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Feasibility Study of LEED Certification for Union Station Parking Garage

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by

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Abstract

This project examined the feasibility of LEED certification for the Union Station Parking Garage located in Worcester, Massachusetts. A proposed green roof was designed to reduce water runoff and the heat island effect. This study also determined the cost of potential implementation to get the facility LEED certified.

Authorship

Organizational Breakdown Structure

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Abstract				
Capstone Design Experience				
Introduction				
Union Station Parking Garage				
Politics				
Construction Information				
Worcester's Position on LEED				
Literature Review				
Introduction				
LEED: General Information				
LEED in Construction				
Green Roofs: General Information				
Green Roofs: Benefits				
Green Roofs: Examples				
LEED Certification				
Green Roof Design				
Cost Implications				
Green Roof Costs				
Costs for Other LEED Points				
LEED Certified vs. LEED Certifiable				
Conclusions				

Capstone Design Experience

Green building is a practice that alters design and construction practices in favor of environmental sustainability and social consciousness, and as a result, leads to economic benefits. This project focuses on implementing green building practices with the Union Station Parking Garage in Worcester, MA using the LEED rating system. To meet WPI's Capstone Design requirements, this project designed an additional story on the parking garage that would support a green roof. The intention of the design process was to develop a lightweight, cost-effective structure that could be retrofit on the uppermost deck of the parking garage and allow for unobstructed vehicular movement.

The design problem was systematically approached using the following process:

1. Determine dead and live loadings
2. Determine design material
3. Determine column grid and spans for beams and girders
4. Design green roof components (all members and green roof material)
5. Analyze preliminary design
6. Redesign members and connections
7. Determine weight of green roof
8. Review capacity of existing structure
9. Determine total cost of green roof

The constraining parameters of the design were economic, environmental, sustainability, constructability, and health and safety. Up-front costs needed to be minimized to maintain the feasibility of having the garage LEED certified. The green roof addresses environmental and sustainability issues such as the reduction of storm water flow and reduction of the urban heat island effect, which reduces demand from infrastructure and attributes to economic benefits). Constructability issues are addressed in an effort to keep costs down. If the structure is easier to build then it accrues less cost which again enhances the feasibility of the project. Finally, health and safety issues such as the reduction of carbon emissions and collection of dust are mitigated by the green roof.

Acknowledgements

We would like to first thank the Gilbane Construction for allowing us to work with them on this project. Project manager Albert Abdella, project engineer Thomas Place, and co-op student Megan Hogan were extremely helpful in getting us information we needed for the project. They were also very gracious in allowing us to sit in on their weekly site meetings which allowed us to stay connected to the project.

Many thanks also go to the client on this project which was the city of Worcester. Most of our correspondence with the city was done with project engineer Paul Moosey, who was very helpful in answering all of our questions and allowing us to sit in on the project's weekly meetings.

We would also like to the Green Roundtable in Roxbury, Massachusetts for allowing us to visit and answer some of our questions about green building. They provided a comfortable forum for us to ask about the LEED rating system and learn more about its role in current construction.

We would also like to extend thanks to our structural advisor, Professor Paramasivam Jayachandran, whose guidance during the design phase of our green roof was crucial to the successful completion of our project.

Finally we would like to thank our main advisor, Professor Guillermo Salazar. Thank you for allowing us the flexibility in this project to further explore our individual interests and complete a project we are proud of. Thank you for extending yourself to work with us when you already had a full plate of projects to attend to. We appreciated your uplifting personality and the creative energy you gave to our project.

Table of Contents

Table of Figures

Table of Tables

1. Introduction

As American awareness of environmental protection grows, buildings are being recognized as having a significant impact on the environment. Buildings account for nearly two-thirds of America's electricity consumption and over one third of total energy use, while also being responsible for nearly one third of greenhouse gas emissions.[1] Structures that are built without the environment in mind reduce air and water quality, increase solid waste, and damage ecosystems.

The Union Station Parking Garage in Worcester, Massachusetts is a six-level, $21.5 million dollar project that will provide parking for 500 cars of commuters looking to travel from Worcester towards Boston. This structure will be a site for production of many car emissions as well as over 800,000 gallons of storm water runoff per year[2]. 10,000 square feet of this establishment will also be dedicated to retail space that will be consuming water, creating solid waste, and using a large amount of electricity.

Despite the fact that the Union Station Parking Garage used a lot of resources and created some pollution, the project was not environmentally harmful on all fronts. The structure is made mostly of pre-cast concrete slabs which were extremely efficient and produced almost no waste during construction. The project is also located directly next to Union Station which means that commuters looking to ride the train or bus to Boston or elsewhere will be able to walk from the garage to the station, eliminating the need for any type of shuttle or taxi service to get to where they need to go.

[1] http://www.usgbc.org/DisplayPage.aspx?CMSPageID=291&
[2] http://www.city-data.com/us-cities/The-Northeast/Worcester-Geography-and-Climate.htm

The Union Station Parking Garage shows some signs of being an environmentally conscious building, but there could be some improvements in this regard. Green buildings are becoming increasingly popular in the United States in recent years because of a trend of environmental awareness. The Leadership in Energy and Environmental Design (LEED) rating system, created by the United States Green Building Council (USGBC) in 1998, is currently the benchmark for design and construction of green buildings. The Union Station Parking Garage is not currently a LEED certified building so it was not designed for compliance with LEED standards that are relevant to this type of structure.

The goal of this study was to improve the sustainability and the environmental compatibility of the Union Station Parking Garage through a plan that integrates LEED standards and a green roof into the project. This was achieved by first examining all LEED standards that could possibly apply to the project and determining which were currently being met. The team then evaluated the plans and construction of the project to determine the feasibility of meeting any standards that were not being met. Finally, the team designed a green roof for the structure to reduce storm water runoff and the urban heat island effect, therefore reducing temperature extremes in the building. A cost/benefit analysis of all proposed improvements was completed so that all recommendations could be put into economic perspective. Implementation of these design changes could help make Union Station Parking Garage a LEED certified building and greatly reduce its impact on the environment without reducing service to the city of Worcester.

2. Background

The purpose of this chapter is to describe the Union Station Parking Garage and then provide general information about LEED standards as well as green roofs.

2.1 Union Station Parking Garage

The Union Station parking garage, designed by the Maguire Group of Rhode Island, was "designed to look like a building, not a parking garage," to match Union Station itself. Adding more decks was an option. It would have added more parking spaces and allowed for greater revenue, but the city did not want to take away from Union Station by making the focus of the Union Station area a much taller parking garage. Therefore, a helix ramp (shown in Figure 1) and other high cost components were added to increase the capacity and efficiency of the garage.

Figure 1 – Union Station Parking Garage Rendering[3]

[3] Gilbane Co.

