Technical Assignment 3: Alternative Methods Analysis

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Building Statistics

- Size: 1,500,000-SF base building and 600,000-SF parking garage
- Number of Stories: Three-level underground parking garage, 10 stories + Pent House
- Occupancy Type: Class A Office Space
- Cost: $246 Million GMP
- Construction Dates: July 2007 - November 2009
- Delivery Method: Design-Bid-Build
- LEED Gold Project

Mechanical & Electrical

- Centralized Plant in the Penthouse Housing:
  - Two 800 h.p. Boilers
  - One 350 h.p. Boiler
  - Three 1200 ton Trane Chillers
  - Eight 30,000 CFM Trane Air Handlers
  - Eight 30,000 CFM Semco Energy Recovery Units
  - Four 1200 ton Cooling Towers utilizing 6,700 Active Chilled Beams
- Power distribution system of 13.8 kVA feed from four primary switchgear connected to Pepco feeders
- 10 secondary 4000A transformers within the garage and Pent House levels
- Two 1000 kilowatt generators are roof mounted to provide power back-up to the critical building systems during a power outage
- Two dedicated chiller/purifier drinking water systems that continuously circulate water throughout the building
- Custom made Chilled-Beam System from Germany

Project Team

- Owner/Developer: David Nassif Associates
- General Contractor: James G. Davis Construction Corporation
- Owners Representative: Kramer Consulting
- Architect: SmithGroup, Inc.
- MEP Engineer: SmithGroup, Inc.
- Civil Engineer: Wiles Mensch Corporation
- Structural Engineer: SK&A

Structural

- Precast panels found at all four corners of the building, which frame the spandrel glass
- Blast resistant curtainwall throughout at Streetscape and Courtyard, with floor two being the most resistant including an air barrier system
- Metal panel on the Pent House level to conceal the MEP equipment
- Blast protection in garage tenant space, entrance ramp, internal ramps, electrical rooms, telecom rooms, elevator shafts, egress stairs, and exposed columns
- Two-way waffle slab on all floors except the Pent House

Architecture

- Renovation of an existing building, originally constructed in 1976 and occupied by the Department of Transportation (DOT)
- 4 separate, but integrated quadrants that have their own elevator, stairs ways, bathrooms, electrical closets, communication closets
- One acre of courtyard that is a private, secure green space with fountain, seating areas, sculpture, and 32 Honey Locus Shade Trees that are 11'-15' tall
- White Marble and Jerusalem Limestone are located around the first level of the building, creating a boarder for the spandrel glass located at the storefront entrances
- Built-up roofing system and metal panels used to conceal the MEP equipment on the Pent House level

Renderings Provided by SmithGroup, Inc. and Studio Christen

http://www.engr.psu.edu/ae/thesis/portfolios/2009/nlb5002/

EXECUTIVE SUMMARY

Technical Assignment three consists of information pertaining to the alternative methods and the analysis of these methods. In the first section, one can find a study of the constructability challenges that were faced on Constitution Center. The items that were examined were the weight of the boilers, the metro station entrance, and the density of the MEP installation. The weight of the boilers posed a problem since none of the four tower cranes on the site could perform the lift. The metro station entrance was a challenge because the Washington Metropolitan Area Transit Authority (WMATA) would not permit the entrance, show in Figure 1, to be closed during the entire construction. The final constructability challenge that was studied was the density of the MEP installation and how DAVIS redesigned the largest chilled beam system being installed in the United States.

Figure 1: Rendering of the L'Enfant Metro Station Entrance.

The second section of this analysis is ondifferent types of schedule acceleration scenarios. It is noted that there are several items apart of the critical path on Constitution Center, such as demolition, curtainwall, permanent power, mechanical systems completion, commissioning by phase, and final inspections. Additionally, one can find information on the biggest risks to the completion date, which include the amount of the liquidated damages. Finally, two areas of potential acceleration are discussed, along with the costs and techniques of both having multiple crews working and how DAVIS is accelerating the permanent power transition.

Value Engineering topics are outlined in the third section of this evaluation. One can find information on actual topics that were implemented on Constitution Center, along with how they correlate with the goals of the owner. Also, several value engineering ideas are discussed that were considered but not implemented.

In the fourth section of this analysis, one can find several problematic features that could be furthered outlined through a detailed analysis of technical building systems and construction methods. The features that are outlined include the density of the MEP installation, curtainwall, site layout, waffle slab renovation, CCIP, and pedestrian safety.

