PENN STATE AE SENIOR THESIS 2011 - 2012

FINAL THESIS PROPOSAL

Technical Analysis Areas and Breadth Topics

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RIVER VUE APARTMENTS | NEW LUXURY APARTMENTS RENOVATION| PITTSBURGH, PA

Executive Summary

The Final Thesis Proposal is intended to identify the four technical analyses topics that will be researched and conducted for the final thesis report on River Vue Apartments. The central theme of these technical analysis topics is efficiency including energy efficiency and construction efficiency.

Technical Analysis #1: Photovoltaic Glass Window System Replacement

Very few sustainable design techniques were used on the project that could provide financial benefit to the owner, River Vue Associates, LP. The goals for this technical analysis are to develop a preliminary photovoltaic glass window system design and to determine the financial and energy feasibility of incorporating this new type of window system into the existing electrical power source. Also, an electrical/renewable energy breadth will analyze how the photovoltaic glass window system will be connected to the electrical system. An architectural breadth will analyze how the new window system is incorporated into the architectural patterns and aesthetics of the building.

Technical Analysis #2: Green Roof Terrace Implementation

Very few sustainable design techniques were used on the project. The goals for this technical analysis are to develop a preliminary resident-accessible green roof terrace design, analyze the structural impact of the load-bearing green roof terrace, and determine the financial and energy feasibility of incorporating this new roof system into the existing building. Also, an architectural breadth will analyze how the new green roof terrace is incorporated into the architectural patterns and aesthetics of the building. A structural breath will analyze how the load-bearing green roof terrace affects the existing Level 2 roof's structure.

Technical Analysis #3: 3D Laser Scanning & 3D MEP Coordination Implementation

As-built drawing inconsistencies and MEP systems coordination were two of the most significant challenges on the River Vue Apartments project. Building Information Modeling (BIM) was not used in the designing, analyzing, integrating, and documenting processes. The goals for this technical analysis are to analyze the effects of using 3D laser scanning technologies to evaluate existing building conditions and to determine the time saved and money spent on this type of technology. Also, identifying the MEP system clashes in the key areas of the building affect and determining the costs and schedule effects of the 3D MEP coordination are other important goals for this technical analysis.

Technical Analysis #4: Critical Industry Issue – Energy Management

Since River Vue Apartments is a residential building, it is a challenge to keep all the residents comfortable while having an energy efficient MEP system that is beneficially used. Most building occupants do not understand how much their behavior in a building can harm the environment. The goal for this technical analysis is to research MEP systems that are energy efficient, but simple enough for the occupants of the building to use the system correctly without jeopardizing their comfort.

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Project Background

River Vue Apartments is the innovative reuse of the former Commonwealth of Pennsylvania State Office Building located in Pittsburgh, PA. Across from Point State Park in the Golden Triangle, these new luxury apartments will offer some of the best views of the city to its residents. The existing building was constructed in the 1950s and renovated in the 1980s, and through its simplicity and clarity of its form, it reflects a more modern architectural style. Modern materials such as metal and marble panels are a consistent theme throughout the architectural features of this building. Since the building project is mainly a 295,000 SF interior renovation, the new River Vue Apartments building, shown in Figure 1, will conserve these metal and marble panels. New bronze-clad window systems and existing metal-paneled columns will remain as key architectural features as well.

Figure 1 – Rendering Of River Vue Apartments Provided By IDG, LLP.

Interior Function

Looking at the functional interior components of the building, the new River Vue Apartments building will include a two-story interior valet-parking garage on the basement and first floors of the existing building. This parking garage will have the capacity for 208 parked cars by the utilization of mechanical double-stacking parking lifts. Also, some components of the new mechanical and electrical systems for will occupy the remaining space on the basement floor. Even though most of the first floor is engrossed by the parking garage, several other spaces will complete the function of this floor. These spaces include the new building lobby with elevator access, a small retail space of approximately 1,900 SF, sales office, and other required accessory areas such as tenant mail boxes for the apartment residents.

Figure 2 – Interior Rendering Of Typical Apartment Unit Provided By IDG, LLP.