2.1.1 Garage Pricing Controversy

Nicknamed the “Garage Mahal”, the Union Station Parking Garage has one of the highest costs per parking space in Worcester, MA. When the garage opens, the first cars to park may cost less than an individual space. Each space costs $40,000 and the total for the garage is $21.5 million. The helix ramp added $3 million to the project cost while an ornamental façade added another $1 million. Other high cost contributors included a $250,000 snow melting system, a $500,000 security and aid system, and a $1 million renovation of the existing tunnel.[4]

Critics estimate that city of Worcester could have saved over $4 million, or $8,000 per parking space had the bidding been open to all contractors instead of strictly union shops. This kind of exclusive agreement is called a Project Labor Agreement (PLA). The primary goals of PLA’s are to ensure an open flow of communication amongst all parties involved, to save money by reducing the risk of delay and cost overruns due to labor disputes, to ensure the fairness of pay and safe working conditions to all workers, and to be able to manage all trades and unions by standardizing decisions, leadership, and dispute management.[5] Critics of the Union Station Parking Garage say that PLA’s offer absolutely no benefits to the city and only come with very high costs; however, it has very strong support by most of the city’s officials.

In comparison with other parking garages the Union Station Parking Garage, at $21.5 million with 500 parking spaces and 10,000 square feet of retail space, is far more expensive than most. Worcester State College recently finished a 569 spot parking garage for $10 million and Holy Cross has a 446 spot parking garage, completed under a PLA, that was built in 2003 for $7.1

[4] *Telegram & Gazette*. June 4 , 2007.
[5] http://www.plafacts.org/

million - an expensive garage at the time. The city of Lowell is currently building a parking garage that also costs $21.5 million, but is twice the size of Union Station's. The 680 space parking garage at Gateway Park Life Sciences complex, about a mile away, was completed for $10 million.[6] All of these garages utilize up-to-date standards, are made with pre-cast concrete, and employ contemporary brick façades.[7]

There has been much debate throughout the City of Worcester about the Union Station Parking Garage. Had the bidding been open to all suitable contractors, as opposed to using a PLA, it would have been more competitive and, as a result, would not have cost the city as much.

2.1.2 Worcester's Position on LEED Certification

Paul Moosey, the Assistant Commissioner of Engineering and Architectural Services for the city of Worcester was interviewed and explained the city's involvement and stance on LEED Certification. The officials in Worcester are aware that Green Building has significant benefits to the environment, however there are no financial incentives set up for municipal projects. Right now there is a high school being built by the city that is following green guidelines; however city advisors came to the conclusion that paying for the LEED Certification title would not be profitable. Despite not having the LEED certification, the school is eligible for federal grants by taking such guidelines into account during design, construction, and use. Moosey says there are benefits set up for private owners on the federal level for LEED certified buildings, however since it doesn't help city owned buildings, the city of Worcester currently does not own any. Worcester currently does not have any regulations for buildings to be environmentally friendly, however there are guidelines set up to make sure that it is taken into account.

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[6] http://cpe.wpi.edu/Industry/gatewa817.html
[7] *Telegram & Gazette*. May 29, 2007.

2.2 LEED

"Although our planet is 71 percent water, humans depend on a mere .65 percent of the water for survival – much of which is polluted."[8] The LEED certification process promotes green building which is becoming more important every day. Green building is a practice that alters the design and construction to be conscious of social, environmental, and as a result, economical factors in the building process. Since the building is going to need constant resources as it functions every day, LEED certification addresses the interior finishes as well.[1]

In 1973, the American Institute of Architects (AIA) formed a taskforce to research the energy crisis problem. By the late 1970s, research was being done on solar energy, and soon after, the word sustainable surfaced when referring to a building's resource usage.[1] Then in 1987, the United Nations World Commission on Environment and Development provided the first definition for sustainable development which is defined as meeting "the [human] needs of the present without compromising the ability of future generations to meet their own needs."[9] At present, there is a constantly increasing interest in green building, and it is becoming a norm, if not a requirement for large corporations and government construction projects to follow.[1]

The United States Green Building Council (USGBC) saw the demand for green building, and the movement toward sustainable development. The USGBC also saw that there was no sufficient rating system to compare conservation efforts between green buildings. To create such a system, the USGBC called on a diverse committee of people involved with the industry such as

[8] http://www.greenbuilding.com/fastFacts.html

[9] http://www.wsu.edu:8080/~susdev/WCED87.html

architects, environmentalists, lawyers and more to come up with a conclusive list that could apply for many different applications. This version was released at the USGBC Membership Summit in August 1998 and was called LEED Version 1.0. For the next three years, appropriate modifications were made, and version 2.0 came out in 2000; this version is now called LEED for New Construction. The LEED requirements are broken down into five categories which each have their own list of requirements. The categories are *Sustainable Sites*, *Water Efficiency*, *Energy and Atmosphere*, *Materials and Resources*, and *Indoor Environmental Quality*. There is also a separate category, *Innovation and Design Process* which is not included in the five, but awards points for special designs that take sustainability into account. Due to the flexible nature of sustainability, there are four levels that can be reached based on the number of points the building earns for the design and construction: Certified, Silver, Gold, and Platinum.[10]

Level	Number of Required Points
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

Table 1 - Certification Levels

2.2.1 LEED Practices in Construction

The checklist for LEED certification applies to many different areas of the project. First, it looks at the site, and especially whether it was previously a brown field, which is a previously polluted industrial site. It looks at whether the site is close to public transportation or not, since promoting public transit reduces on pollution. Next it looks into the design of the project to

[10] http://www.usgbc.org/DisplayPage.aspx?CMSPageID=174&

determine whether it was designed to be environmentally friendly. After a building is designed, it must be built and at this point there are countless practices that can make the construction process more environmentally conscious. The last step the LEED checklist evaluates is its long term usage on energy by looking at the interior finishes.

The first item on the checklist is *Construction Activity Pollution Prevention*. This is a requirement for a site to be LEED certified and it ensures the site and the work being done on it does not directly affect the surrounding environment. This prerequisite prevents harmful erosion of sediment or pollutants and dust control. To meet this expectation, the general contractor is responsible for making sure polluted water and soil is not infiltrating the system, or contaminating nearby bodies of water.

Another item on the list that is pertinent to the construction practices is *Construction Waste Management*. There are two possible points for this category, one for recycling or salvaging 50% of non-hazardous construction or demolition debris, and the other if the site also reaches 75%. Excavated soil or other land-clearing materials do not count toward this number.

There are eight more points that can be awarded for reusing building materials, using materials from local distributors, using rapidly renewable resources, and using certified wood. Some of these can earn up to two points each based on the percentage of usage. Reusing building materials is very important on a big scale, the point being to promote using leftover material from a previous task rather than ordering more “virgin” material. Supporting local suppliers is encouraged to reduce the negative impacts of transportation and ultimately to support the use of indigenous resources. The use of rapidly renewable resources encourages selecting materials that can be replaced easily, such as cotton insulation. Finally, a point can be awarded for using certified wood which ensures safe forestry practices.

The last relevant point that can be awarded for construction practices is *Construction IAQ Management Plan: During Construction.* IAQ stands for Indoor Air Quality, and this point ensures the construction practices do not harm the construction workers. This item calls for moisture control and proper ventilation for any metals or other harmful elements that can travel by air.

LEED Construction for new buildings can be completely different from case to case depending on the use of the building; however, most of these construction points are relevant to any type of project. Our team is dedicated to reviewing the Union Station Parking Garage, determining how many points it currently meets or will meet, and how many more it can meet through reasonable modification.

