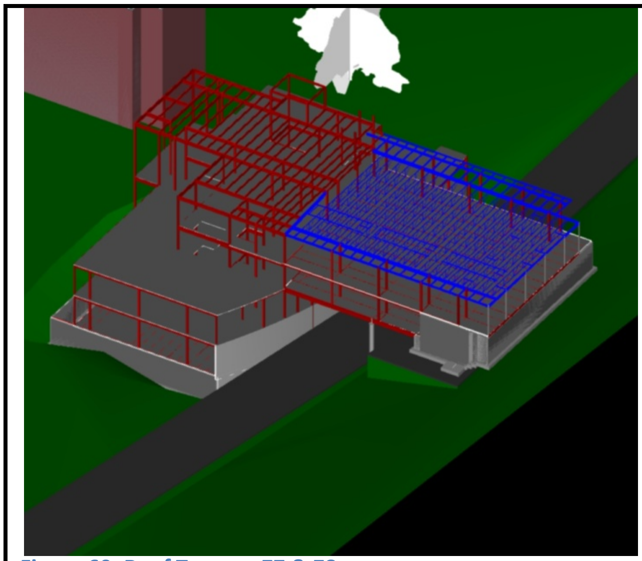


Figure 60: Roof Trusses, Z7 & Z8

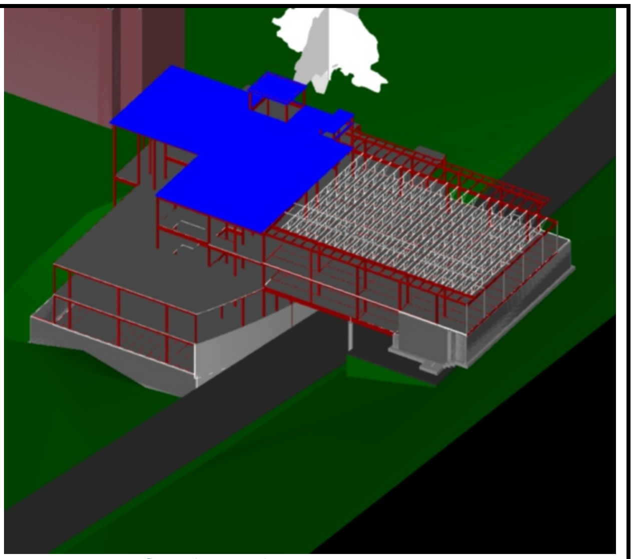


Figure 61: Roof Deck, North

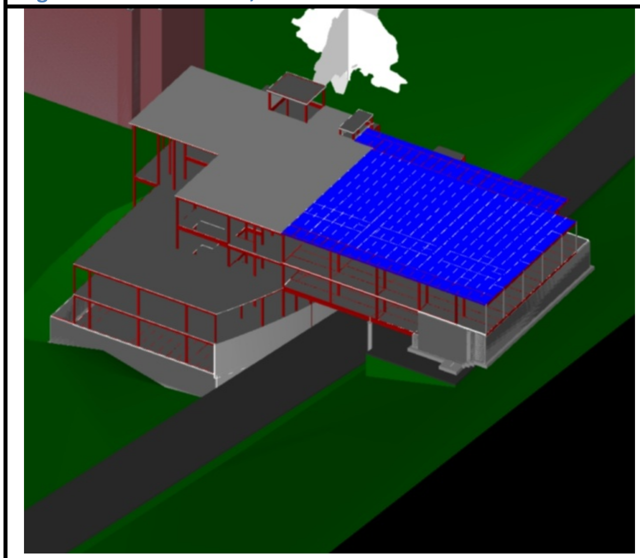


Figure 62: Roof Deck, South

General Conditions Savings

Note that the critical path schedule can be found in Appendix B

- Original Duration on Critical Path
  - 118 days = 23.6 weeks
- New Duration if entire structure lies on Critical Path
  - 68 Days = 13.6 weeks
- Savings
  - 10 weeks = $271,061 in Construction Manager General Conditions

Safety

As stated before, the safety of the on-site personnel and of the pedestrian students is a compensation criteria for the Integrated Project Delivery contract. Zero loss time injuries and zero pedestrian injuries can occur. The introduction of steel will present a few more safety risks to the project. Below is a list of safety concerns and brief remedial actions. A full safety plan should be developed by the site and safety design cluster.

- Fall protection
  - With steel erection, there is always the possibility of fall injuries. This site will be 100% fall protection at heights designated by OSHA standards. Equipment will be checked by foreman, and Barton Malow has the right to remove any employee not following OSHA Fall standard operating procedures.
  - Metal decking must be placed when scheduled to decrease the distance of fallen objects.
  - Temporary fencing will be installed on levels during erection sequencing.
- Fallen Objects
  - From bolts to tools, falling during steel erection can cause injury to pedestrians and workers.
  - All workers will wear hard hats, safety glasses, and reflection vests 100% of the time
  - Over head protection will be built on the north side of the safety fence to protect pedestrians
- Crane Picks
  - All crane picks will not exceed the crane limits for weight or boom extension
- Site traffic
  - Because of the tight site restrictions, all subcontractors must adhere to the site plan for the steel erection phase.
  - A clean site will prevent traffic incidents.
  - Day of delivery of steel members must be coordinated with the Superintendent on site.

Conclusion and Recommendation

Integrated project delivery allows the possibility of involving a steel fabricator early in the process, eliminating much of the procurement time and beginning fabrication earlier. This effectively allows the steel erection to begin at the same time as concrete would have with the original design. The steel also is not subject as much to weather conditions, in terms of curing issues. Weather would still have an effect on construction activities, but not as big an effect as it has on concrete. A possible acceleration scenario could bring a second crew and a mobile crane on to construct the south end of the building simultaneously as the north. This would though congest the site and add increase traffic. This analysis shows that a structural steel design would have a cost savings of $505,040 and save 2.5 months off of the critical path.

The structural re-design is to represent the basic layout and member sizing that would occur at the beginning stages of engineering. It gives a base for the engineer and subcontractor to build off of and would be the status of the design at the beginning stages of "Detailed Design" phase. Even if the structural steel members could not be manufactured ahead of time, there is a 2.5 month window in which they can be delayed (savings on critical path). The estimate that goes along with this structural design could be labeled with a few more refinements as the "Target Value Design" for the structural budget. This value would then be added to the overall Target Value Design, and written into the contract. This would be the basis for shared savings or shared risk at the end of the project. This provides an incentive to innovate ideas to accelerate the schedule to saving in General Conditions, design a more economical system, or other value engineering concepts. The shift toward incentives instead of bottom line will create a better product for the owner. This is the same for all aspects of an IPD project.

-BUILDING ENVELOPE STRATEGY-

PREFABRICATED MASONRY PANEL AND UNITIZED CURTAIN WALL SYSTEMS

Opportunity for Resolution

The longest durations on the schedule involves interior work to the building, approximately 11 months. Beginning this work earlier will ultimately shorten the overall project schedule, though the majority of this work cannot begin until the building is water tight. By examining the current construction schedule, the trade that drives the exterior façade is the installation of the exterior metal framing and sheathing, construction of the brick masonry walls, and the curtain wall installation.