In the final section of this report, four construction management analysis activities are summarized, along with how it will be completed, and the research that may be necessary. The four sections that are discussed include the chilled beam system, the façade, pedestrian safety, and the structural integrity of the parking garage waffle slabs.

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CONSTRUCTABILITY CHALLENGES

Constitution Center is a million and a half square foot renovation, with a project this size, one would expect there to be several constructability issues on the project. The top three unique and challenging constructability issues are discussed in the following section. The issues are the weight of the boilers, the metro station entrance, and the density of the MEP installation.

Figure 2: Structural Engineers' sketch of the boiler supports.

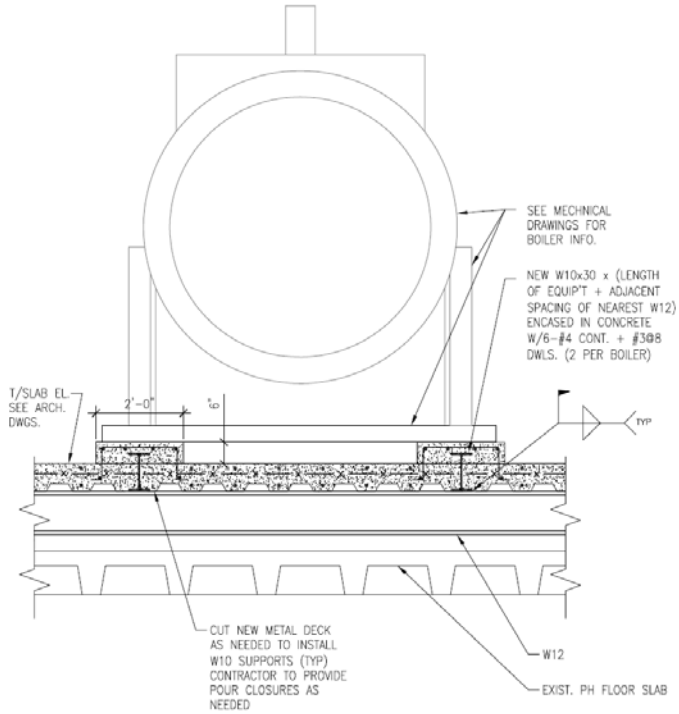


Figure 3: Installation of a boiler, please note the spring isolators, which sit upon the steel beams encased in concrete.

The weight of the three new boilers was a challenging constructability issue because the two 350hp boilers weights 27,500lbs (138 tons) and the 800hp boiler weights about 49,750lbs (250 tons) . With this weight, steel beams had to be added perpendicular to the support steel below the boiler spring isolators. Theses steel beams transfer the weight out of the columns. Figure 2 is a sketch provided by the structural engineers to show the W10x30 that were installed and encased in concrete in order to support the boiler weight. Figure 3 documents the actual installation and provides a visual of the spring isolators. One limiting factor of the steel beam installation was that the roof could not be raised so the additional steel had to be low profile so the top of the boilers did not hit the roof but are strong enough to handle the weight. Additionally, since the boiler weight was so large, a separate crane had to be brought onto site in order to set the boilers into place. The crane is a Manitowoc GMK7550 mobile hydraulic crane with a capacity of 450 metric tons on a seven-axle carrier. This crane was set up parallel to the north façade on D Street, which meant that coordination with the District of Columbia had to occur in order to temporarily shut the street down. This closure took place from 6:00pm on Friday to 7:00am Monday. Figure 4 shows the installation of the boilers. The photo on the left exhibits the closure of D Street in order for the crane to be set up. The middle and right photos illustrate the actual installation process, which took about 4 hours to rig, lift, and set all three boilers. Although the installation only took 4 hours, it took a total of 16 hours to set, assemble, and take down the crane. Overall this issue took coordination with DAVIS, SmithGroup, SK&A, and Pierce in order for the boilers to be properly installed.

Figure 4: The photos show the installation of the boilers along D Street.



