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Construction Management
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TECHNICAL ASSIGNMENT III

LancasterHistory.Org
Lancaster. PA

EXECUTIVE SUMMARY

Technical Report III focuses on addressing challenges for the LancasterHistory.org project, particularly that of establishing a quality product. It covers areas of LEED Certification, Project Critical Path & Acceleration methods, Value Engineering, and relating Critical Industry Issues of PACE Roundtable. Brief findings for each of these categories are stated below.

LancasterHistory.org LEED certification went very well with the project achieving gold certification. More importantly, system efficiency and other important green criteria of the owner were met, pending a successful completion of the project's geothermal system that had to be redesigned due to unforeseen conditions.

Value engineering was performed for several aspects of the project, including the aforementioned geothermal. In addition, exterior glulam beams were replaced by concrete bond beams to save money, later in the project's design stage. Multiple other considerations could have been implemented.

Critical industry issues discussed at the PACE roundtable include supply chain and model handover. Such discussions lead to an industry feedback session, where it was discussed how break-out sessions could relate to the LancasterHistory.org project. This lead to various BIM problem identifications, including an application of prefabricated MEPF systems and model turnover to the owner. Other key research topics include further value engineering analysis such as the project geothermal system and soil remediation. These were two major issues for the LH.O project.

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LEED Evaluation

Overview

The US Green Building Council (USGBC) defines Leadership in Energy and Environmental Design (LEED) as "A voluntary, consensus-based, market-driven program that provides third-party verification of green buildings… [and] provides building owners and operators the tools they need to immediately impact their building's performance and bottom line, while providing healthy indoor spaces for a building's occupants." In applying these tools to the LancasterHistory.org project, it is important to remember the rationale behind scoring and not just meet requirements to achieve certification. Therefore, the various LEED categories are considered during all phases of the project lifecycle to maximize building system efficiency. As a corollary, the LH.O project is able to earn at least 69/110 points on the Project Checklist (see Appendix A for complete scorecard), earning Gold Certification. Summaries by LEED category can be found below (reference Table 1), followed by a LEED Critical Evaluation.

LEED POINTS SUMMARY				
Y	**M**	**N**	**Category**	**Points Possible**
13	0	13	Sustainable Sites	26
6	2	2	Water Efficiency	10
24	5	6	Energy & Atmosphere	35
9	0	5	Materials & Resources	14
12	0	3	Indoor Environmental Quality	15
2	2	2	Innovation & Design Process	6
3	0	1	Regional Priority Credits	4
69	**9**	**32**	**Total**	**110**

Table 1: Summary of LEED Points

Sustainable Sites

A prerequisite of this portion of the LEED Checklist is to prevent construction pollution. This means controlling soil erosion, waterway sedimentation and generation of airborne dust. To address this important matter, the LH.O civil engineer, XX, worked with Benchmark to develop a custom erosion and sediment control plan. In addition, XX made various storm-water designs including 6 rock bins to prevent future runoff and minimize the buildings impact on the site, even after construction is over.

Various other key criteria met in this category include site selection, public transportation access, low-emitting & fuel-efficient vehicles, and roof heat island effect. The LH.O site, located just outside of Lancaster city, is a renovation project, so by nature it is already developed, and the site selection may be considered appropriate. Further, it lies less than a ¼ mile from a prominent, city bus loop and a ½ mile away from another (see Appendix A for Transit Map). Last, preferred parking is included in civil designs, and the building roof design contains photovoltaic panels with high solar reflectance index that minimize heat-island effect.

Water Efficiency

The water efficiency category is important to consider in design as a great deal of potable water is wasted in the United States every year, predominantly from buildings. Therefore LEED has made it a requirement that water use be reduced by at least 20%. LancasterHistory.org realizes the importance of this criterion and has taken initiative to not use potable water for irrigation, and has reduced in-building water use by at least 30% by installing efficient fixtures fittings and appliances.

Energy & Atmosphere

Before any points can be garnered for this category, very specific, important requirements must be met being, fundamental commissioning of building energy systems, minimum energy performance and fundamental refrigerant management. Commissioning is very important to make sure systems are working properly and to reduce facility energy consumption and life cycle costs. As the LH.O project is smaller than 50,000 gross square feet, Benchmark is the commissioning authority, and the company meets the enhanced commissioning credit. To meet minimum energy performance, LH.O design is analyzed per ASHRAE Standard, and energy usage/costs are reduced. Last, HVAC refrigerants are to be reduced or not used at all to reduce stratospheric ozone depletion and help stop global warming. The project exceeds this requirement based upon LEED's refrigerant management formula.

Optimal energy performance is very important to all involved parties of the LancasterHistory.org project. In fact, percent improvement of building performance over its baseline evaluation is simulated to be between 35% and 45%. This is achieved with a very efficient architectural design, combined with a highly efficient HVAC system, including an open-loop geothermal system. In addition, the roof's photovoltaic panels are estimated to provide 4.5% of the facilities energy cost, as a renewable source. These panels also allow for the green power credit to be met. As previously stated, the project owner greatly values an energy efficient facility, and has established a measurement and verification plan that follows IPMVP protocol for at least a year and a two year renewable energy contract.