Masonry wall construction can be a lengthy process, especially when using stick built scaffolding. Scaffolding needs to be inspected every time it is moved, and the actual installation of the brick requires extensive man-hours. The West Village Commons site is extremely tight, making material layout and scaffolding space limited. The installation of the exterior metal framing and sheathing must occur before masonry work can begin.

Integrated Solution

The aspects of IPD open the door to system prefabrication due to early contractor involvement. This is true for systems other than the exterior façade, such as main mechanical duct runs, unitized curtain wall panels, MEP connections to structure, or main mechanical equipment. The involvement of the structural engineer and a precast manufacture will allow a prefabricated masonry panel design to be engineered and detailed at the same time. The estimate will be more accurate, buyout and fabrication can occur earlier, and there will be no rework of the exterior architecture. The system will be design in coordination with the architect so that door, window, and other various room layouts can be coordinated. Main exhaust vents in the current masonry walls are limited, so coordination early can help dictate panel sizes.

This analysis will research the advantages and disadvantages of a prefabricated masonry panels, including cost differences, schedule improvements, schedule impacts on other trades, constructability issues, transportation planning, general conditions savings, and site condition impacts. Research for this project can be contributed to a phone interview with Jim Olsen of The Shockey Precast Group (Olson, 2010).

Advantages and Disadvantages

The following lists the advantages and disadvantages of prefabricated masonry panels.

Advantages

Figure 63: Brick masonry panels (The Shockey Precast Group, 2008/2009)

- New manufacturing techniques allows for all types of patterns, colors, and courses. Shockey Precast has had architects and owners visit who cannot tell the difference between hand laid brick and precast panels. Figure 64 is an example of a parking structure that used masonry panels.
- Extremely fast erection time. Many manufacturers, such as Shockey, erect panels as well, allowing for a sole contractor. Figure 65 is a diagram of a comparison to brick and block traditional method.
- Cast in a controlled factory environment, unaffected by temperature.
- Silica fume, fly ash, and slag cement are considered green products that can help accumulate LEED points (IPD Incentive Goal).
- Durability of the system allows for a longer life expectancy with proper maintenance.
- There is no mortar used and the brick tiles are thin and dense. This minimizes the risk of water infiltration, freeze/thaw cycle, and almost no susceptibility to efflorescence.
- Staging area can be directly off of the delivery truck. West Village has little layout area to begin with, so this greatly reduces site congestion.
- Labor costs are reduced.
- Can be designed so no overhead welding occurs (increased safety and efficiency).
- Low Maintenance needs.
- Insulation can be installed in the factory and erected as one material
- Little wasted materials
- Curved shapes can be created (such as the wall facing the road passing under the south end of West Village Commons).

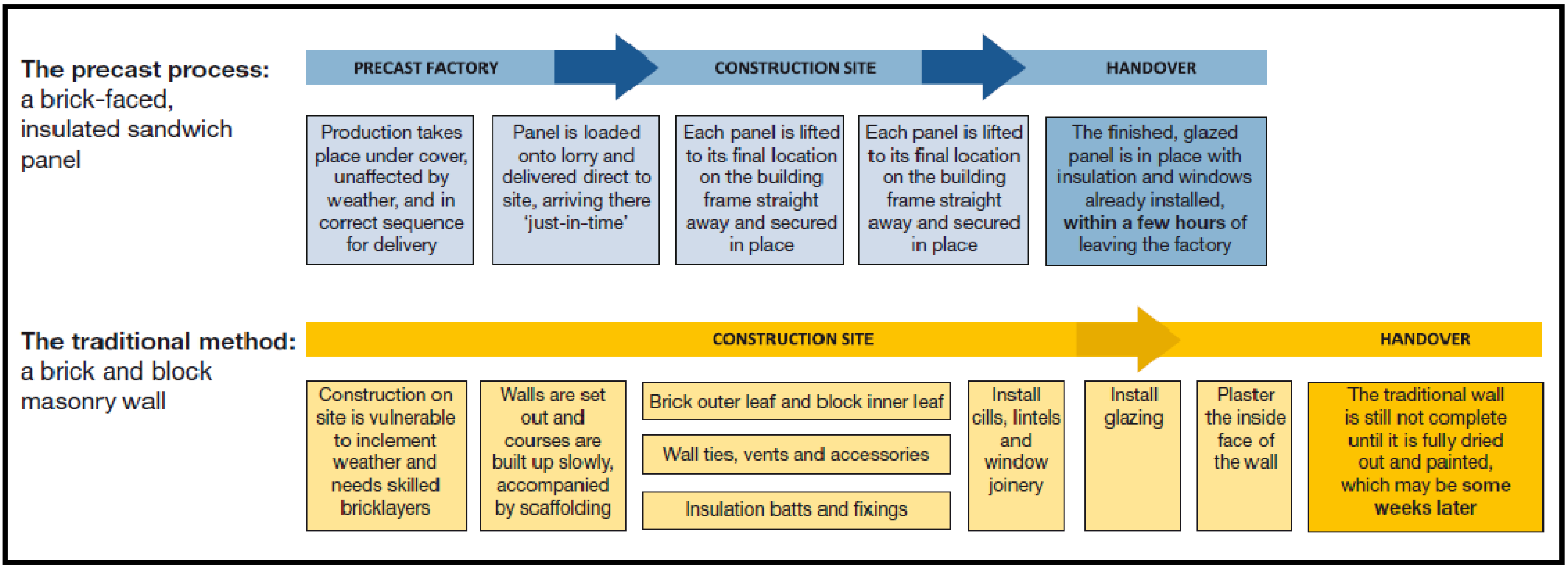


Figure 64: Installation process for Precast Masonry and Brick and Block (Architectural Cladding Association)

Disadvantages

- Panels are a heavier construction material, increasing the size of exterior beams and foundations. Brick is 125 lbs per cu. ft. and masonry panels are 155 lbs per cu. ft.
- The material is more expensive than brick blocks.
- The procurement time can make the use impossible.
- Trucks are limited to 8' tall, 8' wide, 40' long, and a weight limit of 8 tons. If the truck exceeds this amount, special permits will be needed.
- Transportation in general can be complicated if the route goes over bridges, multiple states, etc.
- Long transportation from factory to site is unsustainable and costly. Damage during transportation could cause delays in productivity.
- There is a need for a crane which will cost money.
- Panel size, shape, and orientation could dictate window, door, and other penetration locations.
- Bracing during onsite construction (though Shockey Precast states that they use bolted connections for temporary bracing then follow up with permanent welds).
- There is limited design flexibility in some instances.