The second constructability issue that occurred on the site of Constitution Center was that the L'Enfant Plaza metro station entrance is directly beneath the building. One issue was that the metro did not permit the entrance to be closed for the full duration of the project. The only time frame they allowed it to be closed was during the overhead curtainwall work along D Street. One stipulation for the closure was that it had to be fully reopened by the July 4th holiday since the National Mall is two blocks away. Therefore, from October 2007 till June 2008, the metro escalator was shut down and the curtainwall installation took place along D Street and the ceiling work directly above the escalators was completed. Figure 5 shows the ceiling work taking place over the metro escalator. From the start of the project, overhead protection was in place in order to protect pedestrians while demolition was taking place. Finally, the metro entrance was reopened on July 1, 2008 and overhead protection was eliminated since all overhead work was complete. Additionally, special measures were implemented to protect pedestrians while the remaining work along the streetscape and lobby are being completed. Some of the special measures were:[1]

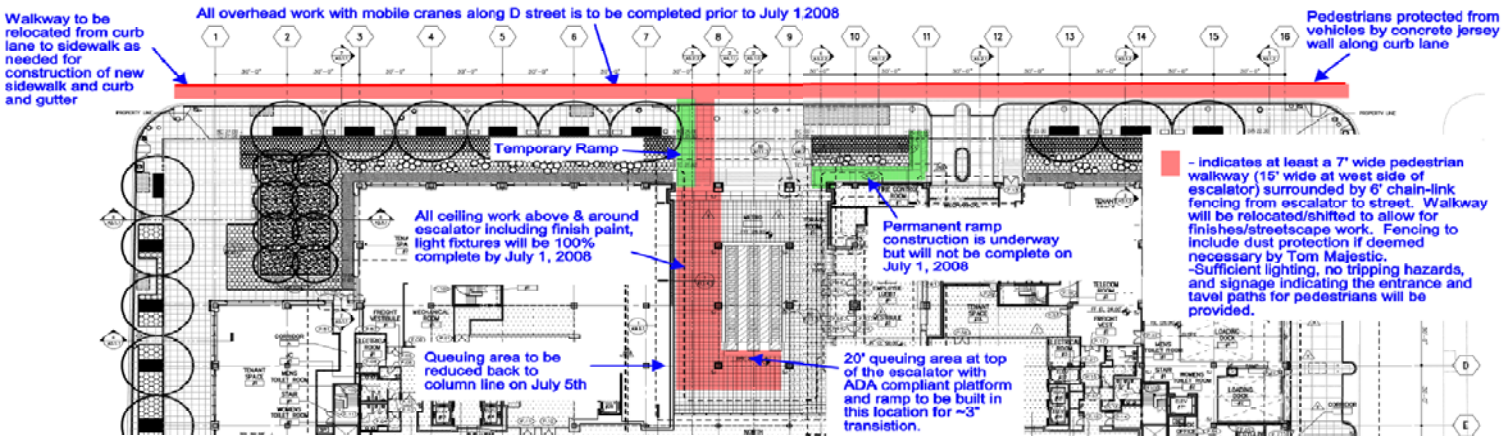
Figure 5: Photo showing the escalator ceiling work.

- All ceiling work above and around the escalator is in the finishing stages – finish paint, final light fixtures, etc. will be completed by July 1, 2008.
- All overhead work involving mobile cranes along D Street will be completed by July 1, 2008.
- Construction of an ADA compliant platform and ramp at the escalator entrance to accommodate for the ~3" transition until the finish stone can be installed
- 6' high chain link fence surrounding the perimeter of the pedestrian pathway – dust protection will be provided if deemed necessary by site conditions and WMATA.
- Although the original metro easement did not include a ramp from the sidewalk to the escalator entrance, DAVIS constructed the new final ramp. While this construction was underway, it was not be completed by July 1, 2008.

Figure 6 is the plan that was executed in order to have the L'Enfant Metro entrance reopened by July 1, 2008.

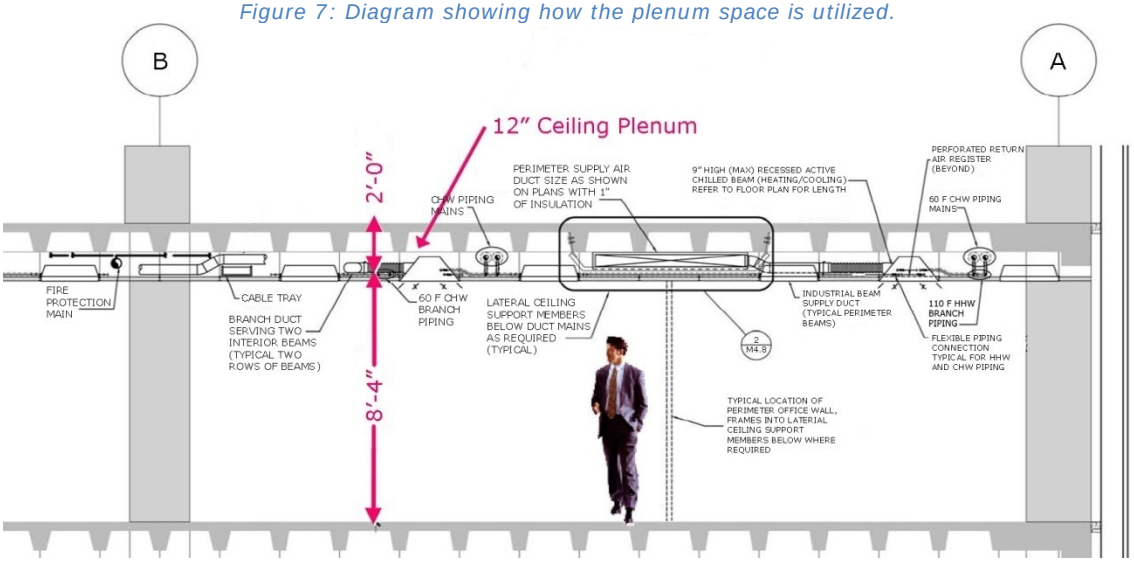
[1] (Sterba)

