Architectural Engineering 2012 Senior Thesis

# Senior Thesis Proposal

## Reston Station Phase 1 Garage | Reston, VA

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## Executive Summary

This proposal is intended to present 4 topics of construction related analysis for further investigation and research on the Reston Station Phase 1 Garage project. The 4 analyses that will be performed include SIPS and matrix scheduling, addition of mechanical chases to the garage design, supply chain and BIM capabilities, and the public-private partnership ownership agreement. These analyses will be developed throughout the spring semester of the 2013 academic year and will be presented to faculty and panel members at the conclusion.

***Analysis 1: Public-Private Partnerships***

Public private partnerships (PPP) are a relatively new form of dual owner partnership in building construction projects. This mix of private companies and government bodies creates unique challenges and concerns that should be addressed. This analysis will define what a PPP is, why it was chosen for this project, and how PPP's impact the construction industry and the project on which they exist.

***Analysis 2: Equipment Staging and Material Storage Coordination***

Equipment and material staging has become a challenge at the Reston Station job site as a residual effect of delays. Expensive fans and escalators are currently being stored in the project work areas where they are exposed to a significant risk of damage. This analysis will utilize supply chain mapping techniques and 4D modeling to better understand the procurement methods for these long lead time items. The alternative solution of temporarily storing these items in off-site facilities will be analyzed and a conclusion will be determined concerning which solution provides a better outcome for the project goals.

***Analysis 3: SIPS and Matrix Scheduling for Trade Sequencing***

Short interval production scheduling (SIPS) and matrix scheduling are both detailed ways to evaluate the durations and sequencing of construction trades on complex projects. At Reston Station, design delays have pushed back the critical path which means a delayed substantial completion. In an effort to restore the schedule to original finish date, finish trades must be accelerated. This analysis will utilize SIPS and matrix scheduling to determine the most critical tasks on the schedule and alternative possible sequences to arrive at the original date of completion.

***Analysis 4: Impact of Including Mechanical Chases to the Garage***

The underground garage and the above ground buildings at Reston Station are being designed concurrently due to the fast-track construction schedule of the 1st phase. Significant construction delays have been encountered due to the complications with structural and mechanical system design where the garage meets the 5 other buildings on the P1 level. Further complicating this issue is that Luis Fernandez and Associates is the structural engineer for the garage but Structura is the structural engineer for the apartment building and hotel. There are 3 separate design teams involved throughout the entire project. Without changing the party involvement or contract arrangements the inclusion of mechanical pipe and duct chases through the garage could greatly benefit the coordination between the buildings.

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## Project Background

The Reston Station Phase 1 Garage project is the first of several building projects on a development property in Reston, Virginia. The development is being built to take advantage of a future station for the Metro Rail Silver Line Expansion project that will be adjacent to the property. The Reston Station Garage is owned by Comstock Partners and Fairfax County Virginia (a public-private partnership). Comstock has a 99 year lease with the county on the property and holds all of the construction contracts for the project. The garage project consists of a 7 level, 1.3 million square foot underground garage that will accommodate over 3000 personal vehicles as well as a bus terminal and a ride share area.

Davis Construction served as the Construction Manager for the construction of the garage and the delivery method was a Guaranteed Maximum Price (GMP) contract. The project began construction in April of 2011 and is schedule for substantial completion in July of 2013. The construction schedule has been fasto-tracked which means construction can occur concurrently with design. Construction cost of the garage is approximately $95 million.

Excavation on the project took over 10 months and was temporarily delayed due to a seismic event in the area and hurricane Irene. The structural system used for the garage is cast-in-place concrete, the contract to perform this work is approximately a third of the project budget. Mechanical systems in the garage focus on ventilation of the large volume of underground space and almost 1.5 million cubic feet of air are circulated each minute. The interior garage is finished with traffic coating and paint and the majority of lighting is supplied by highly efficient LED fixtures. Finish materials on the plaza level are the aesthetic highlight of the project and include decorative pavers, planters, street lights, and ornate stone façade.

The greatest challenges for the project stem from the fast-track construction delivery and design delays. Concrete design has fallen behind the pace of construction and since the structural cast-in-place system is a key component of the critical path every day lost in progress of the concrete design is a day lost in project completion. Figure 1 shows many aspects of the construction of the garage happening concurrently.