The second floor improvements will consist of one-to-two bedroom apartments with a common elevator lobby and corridor connecting the two main egress stair towers. Also, on the second floor, a building party/media room and a small fitness center will be provided for the apartment residents. Floors three through fourteen will consist of studio and one-to-two bedroom apartments as well. A mix of flats, walk-up and studio apartments, and one-to-three bedroom apartments will utilize the fifteenth and sixteenth floors. On the fifteenth and sixteenth floors, each unit will have a private exterior inboard balcony.

Building Systems Summary

Structural System: Once demolition and asbestos abatement is complete, the existing structure of the building is the main building component preserved and reused for the renovation of the new River Vue Apartments. The existing structure of the building is composed of a steel superstructure with concrete floor slabs**.** For the existing second floor, the existing concrete slab system is 5 $^{5}/_{8}$" thick. Low roof construction consists of 1 ½"x20 GA wide rib galvanized Type B roof deck. In addition, for the existing third through sixteenth floors, the existing concrete slab system is 5 $^{5}/_{8}$" thick. Also, to accommodate for the new balcony slab, the existing slab on deck will be removed and replaced with the new 5 $^{5}/_{8}$" normal weight concrete slab with 1 ½"x20 GA composite deck.

Mechanical System: For the entire mechanical system of the building, the major component is the single 26,300 CFM air-handling unit located on the roof. Hidden behind three new curved and perforated stainless steel panels, the unit will serve two supply risers and two exhaust risers. To heat the water for the building, two 200 GPM boilers will be installed with a connection to the pumps that will distribute the water to the various spaces. Each apartment unit is handles by an individual heat pump. Also, a 1024 GPM plate heat exchanger will collect residual heat and conserve energy for the mechanical system.

Electrical System: The new electrical system will operate on a three-phase 120/208V system powered by the main electrical room on the basement floor. Electrical power will be brought into the building's 200A switchboard at a voltage of 208V from a ground bus located on the north side of the building.

Construction

A detailed construction plan and sequence was utilized for the project to ensure timely project completion. When official work began on Monday, June 13, 2011, the beginning stages of the construction phase included the demolition of all the existing systems and asbestos abatement. With the superstructure of the building remaining, the construction of the basement and first floors parking garages begins. During this construction sequence, the site work for the new parking garage ramps is completed. In addition to the site work occurring during the construction of the parking garages, the 218 apartment units are constructed starting on the second floor and moving up to the sixteenth floor. The building is turned over to the owner in two phases. The basement through the fifth floors will be available in April 2012, and the entire building will be turned over by October 2012.

The construction process of the new renovation will be achieving LEED Certification. Some of the major components for achieving this rating include Building Reuse, Construction Waste Management, and Low-Emitting Materials. Since the River Vue Apartments project is a renovation, over 75% of the exiting walls, floors, roof, and any other components of the structure will remain for the completion of the building. Another major component will be the waste management and recycling of materials throughout the life of the project. Also, throughout the installation of major building components, low-emitting materials will be used.

Technical Analysis #1: Photovoltaic Glass Window System Replacement

Problem Identification

The River Vue Apartments project is achieving LEED Certification for its sustainable construction techniques including pollution prevention, materials and resources reuse, low-emitting materials use, and construction waste management. However, very few sustainable design techniques were used on the project that could provide financial benefit to the owner, River Vue Associates, LP.

Background Research: There are several techniques utilized to make a building's design more sustainable in the energy sector including solar, wind, hydro, bio-energy, geothermal, and hydrogen. For solar power, building-integrated photovoltaic technologies are energy sources that generate and transfer electricity. Specifically, photovoltaic glass is one of the most advanced building-integrated photovoltaic technologies used in sustainable building design (*Windows for High Performance Commercial Buildings* et al.). These glass systems are increasingly implemented into the façade's window system design of new building as a source of electrical power ((*Windows for High Performance Commercial Buildings* et al.). To an observer, the photovoltaic glass window system looks exactly like a typical glass window system. However, these windows can generate electricity, reduce heat, and provide a semi-transparent or transparent display (*Windows for High Performance Commercial Buildings* et al.). The generated electricity's power is converted and transferred into the building's electrical distribution system. Also, even though the initial costs for a photovoltaic glass window replacement are expensive, these windows can reduce the life-cycle costs of the building.