Material & Resources

The intent of this LEED certification category is to encourage and facilitate waste reduction in design and construction. Therefore, it is required that an easily-accessible recycling area is located on site for construction waste. Benchmark meets this requirement, further reusing a minimum of 75% of the existing building. Recyclables are transported to the nearby recycling plant and records of this are documented. Materials used in LH.O's construction materials consist of at least 20% recycled content by cost, which helps to reduce environmental impacts associated with extracting and processing virgin materials. Also, regional materials are utilized for the building wherever possible to reduce transportation impacts. At least twenty percent of materials by cost come within a 500 mile radius of the site, often less far (note - steel is at least

75% US made by RACP policy). Finally, the responsible forest management credit is met by the project, as at least half of the wood by cost is certified in by the Forest Stewardship Council's principles and criteria.

Indoor Environmental Quality

Indoor air quality (IAQ) and environmental tobacco smoke (ETS) control are very important features to the owner to ensure the comfort & well-being of building occupants. Further, this area is particularly important to help preserve historical books and artifacts to be stored, and to protect occupants from radon to be utilized in the artifact preservation room. IAQ and ETS are also important to LEED and are required for the category.

LH.O is able to supplement these requirements, receiving credits for OA delivery monitoring, IAQ management, low-emitting materials, indoor chemical and pollutant source control, controllability of systems and thermal comfort. OA delivery monitoring is pretty standard for modern buildings, and is required for rental properties. It basically is a carbon monoxide detector. IAQ management deals with the proper storage and installation of materials and filtration. Filters are replaced and air is flushed out prior to occupancy. Low emitting materials utilized on the LH.O project consist of adhesives, sealants, paints, coatings, flooring systems, composite wood and agri-fiber products. Low emitting means that the materials are low VOC and do not present an odor. Chemical and pollutant source control is conducted by exhausting hazardous gasses and by capturing dirt and particles entering the building at double doors and using proper filtration. Controllability of systems was very important for the owner. At least half of building occupants can control for thermal comfort and nearly all can control for lighting. Most of the lights are set to dim depending on natural light availability to maintain comfort. These dims are automatic but can be adjusted by the owner or dimmed manually. Thermal comfort is designed per ASHREA Standard and is to be verified via survey within a year of occupancy.

Innovation & Design Process

This LEED criterion is established to provide the design team involved on the project with an additional opportunity to earn points based upon credits that are not addressed in other categories but that deserve merit. One point is earned by LH.O because Peter Cornel, the project Architect, is a LEED AP. Another point is awarded for an innovation in design dealing with architectural aspects of the project.

Regional Priority Credits

Regional priority credits are accounted for by LEED to "provide an incentive for the achievement of credits that address geographically specific environmental priorities." The LH.O building earns three credits, as Lancaster, PA is construction isn't particularly green or at least not LEED certified. Further, the building is a renovation and counts as a reuse.

LEED Critical Evaluation

The application of USGBC's LEED to the LancasterHistory.org project shows that the efforts by Centerbrook, Benchmark, ASW and the owner to create a green, energy efficient, quality building are able to pay off. Commissioning went well, and systems are performing as designed apart from the geothermal system which is undergoing testing. Owner requirements for indoor environmental quality are met, as LEED shows 12/15 points, and energy use & atmosphere have potential to earn up to 27/35 points if the open-loop system works out. Areas for improvement include innovative wastewater technologies and other innovations in design. However, this is easier said than done. Another area for improvement would be to VE more renewable energy sources into the project without going over budget if possible. Overall, LEED scoring notes the LancasterHistory.org project to be pretty green pursuant owner goals.

SCHEDULE ACCELERATION SCENARIOS

Overview

According to the Project Management Institute, the Critical Path Method (CPM) is an algorithm used to schedule a group of project activities (2008). This project management technique is quite effective for the construction industry, given schedules' multitudes of tasks. Like any construction project, the CPM for the LancasterHistory.org building is established by determining dependencies between activities on the projects schedule. After, an early completion can easily be determined with scheduling software such as Oracle Primavera. As such, the critical path may be determined, showing which activities are a priority and directly affect project completion date if delayed (see Figure 1: Critical Path Summary). Activities not on the critical path have float and may be delayed to an extent without affecting the overall schedule. The critical path and path with float may be separated to analyze if construction duration can be expedited. A project's schedule may be shortened by fast-tracking floated paths or by crashing the critical path. Fast-tracking is when non-critical activities overlap, and crashing is when critical activities are shortened by increasing their resources. All things considered, Benchmark was able to get its fourteen month schedule approved by the owner, slating a date of substantial completion for December 3rd of 2012.