Cost

The advantages clearly outweigh the disadvantages of using the masonry panels, but do the upfront costs of materials pale to the speed of construction? A cost and schedule comparison needs to be made to prove that the use of prefabrication in this instant is appropriate. Appendix G is a complete take-off of the brick façade for the entire building. The panels are designated first by the elevation (ex. E for east elevation), then by zone number (see Figure 65 to Figure 68 for zone designations), and then by a letter. For example, the "A" panel for zone one of the east elevation is labeled "E1A." This labeling system is seen in Appendix G and on the zone figures below. The cost information was provided by the Barton Malow Company estimating department.

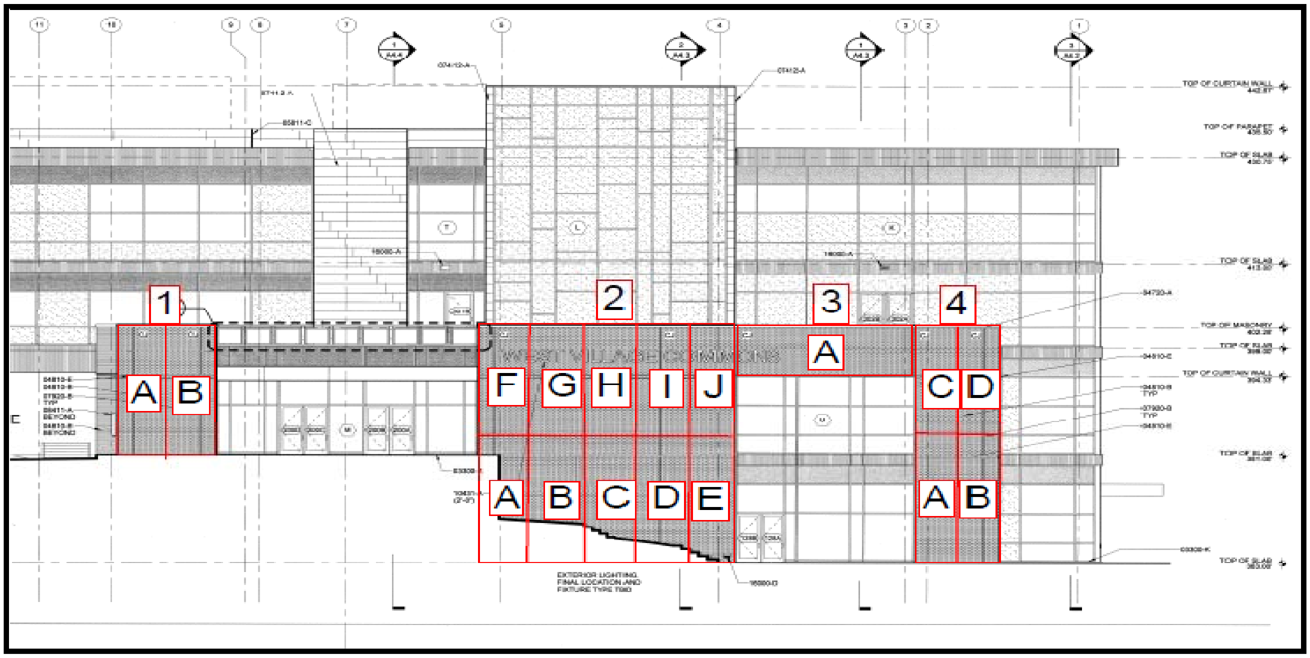


Figure 65: East Elevation Panel Designations

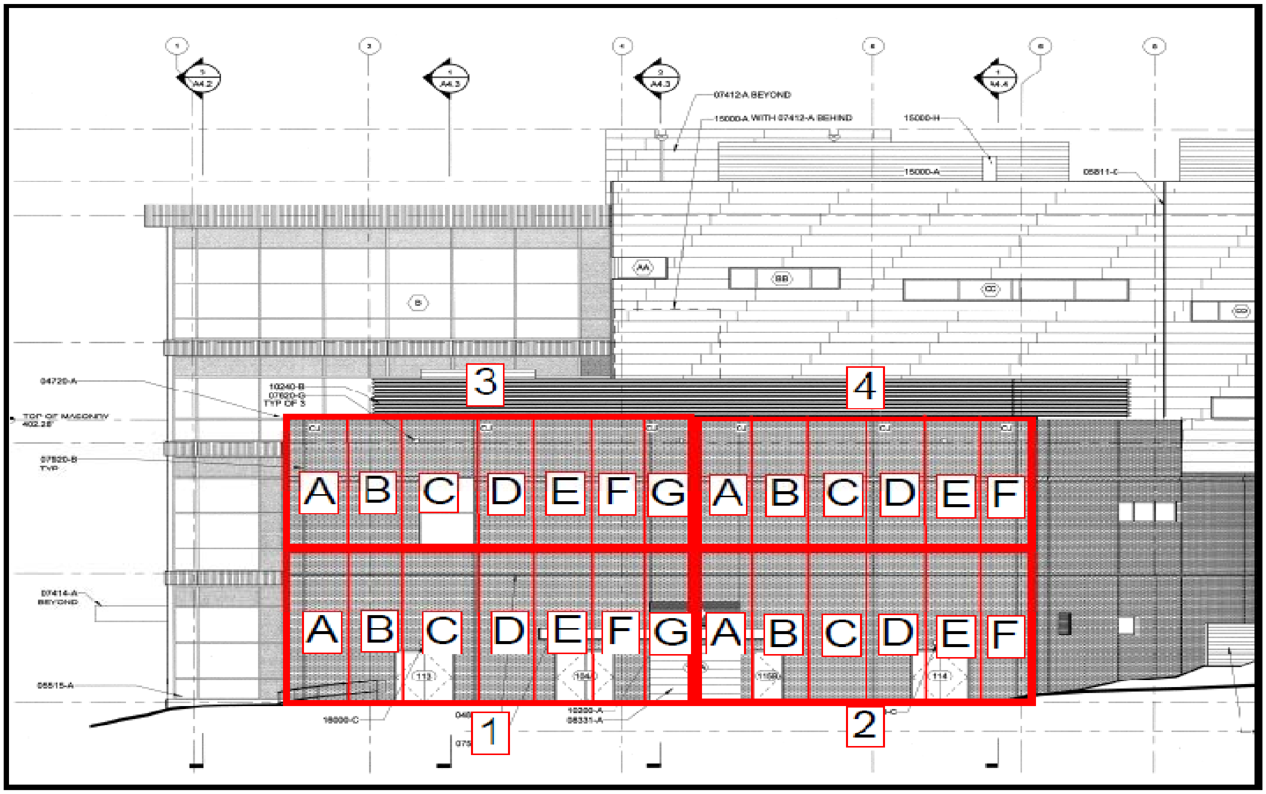


Figure 66: West Elevation Panel Designations

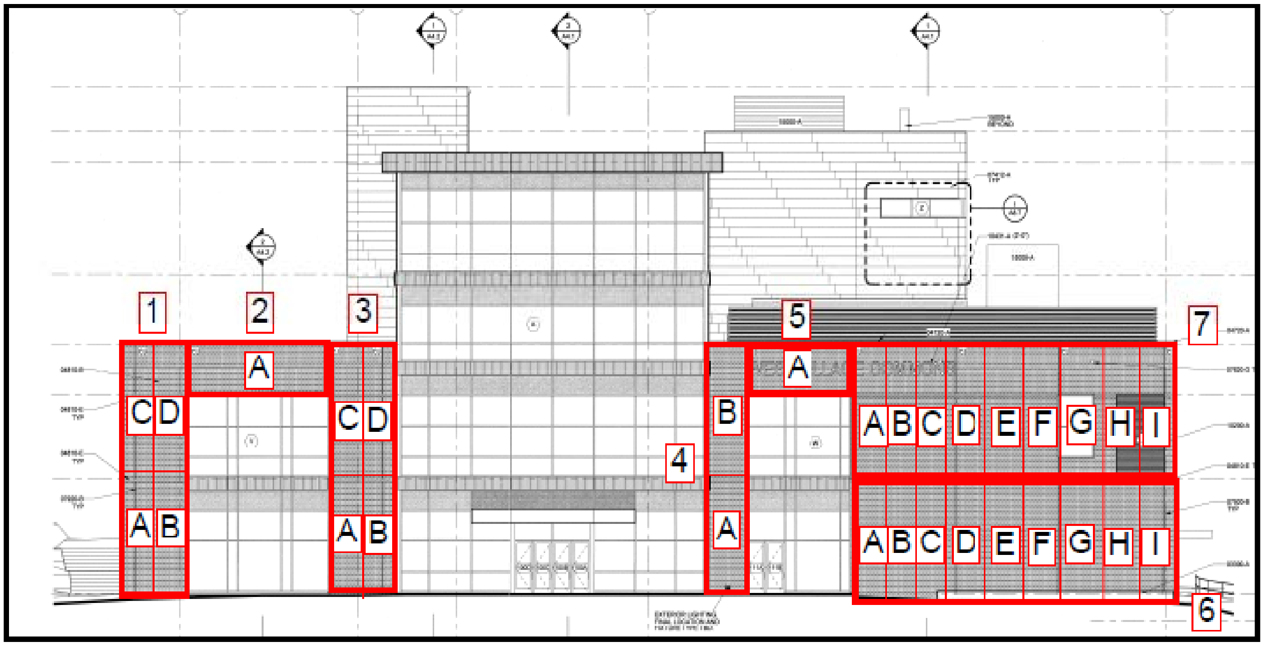


Figure 67: North Elevation Panel Designations

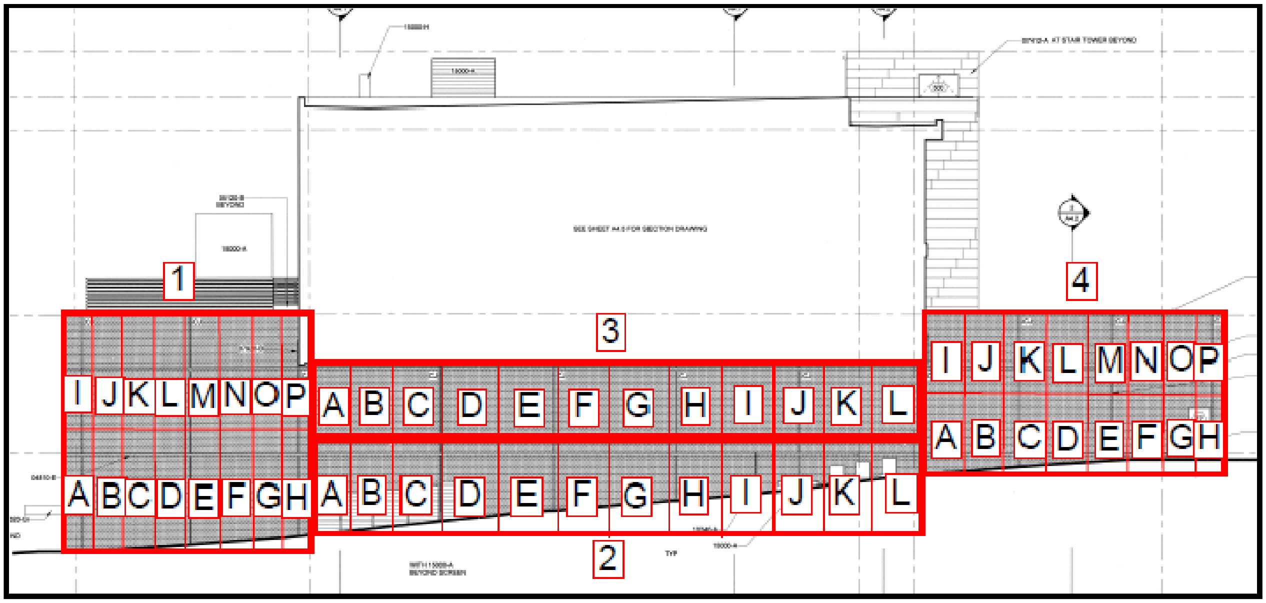


Figure 68: South Elevation Panel Designations

Table 4 is a take-off and estimate of 4" brick block masonry and 7" precast masonry panels.

Façade Construction Costs									
System	Elevation	Unit	QTY	Thickness (in)	Cubic Feet	Unit Wt	Total Wt (tons)	Cost ($/Unit)	Total Cost ($)
7" Normal Wt Precast Concrete with Thin Brick Veneer									
	East	SF	2,180	7	1,272	155 pcf	99	$55.00	$119,900.00