Potential Solutions: Since the River Vue Apartments building's façade has a significant amount of glazing, a photovoltaic glass window system could be very beneficial to life-cycle of the building. Even though these systems can generate up to 250 watts, it is not feasible to produce all of the building's electrical loads with the photovoltaic glass window system. However, a significant portion of the electrical loads will be reduced by this system while benefit the building's energy consumption life-cycle costs.

Research Goals

The goals for this technical analysis are to develop a preliminary photovoltaic glass window system design and to determine the financial and energy feasibility of incorporating this new type of window system into the existing electrical power source.

Research Methods

- Research photovoltaic glass advantages and disadvantages
- Research types of photovoltaic glass window systems
- Contact photovoltaic glass manufacturers for design consultation
- Determine amount of glass in the building's façade
- Compare the costs of photovoltaic glass windows to typical glass windows

- Determine the electrical energy consumption of the building
- Determine amount of kwH able to be produced be the photovoltaic system
- Analyze the energy savings associated with the photovoltaic glass
- Analyze how the photovoltaic system will connect and operate with the electrical power system
- Calculate upfront costs for the photovoltaic glass window system
- Calculate life-cycle costs for the photovoltaic glass window system
- Analyze how the photovoltaic glass will add long-term quality and value to the building
- Analyze the schedule impact to replace the typical glass window system with the photovoltaic glass window system
- Determine if the window system will be prefabricated off site or constructed on site.
- Make a recommendation for photovoltaic glass window replacement feasibility

Research Tools and Resources

- Industry Professionals
- AE Faculty – Construction Management and Electrical
- AE 498D – Photovoltaic Systems Design and Construction
- River Vue Apartments Project Team
- Claitman Engineering Associates, Inc. (MEP/FP Engineers)
- AE Classmates
- United States Green Building Council
- United States Department of Energy
- Rainbow Solar, Inc.
- Whole Building Design Guide

Expected Outcome

After extensive research and design, it is expected that River Vue Apartments will benefit from a photovoltaic glass window system replacement. Even though these systems can generate up to 250 watts, it is not feasible to produce all of the building's electrical loads with the photovoltaic glass window system. However, a significant portion of the electrical loads will be produced by this source of electrical power to decrease energy consumption. This reduction will financially benefit the owner, and increase the building's energy efficiency and its long-term quality and value. The new photovoltaic glass window system will be an upfront investment that will benefit the life-cycle costs of the building.

Technical Analysis #2: Green Roof Terrace Implementation

Problem Identification

As previously stated in the section above, the River Vue Apartments project is achieving LEED Certification for its sustainable construction techniques. However, very few sustainable design techniques were used on the project that could provide financial benefit to the owner, River Vue Associates, LP

Background Research: There are several techniques utilized to make a building's design more sustainable. Incorporating a green roof into the design of a new or existing building can benefit the environment and the building's energy efficiency. Green roof terraces, or green roof gardens, are becoming increasingly popular in urban environments because they provide a relaxing green space in a concrete jungle. They are partially covered with vegetation, various plants, and a growing membrane that is planted over a waterproofing membrane (*ZinCo-Green Roof* et al.). A typical green roof terrace is composed of many layers that add to the durability and life-cycle of the roof. These layers include native plants, light weight soil mix, soil retention mat, water drainage and retention material, root barrier mat, foam insulation, hot applied asphalt, and concrete (*ZinCo-Green Roof* et al.). In addition, a green roof terrace serves several different purposes for a building including absorbing rainwater, providing insulation, and altering the "heat island effect" (*Green Up the Roof* et al.).

Potential Solutions: Since River Vue Apartments is located in an urban environment, Pittbsurgh, PA, incorporating a resident-accessible green roof terrace onto the Level 2 roof can sustainably benefit the life-cycle of the building. The green roof terrace can capture up to 75% of rainwater, provide greater insulation, and reduce heat loss during winter by 30% (*ZinCo-Green Roof* et al.). These aspects can decrease life-cycle costs for the owner.

Research Goals

The goals for this technical analysis are to develop a preliminary resident-accessible green roof terrace design, analyze the structural impact of the load-bearing green roof terrace, and determine the financial and energy feasibility of incorporating this new roof system into the existing building.