Figure 6: Metro entrance protection plan.



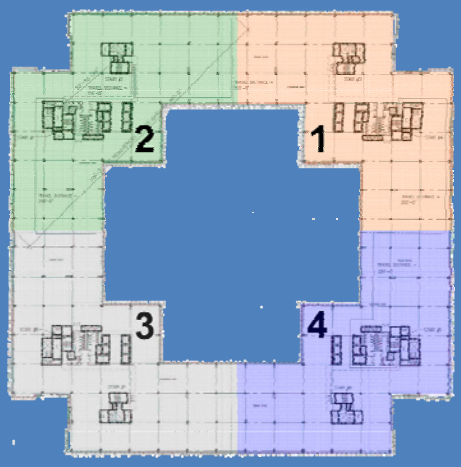
Finally, the density of the MEP installation at both the typical floors and the Penthouse was a constructability challenge. This challenge required atremendous amount of time to study the shop drawings. One recommendation that DAVIS provided to the ownership was to complete BIM studies with the shop drawings. However, they did not feel it was necessary, and "took a less costly study by using the contract design drawings by SmithGroup."[2] The way that DAVIS overcame one of the density issues was to customize the typical floor chilled beams. The original design was to have the system be made up of a beam that is 8' in length and 11" deep. "Through coordination with Trox (Chilled Beam Manufacture), SmithGroup Engineering and DAVIS, they were able to develop a beam that is typically 6' in length, about 7" in depth with pipe and duct connections that do not have be predetermined."[3]Figure 7 shows how the plenum space is utilized and how it was necessary to reduce the chilled beams depth. This coordination was about 8 months long, which included a visit to both Trox in Germany and Trox in the United Kingdom to visit with the various engineers and testing facilities. Overall, since the plenum space is only 12" in depth, the customization of the chilled beams were critical since there are over 6,600 units. Finally, this constructability challenge will be beneficial to the United States market because the units will start to be utilized in construction and become the standard size.

Figure 7: Diagram showing how the plenum space is utilized.



[2] (Holt)
[3] (Holt)

Start Construction	07/02/07
Curtainwall Release Dates	
Bid Curtainwall	11/03/06
Release Curtainwall	01/01/07
Initial Installations	02/19/08
Weatherright Ready for Davis to Start Tenant Construction	
NE Quadrant 1	07/25/08
NW Quadrant 2	10/15/08
SW Quadrant 3	12/05/08
SE Quadrant 4	12/05/08
Tenant Buildout Availability for Other Interior	
NE Quadrant 1	01/01/09
NW Quadrant 2	04/01/09
SW Quadrant 3	06/01/09
SE Quadrant 4	07/15/09
Substantial Completion	
NE Quadrant 1	05/01/09
NW Quadrant 2	07/01/09
SW Quadrant 3	09/01/09
SE Quadrant 4	11/01/09



Schedule Acceleration Scenarios

The schedule plays a large part in the construction of Constitution Center. Since the project is divided into four quadrants, the turnover is phased. Quadrant one will be turned over May 1, 2009, with each subsequent quadrant turning over two months later, for a final project completion of November 1, 2009. Please see the chart to the left for a more detailed breakdown of the substantial completion dates. The critical path of the project was: demolition, curtainwall, permanent power, mechanical systems completion, commissioning by phase, and final inspections. In order to study the critical path items, along with delay fragnets, DAVIS has regular monthly meetings to discuss schedule updates.