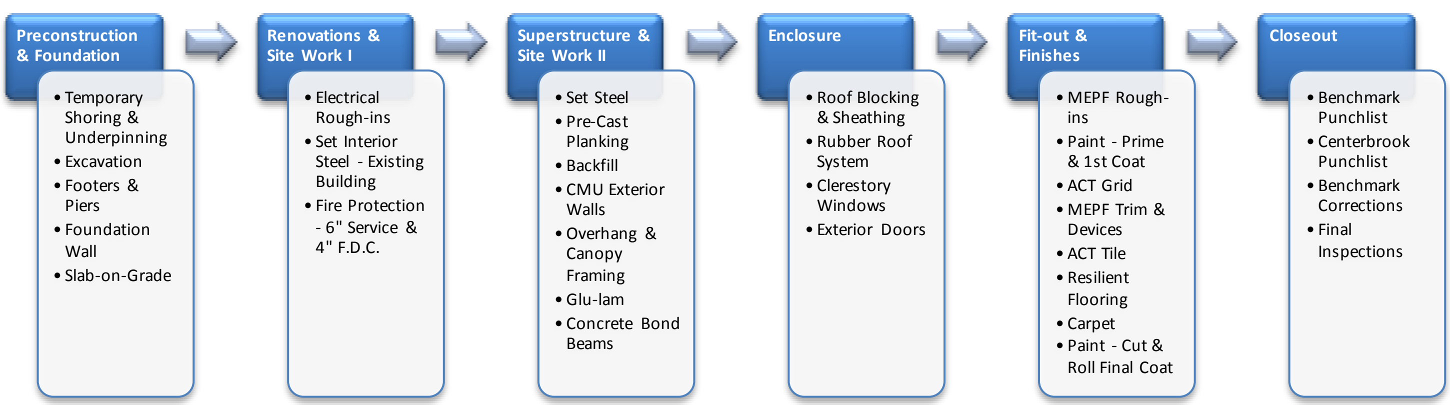

Figure 1: Critical Path Summary

High-Risk Activities

All critical path activities should be considered high risk for a project's schedule, but some tasks require extra attention for whatever reason and are denoted high-risk. For the LancasterHistory.org project, site work and various customized building features are considered high-risk. Given LH.O's numerous & expansive civil activities, paired with its stringent workspace limitations (see Tech. Reports I & II), Benchmark wanted to pay extra attention to site completion, or as Bobby Brandt III puts it, "Expedite the site." In doing so, site work merits its own schedule with two phases, having more tasks associated with it than construction itself. Such detail is highly unusual for a building of LH.O's size. Though, the denoting of site work as high-risk later paid dividends for Benchmark and the owner, as differing soil conditions plagued the schedule early on (note: the year 2011 was the wettest year for PA on file). Complications included: unsuitable backfill soil, extra excavation & rock bins needed, and the associated tests & change orders. Because site activities were meticulously planned, Benchmark was able to get it out of the way without disturbing the operational Wheatland or its arboretum.

In addition to considering site work a high risk activity, customized building features on the critical path of the LancasterHistory.org project schedule are denoted high risk. Because of the unique nature of the building's architectural design, it requires installation of several customized parts. As such, there is high potential for error and schedule delay during their construction. In particular, the concrete bond beams, located above the CMU exterior walls present the largest risks to the overall project schedule. The concrete bond beams are unique structural features simply because the pieces are curved vertically (see figure 2 on next page). As such, these elements necessitate unusually shaped plywood formwork, unusually curved rebar and design strength concrete that wouldn't run down and flow-over at the bottom of the arc. Improper installation would negatively impact building dry-in date and date of substantial completion. In response, extra attention is paid to concrete tests and installation techniques. It is important to closely work with subcontractors in the field when installing the concrete bond beams.

Figure 2: Concrete Bond Beam Form

Schedule Acceleration Techniques

The LancasterHistory.org project schedule is accelerated in numerous key areas. As mentioned in the previous section, project site work is fast tracked and front loaded to compensate for its high risk. In addition, extra resources such as upper management are required for bond beam installation to crash its sequence. Many other areas of the project schedule are accelerated to help meet the substantial completion deadline. For example, existing building renovations were pushed forward during delays from the differing soil conditions. This would save time later in the construction schedule by approximately a month. However, no overall cost savings were achieved by this method, as activities were simply rearranged.

Further, the lower-level activity sequence and ground-level activity sequence are fast tracked. Within several sequences, many activities are also fast-tracked. By overlapping the lower-level and ground-level sequences, work is completed from the lower level up to the ground level.

After a task is completed on the lower level, that crew moves work upstairs, and the next task begins on the lower level by a separate crew. As an example, the installation experience and knowledge from the project's customized casework can be retained this way. This is particularly important for the LH.O project because the learning curve is so great for various tasks like casework and various other wood system installations. In addition to fast tracking sequences, various tasks are completed simultaneously. For example, CMU basement shear walls are installed at the same time as the foundation walls are formed and rebar installed. Such methods reduced the foundation construction duration by up to two weeks, helping get the schedule back on track and saving general conditions costs and time with the structural engineer on site.

