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FINAL PROPOSAL

LancasterHistory.Org
Lancaster, PA

EXECUTIVE SUMMARY

This proposal identifies four technical analyses to be conducted for the LancasterHistory.org project. These analyses include critical industry research topics to be conducted. Further, analyses are proposed to demonstrate two breadth areas. The four technical analyses proposed in this report include a study of soil remediation effects on constructability and schedule, an investigation of a conventional mechanical system, application of MEPF prefabrication, and a greater use of BIM.

The study of soil remediation is to be conducted due to the fact that unsuitable soils caused construction issues and schedule delays early into the project. This analysis will include critical research in the form of a cases study to show the importance of a well conducted geotechnical report. Also, it will include a structural breadth regarding subsurface design. The analysis is expected to show that a combination of soil remediation and structural redesign are the best resolution.

The second analysis investigates LH.O's potential for a conventional mechanical system to replace its geothermal one, considering value. This is because the geothermal system has not been able to meet performance requirements to date. The analysis will include a structural breadth regarding value. A central plant system is anticipated to have the lowest life cycle cost of the studied systems.

Application of prefabrication presents an opportunity for LH.O because its MEPF systems are fairly complex. It is anticipated that select aspects of these systems will be determined to be prefabricated in order to reduce construction schedule and improve constructability.

The final analysis described in this proposal will be a greater use of BIM on LH.O. This analysis is intended to increase value for the project, and it will include a case study as critical research. It is expected that use of BIM in construction will be deemed valuable and that record modeling will not. However, the case study is expected to serve as a basis for determining when record modeling is valuable for the industry.

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PROJECT BACKGROUND

The LancasterHistory.Org (LH.O) project includes both a renovation and addition to the existing Lancaster Historical Society Building. Additional infrastructure is required, as the organization adjoins with the neighboring Buchanan Estate, forming the Lancaster Campus of History (LCH). The 32,068 square foot project includes 14,121 square feet of renovation work and a 2-story 19,755 square foot addition. The renovation expands the existing library and includes a rare book room. The addition includes research facilities & archive, exhibition galleries, a multi-use educational auditorium, offices and additional space for collection storage & conservation. In addition to expanding infrastructure, LH.O has invested in upgrading various building systems. The upgrade includes complex mechanical & electric systems, reducing its environmental & energy impacts and helping it reach LEED gold certification.

The project is being delivered via a Design-Bid-Build method for $13.5 million, having a 14 month construction schedule. The delivery method is actually more of a Design-Fundraising-Bid-Financing-Build structure, because the building is a cultural one and is funded entirely by private donations and state grants. Project start was October 3, 2011, and substantial completion was reached on November 28, 2012 despite early schedule delays.

Located in Lancaster, Pennsylvania on a ten acre arboretum next to a historical landmark, LH.O inherits various, unavoidable construction concerns associated with the site. Not to mention, 2011 was the wettest year on file for the area (Brandt, 2012). The owner required that its various trees be protected, limiting space for construction amongst other concerns. Also, the LCH contains the Buchanan residence, a designated National Historic Landmark as of 1961. Naturally, this building had to be protected, especially because its museum remained in operation for the duration of construction.

TECHNICAL ANALYSIS 1:
Study of Soil Remediation Effects on Constructability & Schedule*

*Includes Structural Breadth (see Appendix A)

Problem Identification

Unsuitable soil conditions at LH.O negatively impacted project construction efforts and schedule. Substructure design changes required additional excavation and rock-bins. In addition, soil could no longer be backfilled. As a result, CMU exterior wall installation was delayed, and the dry-in milestone could not be met. Would a different soil remediation tactic improve constructability and shorten project schedule?

Background Research

A comprehensive geotechnical report can improve a project's constructability and shorten its schedule, depending on geographical location. Not all subsurface concerns can be realized from a report, but an effectively managed investigation and evaluation improves the odds. This could be the case for LH.O, given Lancaster's often clayey conditions (Brandt, 2012). According to the geotechnical report conducted prior to construction, two soil samples were analyzed in the lab. These samples include elastic-silt with sand and silty-sand with gravel, which are expansive in nature. The soils did not meet required compressive strength upon analysis. Rock bins were engineered to address this issue, simultaneously reducing storm water runoff from a green perspective.