Research Methods

- Research green roof terrace advantages and disadvantages
- Research types of green roof terrace systems
- Contact green roof manufacturers for design consultation
- Design green roof terrace
- Analysis how the load-bearing green roof terrace affects the existing roof's structural system
- Determine energy consumption of the building
- Analyze the green roof terrace will contribute to energy savings

- Calculate upfront costs for the green roof terrace
- Calculate life-cycle costs for the green roof
- Analyze how the green roof terrace will add long-term quality and value to the building
- Analyze the schedule impact to construct the green roof terrace
- Make a recommendation for photovoltaic glass window replacement feasibility

Research Tools and Resources

- Industry Professionals
- AE Faculty – Construction Management and Mechanical
- River Vue Apartments Project Team
- Claitman Engineering Associates
- Intelligent Design Group (IDG), LLP
- AE Classmates
- United States Green Building Council
- Applicable Literature

Expected Outcome

After extensive research and design, it is expected that River Vue Apartments will benefit from incorporating a green roof terrace onto the Level 2 roof. Even though the upfront costs will be more expensive and the schedule could be affected, the green roof terrace will absorb rainwater, provide insulation, and alter the "heat island effect". The new residential-accessible green roof terrace will be an upfront investment that will benefit the life-cycle costs of the building.

Technical Analysis #3: 3D Laser Scanning & 3D MEP Coordination Implementation

Problem Identification

After analyzing the unique and challenging constructability issues on the River Vue Apartments project, as-built drawing inconsistencies and MEP systems coordination were two of the most significant challenges. Since the existing building was constructed in the 1950s and renovated in the 1980s, the as-built drawings are not up to date, and they caused two challenges on the project. These challenges included a column located on the sixteenth floor in the middle of Apartment #1510's bedroom and unknown façade waterproofing details. In addition, MEP systems coordination was a very significant challenge as well. Coordination of the MEP systems took an extensive amount of time because of the existing steel and the tight constraints between the structure and the future building heights. For the River Vue Apartments project, Building Information Modeling (BIM) was not used in the designing, analyzing, integrating, and documenting processes. The MEP designers coordinated the MEP systems without using coordination software.

Background Research: There are several techniques utilized to capture and evaluate existing building conditions. Specifically, three-dimensional laser scanning is very beneficial on renovation construction projects. "The laser scanner creates an accurate model of the existing building conditions to better understand the current structure and spatial utilization of the building" ("Trimble Cx 3D Laser Scanner" et al.). "Other applications of the laser scanner include comparing the existing structure to the planned design to identify clashes prior to construction, ensuring pre-fabricated components will fit in their intended location prior to transportation and installation, creating as-built construction drawings for quality assurance purposes, and creating a 3D model of the complete facility for daily operation planning and analysis by the building's owner" ("Trimble Cx 3D Laser Scanner" et al.).

To coordinate the MEP systems more efficiently and effectively, the BIM Use that could have been implemented on the project is 3D Coordination. According to the BIM Project Execution Planning Guide developed by the Computer Integrated Construction Research Program at the Pennsylvania State University, "3D Coordination is a process in which clash detection software is used to determine conflicts by comparing three-dimensional models of the building systems" (Messner, "BIM Uses").

Potential Solutions: 3D laser scanning technologies can reduce constructability challenges and construction time. Also, it can be used to create as-built drawings for the existing building undergoing a complete renovation as well. For the River Vue Apartments project, the MEP systems are to be newly installed. Therefore, visual coordination between these trades could reduce or eliminate major system conflicts that could occur in the field.

Research Goals

The goals for this technical analysis are to analyze the effects of using 3D laser scanning technologies to evaluate existing building conditions and to determine the time saved and money spent on this type of

technology. Also, identifying the MEP system clashes in the key areas of the building affect and determining the costs and schedule effects of the 3D MEP coordination are other important goals for this technical analysis.