With a project this size, there are several critical risks to the project completion date. The largest risk is not finishing on time. If this would occur, the project has liquidated damages, which are "$20,000 each day for first 15 days, $50,000 for 16 through 30, and $80,000 for beyond 30 days."[4] Another risk with the project not finishing on time is that it would result in poor public relations for DAVIS. Since this is the largest project for DAVIS, word could travel fast that they failed to deliver the project on time, and this could result in difficulty procuring future projects. The majority of DAVIS' projects are with repeat clients;therefore if the project was to be turned over late, one of DAVIS' core values of building relations may become hard.

There are several key areas that have potential to accelerate the schedule if needed. One key area is that each of the four cores are similar in design, therefore the areas could have multiple crews working multiple cores to accelerate the job. However, to keep the project moving and sequential, every trade would have to participate. In order to have this acceleration occur, there would be costs associated with more subcontractor laborers and additional DAVIS supervision to keep all of the crews coordinated.

At the current time, DAVIS is not pursuing many acceleration options since there is not a tenant for the building. One way DAVIS considers schedule acceleration is to focus on specific trades and/or isolate specific tasks that have the largest impact on the overall project. DAVIS has chosen to do this for the permanent power sequences. One option was to have "half the gear be replaced while using the old gear for construction, then use half the new gear for construction and replace the old 2nd half, eventually turning both sections on as permanent. The other option was to take advantage of utilizing generators for construction power while installing the

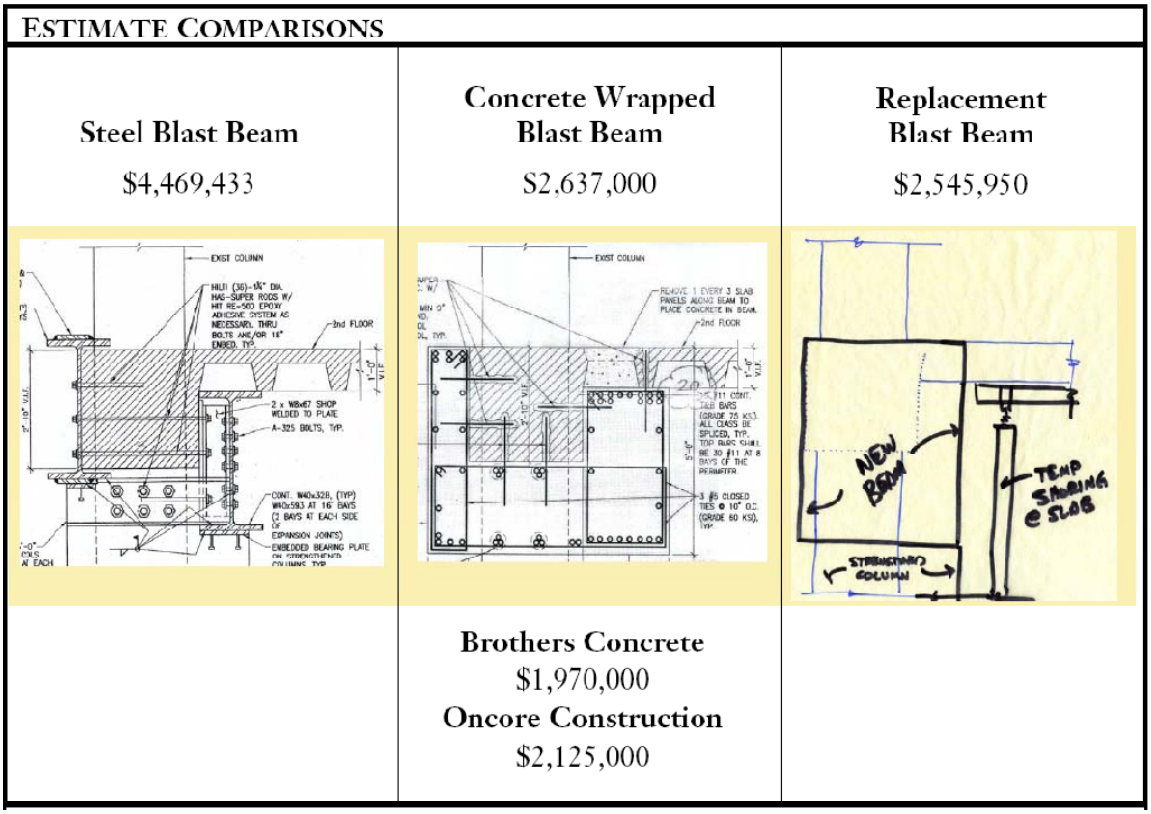
[4] (Cordek)

permanent power gear in one sequence." [5] The reason why DVIS has chosen to accelerate the permanent power is because coordinating with the local utility company PEPCO is the longest path to energize the permanent gear. There is a projected cost of about $400,000 to work off of generators and it is expected to stay on schedule overall. There are several benefits to accelerating the permanent power. Initially, during a "phased de-energizing and energizing sequence they expected the work to take 5-6 months, however utilizing a single de-energize/energize sequence, they can complete this work in about 3 months."[6] Overall, DAVIS will be expending about $400,000, but will avoid a 3-4 month late start with the commissioning process, which is an activity on the critical path/highest risk radar.