Substructure constructability would improve with an enhanced geotechnical report, because lower level designs would have probably allowed for backfill. However, soil remediation was required due to its unsuitable condition, requiring more field labor and more diesel trucks, which is not very green. In addition, safety concerns associated with deeper excavations arose, given the sites special restrictions. Soils hauled on and off site caused logistics issues. Further, this remediation tactic required additional time.

Project schedule was 10 work days behind schedule following LH.O substructure completion. This was due to logistics issued with soil hauling, deeper excavations, larger rock bins and the associated tests and design considerations. Based upon lessons learned in CE 397A, alternate soil remediation tactics and/or redesigns would have most likely improved constructability and shortened schedule.

Critical Industry Issue Research

Given the potential benefits of reduced construction schedule and improved constructability, the importance of an enhanced geotechnical report will be further researched in providing critical industry issue research. The research will be aimed at whether a contractor should recommend further investigation, considering contract type. Research should determine the impacts placed on a project's schedule and constructability, when incorporating additional, pre-construction tests and analysis of soil conditions. The goal will be to determine to what extent supplemental geotechnical information is effective, regardless of responsibility. The study should be interesting because many projects could potentially benefit from additional subsurface research and planning.

Application Methodology

In conducting research for this technical analysis, the following steps are to be executed:

1. Conduct critical industry issue research
    a. Utilize Engineering Library resources
    b. Write a critical literature review for the industry
    c. Perform case studies of the following projects:
        i. Pegula Ice Arena, State College, PA
        ii. Forestry Building, State College, PA
        iii. Crystal Bridges Museum of American Art, Bentonville, AR
    d. Report geotechnical effects on construction management and project delivery
2. Determine special provisions research and develop structural breadth (see Appendix A)
    a. Study the construction methods conducted for the implemented soil remediation tactics
    b. Evaluate soil remediation tactics using developed geotechnical report
    c. Engineer practical designs for problem areas
3. Analyze LH.O engineering design options for schedule and constructability
    a. Interview the project manager, Bob Brandt III, civil engineer, Bill Swiernik, and structural engineer, Charlie Brown, to better understand issues encountered and steps taken
    b. Interview Walt Schneider, a PSU soils and foundations instructor, for impartial opinion
    c. Utilize Engineering Library resources
    d. Create a weighted matrix table to determine the best available solution

Preliminary Analysis

Having reviewed LH.O's geotechnical report information and considered its impacts on the project schedule and subsurface constructability, it is clear that the report is lacking in detail. This understanding is corroborated by the GC and by a panel of judges in a preliminary proposal presentation. Therefore, critical industry research is required to demonstrate the importance of a well conducted geotechnical report. A cases-study is feasible based on the fact that there is an abundance of information available.

An analysis of soil remediation versus other construction options on the bases of schedule and constructability is required. The owner has pondered the very question. Also, Dr. Anumba and the proposal judge panel have expressed interest in this analysis. Research is feasible given the abundance of industry professionals whom are willing to contribute. Walt Schneider an AE alumnus has agreed to offer his professional opinion.

Potential Solutions

Based upon the contract between the owner and the GC, Benchmark was not required to conduct further preliminary geotechnical research. As this is a construction management proposal, only solutions in response to differing soil conditions will be presented; not geotechnical reporting. Potential solutions to LH.O's unsuitable soils are as follows:

- Soil remediation
    - Excavate expansive soil and replace with non-expansive fill
    - Application of hydrated lime to swelling soil
    - Pre-wet soil to increase moisture content
- Structural redesign
    - Footing piers
    - Slab-on-grade
    - Rock bins
- Combination of soil remediation & structural redesign aspects

Expected Outcome

It is anticipated that a combination of soil remediation and foundation structural redesign aspects will be the best option to resolve the issue of unsuitable soils, considering schedule and constructability. Specifically, it is anticipated that a combination of applying hydrated lime to the soil and designing footing piers are most effective, based upon a preliminary conversation with Schneider (2012).