**Figure 1: Construction of the Reston Station Garage**

## Analysis #1: Implications of Public-Private Partnerships

***Problem Identification:***

The Reston Station Phase 1 Garage project has a public private partnership (PPP) ownership structure. Comstock Partners is a commercial and high density residential developer in northern Virginia and acts as the private industry partner while Fairfax County is the government owner. PPP's have been prevalent in some forms for a long time but it has only been recently that their use is being seen more and more in construction. While Davis Construction (the contractor) has only one contract with Comstock Partners, Fairfax County owns the land and is contributing a majority of the funding for the public parking structure through County bonds as a funding source. The two owners have their own goals and opinions but have to come to agreement on many issues pertaining to garage design and construction. This is a relatively rare opportunity to see a partnership in building construction so it has many unique characteristics. By understanding more about PPP's, construction professionals can manage the projects that have partnered owners more effectively.

***Research Goal:***

The goal of this analysis is to understand and present how a PPP works, determine the pros and cons of a PPP, and speculate how a PPP can be beneficial in other areas of the American construction industry. Construction Managers and Owners could both benefit from this research because it could provide a solution to many owner concerns and can help construction professionals understand the relationships between owners. Reston Station Phase 1 Garage will serve as a good case study for this analysis.

***Methodology:***

- Review academic articles pertaining to Public-Private Partnerships
- Interview Project team members and partners to fully understand project specific PPP scenario
- Relate findings to the construction industry as a whole
- Develop a system to simplify decision making processes within partnered ownership arrangements
- Develop conclusions and present results

***Available Resources***

- Construction Management Project Team
- Fairfax County and Comstock Partners
- AE Faculty
- Industry Professionals via LYRIS Discussion Boards
- Available case studies and literature (Keith Molenaar, John Miller, Michael Garvin)

***Expected Outcome***

The anticipated results from this research topic include defining what a public-private partnership is, the reasons one was selected for this specific project, and the benefits and drawbacks to using a PPP on a building project. The research should also reveal trends for future use of partnerships elsewhere in the industry.

## Analysis #2: Using Bonded Warehouses as HUBs for Equipment Staging

### *Problem Identification:*

At Reston Station, the exhaust/intake fans and escalators were delivered to the site and needed to be stored on the concrete slabs in various locations around the building for approximately 1 month longer than what was originally intended. The extra month was due to design delays in the fast-track construction schedule and the need for equipment to be delivered to the site was primarily due to the cash flow concerns of subcontractors. Contracts allow for materials to be billed once they have been delivered and stored on site. In order to remain on the planned cash curve, materials could not be held indefinitely on subcontractor liability. There are several other long lead-time items being delivered in the future that will likely face the same challenges. Storing critical pieces of equipment on site for prolonged periods of time exposes equipment to heightened risks of damage. In addition, the storage of the equipment on the slabs causes a problem in productivity due to the need to work around these items. This is an issue that may occur on other construction sites as well and general contractors may be able to utilize bonded warehouses in a way to alleviate some of these concerns.

### *Research Goal:*

The purpose of this analysis is to develop an alternative solution for the equipment procurement and delivery process and to create a 4D model of the garage during the material delivery stages of construction. These tools will be used to compare the current on-site storage solution to the alternative solution of storing materials in an off-site facility nearby. The impacts on both cost, on site productivity, and overall schedule will be evaluated in this analysis of equipment staging.

### *Methodology:*

- Interview of general contractor team members to understand current situation and problem solving approach
- Consult with logistics industry professionals to determine additional costs and other considerations
- Determine the implications of moving equipment around site on productivity by using productivity data provided by sub-contractor
- Utilize Revit Architecture to show schedule and site congestion impacts with modeling

### *Available Resources*

- Construction Management Project Team
- Software tutorials and guides
- AE 372 and 473
- AE Construction Faculty
- Industry Professionals via LYRIS Discussion Boards
- Available case studies and literature

***Expected Outcome***

The analysis of equipment staging is intended to compare the current staging situation with an alternative solution that includes off-site storage. While this alternative option lowers the risk of damaging the materials and equipment it will result in added costs in both space rental and added transportation.