Research Methods

- Research advantages and disadvantages of the 3D laser scanning technology and 3D coordination
- Determine what contributes to costs savings and losses
- Determine schedule impact by utilizing laser scanning
- Analyze how 3D MEP coordination is incorporated into a 3D laser-laser scanned model
- Develop 3D model of several key areas of the building
- Perform clash detection analysis on these key areas
- Determine and analyze clash locations
- Calculate cost effects of implementation the 3D laser scanning technology and BIM
- Analyze the schedule impact when implementing 3D laser scanning and 3D MEP coordination

Research Resources and Tools

- Industry Professionals
- AE Faculty – Construction Management
- River Vue Apartments Project Team
- Claitman Engineering Associates, Inc.
- AE Classmates
- BIM Project Execution Planning developed by the Computer Integrated Construction Research Program at the Pennsylvania State University
- AE 473 – Building Construction Management and Control
- AE 476 – Building Construction Engineering II

Expected Outcome

After extensive research, the expected outcome is that the implementation of 3D laser scanning technologies and 3D MEP coordination will be very beneficial for the River Vue Apartments project by reducing constructability challenges, the construction time, and project costs by detecting MEP system clashes during the preconstruction phase.

Technical Analysis #4: Critical Industry Issue – Energy Management

Problem Identification

During the PACE Roundtable's Energy Management Services session, many key topics were discussed about energy management for residential buildings. Since River Vue Apartments is a residential building, occupant comfort is very important. However, it is a challenge to keep all the residents comfortable because comfort is an individual feeling. Also, it is a challenge to have an energy efficient MEP system that is beneficially used. Most building occupants do not understand how much their behavior in a building can harm the environment.

Background Research: Many of the industry professionals agreed that the major part of energy management is determining the efficient operation of the MEP systems in a building ("Energy Management Services" et al.). After the preconstruction, procurement, and construction phases, energy management still needs to be enforced when the building is occupied. Occupant behavior has a huge impact on energy management. For instance, since the building occupants want to be comfortable, the MEP systems are automatically controlled by the individuals seeking their comfort level. Therefore, the controls and systems need to be simplified to the degree that the occupants will be able and willing to properly use them ("Energy Management Services" et al.). Also, if the building occupants are aware and trained about their energy consumption and how it affects the environment, they would be willing to contribute more to the lifecycle of the building ("Energy Management Services" et al.). In addition, even though energy management is mainly focused on the efficiency of the building's systems, it is not about making only the building efficient. The industry members stated that the fuel and power coming into the building to operate the systems need to be efficient as well ("Energy Management Services" et al.). If the fuel, power, and systems are efficient, the building will definitely have a longer lifecycle and will consume less energy.

Potential Solutions: Simplified controls and MEP systems could be very beneficial to the River Vue Apartments building because it is a residential apartment building. Also, occupant behavior is a major factor incorporated into design energy efficient systems. Therefore, if the building occupants are aware and trained about their energy consumption and how it affects the environment, they would be willing to contribute more to the lifecycle of the building.

Research Goal

The goal for this technical analysis is to research new ideas for MEP systems that are energy efficient, but simple enough for the occupants of the building to use the system correctly without jeopardizing their comfort.

Research Methods

- Evaluate the types of MEP systems used in the River Vue Apartment building
- Research simplified energy efficient MEP systems and controls

- Analyze the occupant behavior in the building
- Determine potential simplified MEP systems and controls that could be used for the River Vue Apartments building
- Determine how the simplified MEP systems and control affect the building's energy consumption
- Determine the life-cycle costs of the new simplified MEP systems and controls
- Compare the life-cycle costs to the actual building costs
- Evaluate the efficiency of the incoming power
- Research how to make the incoming power more efficient
- Make a recommendation for new simplified MEP systems and controls

Research Tools and Resources

- PACE Roundtable Industry Professionals
- AE Faculty – Construction Management, Mechanical, and Electrical
- River Vue Apartments Project Team
- Claitman Engineering Associates, Inc.
- AE 456 – Solar Energy Building System Design
- Applicable Literature

Expected Outcome

After extensive research, the expected outcome is that the MEP systems will be more energy efficient if the systems were designed with simplified controls for occupant use. The new simplified MEP systems and controls will decrease the life-cycle costs for the River Vue Apartments building and increase the quality and value of the building for the owner, River Vue Associates, LP.

Technical Analysis Weight Matrix

The technical analysis weight matrix, shown in Table 1, determines how the core thesis investigation areas are distributed among the different technical analyses proposed for the spring semester. The core investigation areas include Critical Issues Research, Value Engineering Analysis, Constructability Review, and Schedule Reduction/Acceleration Proposal.