TECHNICAL ANALYSIS 2:
Investigation of a Conventional Mechanical System*

*Includes Mechanical Breadth (see Appendix A)

Problem Identification

Water wells were hit when geothermal wells were drilled at LH.O, requiring additional testing and a mechanical system re-design. The closed-loop system was scrapped because its 26 well loops would have to be encased, estimated to cost an additional $1,000,000 for the project. An open-loop system is currently being tested for, but a practical drilling location remains to be determined. Would a conventional mechanical system be more valuable to the owner than an open-loop geothermal system on the bases of cost, durability and schedule savings?

Background Research

The project's geothermal system could have benefitted from more extensive testing done earlier on, as it is still being tested, even though the building is otherwise complete. However, it was not, and costs for the HVAC system keep going up. The original HVAC system estimate was estimated to be $1.3 million in *Technical Analysis 1*, but this number continues to go up for every test drill performed for the geothermal system. HVAC performance is required by the owner, it affects the project's LEED certification, and it impacts the overall value of LH.O. This performance may or may not be realized if another design solution is not implemented (Sarratt, 2012). In performing value engineering, a more conventional mechanical system may replace the geothermal one.

Application Methodology

In conducting research for this technical analysis, the following steps are to be executed:

1. Analyze LH.O mechanical engineering design value and consider re-design
    a. Interview the project geotechnical engineer, Bradley Randall, and mechanical engineer, Andrew Sebor, to better understand steps taken and issues encountered
    b. Interview Robert Leicht, a PSU construction professor, to get an impartial opinion
    c. Utilize the Engineering Library
    d. Conduct a feasibility study of alternate mechanical systems

2. Research and develop mechanical breadth
    a. Study the Life Cycle Cost (LCC) of the implemented geothermal system
    b. Develop alternate mechanical system LCC estimates
    c. Compare LCC of the geothermal system versus more conventional systems
    d. Determine the most valuable mechanical system that meets owner criteria

Preliminary Analysis

Value engineering is a very effective and important tool, especially when performed by the construction industry. Given the cost and performance issues associated with LH.O's mechanical system, it makes sense to consider alternate options. Performance and cost data is available from Centerbrook and Benchmark, which will be considered. Lessons learned from AE 310 and AE 475 regarding HVAC systems and value engineering show that a conventional system is practical. This is corroborated by Brandt and Anumba. A structural option AE has suggested mechanical systems for analysis found below in *Potential Solutions*. The mechanical breadth will be addressed using lessons to be learned in AE 476.

Potential Solutions

In value engineering a conventional mechanical system for LH.O, foreseeable outcomes include the following:

- Closed-loop geothermal system (encase wells)
- Open-loop geothermal with chillers
- Central plant system (cooling tower with chillers)
- Additional AHUs

Expected Outcome

It is anticipated that a central plant system will be most valuable to the LH.O project on the bases of cost, durability and schedule savings. This theory is predicted, given that LH.O geothermal system problems were encountered extremely late in construction. A central plant system can be more easily be designed and incorporated than other options. Its initial cost is predicted to be much lower than the options', lowering its LCC as well. System performance is expected to address owner needs.

TECHNICAL ANALYSIS 3:
Application of MEPF Prefabrication

Opportunity Identification

LancasterHistory.Org's design includes highly customized MEPF systems, which are fairly complex and time-consuming to install. Further, many aspects of the building are already documented in computer models. Would an application of MEPF prefabrication increase constructability and shorten project schedule for LH.O?

Background Research

Prefabricating MEPF systems can improve system constructability and shorten project schedule, depending on system types and connections. An application of MEPF prefabrication should be analyzed for the LancasterHistory.org project due to its system interactions and complexities. For example, the electric system includes eleven 120/240V panel-boards feeding the building's systems, Lutron light fixtures, and a photovoltaic system. In an interview, Brandt specifically mentioned that the panel boxes for these electrical features could have been prefabricated to facilitate installation and reduce schedule (2012).