	West	SF	2,993	7	1,746	155 pcf	135	$55.00	$164,615.00
	North	SF	3,472	7	2,025	155 pcf	157	$55.00	$190,960.00
	South	SF	4,969	7	2,899	155 pcf	225	$55.00	$273,295.00
		Total	13,614	Total	7,942	Total	615	Total	$748,770.00
Regular Masonry Face Brick, 4"									
	East	SF	2,180	4	727	42 psf	46	$24.00	$52,320.00
	West	SF	2,993	4	998	42 psf	63	$24.00	$71,832.00
	North	SF	3,472	4	1,157	42 psf	73	$24.00	$83,328.00
	South	SF	4,969	4	1,656	42 psf	104	$24.00	$119,256.00
		Total	13,614	Total	4,538	Total	286	Total	$326,736.00

Table 4: Facade System Construction Costs

Discussion

The cost of the precast masonry system has many upfront costs associated with it - there is $422,000 difference in material price. A closer look at the critical path schedule will have to generate significant savings for the masonry panel system to be appropriate. There are some attributes that will still contribute to cost savings. First they are an extremely durable material, cutting down on lifecycle maintenance costs. Secondly, the material is virtually water-proof, lessening the need for moisture protection found in cavity walls. Efflorescence will not occur, again lowering maintenance and clean up costs. The other side of the coin though, is the increase in exterior beam sizes, and possibly footings. Precast masonry panels are about 25 pcf less than normal weight concrete. Only after a schedule analysis will it be clear if masonry panels should or should not be used in this situation.