VALUE ENGINEERING TOPICS

DAVIS Construction utilized several value engineering areas for Constitution Center. The first was to do a cost analysis of the blast beam for both value engineering and constructability reasons. The Principal-In-Charge and Senior Project Manager determined that steel would cost over four million dollars; while concrete would be about two million dollars; and the replacement blast beam would be slightly less than the concrete. They also determined that it would allow for manageable rebar weights, less column penetrations, and easier demolition. Figure 8 contains the costs that DAVIS presented to the ownership in order to visualize the comparisons. This value engineering idea correlated from the owners needs because it reduced the cost of the construction.

Figure 8: Slide from a DAVIS presentation to the ownership.



[5] (Holt)
[6] (Holt)

Another value engineering topic that DAVIS chose to pursue was the anchor system used for the curtainwall. They determined that this again was both value engineering and a constructability issue. It was established that the anchorage was to be changed to the face of the beam instead of the top/bottom of the beam installation. One main reason this occurred was because it is nearly impossible to have the top/bottom of the beam installation. The underslab mounting location increases the difficulty in erecting the panels, especially because they exceed 800 pounds. Another reason is because the "embed anchors are likely to conflict with existing rebar and stirrups, along with the installation being difficult which would result in low labor production and potentially dangerous edge conditions."[7]Figures 9 and 10 are visual representation on how the anchorage detail changed. This value engineering idea correlated with the owner because it was less expensive, faster, and easier to install.

Figure 9: Details of the existing curtainwall anchorage.

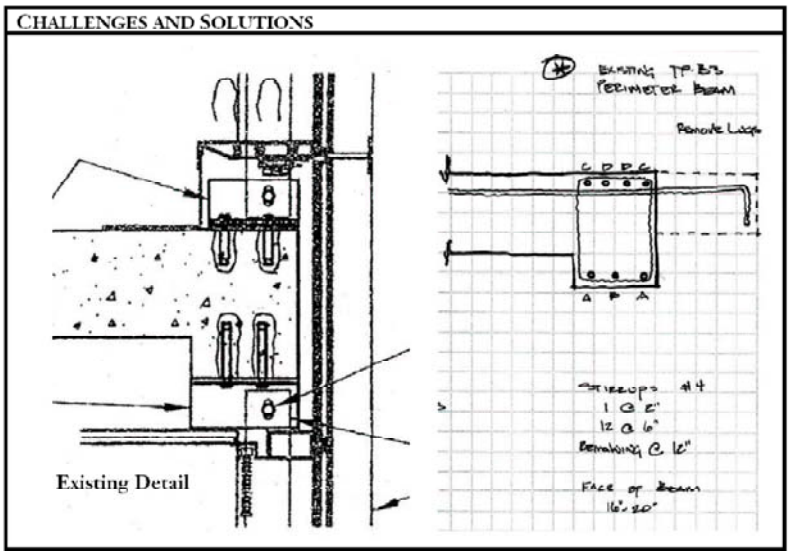
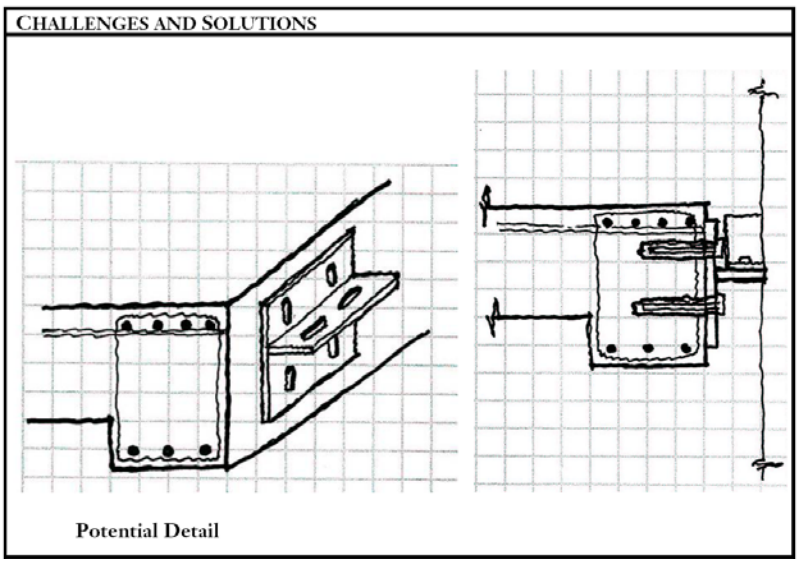
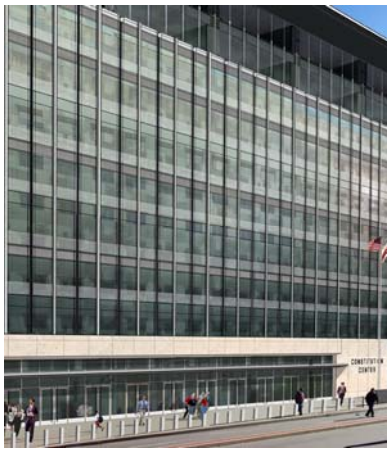