Though not addressed in the Brandt interview, aspects of LH.O's mechanical and fire protection systems could have also been prefabricated to this effect, given their relatively complex designs. The mechanical system includes a DOAP with enthalpy wheel and 3 VAV ACU's with humidifiers and dehumidifiers. A computer model has been created for the system, which could be used to facilitate communications with fabricators. Fire protection includes a 500 GPM split-case fire pump, laser smoke detection, both wet and dry sprinkler systems, and a visual display communication system.

Application Methodology

In conducting research for this technical analysis, the following steps are to be executed:

1. Analyze MEPF schedule and constructability
    a. Interview the CM, Bob Brandt III, to gain further insight about MEPF scheduling and installation
    b. If possible, interview subcontractors about their experiences installing these systems at

LH.O and inquire about any past experiences with prefabricated system installation

c. Determine which MEPF systems were the most difficult and/or time consuming to install

2. Perform MEPF feasibility study
   a. Contact fabricators, preferably local, that produce these respective systems
   b. Perform a feasibility study, based on the project schedule, availability of prefabrication, lead times and construction logistics
3. Make recommendations and produce a 3D model
   a. Recommend certain MEPF systems to prefabricate, and demonstrate expected scheduling impacts
   b. Produce a model to demonstrate installation & constructability benefits

Preliminary Analysis

In regards to electrical prefabrication, essentially everything can be prefabricated from pre-punched junction boxes and panel ends to custom wire assemblies to lighting assemblies. Companies such as Marathon Electrical Contractors provide this service. If the application is properly planned, labor efficiency should increase, non-productive time should be reduced, work environment should be cleaner and safer, and overlapping work areas of trades should be reduced.

HVAC and plumbing prefabrication is anticipated to provide similar benefits to LH.O. Companies such as HiMEC Mechanical fabricate these building features and even specialize in green/sustainable projects. In the case of LH.O, these systems were already designed in 3D models, which could be sent to the fabricator for production. System design would include everything from photovoltaic panels to heat pumps to heat recovery coils.

Fire protection sprinklers, pipes, fire department connections, sensors, and communication systems could likewise be prefabricated. Companies such as GEM Fabrication perform this service and utilize green building practices per USGBC.

Potential Solutions

In determining MEPF systems to prefabricate for LH.O on the bases of scheduling and constructability, foreseeable outcomes include the following:

- Prefabrication of all systems will be found beneficial
- Lead times considerations, party communication issues, transportation issues or other

restrictions will render one of the systems impractical for prefabrication

- Only prefabrication of electric panel boxes will be found beneficial

Expected Outcome

It is anticipated that select aspects from each of the MEPF systems which presented the biggest installation and scheduling challenges will be deemed feasible for prefabrication on the LH.O project. This is predicted, given the complexity of various electrical system features and the availability of computer models. Prefabrication can increase labor efficiency, reduce non-productive time, reduce work overlap between trades, and allow a cleaner safer workspace. The project schedule is predicted to be shorter as feasible MEPF prefabrications are implemented, further increasing constructability for those systems.

TECHNICAL ANALYSIS 4:
Greater Use of BIM

Opportunity Identification

Building Information Modeling (BIM) can be effective for essentially any aspect of a building's creation when used effectively. In the case of the LancasterHistory.org project, BIM was helpful in the design phase but could have been used more in the construction phase to increase project value. Further, there is potential for BIM to be handed over to the owner for operations. Creation and detailing of various BIM models should facilitate analyses of BIM utilization values and serve as a case study for industry research.

Background Research

Based upon conversations with the owner and project manager and based upon lessons learned in AE 473, potential utilizations and respective intents for LH.O are as follows:

- Code validation - eliminate code design errors
- Digital fabrication - adapt to late design changes
- 3D coordination – perform clash detection
- Record modeling - LCC considerations

According to Robin Sarratt, LH.O VP, various codes were not met (2012). For instance, some handrails were not included in design or budget that had to be later installed. In addition, a shower was not handicap accessible by the Americans with Disabilities Act (ADA), and it cannot be used. The shower's exterior dimensions were per code but its interiors' were not. Code violations such as these can easily be checked with computer models.