In addition to fast tracking sequences and activities, various tasks are crashed in order to accelerate the construction schedule. A prime example of this is the superstructure installation. Due to the site's differing soil conditions, superstructure construction was crashed in attempt to meet the building enclosure date. According to Brandt, the additional labor resources applied to the structural steel allowed for it to be set two weeks faster than expected and reduced crane costs. CMU exterior walls were also crashed and completed a few days ahead of schedule. In turn, the building was able to meet its dry-in deadline (note: during the extra lag-time from soil delays, resources were reallocated to ensure proper water proofing installation below grade). Costs of crashing the schedule early on are felt by the owner. Overall, these costs accumulate to an estimated $21,000, accounting for general conditions savings and prevailing wage expenses.

VALUE ENGINEERING TOPICS

Overview

According to the US General Services Administration, Value Engineering (VE) is, "An organized effort directed at analyzing the functions of systems, equipment, facilities, services and supplies for the purpose of achieving the essential functions at the lowest Life Cycle Cost (LCC) consistent with the required performance, reliability, quality and safety." Simply put, VE is intended to increase a construction project's value, measured as a ratio of function and cost, while delivering all required project features and functions. This analysis is most effective when performed in the early stages of project design and may persist through construction if needed. It is not meant to question architects or engineers. Rather, it provides the best service possible to the owner. As such, VE was performed by Benchmark Construction Company, Inc. for the LancasterHistory.Org (LH.O) renovation & addition project, and some of the topics considered in VE have been implemented.

Value Engineering Topics Implemented

Perhaps the most effective VE topic implemented on the LH.O was actually engineered during the project's construction phase. After differing soil conditions were encountered, design changes had to be made to ensure structural integrity of the building. Options included foundation redesign, soil remediation or utilization of more rock bins. All would negatively impact the project's schedule and budget, so it was up to the owner to evaluate the pros and cons of each option. Rock bins were eventually decided upon as a solution, requiring more excavation and stone hauling. However, this solution would allow for a timelier and higher quality product than a foundation redesign, according to Benchmark. It would cost much less than soil remediation by an estimated $275,000. However, the owner is unconvinced of this (see *Value Engineering* on page 19).

Another Example of VE applied to the project was the design change of exterior glu-lam structural arcs to concrete bond beams. The design change would present new challenges for the general contractor in terms of installation (see *High Risk Activities* on page 9), but it greatly reduced costs while meeting owner concerns. The main issue was that the concrete arc wouldn't be aesthetically pleasing from an architectural standpoint. In a weekly project meeting of involved parties, it was determined that exterior glu-lam arcs wouldn't be eliminated, only made thinner. Their thicknesses would extend just to the wall to simulate continuity, while the lumber void above the exterior walls would be replaced with concrete and metal reinforcing. The architect and structural engineer were able to work with Benchmark to design the glu-lam dimensioning and concrete beam designs. The last qualm of the owner was that the faux structural lumber on the exterior walls wouldn't be an authentic representation of the building's engineering, but the potential cost savings outweighed such worries, as LH.O approved the design.

The LH.O building construction team experienced another unforeseen condition when a well of water was discovered drilling holes for the geothermal loops. This discovery presented the possibility of substituting an open-loop system for the already designed closed-loop system. It was decided that the open loop system could save money. However, this change happened a bit too late into the project and has proven to be tricky (see *Geothermal Loop System Testing* on page 20).

Value Engineering Ideas Not Implemented

Other value engineering ideas considered for the LH.O project were not implemented. Please see *Value Engineering* on page 20 for more details. In an interview with LH.O VP Robin Sarratt, it seemed as if value engineering was mostly foregone in this construction project. Designs by the architect were overseen by LancasterHistory.org worker who also happens to own a construction company. As such, Benchmark was encouraged to follow designs that were bid.

CRITICAL INDUSTRY ISSUES

At the 21st Annual PACE Roundtable event, students and industry professionals came together to discuss specific topics as they relate to "Improving Efficiency through Innovation," the title of this year's meeting. The event was held on Tuesday, November 6th at The Penn Stater Conference Center, and it had a mixed format of a panel discussion, two break-out sessions and a focus group. Penn State AE CM Option students were expected to gain understanding of current industry issues and generate relevant research topic ideas to consider for their thesis proposals. This report details PACE Roundtable happenings, leading to potential research ideas for the LancasterHistory.org project that relate to efficient innovations.

To start the meeting, Professor Holland introduced PSU's Integrated Educational Experiences for the AE program, which is meant to simulate real-world interactions between parties involved in the construction process, from design to turnover. For example, students from the AE department work with Architectural students, enforcing design deadlines and coordinating BIM work. A student panel discussion was had by these AE students, giving industry attendees an opportunity to further understand the program, asking questions and making comments. One industry representative suggested simulating owner involvement by establishing a stringent budget. Student takeaways from the experience included: conflict can be good, understanding of other disciplines, time management skills and the importance of presentations.