*Possible LEED Points by Category**

Category	**Points Possible**
Sustainable Sites	14 Points
Water Efficiency	5 Points
Energy and Atmosphere	17 Points
Materials and Resources	13 Points
Indoor Environmental Quality	15 Points
Innovation and Design Process	5 Points

Table 2 – LEED Points by Category

*A full version of LEED Checklist 2.2 for New Construction can be found in Appendix A

2.3 Green Roofs

Buildings contribute to many urban environmental issues including storm water runoff and the heat island effect. In larger cities, such as Worcester, these issues are all exacerbated and contribute to more problems including global warming. These issues, however, may be alleviated through meeting the LEED certification requirements. To obtain the lowest level of LEED certification, a project must meet at least 26 out of the 69 available points. The addition of a green roof can contribute eight points towards meeting LEED certification[11] and offer other environmental and social benefits.

A green roof, in its most abstract form, is a roof that has been designed to accommodate vegetation, while still protecting the underlying building from the elements. This is done through the combination of several basic components, which are (listed from the most underlying layer to the top in Figure 2 shown below):

- **Waterproofing Membrane**: an impermeable layer of rubberized asphalt or solid PVC that protects the roof from and building from water.
- **Root Barrier**: prevents aggressive roots from puncturing the waterproofing membrane
- **Insulation**: required for any roof (green or not) to reduce a building's heat loss during winter
- **Drainage Layer**: allows excess water (that which is not absorbed by green roof) to flow off the roof
- **Filter Fabric**: keeps the growing medium from getting into the drainage layer

[11] http://www.greenroof.com/greenroofbene_urban_heat_island.shtml

- **Growing Medium**: lightweight material composed of minerals and organic compounds

- **Vegetation**: types can range from drought tolerant succulents to small trees, depending on the thickness of growing medium

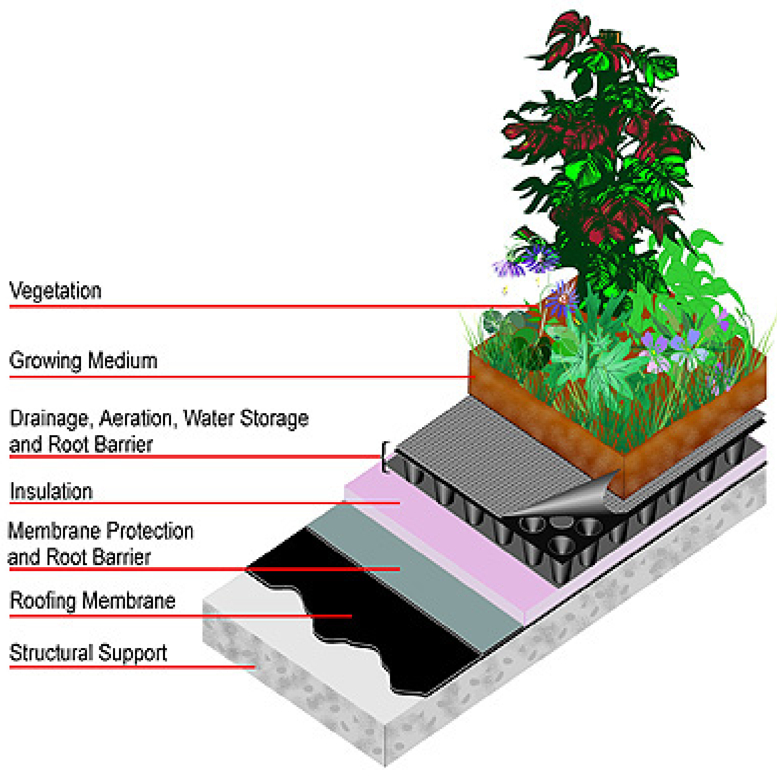

Figure 2 – Green Roof Section[12]

This design was developed by the German Society for Landscape Development and Landscape Design and is considered to be the most comprehensive and effective list of materials for green roof construction.

[12] http://www.usemenow.com/web-log/greenroof1.jpg

These materials can be used to create two basic types of green roofs: intensive and extensive. An intensive green roof uses 30-40 inches of growing medium and can accommodate large plants and small trees. This allows for the maximum absorption of water, but thorough maintenance is usually required. Extensive green roofs use only 3-4 inches of growing medium and are planted with drought tolerant succulents or grasses. This system requires minimal maintenance and a lower up-front cost, but it is not capable of absorbing as much rainwater as the intensive roof.[13]

2.3.2 Storm Water Runoff

"The mitigation of storm water runoff is considered by many to be the primary benefit because of the prevalence of impervious surfaces in urban areas."[14] Depending on the intensity of the storm, rainwater runoff from roofs can cause flash flooding and increased erosion, and carry harmful pollutants to rivers and lakes. Storm drains at curbs or in parking most collect storm water and move it away from buildings. They often empty quickly and directly into rivers and lakes, not a sewage treatment plant, rapidly introducing high volumes of contaminated water into aquatic systems. Pollutants commonly found in urban runoff include sediment, fertilizer, animal feces, cleaning products, pesticides, paint, and specifically with parking garages, road salt, metal particles, oil, gasoline, antifreeze, and other toxics. Green roofs dramatically reduce the amount of runoff as well as the peak flow rate. They have been shown to retain 60% to 100% of the water that they receive.[10] This storage provided by green roofs helps reduce the runoff that would have to be controlled by other means.

[13] Green Roofs: Ecological Design and Construction (Earth Pledge, 2007)
[14] http://www.hrt.msu.edu/faculty/Rowe/Green_roof.htm

The effectiveness of the roof depends upon major components of the roof. A roof with greater grass and plant diversity will have better plant uptake and increased friction, creating less runoff while retaining more water on the roof's surface. Another major component of the roof is the growing medium. The growing medium traps particles, thereby treating the soil before it enters an outlet. The amount of water retained depends upon the depth of the medium as well as the vegetative cover:

- A 1-inch deep moss and sedum layer over a 2-inch gravel bed retains about 58% of the water.
- A 2.5-inch deep sedum and grass layer retains about 67% of the water.
- A 4-inch layer of grass and herbaceous vegetation retains about 71% of the water.
- A major 2-inch rainstorm, generating about 1.25 gallons of water per square foot, on a 2.5-inch thick extensive green roof would retain approximately 0.50 gallons of water per square foot, or 40% of it. [15]

There have been some case studies on the effectiveness of green roofs on water runoff. In Toronto, Canada, where the average rainfall event is 1.6 inches, a three-month long summer study showed that a green roof with a 2.8 inch deep vegetation layer produced no runoff, while the soil surface at grade, without planting, produced 42% runoff and a gravel surface produced 68% runoff. Another study, in Berlin, Germany showed that green roofs can absorb 75% of the precipitation that falls on them, which translates into an immediate discharge reduction to 25% of normal levels. In Portland, Oregon a garage roof top planted with a mixed layer of sedum and grass retained up to 90% of all the rain that fell on it, becoming less effective only during

[15] http://www.roofmeadow.com/technical/benefits.shtml

continuous and heavy rainfall. The effectiveness of the roof top could have been improved upon if additional storage had been provided through the use of additional detention devices such as modified roof drains and water tanks.[11]

2.3.3 Heat Island Effect

Urban areas are significantly warmer and produce more harmful ozone than surrounding suburban areas due to the vast amount of heat absorbing buildings, dark surfaced pavements, and hot air vented through cooling systems. The envelope of hot air that hovers over cities, due to these heat reflective materials and the lack of vegetation is known as the urban "heat island" effect. It can result in cities being as much as 7 to 10 degrees warmer than the surrounding suburban and rural towns and cities, and in higher levels of smog and ozone. This additional heat can actually disrupt weather patterns, leading to droughts or increased electrical storms within the city and surrounding areas.