As mentioned in the proposal for *Analysis 3,* prefabrication would have greatly simplified electric panel installation. Assuming implementation of this and prefabrication of other MEPF features, digital fabrication could greatly increase project value. LH.O received a grant by the Redevelopment Assistance Capital Program (RACP) which requires prevailing wage in construction but not for prefabrication (Brandt, 2012).

From lessons learned in AE 473 and various other AE classes at PSU, 3D models can increase project value by detecting system clashes before construction even begins. Due to the fact that 3D models are already available, clash detection may easily be performed to increase LH.O value. Sarratt mentioned various clashes at LH.O such as ductwork and structural steel (2012).

Critical Industry Issue Research

From lessons learned at the Partnership for Achieving Construction Excellence (Model Handover, 2012) Roundtable event, model handover may be implemented as a BIM use, because it is easier and more manageable for the owner than paper records alone (2012). In fact, cost savings associated with use of BIM record models primarily stem from time savings by maintenance personnel. Also, models help establish continual relationships between parties. Industry professionals at the PACE event realize a dilemma arises, as most owners do not realize tangible benefits of a record model. For further industry issue information, please see Technical Report III. LH.O record modeling could include MEP equipment with moving parts and LEED items. Ideally, file LCCs would be practical. Research is required to determine at which point record modeling would be valuable for LH.O.

Application Methodology

In conducting research for this technical analysis, the following steps are to be executed:

1. Prepare a record model for LH.O
    a. Inspect for systems included
    b. Consider thoroughness and detail
    c. Check for change orders
    d. Attempt to correct model shortcomings using Revit and AutoCAD
    e. Perform clash detection to ensure accuracy
2. Analyze utilizations of BIM for value
    a. Interview the project manager, Bob Brandt III to better understand detail of existing computer models and extent of BIM implementation
    b. Interview project architect, Pete Cornell, to better understand the following:
        i. Extent of BIMs implementation and application in design
        ii. Communication agreements and techniques between parties
        iii. Local BIM design personnel costs and fees
    c. Utilize the Engineering Library & BIM Execution Planning Guide
    d. Estimate potential savings and added values of BIM utilizations

   e. Weigh cost of implementation with savings and added value
   f. Make recommendations for BIM utilizations to be implemented
3. Conduct critical industry issue research
   a. Interview with industry contacts such as Bill Moyer to inquire about past trials and tribulations with BIM
   b. Conduct a case study of similar project types where record modeling was required by owner for costs of implementations and added value
   c. Report LCC of BIM record models

Preliminary Analysis

Upon preliminary research, this analysis is feasible. A record model can be generated for LH.O because design models are available from Centerbrook architecture. Also, various AE teachers and graduate students have offered assistance. The model detailing process is anticipated to take a long period of time which is accounted for in the *Proposed Schedule.*

In creating a record model for LH.O, value of BIM utilizations will be realized, because code violations and system clashes can be seen simply by using the design model available. This shows that costly change orders could be prevented before construction. Time spent in analysis will be recorded to prove value.

Critical industry research information regarding record model value is essentially non-existent according to industry professionals such as Bill Moyer (Model Handover, 2012). Therefore, this research will come secondary to the critical industry issue research described in *Technical Analysis 1,* which is reflected in the *Proposed Schedule*. However, the research is deemed feasible, because PSU OPP personnel such as Craig Dubler have relevant information and are willing to help. In addition, Moyer has agreed to help.

Potential Solutions

In analyzing a greater use of BIM on the basis of value, foreseeable outcomes include the following:

- Costs associated with BIM personnel and communications will render BIMs use in construction & operations impractical
- Only BIM used for construction will be deemed valuable
- BIM used for construction & operations will be deemed valuable

Expected Outcome

Based upon preliminary analysis and past reports, it is expected that a greater use of BIM in construction will be valuable for LH.O and model turnover will not be valuable. BIM is expected to be valuable in construction based on lessons learned at PSU. Model turnover is anticipated to be deemed impractical given the size of LH.O's infrastructure. However, it is expected that the value of record modeling will be proven for large establishments such as PSU. Information discovered for PSU and LH.O could be compared to show at which point infrastructure size renders a record model valuable. It is expected that further research will be required by the industry to determine this.