Schedule

The ultimate savings associated with precast masonry panels will be with schedule savings. Table 5 shows the durations for both the brick masonry wall and the precast masonry wall. The duration output for the masonry panels was given by Jim Faust, faculty advisor (approximately 1 per hour to stay conservative). The masonry wall duration comes from *RSMeans Cost Data* and is compared with the original scheduled duration by Barton Malow.

As it shows, there is almost a 13 week schedule savings by using the precast panels, though not all of the brick masonry wall is on the critical path. Taking a look at the critical path schedule provided by Barton Malow (unable to publish), only 17days occur on the critical path (3 weeks). The exterior perimeter metal framing and sheathing can be taken off the critical path, because the masonry panels can be installed independent to the metal framing. The roof system and all interior work on the critical path may also begin earlier, effectively shortening the entire schedule down the line. There is a total of 70 days (14 weeks) on the exterior metal framing, of which 70% relates to the masonry walls and 30% to the metal panels. Therefore approximately 47 days will be saved on the critical path for the metal framing for masonry. Between the masonry wall and exterior metal framing schedule savings, it is safe to assume that a total of 48 days (2.4 months) will be saved off of the critical path. With the general contractor alone, this equates to $260,218 in general conditions savings and $7,806 in mark-up fee (assuming 3%).

Duration					
System	**Elevation**	**Duration Unit**	**Qty**	**Daily Output per Unit**	**Duration**
7" Normal Wt Precast Concrete with Thin Brick Veneer					
	East	# of Panels	17	8.00	2.1
	West	# of Panels	26	8.00	3.3
	North	# of Panels	30	8.00	3.8
	South	# of Panels	56	8.00	7.0
		Total	**129**	**Total**	**16.1**
Regular Masonry Face Brick, 4"					
	East	SF	2,180	215	10.1
	West	SF	2,993	215	13.9
	North	SF	3,472	215	16.1
	South	SF	4,969	215	23.1
		Total	**13,614**	**Total**	**63.3**
				BMC Duration	**80**

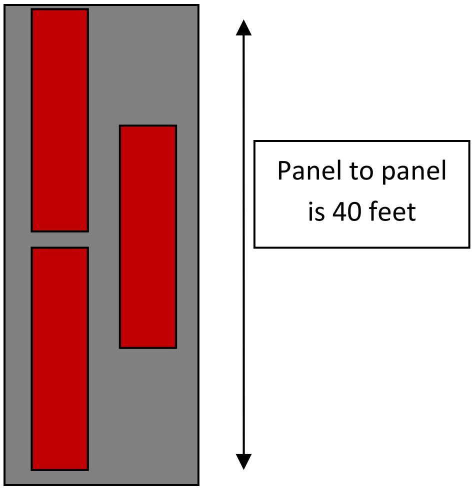
Table 5: Masonry Wall and Precast Masonry Panel Durations

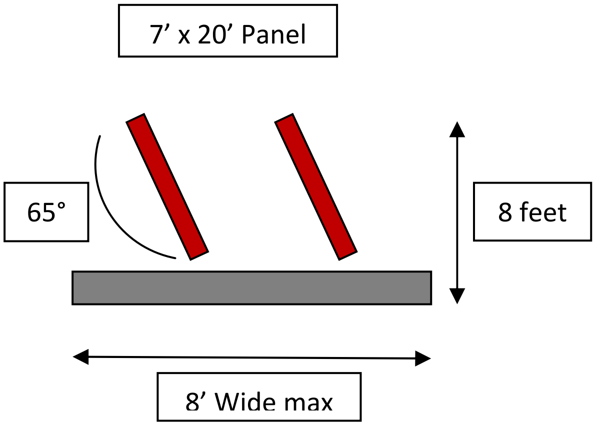
Transportation Impact

Transportation of the precast panels has a major impact in cost (the costs in Table 4 take transportation into account), and can be a deal breaker on whether or not to use precast panels. It is important to maximize the amount of panels that can be transported per truck. To transport the panels without the need of a special permit, the size of the truck bed must be 8 feet wide by 8 feet tall (off the bed) by 42 feet long. The load on the truck must also be below 40,000 pounds (8 tons). The panel sizing took great care to keep this in consideration, with the aim of fitting three panels on the majority of the trucks. The drawings below show the layout for the most typical panel sizes, 8' x 20', and when angled at 65° two panels can fit next to each other (each panel only takes up 3' wide). Two 20' panels can be placed next to each other to fit on the bed. The total weight of three of these panels (7" thick at 155 lbs per cu. ft.) is 37,975 pounds (less than the required 8 tons).

Not all of the panels will be able to fit three at a time, especially the more unique pieces. An attempt was made to standardize as many of the pieces as possible to keep price down. There are 129 pieces in total, which will take approximately 45 to 50 truck loads when taking the larger pieces into account.

The use of these panels may have an impact on LEED points, though there is a possibility it may be a trade off. There are only a few plants in the Mid-Atlantic region that can serve the Baltimore area, possibly eliminating it as a regional material. Though the recycled content used to produce the panels could reclaim some LEED value.





Site Impact

The current plan for the brick masonry wall construction requires ample space for scaffolding and material layout. The site as mentioned before is already tight to the limit of disturbance. Special permission from Towson was needed to move the site fence out in the north area so that scaffolding could be erected. The use of brick masonry could cause congestion and inefficient progression.

Precast masonry panels do not require scaffolding or layout space, as the material can be lifted right off of the truck. The connections can be made inside the building after the structure is complete. Bolted connections are made and then the erection crew can move on to the next panel. A second crew follows to plumb and weld permanent connections. Very little material is needed to make the connections, allow other MEP trades ample room for material layout and workspace. The construction itself does not require many laborers. The tower crane will be utilized for the East, North, and West Elevations, but a mobile crane or lift will be needed for the south. The bridge structure above will prevent the tower crane from reaching that area. Truck access and exit will be the same as steel erection, entering the site from the east and exiting to the west on Emerson drive. Deliveries will need to be closely coordinated with the superintendent as there is only one road through the site.

Summary and Recommendations

The schedule savings by using precast brick masonry panels is significant, almost two and a half months. The intangible schedule savings can be seen by earlier work on the interiors beginning, which was not quantified. Other unquantifiable advantages are the ease of construction, the safety in installation, the decongestion of the site, the durability and lifecycle of the material, the increased moisture and thermal protection, the sustainable material used, and the lack of waste generated.

The downside to using precast masonry panels is closely regarding the cost. It will cost $154,010 more to construct the masonry panels as opposed to the block construction. This cost though is missing the savings that could be utilized on the interior. Other rough-in trades on the critical path can begin earlier, speeding the work to complete for the interior. Transportation impacts on the sustainability in construction can also be a turn off for using the precast.