## Analysis #3: SIPS Analysis of Finish Sequence

***Problem Identification:***

Comstock Partners and Fairfax County, the owners of the Reston Station project, chose to fast track the construction of the garage phase in order to ensure project completion prior to the opening of the Metro Silver Line and maximize revenues through parking fees and bus terminal operation. The design delay of the cast-in-place concrete structure of the garage has caused significant construction schedule consequences. Progress on the project currently faces a 31 day negative float from the baseline schedule. Since the concrete is dependent on structural design drawings, MEP and finish trades must be evaluated for acceleration opportunities. In addition, the reshoring requirements of the garage are prohibitive to the progress of these trades. Since construction loads are greater than the final service loads, reshores are required in the entire

***Research Goal:***

The purpose of this analysis is to identify the most critical tasks in finishing the underground levels of the garage and develop a sequence of tasks utilizing a short interval production schedule (SIPS). The detailed duration of time for each task (Masonry, Painting, traffic coating, MEP rough-in) on a typical level of the garage will be determined and sequenced accordingly. Each trade will be organized by subcontractor and their tasks (i.e. hang sprinkler pipe hangers, install sprinkler main runs, etc.) This sequence will be presented using a matrix schedule that highlights the presence of work crews in an area and the duration of time spent there. This matrix schedule will also be graphically organized to show the sequence in a section view of the building for better understanding.

***Methodology:***

- Utilize project team members and schedule data to determine finish trade productivity rates
- Create a SIPS schedule for a typical bay and determine the most advantageous sequencing
- Extrapolate sequencing to full project schedule using Microsoft Project
- Illustrate results using a matrix schedule
- Redesign slab to require 2 formed levels with 2 shored levels of reshoring under construction loading.

***Available Resources***

- Construction Management Project Team
- AE 473 and 476 course material
- AE Construction Faculty
- Industry Professionals via LYRIS Discussion Boards
- Available case studies and literature

***Expected Outcome***

The SIPS analysis will reveal which tasks pose the biggest challenge to finishing the underground garage. In addition, a matrix schedule will help visualize the sequence of

construction and highlight any possible overlaps or unnecessary lags. In the best case scenario, a more efficient construction sequence will be realized through the creation of these schedule analysis tools.

## Analysis #4: Results of Adding Mechanical Chases between Garage and Future Building Areas

***Problem Identification:***

The underground garage and the above ground buildings at Reston Station are being designed concurrently due to the fast-track construction schedule of the 1st phase. Significant construction delays have been encountered due to the complications with structural and mechanical system design where the garage meets the 5 other buildings on the P1 level. Further complicating this issue is that Luis Fernandez and Associates is the structural engineer for the garage but Structura is the structural engineer for the apartment building and hotel. There are also 3 separate architects and 3 separate MEP engineers involved throughout the entire project. In order to reduce the impact that the future building designs have on the underground garage, the benefits and costs will be evaluated of including 5 mechanical chases in the garage design.

***Research Goal:***

The purpose of this analysis is to determine the impact that mechanical chases will have on the cost, schedule and work management process of the garage. Since the original design of the garage did not account for future buildings to be built above, including mechanical chases will eliminate the need to coordinate garage pipe and duct penetrations with a variety of designers of the future buildings. In this analysis, the maximum size of sanitary pipe and storm water drain pipe will be determined as a breadth analysis.

***Methodology:***

- Review design coordination scenario and current project experiences with pipe penetration coordination.
- Determine the pipe sizing for building storm and sanitary drains of the future buildings on site using International Plumbing Code compliance.
- With the size of these pipes decide on the location and size of mechanical chases within the original garage space to eliminate slab penetration ambiguity
- Determine the added and/or saved costs associated with this solution

***Available Resources***

- Interviews with A/E team members
- Applicable codes
- AE Construction Faculty
- Industry Professionals via LYRIS Discussion Boards
- Available literature

***Expected Outcome***

The anticipated result of this analysis is that the project will save critical time as a result of lowering the importance for tightly coordinated designs. It is expected that the cost of the project will likely increase due to the higher cost of materials and construction of the mechanical chases. Overall, the management process and coordination between engineers and architects will be

simplified by this chase system because it makes the design of the future buildings conform to the systems in place in the garage.

## Weight Matrix Analysis

The weight matrix of the analysis topics in figure 2 indicates the relative amount of time and effort that is expected to be given to each area of analysis topics.