Table #1: Technical Analysis Weight Matrix for the Distribution of the Core Investigation Areas

Description	Research	Value Engineering	Constructability Review	Schedule Reduction/Acceleration	Total
Photovoltaic Glass Window System Replacement	10%	10%	-	-	20%
Green Roof Terrace Implementation	10%	10%	10%	-	30%
3D Laser Scanning & 3D MEP Coordination	10%	-	10%	10%	30%
Critical Industry Issue – Energy Management	20%	-	-	-	20%
TOTAL	**50%**	**20%**	**20%**	**10%**	**100%**

Spring Semester Preliminary Schedule

See Appendix B for the Spring Semester Preliminary Schedule

In order to meet the senior thesis project goals and requirements, a spring semester preliminary schedule was developed to determine the amount of time needed to complete all of the technical analyses.

Conclusions

After completing the in-depth research and investigation required, the proposed technical analyses areas will demonstrate the sustainable design techniques and technologies used in the construction industry. For the Photovoltaic Glass Window System Replacement technical analysis, it is expected that a significant portion of the electrical loads will be produced by this source of electrical power to decrease energy consumption. For the Green Roof Terrace Implementation technical analysis, it is expected that new resident-accessible green roof terrace will be an upfront investment that will benefit the life-cycle costs of the building. For the 3D Laser Scanning and 3D MEP Coordination Implementation technical analysis, it is expected that these technologies will reduce constructability challenges, the construction time, and project costs by detecting MEP system clashes during the preconstruction phase. Finally, for the Critical Industry Issue, Energy Management, technical analysis, it is expected that the MEP systems will be more energy efficient if the systems were designed with simplified controls for occupant use. The new simplified MEP systems and controls will decrease the life-cycle costs for the River Vue Apartments building and increase the quality and value of the building for the owner.

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Appendix A: Breadth Topics

Breadth Topics

The Breadth Topics are intended to demonstrate the breadth skills developed from the Architectural Engineering course work. These breadth topics include the areas of Architectural Engineering outside of construction, e.g., architectural, acoustics, electrical, lighting, and structural. After identifying an analysis that requires a more detailed breadth study, the demonstration of breadth in Architectural Engineering will successfully complete the analysis.

Breadth Topic #1: Architectural Breadth

****Contributes to Technical Analysis #1 and Technical Analysis #2***

The existing building reflects a more modern architectural style. Modern materials such as metal and marble panels are a consistent theme throughout the architectural features of this building. Since the building project is mainly a 295,000 SF interior renovation, the new River Vue Apartments building, will conserve these metal and marble panels. New bronze-clad window systems and existing metal-paneled columns will remain as key architectural features as well.

Incorporating a photovoltaic glass window system into the River Vue Apartments building's façade and a green roof terrace on the Level 2 roof will change the architectural features of the building. Therefore, an architectural analysis will be conducted to define the architectural patterns and key mechanisms and to determine how these new features are incorporated into the aesthetics of the building.

Breadth Topic #2: Electrical/Renewable Energy Breadth

****Contributes to Technical Analysis #1***

The new electrical system will operate on a three-phase 120/208V system powered by the Duquesne Light Company vault to the main electrical room on the basement floor. Electrical power will be brought into the building's 200A switchboard at a voltage of 208V from a ground bus located on the north side of the building.

By utilizing a building-integrated photovoltaic glass window system, the existing energy system will need to be analyzed to determine the required electrical components and connections. To allow for the photovoltaic glass window system to be connected to the electrical system designed by Claitman Engineering Associates, Inc., the system will be altered to accommodate the renewable energy source produced by the photovoltaic glass. In addition, research on the different photovoltaic glass window systems connection types, e.g., grid connected, off-grid, and hybrid system, will need to be conducted because the connection type determines the connection requirements to the new electrical system. Also, a constructability review will be conducted to determine if the new electrical system meets with requirements of the photovoltaic glass window system.