This analysis shows a trade off for using the precast panels, and would ultimately be up to the owner's goals. If this project was aiming to be completed earlier, the added cost may pale in comparison. A deeper analysis into the entire façade system could prove a break even or positive value in terms of cost. Currently, the other two façade systems are not prefabricated; the curtain wall is stick built and the metal panels are installed sheet by sheet. The curtain wall in particular has a long duration on the critical path, approximately 15 weeks. A prefabricated unitized system could easily speed the construction process up. The same goes for the metal panels; larger prefabricated sheets would be more efficient. The speed of installation would, like the precast panels, allow for interior trades to begin earlier. With early contractor involvement, this could be possible. If these systems are shown to give a break even value at the least, the recommendation would be to use the masonry panels, unitized curtain wall, and larger metal panel construction. If the owner has an incentive for completing the project earlier, than precast panels is still great option. If either of these two scenarios are not the case, then brick block construction would be the best means of construction.

Impact of Integrated Project Delivery

This analysis is a great example of how Integrated Project Delivery can increase the value of the project to the owner. For instance, on a project where precast panels would show a savings in material costs and general conditions cost, there is little incentive for a contractor to suggest this means of construction. If the schedule of the project already meets the owner requirement, and there is not a shared savings clause, there is very little incentive to suggest the panels. A decrease in general conditions and material costs lowers the mark up the contractor receives. In a traditional cost plus fee contract, there would not be a reason for the contractor to suggest this as a value engineering option if they will lose profit. With IPD, there is a monetary incentives to deliver the project below the target value cost; part of the percentage fee will be based on cost and schedule goals.

-ENERGY REDUCTION STRATEGY-

WEST CAMPUS UTILITY PLANT

Opportunity for Resolution

Towson University's campus utilities stream from a central plant on the east side of campus. Electric, steam, and cooling systems are produced by this plant, but age is beginning to take a toll on the old system. Renovations, upgrades, and retrofits are in the process of being designed, as well as additional building specific upgrades. The plant has maxed out its capacity forcing further expansion of the campus to seek other means of heating, cooling, and electrical needs. West Village was deemed too far from the center of campus to be considered part of these new utility designs. The new buildings in West Village will have to have their own utility production, diminishing chances to utilize efficient energy production.

Central utility plants have become a trend on college campuses around the country due to the rise in energy costs. Texas A&M University uses 4,400 ton central plant that houses three 1,100 ton chillers and two 8.4 million btuh domestic water generators. The plant has shown dramatic savings in utility costs and simpler maintenance operations (Ball, 2008). Clark University utilizes a cogeneration plant that they call the Clark Integrated Community Energy System (ICES) to generate electricity. 35% of the energy is used for electricity and another 34% is recaptured in the form of heat exhaust used to create steam and hot water; the savings amount to around $250,000 a year (Clark University, 2010).

West Village Commons, as well as West Village is missing out on a great savings in utility costs by not constructing a "West Village Utility Plant." This energy breadth will attempt to compile the energy needs of the surrounding apartments and of the commons, calculate current energy costs, and make a comparison to a similar campus setting. Shippensburg University explored the idea of using a Central Utility Plant for heating and cooling and can be used as a case study. The main criteria for recommending the use of a utility plant will be based on the savings that Towson University could gain versus the upfront costs of construction. Because the key members are brought to the design table around the time West Village is being designed in its entirety, a proper analysis could be made with the IPD team.

West Village Utility Data

Table 6 is a calculation of cooling and heating requirements for the apartments and for the commons. The calculation is based on an HVAC rules of thumb manual, *HVAC: Equations, Data, and Rules of Thumb,* written by Arthur A. Bell, Jr. PE, and published by McGraw-Hill (Arthur A. Bell, 2000). For West Village Commons, cooling requirements were calculated from current drawings, but heating requirements used the btuh/Sq.Ft. estimate. The reason was because the current system has two 3,000 MBH boilers for efficiency and just in case one fails. This analysis still needed the heating requirement for the building.

Heating and Cooling Requirement								
		Cooling Requirement Estimation					Heating Required	
Building Name	Square Footage	Btuh/Sq.Ft.	Btuh required	Sq.Ft./Ton	Tons of Cooling Req'd	Tons Rounded	Btuh/Sq.Ft.	MBH Required
Paca House	78,135	31	2,422,185	400	195.34	200	35	2,735
Tubman House	81,048	31	2,512,488	400	202.62	200	35	2,837
Phase II East	73,696	31	2,284,576	400	184.24	200	35	2,579
Phase II West	85,540	31	2,651,740	400	213.85	200	35	2,994
Phase III A	75,000	31	2,325,000	400	187.50	200	35	2,625
Phase III B	75,000	31	2,325,000	400	187.50	200	35	2,625
Phase IV A	78,000	31	2,418,000	400	195.00	200	35	2,730
Phase IV B	78,000	31	2,418,000	400	195.00	200	35	2,730
West Village Commons	85,000		3,535,000		300	300	35	2,975
Total	**709,419**		**22,891,989**		**1,861.05**	**1,900**		**24,830**

Table 6: Utility Requirement

The current apartments have two 12,000 MBH hot water heaters each and in-closet variable refrigerant volume units. These units are very inefficient in the use of electricity. The commons, as can be seen in Technical Assignment 1, utilize two 3,000 MBH boilers and one 300 ton chiller. After talking to the mechanical engineer on the project, West Village would be a great candidate for a Utility Plant because the peak capacities for cooling of the individual buildings would probably not occur at the same time. The apartments would have a higher capacity in the morning and night, while the commons would have maximum capacity occurring during normal business hours. The diversity of the system would allow for a reduction in cooling required. While an attempt was made to calculate this reduction, energy models for all of the apartments was not possible. Very little information was available for this project.

To infer an idea of what time of system would be appropriate for West Village, a similar situation was sought to compare as a case study. Shippensburg University (Entech Engineering, Inc., 2008) underwent a study to decide how to handle their campus expansion. The University was adding approximately 2 quads of residence halls (total of 2,800 students) and a dining facility. While the square footage of the additional buildings could not be found, the two residence hall areas were sized for two 1,500 ton chillers. Shippensburg also calculated data to build a new gas fire, hot water plant with three 75,000 lb/hr boilers (the third acting as a spare).

West Village Utility Plant

Using Shippensburg University as a guide and the cooling and heating requirements of the buildings, the following is recommended to be explored for a new West Village Utility Plant.

- Cooling
    - Central Chilled Water System
    - Three 900 ton chillers to be run at 75% each. Two chillers would be able to handle the load if one were to go down.
- Heating
    - Three 12,000 MBH rated hot water boilers running on natural gas

This plant would be a starting point for a deeper energy analysis. Natural gas was chosen at it has one of the lowest cost compared to other energy sources, as can be seen in Figure 69.