Once industry professionals had an opportunity to hear about the most recent education experiences, it was time for student-industry break-out sessions. Here, professionals articulated upon their experiences in the construction industry with give and take from the students. The discussion topics for these sessions included Supply Chain, Efficient Delivery of Services and Operations & Maintenance, each having two parts. Individuals chose break-out sessions to attend based off interest or experience in the topics. The writer of this report attended Session 1A: Integrating Strategies and Technologies and Session 2C: Model Handover.

The topic of the first session was integrating strategies and technologies for supply chain. In general, supply chain is a dynamic network of supply and demand. This is particularly true for the construction industry, as various complexities determine a supply chain's profitability. As such, various challenges arise for project managers including, information & availability, delivery delays, international communication and interface coordination. Bill Moyer, an Executive Vice President at Davis Construction, gave an example. His company sought prefabricated walls from a fabricator located in Malaysia, a country with a rapidly expanding economy. As such, it was decided that orders be placed years before installation, because the cost of storage was lesser than the forecasted inflation amount. Supply chain strategies like this are simplified with the assistance of modern technologies.

Various technological opportunities exist to assist in effective supply chain management, and one should consistently set expectations to best take advantage. This often involves contracts between involved parties and setting up a project charter as a guidepost. Transparency in process and responsibility is important. For example, parties could establish open access to superintendent records and testing. Other agreed upon terms could involve electronic integration technologies such as BIM codes & RFID, quality control links & commissions, and logs & OEM implications. Vendor involvement in this process is crucial and can be facilitated with tools such as material status logs, schedules and 4D models. While all of these technologies are important to the advancement of the construction industry, none replace effective management skills like effective preparation, communication and persistence. Thus, the technologies must be integrated, or paired, with time-honored management characteristics. This impacts the LancasterHistory.org project as the ground level's concrete floor was prefabricated.

The topic of the second break-out session was model handover to the owner for operations and maintenance. Model handover may be implemented as a BIM use because it is easier and more manageable for the owner than paper records alone, which is why the US government requires it for all projects. The models help establish continual relationships between parties and save money through the transfer of information. Digital files handed over typically only include MEP equipment with moving parts, but the files could be applied to other various aspects of the construction service. For example, LEED/energy items may be documented to ensure life cycle benefits. However, many owners do not wish to pay the extra initial cost for model handover. This dilemma arises because owners do not realize the product's tangible benefits.

The idea of model turnover is that it is a comprehensive tracking of information. There is potential to utilize every facet of information that goes into a building's existence. However, not all of this information may be useful to the owner. As such, it is the responsibility of the construction service providers to gauge the O&M needs of the owner and explain how BIM can be used to assist with these specific needs. Once a program is validated, empower the owner with model understanding/experience, so it may reap full benefits from the service. This may be achieved by involving the owner or a model manager throughout all phases of the project and by providing trainers for enhanced assistance; as suggested by Andrew Rhodes, a Design Engineer at Southland Industries. Model turnover doesn't directly affect the LancasterHistory.org project, but the owner was involved in architectural design BIM applications, showing potential for understanding.

The PACE Roundtable concluded with student research topic focus groups. At this stage in the event, students met with industry members for a discussion about their potential thesis topics, relating break-out session ideas to their buildings. The writer of this report met with Ralph Kreider Ph.D., who worked with such companies as Warfel Construction and Jacobs Global Buildings before returning to PSU as a Graduate Research Assistant. Key feedback from the industry member covered ideas such as the pros & cons of OM turnover and material/design changes to the LancasterHistory.org project. If a model turnover had been perused on the project, considerations should include cost of materials, Wheatland Operation implications and payback for LEED items. The difficult part for this research idea would be acquiring data from similar projects. This thought was later backed by Dr. Anumba in an advisor meeting.

Material and/or design changes to the LancasterHistory.org project present more flexibility and availability of information. Ideas could include mechanical or structural changes to the building, as these are key defining issues for this project in particular. Mechanical analysis ideas include using air source heat pumps rather than geothermal and comparing the differences between open and closed loop systems. A structural analysis idea would be to introduce modularization to the project, similar to Clara Watson's thesis research last year. The research would check productivity and further analyze construction. This would also allow for structural analysis to relate to BIM analysis, using 4D models for example. Ralph suggested the owner, the MEP contractor and Clara Watson as resources. Contact information for the first two may be found in Technical Report 1, and Ms. Watson's contact information can be found on the PSU's e-studio website.

As final advice from Dr. Kreider, it was suggested that an overall theme be generated that links all research topics together for the thesis project. Kreider recommended asking LancasterHistory.org what it would do differently if it could repeat the whole construction process, asking why it would do that differently and finding reasons for the reasons. Full comprehension of the owner's misgivings would introduce the most relevant research ideas and an overall thesis theme. After all, construction is a service industry.