**Figure 2: Weight Matrix**

| Weight Matrix For Thesis Analysis Areas | | | | | |
|---|---|---|---|---|---|
| Analysis | Research | VE | Constructability | Schedule Reduction | Total |
| *SIPS* | | 10% | 5% | 10% | 25% |
| *Chase Analysis* | 5% | 5% | 5% | 10% | 25% |
| *Material Staging Coord.* | 5% | 5% | 10% | 5% | 25% |
| *PPP* | 20% | | 5% | | 25% |
| Total | 30% | 20% | 25% | 25% | 100% |

## Conclusions

Spring semester will be dedicated to analyzing four depth areas of study that include Short Interval Production Scheduling (SIPS), the impact of adding a transfer slab to the plaza level, material staging coordination, and public-private partnerships (PPP). The SIPS construction schedule analysis will allow the construction manager, subcontractors, and owner to understand what items in the finish sequence are critical and how work can best be sequenced through the final stages of construction. The addition of mechanical chases will greatly benefit the coordination effort between the garage and future buildings because the exact locations of pipe and duct penetrations will no longer need to be determined in garage construction. In addition, 4D coordination of long lead item equipment staging will assist the contractor in mitigating risks associated with onsite long term storage of those items. Finally, the relatively new owner relationship known as the public-private partnership is an interesting factor in this project and research will be done to determine its benefits, drawbacks, and special considerations. This is a first submission of this proposal and it is likely to be revised upon future reviews.

# APPENDIX A

## Breadth Topics

## Breadth Topics

The two additional analyses presented in this section are designed to demonstrate competencies in other areas of the Architectural Engineering curriculum outside of the construction management option. These breadths are issues for investigation that directly relate to one of the construction management analyses that were previously mentioned

### *Concrete Slab Redesign to Accommodate Reduced Shoring Requirements*

The greatest challenge for schedule acceleration with the finishing trades is the 2 plus 4 shoring requirements for slab support. Typically, structural engineers specify that post shores remain on 2 levels beneath the 2 levels formed under the slab being poured. The extra 2 floors of shoring at Reston Station delay all of the trades from gaining access to those floors at an earlier time.