Figure 10: Details of the potential curtainwall anchorage.



[7] (Holt)

Figure 11: Rendering of the main entrance of Constitution Center.

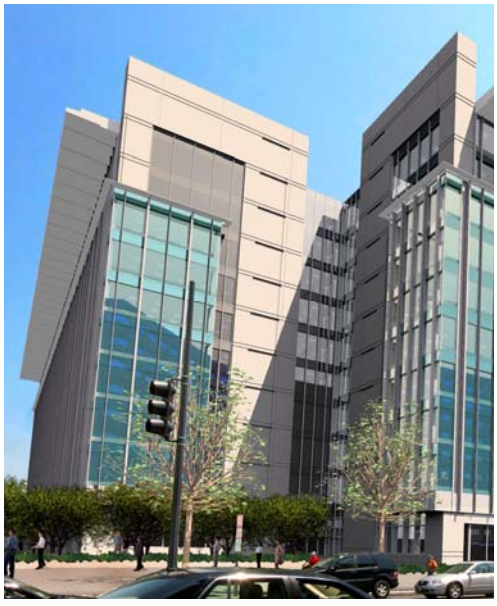


Perimeter site security was another value engineering comparison that DAVIS preformed. They did a cost analysis of a planter wall system and K12 bollards. It was determined that the K12 bollards would provide more protection and are less expensive, however they would have to be 5 feet on center, which would not be aesthetically pleasing. Therefore the result of this comparison was that they would use both perimeter site security planter walls made from either granite or stone and K12 bollards in order to provide the Level IV Security that the owner wished to have. Figure 11 shows the location of the K12 bollards in front of the main entrance to Constitution Center. This value engineering idea correlates to the owner's goal because they wanted to have a Level IV Secured building and that is what the K12 bollards and the planter walls are providing.

The final key area of value engineering that was implemented was with the electrical subcontractors that were bidding for the project. DAVIS set up a meeting with two of the bidders in order to provide electrical cost reduction. They came up with several value engineering ideas. One was to provide metal clad cable for branch power and lighting instead of conduit and wire. Another idea was to provide 20 typical column bay light fixtures with metal clad cable branch distribution. Also, a cost reduction suggestion was to provide basket type cable tray instead of ladder type. The final value engineering item they suggested was to provide unit sub 480V switchboard feeder conduit breaks with "P" trip units in place of "H" trip units. Overall, it was established that if all of the electrical cost reductions were established, they would save over $1.4 million. These items again correlate from the owner's goals because they again reduce the cost of the building.

There were several ideas of value engineering that were considered but not implemented on the project. First was to apply traffic coating to all three levels of the parking garage instead of just levels one and two. The reason why this was deleted is because they did not feel it was necessary to execute since level three only has parking, unlike levels one and two that have electrical rooms located on them. Another idea was to implement the Davis Bacon Law instead of an Open Shop. The reason this was not used was because it would limit the number of subcontractors that were able to bid the job. The suggestion of deleting the precast panels at the Penthouse corners was also a value engineering idea. Figure 12 shows the location of the precast panels. The reason why this topic was cancelled was because they felt it would take away from the aesthetics of the building's design if the panels were removed. One final value engineering idea that was not used was to delete the ladder and platform for the 400hp boiler. The reason why this was not put into action was because they felt it would be easier to access the boiler if the ladder and platform were a part of the system.