The average temperature of North American cities has risen over the past decade, having a range of direct and indirect negative impact on the quality of life of Americans. During a day that reaches 90ºF, a blacktop roof surface can get up to 160ºF. A typical green roof will only reach 95ºF.[16] This is because the soil and vegetation absorb the worst of the heat during the day. This causes cooling of the building underneath, requiring less air conditioning as well as the ventilation of hot air from an air conditioner to the atmosphere. In addition, daytime heat is retained after sunset, keeping the building warm at night. The intensity of the heat retained in green roofs is far less than the way it is in black roofs, thus the city can cool faster. Also lowering the temperature of the city is the plants' ability to transpire and also shade, causing a cooling effect.

[16] http://www.usatoday.com/tech/columnist/aprilholladay/2006-04-24-green-roofs_x.htm

An American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) simulation conducted by the City of Chicago of their City Hall Green Roof showed that for every one degree Fahrenheit decrease in ambient air temperature there is a 1.2% drop in cooling energy use. The study suggested that if, over a period of ten years or more, all of the buildings in Chicago were retrofitted with Green Roofs, which would be about 30% of the area, the reduced cooling would result in savings of $ 100,000,000 annually in all of the buildings in Chicago. The cooling would also slow the chemical processes that produce ground level ozone, nitrous oxides and smog, and help offset the production of sulfur dioxides from coal fired utilities.[9] This would give a lesser contribution to global warming.

2.3.4 Other Benefits of Green Roofs

Green roofs have far more benefits than the ones listed here. These include a more eye appealing roof, a new environment for wildlife, as well as endurance, since green roofs last almost twice as long as regular roofs. However, when talking about parking garages, storm water runoff and the heat island effect reduction are the most prevalent. Although the initial cost is more expensive, savings, both economically and environmentally could outweigh the costs.

2.3.5 Examples of Garages with Green Roofs

University of North Carolina Rams Head Center: Parking Garage

Figure 3 – Green Roof Example 1

The Rams Head Center at the University of North Carolina incorporates a new 700 car parking garage that links two buildings. The roof of the garage serves as a 1-acre, greened courtyard made possible by employing an intensive green roof, which consists of rubberized asphalt membrane, 8 in. of gravel, and 36 in. of growing medium capable of sustaining grass, shrubs, and trees as tall as 30ft. The roof will absorb most of the rainwater that falls, while directing the remainder through the purifying gravel layer and into cisterns that will eventually flow the water to a natural stream. [17] The garage received the 2007 Award of Excellence in Parking Facilities from the International Parking Institute and the 2006 AON Build America Award from the Associated General Contractors of America.[18]

[17] www.thcahill.com/roof.html
[18] www.walkerparking.com

Blue Cross/Blue Shield of Michigan: Parking Garage

Figure 4 – Green Roof Example 2

This green roof surmounts a recently completed nine-story, 1,825 space parking garage in Detroit. 70% of the 75,000 square foot roof is covered with low-maintenance sedum plants as well as walking path made of recycled, rubberized pavement. The primary purpose for the green roof's construction was to reduce the flow of storm water. Vegetation absorbs a large portion of the water while the excess is purified as it passes through the growing medium, and collected for landscape irrigation. Other benefits include an extended life of the garage, moderation of the heat island effect, eliminating the need to physically remove snow from the roof, and cleaner air through the entrapment of dust and absorption of carbon dioxide. To achieve these benefits, the roof utilizes the standard system of green roof components, with a diverse collection of sedum plants to ensure constant growth. [19]

[19] http://www.bcbsm.com/pr/pr_12-11-2006_98693.shtml

One Waterfront Place, Portland: Parking Garage

Figure 5 - Green Roof Example 3

Although still in the design phase this project bears relevance to the Union Station parking garage because it employs an exposed top deck. Instead of using a bed of vegetation, the designers developed a system of trellises that would, in theory, act the same way as a conventional green roof. This system would be ideal for existing garages with exposed top decks.[20]

Although the addition of green roofs to parking garages is a relatively new concept, it has been successfully completed in finite cases around the United States. The aforementioned green roofs have provided the users of parking garages and surrounding areas with a variety of benefits including the reduction and purification of storm water flow, an extended garage life, mitigation of the heat island effect, the elimination of snow removal devices, and cleaner air through the entrapment of dust and absorption of carbon dioxide. Green roofs can be constructed on many

[20] Green Roofs: Ecological Design and Construction (Earth Pledge, 2007)

types of parking garages located in moderate to warm climates, and provide an excellent opportunity for further environmental sustainability.

3. LEED Certification

To improve the environmental sustainability of the Union Station Parking Garage the team determined what LEED standards the project already met and then identified which additional LEED points the project was eligible to meet.

This project uses the *Green Building Rating System for New Building Construction Version 2.2* was used to evaluate the potential LEED certification of the Union Station Parking Garage. After initial review of the garage, it was determined that the addition of a green roof was necessary to meet the minimum credits for certification.

3.1 LEED Standards the Project Already Meets

Project Description	Point Value
Construction Activity Pollution Prevention	Required
Site Selection	1 Point
Development Density & Community Connectivity	1 Point
Alternative Transportation, Public Transportation Access	1 Point
Water Efficient Landscaping, Reduce by 50%	1 Point
Water Efficient Landscaping, No Potable Use or No Irrigation	1 Point
Enhanced Refrigerant Management	1 Point
Regional Materials, 10% Extracted, Processed & Manufactured Regionally	1 Point
Regional Materials, 20% Extracted, Processed & Manufactured Regionally	1 Point
Minimum IAQ Performance	Required

Table 3 - Met Standards

To determine which LEED standards the project was currently meeting, the team developed a checklist of all of the LEED standards that the project was eligible for and investigate each standard to check for compliance. (See Appendix A and B for detailed LEED credit evaluations)

The plans and specifications for the project were reviewed in detail to determine appropriate features of the project with regards to LEED certifications points. Any items that were unclear were visually inspected at the jobsite.

There are standards on the LEED checklist that can be met without any significant pre-construction design or planning. For the Union Station Parking Garage, there were ten of these, two being requirements, and eight attainable points. This was significant because not all LEED standards are applicable to parking garages, which makes these points all the more valuable to this project.

To be LEED certified the project had to comply with the seven requirements, two of which were already met by the original design of the project. The first requirement met was Construction Activity Pollution Prevention. The second was to meet the minimum standards of ASHRAE (American Society Heating, Refrigerating, and Air Conditioning Engineers) for Indoor Air Quality. The goal of the first requirement was to reduce the effect that the construction process had on the surrounding environment and the goal of the second requirement was to ensure the well being of the occupants. Even though these two requirements were being met without any influence from the checklist, they both demonstrate the goals of the LEED process by ensuring a building with minimal disturbance to the environment, or the people who will occupy it.