CONCLUSIONS

A weighted matrix is developed to convey how time and resources will be spent in the spring semester in developing a thesis. The four analyses described in this proposal are allocated a number out of a hundred percent, shown in the total column. This number is broken down further by core thesis investigation area, including industry research, value engineering, constructability review and schedule reduction. See below for the weighted matrix analysis.

Weighted Matrix Analysis

Analysis Description	Industry Research	Value Engineering	Constructability Review	Schedule Reduction	Total
Study of Soil Remediation Effects on Constructability & Schedule	15	-	10	10	35
Investigation of a Conventional Mechanical System	-	20	-	-	20
Application of MEPF Prefabrication	-	-	10	10	20
Greater Use of BIM	10	15	-	-	25

It is shown that soil remediation and BIM analyses will receive the greatest amount of time allotment, as these areas include industry research topics. Further, value engineering receives the greatest amount of time of the core research areas. This addresses the needs of the owner as a nonprofit, and it ensures a quality business relationship for future projects.

A proposed schedule for the spring semester is included in Appendix B. This schedule includes four mile stone dates, Jan. 28, Feb. 11, Mar. 1 and Mar. 25. Various analyses' activities are to be completed by these dates in order to keep the project on schedule. The record modeling and 3D modeling activities are considered secondary priorities and are not reflected in the weighted matrix analyses. These are to be worked on if analyses, research and breadth are considered to be on track.

WORKS CITED

"Brandt, PM, Benchmark." Personal interview. 23 Nov. 2012.

"Checklist and guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications." *Fhwa.dot.gov*. Federal Highway Administration, 4 July 20122. Web. 15 Dec. 2012.

"Model Handover." 21st Annual PACE Roundtable. Penn Stater Conference Center, State College. 6 Nov. 2012. Event.

"Problem Soils." *Az.gov*. The Arizona Geological Survey, n.d. Web. 15 Dec. 2012.

"Sarratt, VP, LancasterHistory.org." Personal interview. 26 Nov. 2012.

"Schneider, Instructor, PSU." Personal interview. 19 Dec. 2012.

APPENDIX A:
Breadth Studies

Structural Breadth

The structural breadth topic for *Analysis 1* will be a redesign of the LH.O substructure, attempting to improve constructability. This task should be facilitated by the project geotechnical report as proposed in the analysis details. Foundation structural analyses will primarily address uplift force from expansive clays. Lateral loads and down-drag will be accounted for. Construction methods utilized in soil remediation will be studied and improved. When unsuitable soils were encountered on site, excavation and replacement was performed as a solution. Alternate remediation methods deemed feasible from a value standpoint will then be analyzed for constructability in detail. Constructability is the focus. Methods to be analyzed for constructability include applying hydrated lime and pre-wetting. As such, new site layout plans will be developed. In addition, LH.O's substructure designs will be assessed for construction safety. The assessment will cover foundations and rock bins. Ideally, soil will not have to be hauled to and from the site and made suitable for backfill, addressing safety and logistics issues and improving constructability. (See page 5 for deliverables).

Mechanical Breadth

The mechanical breadth topic for *Analysis 2* will be a redesign of the LH.O mechanical system, attempting to increase value. Various conventional mechanical systems will be evaluated for system performances to ultimately replace the project's failed geothermal one. Systems will be sized and designed to meet internal cooling loads. Afterwards, Life Cycle Cost (LCC) will be analyzed for each design option. Analyses will be conducted utilizing assembly estimates, vendor quotes, and GC and subcontractor input. Testing and commissioning requirements will be considered. By nature of LCC studies, system initial design and construction costs will be weighed with operating and energy expenses and system life spans. The system providing the most valuable combination of performance and cost will be selected for further analysis for LH.O. (See page 9 for deliverables).

APPENDIX B:
Proposed Schedule for Spring Thesis