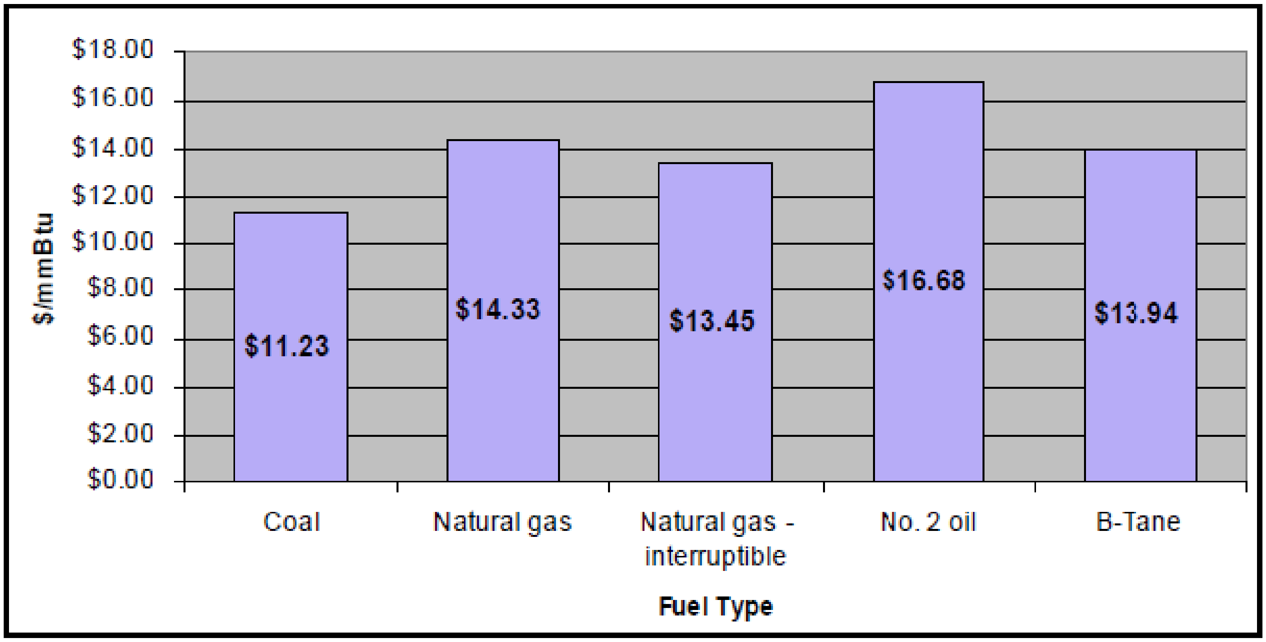


Figure 69: Fuel Cost Comparison (Entech Engineering, Inc., 2008)

Operating Cost

This portion of the analysis proved to be difficult to quantify. Utility bills for another dining commons on Towson's campus was used to estimate natural gas costs for the West Village Commons. The yearly natural gas cost of Glenn Dining Hall was $124,921, which when taken as a $/Sq.Ft and applied to West Village Commons equates to a natural gas cost of $332,272. The same process was used for electricity, which equaled $368,303 a year for West Village Commons. An attempt to acquire utility costs for a typical apartment on campus was made, but the 3rd party property manager could not submit enough data to draw a plausible conclusion.

The issue found when trying to calculate energy savings is that there was no way to separate the natural gas or electricity costs for just heating and cooling without a complete energy building analysis. An energy analysis for the apartments was not possible for reasons stated above. To draw some conclusion on operating savings, Shippensburg University will again be used as a comparison as it is a similar to West Villages Situation. This cost and operating data will be higher than what it will cost West Village to implement a central utility plant, as Shippensburg's plant was designed to be larger. The analysis believes that the plant would save approximately $400,000 to $500,000 a year in operating expenses, and in initial upfront costs of a decentralized system

Shippensburg estimated the following data:

- New Gas hot water
  - Construction cost – $13.1 million
  - Annual Operating cost - $2.0 million
- Central Chilled Water
  - Construction cost - $16.8 million
  - Annual Operating cost - $0.74 million
- Total Cost
  - Construction cost - $29.9 million
  - Annual Operating cost – $2.59 million

This cost and operating data will be higher than what it will cost West Village to implement a central utility plant, as Shippensburg's plant was designed to be larger. The analysis believes that the plant would save approximately $400,000 to $500,000 a year in operating expenses, and in initial upfront costs of a decentralized system. Operating savings derive from the efficiency of larger pieces of equipment and from the diversity of the system. Peak capacities of the buildings are reached at different times, so the total system can be designed for a lower total load, and operate at a more efficient level. The operation and maintenance of a utility plant will also cost less as there are less pieces of equipment compared to a decentralized system, and less workers needed to operate the system.

Location

Several considerations for where to place West Village Utility Plant need to be taken. First of all the noise that the plant will produce will either need to be mitigated or the location of the plant must be far enough away not to disturb residence and commons operations. A second consideration will be the cost of construction; what location will minimize the addition of infrastructure to support the Utility Plant. The third consideration will need to take green space into account; which location will maximize green area and minimize environmental impact. Three options for layout are shown in Figure 71.

Figure 70: West Campus Utility Plant possible locations

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- Location 1 - Connect as part of New West Village Commons
  - Minimizes new facility shell construction
  - Minimizes environmental impact
  - Decreases architectural appeal of commons if added on exterior
  - Increase in noise mitigation requirements to commons
  - Increase construction cost of commons
  - Central location to apartments, decrease distribution, decrease friction and thermal loss
- Location 2 – Connect to proposed Parking Garage
  - Minimizes new facility shell construction
  - Minimizes environmental impact
  - Architectural appeal of parking garage diminished but may not matter

  - Decrease in noise to apartments and commons
  - Increase cost to parking garage
  - Decrease cost to facility shell construction
  - Minimizes environmental impact
  - Increase cost to distribution
- Location 3 – Stand alone structure
  - Zero increase to other building cost
  - Large environmental impact
  - Minimizes noise to other West Village structures
  - Diminished architectural appeal of green space
  - Increase distribution cost

The location that is recommended is location 2, connection to the Parking Garage. The parking garage will need to be constructed earlier than planned, but this area will minimize noise and environmental impact. Because green space is of significant importance, location 3 should not be used. Towson wants this area to remain intact to decrease campus sprawl. Using West Village Commons is a viable option, but it will diminish the architectural value of that particular building. Noise mitigation will be an issue, and because this is to serve as the architectural highlight of the area, a utility plant would ruin the vision for the area. Construction of the distribution system will be a major cost, but the commons is the most central location. This could significantly decrease the overall cost of using a Utility plant.

Summary and Recommendations

This analysis proved to be the most difficult to conduct for several reasons. First it was hard to obtain information for the surrounding apartments to conduct a full energy analysis. Second, an estimation using utility data to calculate operating costs was vague. The commons natural gas and electricity costs do not fully contribute to heating and cooling. Electricity is used for a wide range of needs in the Glenn Dining Hall, and natural gas is also used for the kitchen equipment. Because of this, a comparison to a similar university situation proved to be a good assessment of what West Village could accomplish. Towson will be operating the buildings throughout their entire lifetime, so there will be a return on the initial investment.