PROBLEM IDENTIFICATION & TECHNICAL ANALYSIS OPTIONS

Overview

Based upon various research and findings described in this and previous technical reports, it is safe to assume that, like in any multi-million dollar project, mistakes are inevitable. It is simple to be critical in hindsight, but it is necessary in order to progress. While the LancasterHistory.org project is a success on many levels, all involved parties can agree that it has had its problems which are listed below. Construction & breadth concerns and methodology is summarized for the key improvement areas on the following page.

- Value Engineering
  - Design phase - material & labor cost reductions
  - Construction phase - alternative, suitable soil solutions
- Geothermal Loop System Testing
  - Address safety
  - Maximize energy performance
  - Scheduling considerations
- BIM Utilization
  - Code validation - eliminate code design errors
  - Digital fabrication* - adapt to late design changes & reduce 2D dependency
  - 3D coordination – perform clash detection
  - 4D modeling – increase communication & productivity
  - Virtual mockup –constructability considerations
  - Record modeling - LCC considerations

*Digital fabrication would only be utilized if MEPF systems are prefabricated

Value Engineering

The LancasterHistory.org project is a non-profit facility, and it primarily is funded through private donations and state grants from the Redevelopment Capital Assistance Program (RCAP). Therefore, it is of upmost importance to be fiscally responsible and maximize LH.O's value, as CEO Tom Ryan would agree. Various material and system alterations could potentially provide a similar product for less cost, freeing up funds to return to the state or be applied to research. For example, the building's TPO roof, most-current waterproofing & vapor barriers, light fixtures (lutron), and custom mahogany casework could be replaced.

Another design phase consideration includes replacing precast concrete with cast in place concrete on the lower level. This would save a fair amount of money. Implications of this change include structural, architectural, and MEPF alterations & accommodations. The schedule impact would have to be analyzed as well.

The last design phase value engineering topic that could be considered would be to implement MEPF prefabrication. This would reduce shorten the construction schedule. Further, the project has had encountered various clashes and LH.O is stuck with the change orders. Prefabrication would greatly simplify installation, and it could be used in parallel with digital fabrication and 3D coordinating to eliminate clashes. Something to consider for this topic would be lead time and costs associated with fabrication.

Perhaps the biggest dilemma associated with the LancasterHistory.org project happens to be the unforeseen soil conditions. In fact, soil remediation and related costs totaled $375,000 for the owner, nearly half of its contingency. While unavoidable, the soil problem's impact on schedule and/or cost may have been greatly reduced had options been more fully considered. Alternatives to reaching suitable soil conditions besides re-engineering rock-bins could include putting additives in the soil, re-engineering the foundation, or momentarily stopping construction. Structural and civil engineers should be consulted, regarding details. Further, new site plans should be developed in engineering the most practical solution.

Geothermal Loop System Testing

The second biggest blow to the LancasterHistory.org project is the sites impact on the designed geothermal wells. Originally, there were to be 26 located throughout the site, but large wells were encountered in drilling, which occurred relatively late in the schedule. To stick with the closed loop system, loops would have to be encased, estimated to cost an additional $1,000,000 for the project. The geotechnical engineer suggested implementation of an open loop system for the site, which is theoretically possible but proving difficult. The building is constructed but the geothermal system is still in the works as a practical drilling location is yet to be determined (see Appendix C for well location diagram). Had the system been tested sooner and more extensively a suitable return well location may have already been established. The geotechnical engineer could be contacted in considering the practicality of the open loop system versus the closed in terms of life cycle cost or abandoning the system all-together.

Another issue with drilling above wells is that of a safety concern. Benchmark created sinkholes in testing, which can be dangerous, even detrimental if near a building. A safe method for delivering this type of system must be considered, and a safety engineer could be contacted, as well as a civil and structural engineers. Cost and scheduling implications must be considered for all aspects of this research topic.

BIM Utilization

Building Information Modeling can be effective for essentially any aspect of a building's creation if 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 potentially reduce costs associated with change orders. The research topic idea here would be to analyze at which point BIM applications are effective from a financial standpoint on a project of this magnitude, taking into consideration costs of BIM design personnel verses construction savings. Several LH.o change orders could have been avoided such as structural steel sizing issues, MEPF clashes and code errors. To address this, code validation, 3D coordination and digital fabrication might be implemented. This would require greater collaboration between involved parties.

Time is money. Therefore, productivity increases in a project's construction should be weighed with the cost of implementing 4D modeling and virtual mockups. Brandt III said in an interview that various systems in the building were unfamiliar to contractors, and installation may have been facilitated via these BIM applications. Further, scheduling conflicts and site safety concerns could be addressed with a 4D model. Last, at which point would record modeling be beneficial to LH.O? This research could be conducted by interviewing interview professionals and their clients whom utilize this service.