Out of the 69 attainable points in the checklist, a project must satisfy at least twenty-six to be LEED certified. The Union Station project met eight of these without any modifications from the original scope of work, most of which had to do with the location of the project. An example is the Development Density and Community Connectivity Point, which promotes projects to be located near populated areas and have at least ten basic services within range. To reduce the need to travel by car during the workday, the parking garage has places of worship, laundry mats, banks, and much more located within a half mile in this densely populated section of Worcester. Even more relevant to sustainable development is the services that the garage provided parking for, which is a bus and train station, promoting the use of public transportation.

The LEED rating system awards points for minimizing the use of potable water being used for landscaping, especially if the water came from the public water supply. Since the original design called for minimal plantings and a majority of the space on the site was to eventually consist of concrete or asphalt, the amount of water being used for landscaping was acceptable. In this sense, the garage satisfied this point right from the beginning of the project.

Another two points were awarded for having at least twenty percent of the materials used on site extracted, processed and manufactured within 500 miles of the site. Since the elements of the precast concrete structure constituted a majority of the materials used, and they came from Connecticut, these were points that the parking garage would be awarded with no special changes necessary.

3.2 LEED Standards the Project Could Meet

Project Description	Point Value
Construction Activity Pollution Prevention	Required
Site Selection	1 Point
Development Density & Community Connectivity	1 Point
Alternative Transportation, Public Transportation Access	1 Point
Alternative Transportation, Bicycle Storage & Changing Rooms	**1 Point**
Alternative Transportation, Low-Emitting & Fuel-Efficient Vehicles	**1 Point**
Site Development, Protect or Restore Habitat	**1 Point**
Site Development, Maximize Open Space	**1 Point**
Stormwater Design, Quantity Control	**1 Point**
Stormwater Design, Quality Control	**1 Point**
Heat Island Effect, Non-Roof	**1 Point**
Heat Island Effect, Roof	**1 Point**
Water Efficient Landscaping, Reduce by 50%	1 Point
Water Efficient Landscaping, No Potable Use or No Irrigation	1 Point
Fundamental Commissioning of the Building Energy Systems	**Required**
Minimum Energy Performance	**Required**
Fundamental Refrigerant Management	**Required**
Enhanced Refrigerant Management	1 Point
Storage & Collection of Recyclables	**Required**
Construction Waste Management, Divert 50% from Disposal	**1 Point**
Construction Waste Management, Divert 75% from Disposal	**1 Point**
Materials Reuse, 5%	**1 Point**
Materials Reuse,10%	**1 Point**
Recycled Content, 10% (post-consumer + ½ pre-consumer)	**1 Point**
Regional Materials, 10% Extracted, Processed & Manufactured Regionally	1 Point
Regional Materials, 20% Extracted, Processed & Manufactured Regionally	1 Point
Rapidly Renewable Materials	**1 Point**
Certified Wood	**1 Point**
Minimum IAQ Performance	Required
Environmental Tobacco Smoke (ETS) Control	**Required**
Outdoor Air Delivery Monitoring	**1 Point**

Increased Ventilation	**1 Point**
Construction IAQ Management Plan, During Construction	**1 Point**
Construction IAQ Management Plan, Before Occupancy	**1 Point**
Low-Emitting Materials, Composite Wood & Agrifiber Products	**1 Point**
Indoor Chemical & Pollutant Source Control	**1 Point**
Total	**29 Points**

Table 4 - All Recommended Points

To determine what changes could be made to the Union Station Parking Garage, the team used case studies from other LEED certified buildings (described in the chapter 2) to aid in the engineering of ways to meet these standards. These case studies provided some solutions that were helpful to this project and inspired new ideas about compliance.

Most information regarding LEED compliance was available directly through the LEED handbook. The book was helpful in giving different methods that could be used to satisfy each point. The team had to consider each proposed method and decide which was best for the Union Station Parking Garage project. Each point was reviewed based on cost and time to decide which standards should be met. (See example below or complete list in Appendix B)

(Excerpt from LEED Review Packet – Appendix B)

EA Credit 6: Green Power

1 Point

Intent:

The intent of this point is to promote the use of green power to reduce the effects that burning fossil fuels has on the environment.

Cost Implications:

There is a power company called Shrewsbury Electric and Cable Operations that supplies power to 12,000 Massachusetts residents. The company has an option for customers to purchase green power, which is generated by wind. This is geared more toward residential but can also support commercial, and the calculated premium is 6.67¢/kWh.[21] Since the average price of regular electricity which is 9.46¢/kWh already, this would bring 35% of the energy costs from 9.46¢/kWh to 16.13¢/kWh and add a significant amount of cost to the already pricey parking garage.[22]

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Our team does not recommend meeting this point due to the inconvenience of getting the green power to the site and the dramatic increase of electricity costs. Typically if the project is very close to a level higher of certification, this is an option the owner has of simply spending more money to get another point. So if our final points had come out to a number just below the silver certificate, we would have suggested meeting this, however this is not the case.

[21] http://www.eere.energy.gov/greenpower/markets/pricing.shtml?page=1

[22] http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html

After review of the checklist, it was apparent that the most practical way for the Union Station Parking Garage to become LEED Certified was to design and install a green roof above the original structure. This roof directly attributed to eight of the twenty-nine earned points, and provided benefits to Worcester both environmentally and socially. Some other modifications had to be made, and while none were found to be as costly as the green roof, they were all necessary to meet the basic level of LEED certification.

The 69 possible points are divided up into five different areas of interest. Most of the points that were awarded to the parking garage were in the *Sustainable Sites* and the *Materials and Resources* categories. This was expected because the other areas focused on energy consumption and indoor quality of life, which is more relevant to an enclosed building. In the future it is very likely there will be different rating systems depending on the type of structure, the nature of the construction, or even the location of the project.

The garage met ten of the fourteen points in the Sustainable Sites category after the addition of the green roof, and any other modifications recommended in the LEED Review Packet. These points encouraged the project to be located in a populated area, without necessarily increasing the strain associated with development. As an incentive to cut down on harmful emissions, the city could designate preferred parking spots in the garage for fuel-efficient vehicles and install indoor bike racks. By making these slight, inexpensive changes, the garage would be able to earn two extra points.

With the green roof, more than 50% of the parcel dedicated for this garage could be considered open space because of the vegetated area covering it. The protection of open space is very important in sustainable development, and is therefore worth two points. Since the vegetation was chosen specifically because it was native to Worcester, it needs no irrigation other than rainwater. This eliminates the use of potable water for irrigation purposes, while still allowing a majority of the site to be covered in greenery. Another benefit of this roof is the ability to avoid heating up the surrounding area by exposing vegetation to the sunlight, rather than concrete or asphalt. The grass had a much higher Solar Reflective Index so the garage did not compound the already existing problem of the Heat Island Effect in Worcester.

The materials and resources used for this project could also earn points for the garage. In an effort to promote environmentally friendly waste management practices, a plan could be developed to include an extra dumpster for recyclable materials such as metals or asphalt. Also, the project could be constructed using some reused and recycled materials. In a pre-cast concrete garage, there is very little wood used, so any wood that was needed, would have to be certified wood, signifying safe forestry practices. The materials used for the project had to be approved paints, coatings, and adhesives with low concentrations of harmful VOCs (Volatile Organic Compounds). The last stipulation on the materials was that the building be completely flushed out before it is used permanently.