Figure 12: Rendering that shows the location of the precast panels.



PROBLEM IDENTIFICATION

Since Construction Center is such a large project, there are several problematic features that are outlined below that could be pursued through a detailed analysis of technical building systems and construction methods.

Density of the MEP installation

A problematic feature of Constitution Center is the density of the MEP installation needed to be placed into the 12" plenum space. This space needs to be utilized by numerous subcontractors for items including fire protection, cable tray, branch duct, branch piping, duct mains, supply air ducts, chilled beams, returned air register, and hot/cold water piping.

Curtainwall

Another challenging feature of Constitution Center was the curtainwall. With both the exterior and interior façade of Constitution Center being curtainwall, there is a large amount of glass being used on the project. Additionally, the project team utilized value engineering to determine the best way for the curtainwall attachments to be installed, Figure 13 shows how the actual panel was installed. Also DAVIS created a deficiency list for the curtainwall in order to make the punch list process shorter, however, at times it became hard to create a standardized diagram used for the deficiency lists.

Figure 13: Photo showing the curtainwall panel installation.

Site Layout

Additionally, the limited site layout is a challenging construction method of Constitution Center. Although the site takes up an entire city block, the only storage space is around the perimeter of the site on the existing sidewalks and inside the courtyard. Both of these areas were available for a limited time and heavy coordination was involved with the installation of both façades and the streetscape.

Waffle Slab Renovation

Also, the amount of time spent fixing the waffle slab in the parking garage was very critical in closing out the parking garage. This also meant that a quadrant was unavailable for both construction parking and material storage.Figure 14 shows the damage that needed to be fixed for the waffle slabs in the garage.

Figure 14: Photo of the parking garage waffle slab.

CCIP

The Contractor Controlled Insurance Program (CCIP) also took a lot of time and effort to confirm that all the subcontractors and their tiered contractors were submitting the necessary paperwork in order to successfully hold the CCIP.

PedestrianSafety

Since the L'Enfant Metro Station Entrance was within the construction site, it was a problematic feature to keep the pedestrians safe, but not limiting the use of the metro or the work taking place on the construction site.

TECHNICAL ANALYSIS METHODS

Below are four construction management analysis activities that I would like to address in my thesis that correlate with the problems and challenges in the above section.

Chilled Beam System

The chilled beam system is a construction management analysis activity that I would like to address in my thesis. This is a concern due to the density of the MEP installation in the limited plenum space. I will need to familiarize myself with the system, by completing research on the European system, designed primarily by Trox. Also, I will need to learn why the ownership, SmithGroup, and DAVIS chose to utilize this system. Additionally, I will need to study how this system was redesigned in order to fit into the 12" plenum space. I also plan to explore how the product will be delivered and the schedule for the installation. Overall, the chilled beam system provides a perfect opportunity to expand my knowledge of the mechanical system and how it is integrated into the construction process.

Façade

Another area that I would like to address in my thesis is the façade of the Constitution Center. The way that the façade is attached to the building caused some delays, and I would like to analysis how these challenges were overcome. Additionally, the installation was with 4 ironworkers and a window washing trolley. I would like to become familiar with this process and see if there is a way to accelerate the installation procedure. Finally, I would like to explore prefabrication options to make the façade less expensive to install from a labor point of view. Although I am not permitted to analysis the actual façade panels, I plan to study the façade from a constructability view.

Pedestrian Safety

A construction management analysis that I would like to study is the requirements for safety on the site while specific areas are open for public access. I will have to research the WMATA requirements, along with the OSHA safety requirements. One of DAVIS' biggest concerns and I would like to learn if they applied any special techniques in order to provide a safer site for both the workers and the pedestrians around the site.

Structural Integrity of the Parking Garage Waffle Slabs

By analyzing the waffle slabs of the parking garage, I will have the opportunity to study the structural requirements of the slabs; along with the loads they are experiencing. Additionally, I will be studying the way that they were renovated and how the subcontractor preformed the work. I would also like to study different methods of fixing the system and seeing if any acceleration options are available and used on other sites.

Table 1: Summary of the Technical Analysis Methods

Analysis Topic	Critical Issue	Constructability Challenges	Schedule Acceleration	Value Engineering
Topic 1:Chilled Beam System		X		X
Topic 2: Façade	X	X	X	X
Topic 3: Pedestrian Safety		X		X
Topic 4: Structural Integrity of the Parking Garage Waffle Slabs	X	X	X	X

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