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APPENDIX A: LEED CHECKLIST & TRANSIT MAP

LEED 2009 for New Construction and Major Renovations

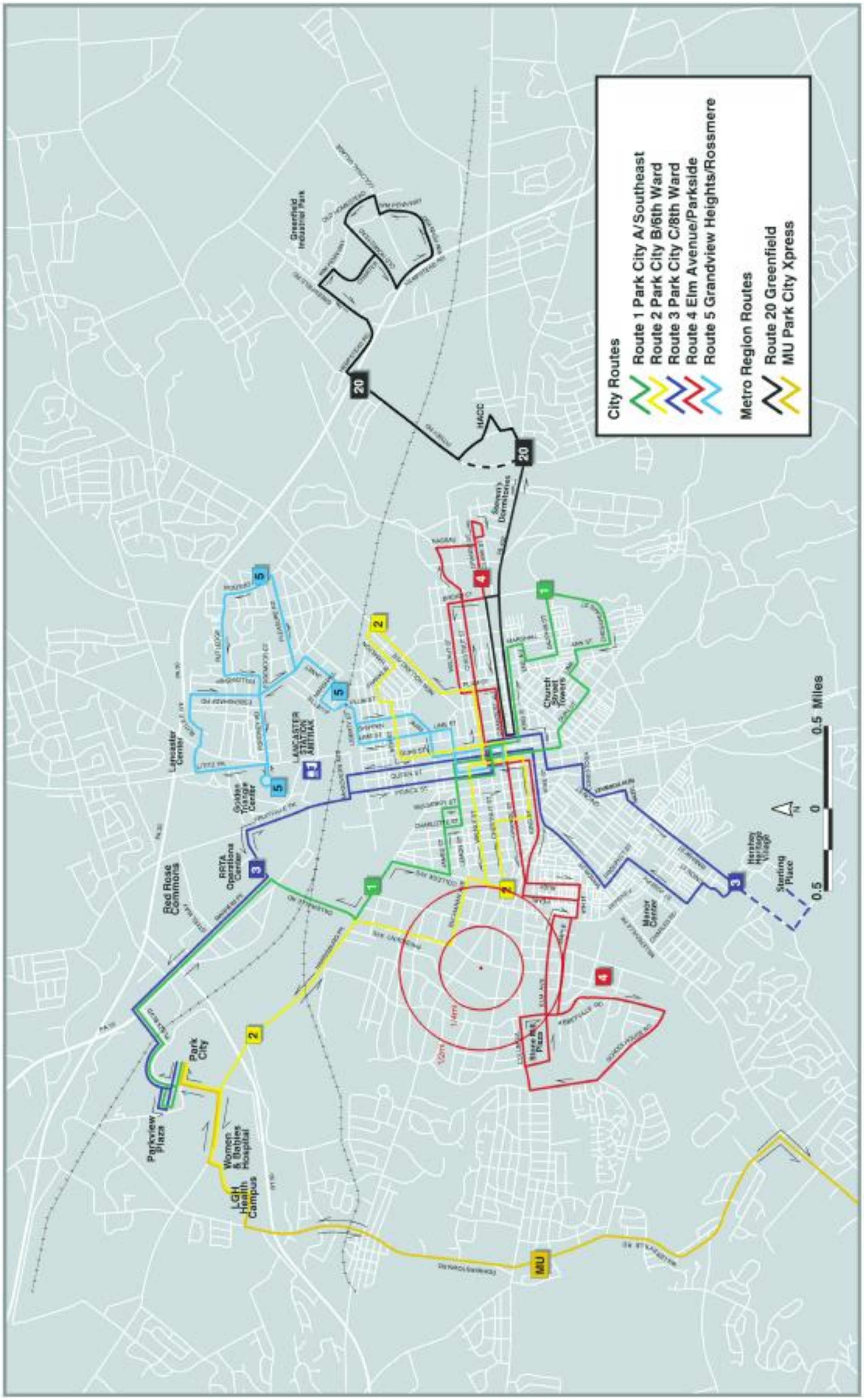
Project Checklist

Lancaster History.org - Addition and Renovations 09/25/2012

Y	?	N			
13			**Sustainable Sites**	Possible Points:	26
Y			Prereq 1	Construction Activity Pollution Prevention	
1			Credit 1	Site Selection	1
		x	Credit 2	Development Density and Community Connectivity	5
		x	Credit 3	Brownfield Redevelopment	1
6			Credit 4.1	Alternative Transportation—Public Transportation Access	6
		x	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
3			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
		x	Credit 4.4	Alternative Transportation—Parking Capacity	2
		x	Credit 5.1	Site Development—Protect or Restore Habitat	1
		x	Credit 5.2	Site Development—Maximize Open Space	1
1			Credit 6.1	Stormwater Design—Quantity Control	1
1			Credit 6.2	Stormwater Design—Quality Control	1
		x	Credit 7.1	Heat Island Effect—Non-roof	1
1			Credit 7.2	Heat Island Effect—Roof	1
		x	Credit 8	Light Pollution Reduction	1
6			**Water Efficiency**	Possible Points:	10
Y			Prereq 1	Water Use Reduction—20% Reduction	
4			Credit 1	Water Efficient Landscaping	2 to 4
		x	Credit 2	Innovative Wastewater Technologies	2
2			Credit 3	Water Use Reduction	2 to 4
24			**Energy and Atmosphere**	Possible Points:	35
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
13			Credit 1	Optimize Energy Performance	1 to 19
2			Credit 2	On-Site Renewable Energy	1 to 7
2			Credit 3	Enhanced Commissioning	2
2			Credit 4	Enhanced Refrigerant Management	2
3			Credit 5	Measurement and Verification	3
2			Credit 6	Green Power	2
9			**Materials and Resources**	Possible Points:	14
Y			Prereq 1	Storage and Collection of Recyclables	
2			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
		x	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
2			Credit 2	Construction Waste Management	1 to 2
		x	Credit 3	Materials Reuse	1 to 2

Y	?	N			
			Materials and Resources, Continued		
2			Credit 4	Recycled Content	1 to 2
2			Credit 5	Regional Materials	1 to 2
		x	Credit 6	Rapidly Renewable Materials	1
1			Credit 7	Certified Wood	1
12			**Indoor Environmental Quality**	Possible Points:	15
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
1			Credit 1	Outdoor Air Delivery Monitoring	1
		x	Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
1			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
1			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
1			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
1			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
1			Credit 7.2	Thermal Comfort—Verification	1
		x	Credit 8.1	Daylight and Views—Daylight	1
		x	Credit 8.2	Daylight and Views—Views	1
2			**Innovation and Design Process**	Possible Points:	6