With all of the modifications, the garage was able to meet the basic level of LEED certification with twenty-nine points.

4. Green Roof Design

As discussed in the background section, the addition of a green roof to a building is a particularly effective method of achieving up to eight LEED points. A green roof meets requirements for LEED points such as the reduction of the urban heat island effect, storm water mitigation, restoration of natural habitat, and maximization of open space, as well as several social benefits such as increased aesthetic value and acting as a visual symbol of a building's commitment to environmental sustainability. Because a green roof addresses multiple LEED points and enhances an area aesthetically, it is an advantageous way to increase a building's environmental sustainability.

Currently, the City of Worcester is not actively seeking LEED certification of the Union Station Parking Garage. This means that a green roof would have to be constructed in a retrofit fashion. Construction of the Union Station parking garage will be completed by December 2007 and the green roof structure would potentially be installed a few months after the completion of the garage.

4.1 Design Procedure

The Union Station Parking Garage is a roofless garage, meaning that the uppermost deck has no overhead covering. For a green roof to be added to the existing design configuration, a frame structure was designed to surmount the existing open deck, allowing vehicles to maneuver underneath. The structure was designed with a minimal number of strategically placed columns so that vehicle travel would be uninterrupted. Minimum clearance requirements between the upper deck and the green roof were maintained by using the deck-to-ceiling distance of the lower levels.

Before design methods could be applied, the construction material had to be specified. The material used had to be able to span large distances (see 4.2 Spanning and Column Layout) and minimize deflections of the green roof. The two most appropriate choices were either pre-stressed concrete or steel, both being applicable for large spans. Since pre-stressed concrete was used for the parking garage itself, its use in the green roof would have maintained some aesthetic continuity. However, pre-stressed concrete beams tend to be expensive. Since minimizing cost is one of the most important factors in this design, it was determined that steel beams, girder, and columns would be more economical framing materials.

The American Institute of Steel Construction's (AISC) Load Resisting Factored Design (LRFD) method was used to determine adequate member sizes for the green roof structure. The dead and live loads used for the green roof structure were dictated by the loads stated in the plans for the parking garage. These loads adhere to standards set forth in the Massachusetts State Building Code.

4.2 Spanning and Column Layout

Since the green roof is designed for retrofit construction, the layout of the structure was chosen to match the existing plan layout top deck of the parking garage shown in Figure 6 below.

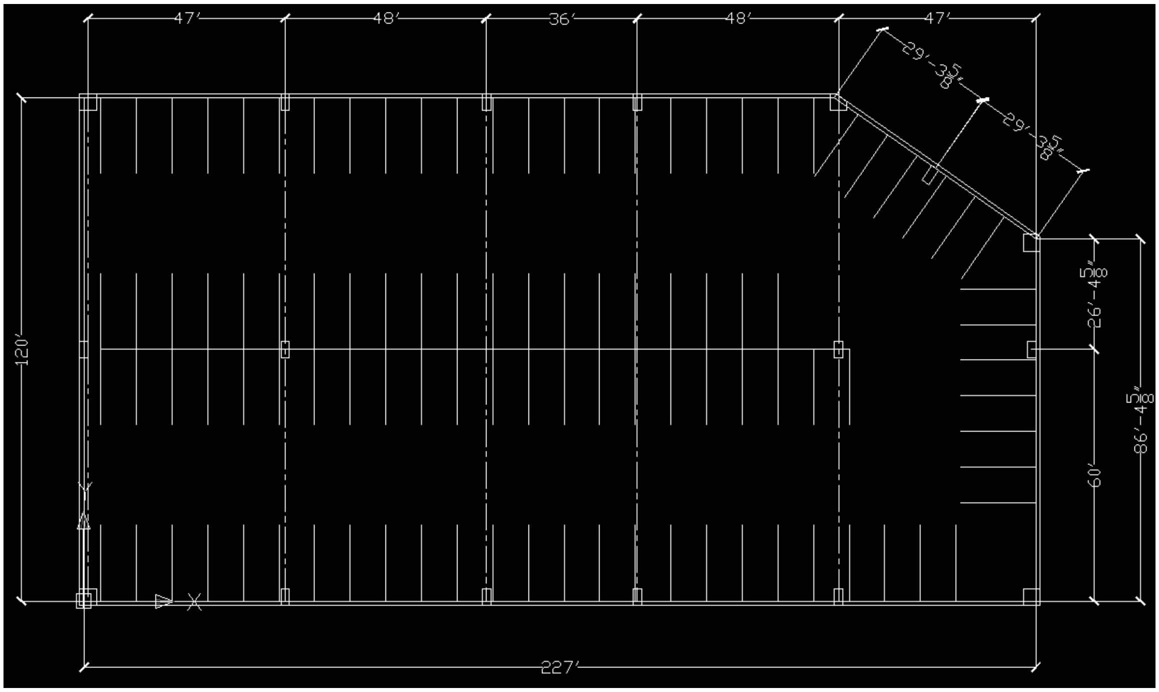

Figure 6 - Existing Parking Deck Layout

Spans were dictated by the existing parking garage layout and the location of existing columns in the parking garage. By placing columns for the roof directly above the columns of the existing parking garage, the loads created by the green roof structure remain as vertical loads and are transmitted directly to the foundation without creating additional moments in the parking garage's structural members. Beams were required to span 60ft, which allows for uninterrupted vehicular flow on the deck below. Girders were required to span between 29ft and 48ft depending on the location of columns in the garage underneath. Column locations (in yellow) are shown in Figure 7 below.

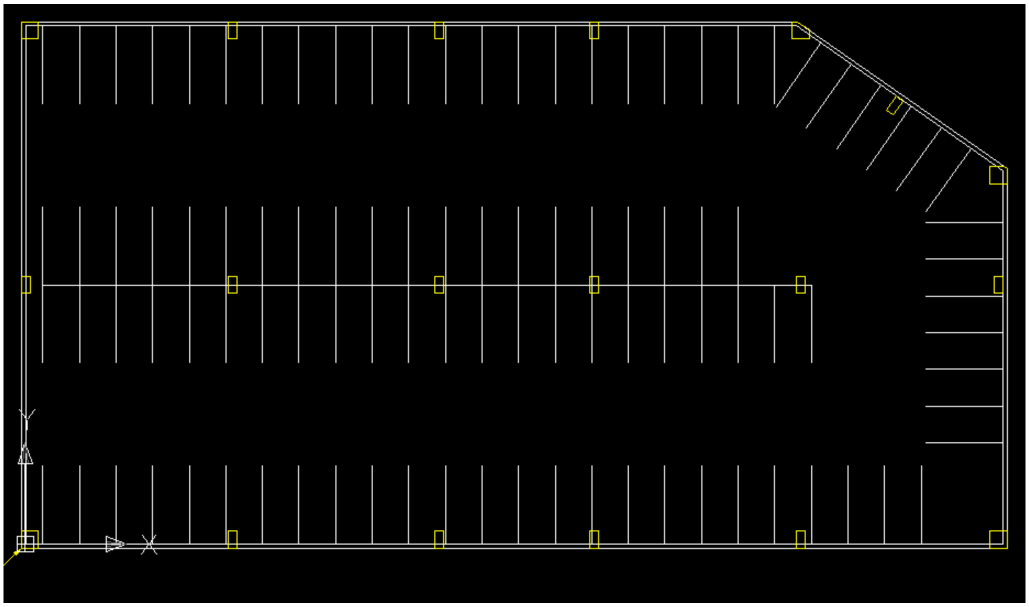

Figure 7 - Column Locations

The column locations then dictated the spans of girders and beams, which are shown in Figure 8 below. Girders are noted in red and run horizontally in the figure whereas beams are noted in green and run vertically. The final design resulted in beams spaced 12ft o.c. to maximize cost savings (see section 4.4 Beam Spacing for a more comprehensive explanation).