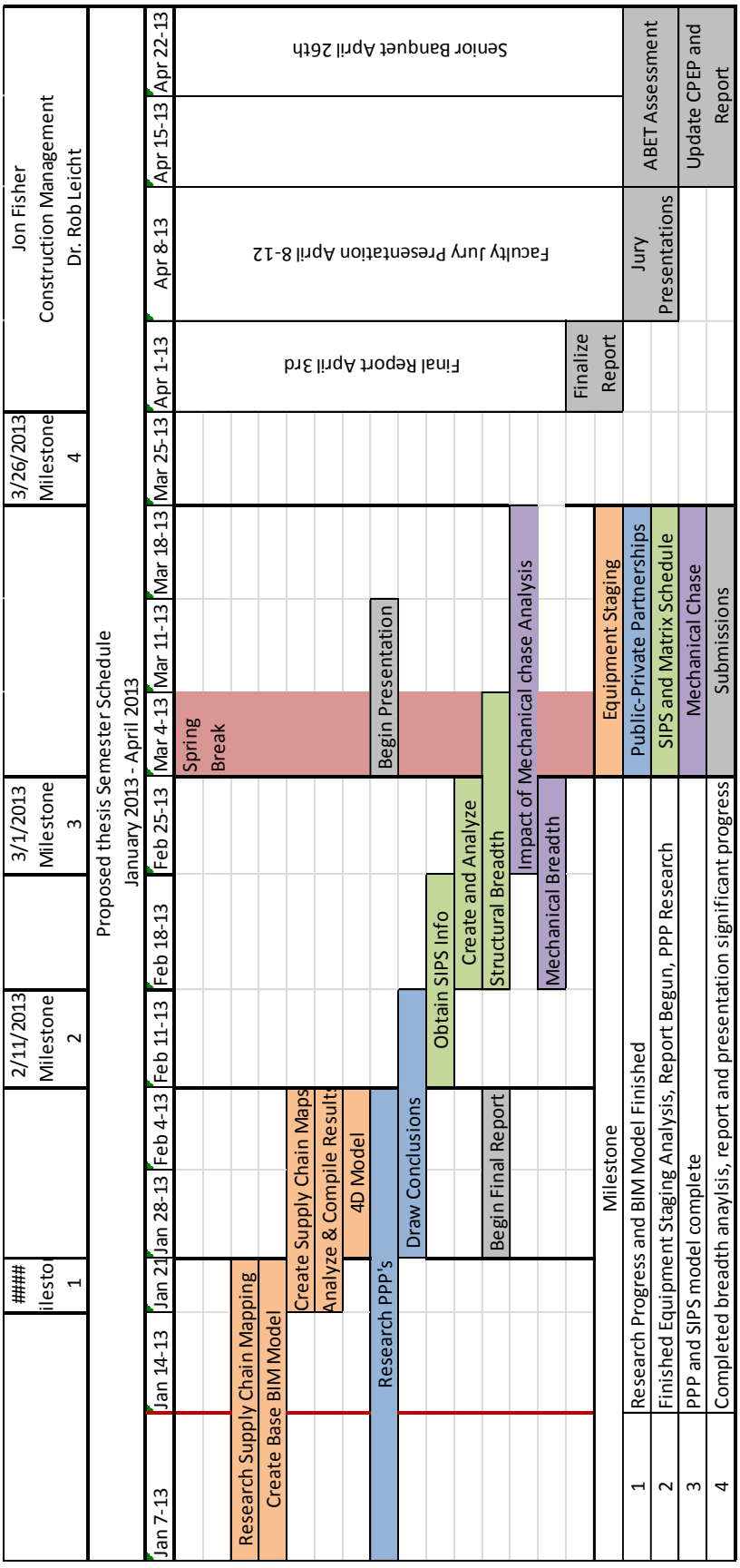
A breadth analysis that would benefit the issue of access to these floors is a redesign of the slabs so that a more typical 2 plus 2 shoring plan would be required. First, research will need to be done to determine the aspects driving the engineering design for the more extensive support requirement. Once it is know what is causing the need for increased support a redesign of the concrete slabs can reduce this requirement. Whether the redesign requires a thicker slab, increased reinforcing steel, or both there will be an increase in material and labor cost. An analysis will be performed to determine this added cost and the approximate savings in schedule that could be a resultant of these changes.

### *Building Storm and Sanitary Pipe Drain Sizing for Future Buildings*

The mechanical system chases from the garage into the future building spaces will need to be properly sized to give realistic results to the analysis. In order to determine the dimensions of the chases, service utility pipes and conduits will be sized to the maximum need of future development. Because the exact requirements were unknown at the time of design for the garage, the sizing of these main utilities will be a "worst case scenario". Codes will be heavily referenced to determine the maximum design loads for sanitary drains and storm drains and these sizes will be used to

# APPENDIX B

## Spring Semester Progress Schedule


Jon Fisher
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Proposed thesis Semester Schedule
January 2013 - April 2013
Jan 7-13
Jan 14-13
Jan 21
Jan 28-13
Feb 4-13
Feb 11-13
Feb 18-13
Feb 25-13
Mar 4-13
Mar 11-13
Mar 18-13
Mar 25-13
Apr 1-13
Apr 8-13
Apr 15-13
Apr 22-13
#### ilesto 1
2/11/2013 Milestone 2
3/1/2013 Milestone 3
3/26/2013 Milestone 4
Research Supply Chain Mapping
Create Base BIM Model
Create Supply Chain Maps
Analyze & Compile Results
4D Model
Research PPP's
Draw Conclusions
Obtain SIPS Info
Create and Analyze
Structural Breadth
Begin Final Report
Mechanical Breadth
Impact of Mechanical chase Analysis
Spring Break
Begin Presentation
Final Report April 3rd
Finalize Report
Faculty Jury Presentation April 8-12
Jury Presentations
Senior Banquet April 26th
Milestone
Equipment Staging
Public-Private Partnerships
SIPS and Matrix Schedule
Mechanical Chase
Submissions
ABET Assessment
Update CPEP and Report
1 Research Progress and BIM Model Finished
2 Finished Equipment Staging Analysis, Report Begun, PPP Research
3 PPP and SIPS model complete
4 Completed breadth anaylsis, report and presentation significant progress