1			Credit 1.1	Innovation in Design: Specific Title	1
		x	Credit 1.2	Innovation in Design: Specific Title	1
		x	Credit 1.3	Innovation in Design: Specific Title	1
		x	Credit 1.4	Innovation in Design: Specific Title	1
		x	Credit 1.5	Innovation in Design: Specific Title	1
1			Credit 2	LEED Accredited Professional	1
3			**Regional Priority Credits**	Possible Points:	4
1			Credit 1.1	Regional Priority: Specific Credit	1
1			Credit 1.2	Regional Priority: Specific Credit	1
		x	Credit 1.3	Regional Priority: Specific Credit	1
1			Credit 1.4	Regional Priority: Specific Credit	1
69			**Total**	Possible Points:	110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110


City Routes
Route 1 Park City A/Southeast
Route 2 Park City B/6th Ward
Route 3 Park City C/8th Ward
Route 4 Elm Avenue/Parkside
Route 5 Grandview Heights/Rossmere
Metro Region Routes
Route 20 Greenfield
MU Park City Xpress
0.5 0 0.5 Miles
Greenfield Industrial Park
HACC
Church Street Towers
Lancaster Center
LANCASTER STATION AMTRAK
Golden Triangle Center
RRTA Operations Center
Red Rose Commons
Park City
Parkview Plaza
Women & Babies Hospital
LGH Health Campus
Manor Center
Hershey Heritage Village
Sterling Place

APPENDIX B: PACE STUDENT FORM

Student Name Eric Buckwalter

Session #1

Topic: Supply Chain - Integrating Strategies & technologies

Research Ideas:

(1) Reducing supply chain resistence
- increase information availability

(2) Apply Prefabrication for MEPF systems @ LHO

Session #2

Topic: Model Handover - Operations & Maintenance

Research Ideas:

(1) What size project makes sense for using a record model?
(saving money thru transfer)

(2) Communicating Importance of model handover and training

~~**Industry Panel: Differentiation in a Down Economy**~~

~~*Research Ideas:*~~

~~(1)~~

~~(2)~~

Student Form Pg. 1

Industry Member Discussion Rob Kreider Ralphkreider@gmail.com

Key Feedback:

Which research topic is most relevant to industry? What is the scope of the topic?

Pros/Cons of OM turnover
- cost of Matl's
- Draw Base
- Implications of wheatland operations

Construction:
- 4D model
- BIM model?
  - decision making

Architectural/~~Structural~~:
Material/Design Changes
- History Society Takes you back
- Balance with saving time/money

Material Payback of LEED items
- Proper maintenance

Mechanical:
- Air Source Heat pumps? Payback
- Open vs. closed system (ie no glycol)

Structural:
- Productivity Analysis
- Modularization

Suggested Resources:

What industry contacts are needed? Is the information available?

MEP contractor

Clara Watson

Owner

Student Form

Pg. 2

APPENDIX C: WELL LOCATIONS

Well Locations

ADVANTAGE ENGINEERS

LancasterHistory.org Site

Lancaster Township
Lancaster County, Pennsylvania

Advantage Project #: 0904166.05
November 2012

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