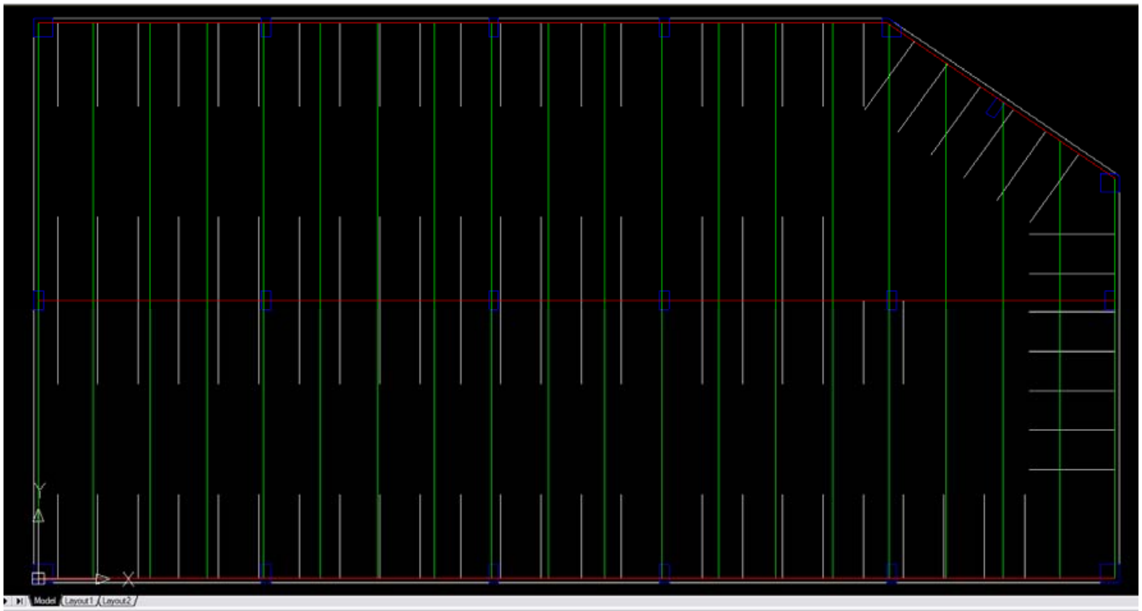

Figure 8 - Final Column, Girder, and Beam Scheme

4.3 Loadings

Dead and Live loadings, listed below, were taken from the Massachusetts State Building Codes and from the loads stipulated in the plans for the Union Station Parking Garage.

Dead Loads	Load (psf)
Corrugated Metal Decking	2.00
Concrete Slab (f'_c = 3500psi, 5in slab depth)	60.42
Suspended Services (lighting, etc.)	5.00
Green Roof Material	50.00
Live Loads	Load (psf)
Snow	35.00
Wind	17.28

Table 5 - Roof Loads

4.3 Member Sizes

Using the aforementioned spans, loadings, and the LRFD method for steel design, the following member cross sections were selected:

Member Type	Design Length (ft)	Tributary Width (ft)	Factored Loading	Determined Size
Beams (12ft o.c.)	60.0	10	1,896.50 plf	**W24x104**
Inside Girders	48.0	60	11,480.76 plf	**W36x160**
Outside Girders	48.0	30	5,893.02 plf	**W21x122**
Columns	10.67	Trib. Area = 60 x 48 = 2880ft^2	600,000 lbs. (axial)	**W12x58**

Table 6 - Member Sizes

Note: For detailed calculations, see Appendix C.

4.4 Beam Spacing

While the layout of columns and spans for girders and beams were dictated by the existing parking garage geometry and were therefore unchangeable, the spacing between beams could be adjusted in order to decrease cost. A change in spacing resulted in an increased beam depth, but this was acceptable because there were height restrictions. For the initial design, beams were spaced at 10ft center to center, resulting in W18x106 beams. A second analysis showed that the beam spacing could be increased to 12ft by using W24x104 beams, which yields significant cost savings by reducing the number of required beams (any spacing over 12ft resulted in no cost savings). Since the W24x104 beams weighed 2plf less than the initial W18x106, the weight of the structure is actually slightly less with an increased spacing. The increased beam spacing required a larger beam depth, but since the thickness of the green roof was not constrained, it was possible to select a beam with a larger depth without an increase in weight per foot, while maintaining adequate clearance underneath. The result was fewer beams with higher strength and no weight increase, and therefore a lower cost for materials and installation. This reduction created the need for a 1in increase in roof slab thickness (see Concrete Slab Design below), but the cost of this increase was offset by the need for fewer beams.

4.5 Concrete Slab Design

For initial calculations of dead load, a 4in thick, one way concrete slab was used, with corrugated metal decking. As the beam spacing was changed from 10ft to 12ft, the required slab thickness changed from 4in to 5in. Although this increase in slab thickness accrues a greater cost of concrete, the cost saving due to using fewer beams results in an overall cost saving. This analysis was done by comparing the ratio of total weight of beams to slab thickness. As seen in the Table 5 below, the 12ft beam spacing offers the lowest ratio of beam weight to slab thickness, with a slab thickness of 5 inches.

	10ft Span	12ft Span	15ft Span
Required Beam Size	W18x106	W24x104	W27x114
Total weight of beams (kips)	293	234	309
Required Slab thickness (in)	4	5	6
Ratio of total beam weight to slab thickness (kips of steel/in conc.)	73	47	52

Table 7 - Beam Weight vs. Slab Thickness Analysis

4.6 Connections

Since the green roof structure must allow for uninhibited movement of vehicles below, a large bayed, rigid frame must be used. This means that moment resisting connections must be used for the intersection of all members, including the connection of columns to the parking garage.

Connection Location	Type	Design Specifications
Beam to Girder	Rigid/Moment Resisting	Bolted shear tab with welded flanges. Weld width = 8.66in
Girder to Column	Rigid/Moment Resisting	Bolted shear tab with welded flanges. Weld Width = 11.2in
Column to Parking Garage (Baseplate)	Rigid/Moment Resisting	Baseplate Dimensions: 1"x1'1"x1'3"

Table 8 - Connections

4.7 Analysis of Existing Parking Garage

The addition of the green roof structure adds to the dead load of the parking garage, therefore it was necessary to check the integrity of the garage. Since the green roof is an open frame structure, it has little effect on lateral loadings of the garage, such as seismic forces and wind. The loads of the green roof are transferred directly to the columns of the parking garage; therefore it is only necessary to check the capacity of the columns in the garage. The concrete columns in the garage must support an additional maximum axial load of 700kips due to the green roof. This results in a required gross area of 388in^2. The smallest column in the garage has a cross sectional area of is 1056in^2, meaning that the garage columns have more than adequate capacity to carry the additional load.