The theme of this thesis project was to not only improve the value of West Village Commons, but also the West Village area. Through shear research it can be seen that a Central Utility plant will significantly decrease the operating costs for West Village. The upfront costs though are significant. There are a few other means in which to decrease this cost. First, the state of Maryland offers incentives to energy efficient mechanical system. This could lower operating costs or upfront costs of the construction. Second, the budget for mechanical systems in the individual buildings will be reduced, lowering their construction costs. If Towson is expecting to expand even further, the plant could be built so as to have the ability to add chillers and boilers. Finally, an analysis into combined heat and power or cogeneration plant could be made to lower operating expenses further.

There were talks originally that the apartments would be built and operated by 3rd party members. If so, involving them early in the process could save them money in construction costs. In return the realtors could invest part of those savings into the Utility Plant. They would gain a cheaper and more marketable apartment building. The utility costs for individual tenants would be less, attracting more students to take advantage of a more affordable deal. The University could even make a steady stream of revenue and profit by selling the utilities to the tenants. There would probably be pushback though on the idea of building a utility plant that would serve only one university owned building. The plant could be built in phases over the ten years that West Village will be built to lower the high initial costs.

A conclusion for this energy breadth is hard to deduce without further exploration into the area. It is recommended to explore the option and conduct full energy analyses on the surrounding apartments. A possible electricity cost analysis needs to be conducted to find the return on investment, and to see if West Village could benefit from combined heat and power. The use of a utility plant will also regain valuable space in individual buildings that could redistributed as meeting rooms, common space, food vendors, etc…

The real value gained this semester while researching this topic is the knowledge gained on Utility Plants and the concern over the rise in energy costs. I was able to learn how mechanical systems are decided on, why utility plants save money, and what considerations are taken into account. The numerous universities that are constructing utility plants to take advantage of the operation and maintenance cost savings shows that a central utility plant should be studied during a campus expansion. While it was frustrating to not come up with more definitive answers to the proposal made, this breadth does show that a utility plant would benefit West Village in the long run.

-SUMMARY OF RESEARCH-

Integrated Project Delivery opens the doors for many benefits in the building industry. It has potential to create a fully integrated mechanical system, a much clearer construction and operating cost estimate, a shortened construction schedule, and most important, an enjoyable and worthwhile design and construction process. Shared risks and rewards will give the design and construction teams incentives to work together to accomplish project goals. Designers will receive much more accurate cost and duration information on the project, allowing true value engineering to take place as opposed to cost cutting. Early involvement from trade contractors can maximize the fabrication process, allowing longer lines of duct and pipe to be manufactured, unitized or prefabricated façade systems designed, and much more coordinated system integration. IPD is very young in development and there are further steps that need to be made. Bob Grottenthaler, Vice President of Barton Malow, claims the following are key next steps in IPD development (Grottenthaler, 2010).

- Program managers of complex building projects need to embrace and convince owners of the benefits of IPD
- Training for constructors, architects, engineers, and specialty trade subcontractors on IPD
- State Agencies allowing IPD to be used as a procurement and delivery method
- Case studies conducted on IPD projects
- IPD must be introduced in college courses to fuel research and allow young engineers to explore the possibilities.

The key steps listed above are very similar to when BIM and sustainability were beginning to be key topics in the industry. A similar advancement could be seen with the development of IPD, as it may serve to be the final piece tying sustainability and BIM together. Both sustainability and BIM potential and effectiveness can be directly related to when key members begin sharing information. The earlier information can be discussed as a design possibility, the less rework later in the project is needed. The contractor utilizes a BIM in many ways, but unfortunately many times they need to recreate models or add significant work into the one that exists. With IPD, this information can be placed in the model early, effectively creating only one BIM model for all uses: estimating, construction phasing, material tracking, field layout, closeout, commissioning, and facilities management turnover. The potential of BIM and IPD heavily rely on each other, and one will only reach maximum efficiency with the other.

In regards to West Village Commons, two possible areas that will benefit from IPD are the structural steel trades and the façade trades. The structural strategy research conducted proves that a structural steel system will shorten the construction schedule and decrease material costs. The current delivery method would not allow for structural steel to be placed and still finish in time. Concrete was used as a way to begin construction earlier, for the fabrication time after trade buyout, extended the schedule past the completion deadline. With IPD, steel fabrication can begin earlier:

the contractor can design steel and connection shop drawings, built right into the model during the design phase; and fabrication can begin earlier when steel subcontractor is already a member of the Lean Core group. Even if steel could not be fabricated earlier in this situation, there is a 2.5 month window to break even. Both the structural and masonry estimates found in this report could be used as Target Value Cost budgets, which gives opportunity to the key members to innovate solutions to decrease this budget. Cost savings, with IPD, gives monetary savings to members.

The façade trades could see a significant cost reduction, if the entire system is taken into consideration. The façade strategy research shows that prefabrication will have an increase in cost, but the schedule is greatly reduced. The use of a unitized curtain wall system would increase initial material costs, but it could lead to an even greater critical path reduction. It would allow for more interior trades to begin work, which accounts for the majority of the West Village Commons critical path. The most important intangible advantage that IPD allows in regards to the façade is greater system integration. Because the designers and contractors for the façade are working together, issues between façade systems (including interaction with the structure) can be foreseen earlier and worked out in the design phases. Costs in fixing tolerance issues, field busts, and façade engineering issues in the field are much more costly than fixing them in the design phases.

Further exploration into the idea of using a West Village Utility Plant would need to be conducted to deduce a definitive answer. Comparisons to other colleges, though, show that the long term operating savings could greatly benefit Towson University. The diversity in peak operating periods will allow a centralized system to be smaller than a decentralized system. IPD allows for key members with design, initial costs, and operating expenses to work together and find a solution. The owner would have several more options when deciding how West Village could operate.

This year has become a major learning experience in all aspects of the building industry. A focus was made on creating a better product for the owner, which should be the goal for all building industry professionals. The analyses and research conducted has provided recommendations that will accomplish that goal. While effort was made to create substantial savings in cost, operation, duration, and process, the biggest draw from this thesis research is the knowledge gained. I have learned practical industry knowledge, researched potential future building and construction solutions, and created a passion within myself for further exploration.

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-APPENDIX A-
WEST VILLAGE COMMONS MILESTONE SCHEDULE

-APPENDIX B-
CRITICAL PATH SCHEDULE

-APPENDIX C-
GENERAL CONDITIONS ESTIMATE

-APPENDIX D-
LEAN CORE SELECTION CRITERIA

-APPENDIX E-
STRUCTURAL CALCULATIONS

-APPENDIX F-
STRUCTURAL TAKE-OFF AND ESTIMATE

-APPENDIX G-

BUILDING FAÇADE TAKE-OFF AND ESTIMATE