Breadth Topic #3: Structural Breadth

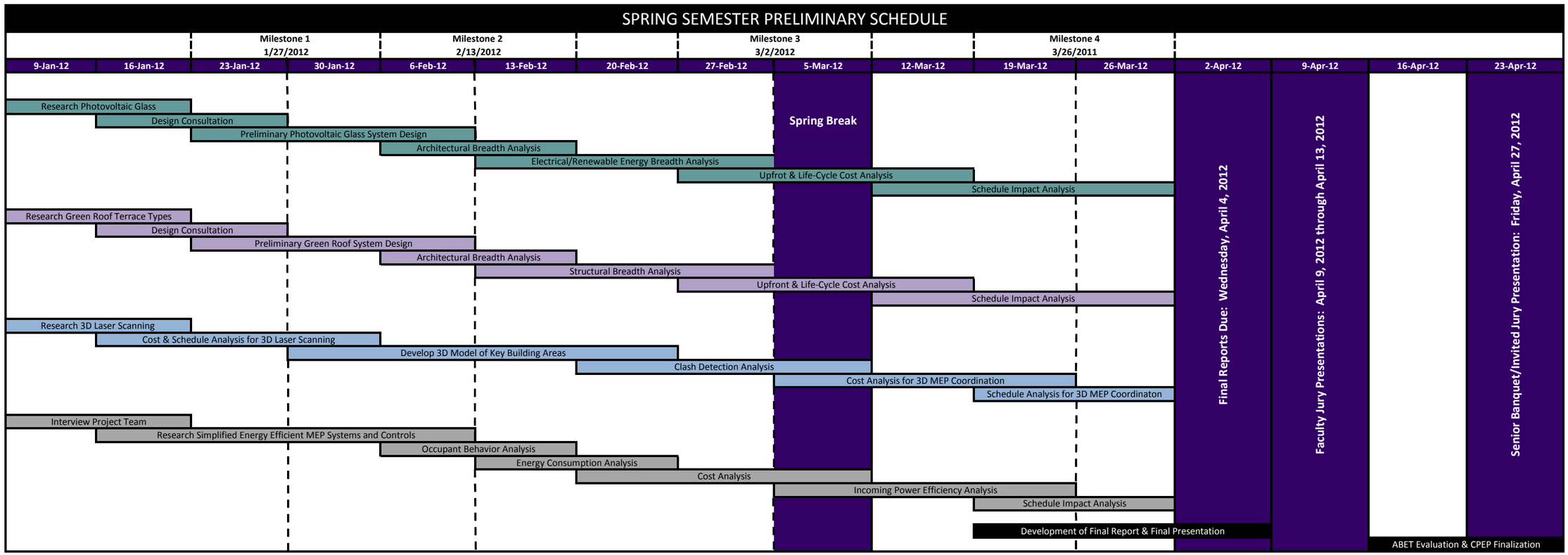
****Contributes to Technical Analysis #2***

The existing Level 2 roof is 53 ft. wide on the north end, 79 ft. wide on the south end, and 208-3/4 ft. long. Composed of 2 in. thick gypsum plank with tapered rigid insulation, the existing Level 2 roof's structure also includes typical wide-flange beams and steel columns. With ASTM A992 steel specifications, the W shaped beams and columns are designed to have the yield strength of FY = 50 kips/in_2. In addition, no additional equipment is housed on Level 2's roof structure.

Incorporating a load-bearing green roof terrace on the Level 2 roof will require a structural analysis of these additional loads on the structural system of the roof. Research will be conducted to determine the required additional support needed to accommodate the dead load of the green roof terrace and the live load of the residential occupants accessing the terrace. The additional support and connections will be designed to efficient merge with the existing roof's structural system and evaluated for cost and schedule impacts.

Appendix B: Spring Semester Preliminary Schedule

SPRING SEMESTER PRELIMINARY SCHEDULE



MILESTONES:
1. Appropriate Research and Design Consultation Is Complete
2. All Research and Design Development Is Complete
3. All Technical Analyses Are In The Evaluation Stage
4. All Technical Analyses Are In The Final Completion Stages & Ready Formatting

TECHNICAL ANALYSES LEGEND:	
Technical Analysis #1: Photovoltaic Glass Window System Replacement	
Technical Analysis #2: Green Roof Terrace Implementaiton	
Technical Analysis #3: 3D Laser Scanning & 3D MEP Coordination	
Technical Analysis #4: Critical Industry Issue - Energy Management	