4.8 Green Roof Type

Since one of the major parameters of the green roof is cost, it was necessary to determine what type of green roof should be used, either intensive or extensive. An extensive green roofs use only 3-4 inches of growing medium and are planted with drought tolerant succulents or grasses. This system requires minimal maintenance and a lower up-front cost, but it is not capable of absorbing as much rainwater as the intensive roof. Despite this drawback, an extensive green roof is the best fit for the Union Station Parking Garage because it requires the lowest up-front and maintenance costs.

4.9 Final Cost

The following tables list the cost analysis for the green roof design with 10ft beam spacing and 12ft beam spacing. The final costs show an approximate cost savings of $40,000 with a 12ft beam spacing.

Trial 1 (10' beam spacing)								
	Size	Quantity	Total Length (ft)	Total Tonnage	Labor hours	Cost/ft	Total Hours	Total Cost
Outside Girders	W21x122	17	464.81	28.35	0.08	$85.00	6.8	39,508.85
Inside Girders	W36x160	9	227.00	18.16	0.069	$108.50	7.5	24,629.50
Beams	**W18x106**	**46**	**2,783.87**	**147.55**	**0.089**	**$75.00**	**6.7**	**208,790.25**
Columns	W12x58	17	181.33	5.26	0.075	$45.00	3.4	8,160.00
						Totals	24.3	281,088.60
Greenroof Material	125x250		31,250.00			$8-20/sf		250,000.00

Total Roof Cost	$531,088.60

Table 9 - Trial 1 Costs

Trial 2 (12' beam spacing)								
	Size	Quantity	Total Length (ft)	Total Tonnage	Labor hours	Cost/ft	Total Hours	Total Cost
Outside Girders	W21x122	17	464.81	28.35	0.08	85	6.8	39,509.06
Inside Girders	W36x160	9	227.00	18.16	0.069	108.5	7.4865	24,629.50
Beams	**W24x104**	**39**	**2,252.63**	**117.14**	**0.076**	**73.5**	**5.586**	**165,567.94**
Columns	W12x58	17	181.33	5.26	0.075	45	3.375	8,160.00
						Totals	23.24	237,869.05
Greenroof Material	125x250		31,250.00			$8-20/sf		250,000.00

Total Roof Cost	$487,869.05

Table 10 - Trial 2 Costs

5. Cost Implications

5.1 Green Roof Costs

The final cost for the green roof is $487,869.05 for materials and construction. This cost can however be lowered. The design of the Union Station Parking Garage calls for a snow melting machine on the top deck that costs $250,000. The implementation of a green roof would however preclude the need for the snow melting machine, meaning that the cost of the snow melting machine can be subtracted from the cost of the green roof. The updated cost is $241,245.

Green Roof Structure Costs								
	Size	Quantity	Total Length (ft)	Total Tonnage	Labor hours	Cost/ft	Total Hours	Total Cost
Outside Girders	W21x122	17	464.81	28.35	0.08	85	6.8	39,509.06
Inside Girders	W36x160	9	227.00	18.16	0.069	108.5	7.4865	24,629.50
Beams	W24x104	39	2,252.63	117.14	0.076	73.5	5.586	165,567.94
Columns	W12x58	17	181.33	5.26	0.075	45	3.375	8,160.00
						Totals	24.337	241,245.44
Greenroof Material	125x250		31,250.00			$8-20/sf		250,000.00
Snow Melting Machine								-250,000.00

Total Roof Cost	$237,869.05

Table 11 - Green Roof Structural Costs

5.2 Cost for Other LEED Points

The team proceeded to do a cost analysis of all LEED points that the project was eligible for. The most recent version of the *R.S. Means* book for construction was used to calculate costs and crews for any of the tasks that had to be completed. Every part of the process did not lie in the critical path of the project and therefore did not postpone the estimated completion date.

The most appropriate modifications to the garage were chosen for the project that represented the least amount of cost for the satisfaction of the LEED point. Some modifications to the project overlapped and covered more than one LEED point, this especially being true for the green roof.

Task	Cost
Construction Activity Pollution Prevention	
Material	$ 678
Labor	$ 386
Time (hours)	17.3 hours
Total Cost including Overhead & Profit	**$ 1,367.00**
Alternative Transportation: Bicycle Storage & Changing Rooms	
Material	$1,170.00
Labor	$141.00
Time (hours)	6.0 hours
Total Cost including Overhead & Profit	**$ 1,515.00**
Fundamental Commissioning of the Building Energy Systems	
Material	$0.00
Labor	$21,500.00
Time (hours)	0 hours
Total Cost including Overhead & Profit	**$ 21,500.00**
Construction Waste Management: Divert 50% from Disposal	
Fee	**$ 5,120.00**
Environmental Tobacco Smoke (ETS) Control	
Material	$94.80
Labor	$62.00
Time (hours)	2.2 hours
Total Cost including Overhead & Profit	**$ 200.00**
TOTAL	**$ 29,702.00**

Table 12 - LEED Point Costs

5.3 LEED Certified vs. LEED Certifiable

Although the environmental sustainability of this project was assessed using LEED standards, it is not necessary to actually have the garage be certified. For municipal buildings in Worcester, there are little economic benefits of going through the formal certification process. In some cases, it can be more beneficial to dedicate the certification funds towards further greening of a building. Conversely, obtaining LEED certification can add to the appeal of the building and surrounding area. Thus the cost of the green roof and the cost for the other LEED points can be combined in two ways: one with the cost to have the parking garage LEED certified, and another to simply meet a LEED certification level. The following tables show the cost difference between LEED certification and LEED certifiable:

Task	Cost
LEED Points	$ 29,702.00
Green Roof	$ 237,869.05
LEED Certification	$ 26,600.00
TOTAL	$ 294,171.05

Table 13 - LEED Certification Cost

Task	Cost
LEED Points	$ 29,702.00
Green Roof	$ 237,869.05
TOTAL	$ 267,571.05

Table 14 - LEED Certifiable Cost

6.0 Conclusions

The LEED Green Building Rating System for New Construction was not drafted with parking garages in mind. Since projects that involve parking garages usually also involve a main office or residence building, the situation encountered with the Union Station Parking Garage was unique. The herein presented did not consider any combined use of the building, which reduced the number of LEED points the project was eligible for from the start. The fact that we were able to present a plan for LEED certification could be a unique asset to the garage since it would be uncommon that a parking garage by itself could be LEED certified.

6.1 LEED Certification

It is recommended that the owner and contractor take following measures to obtain the LEED certification points below. The steps that need to be taken to obtain each point are briefly described under the title of the point. A more in depth analysis of the requirements and specifics on each point and recommendation can be found in the LEED review packet in Appendix A.

- **Alternative Transportation: Bicycle Storage and Changing Rooms (1 point)**
    - Install indoor bicycle and storage for 75 bicycles
- **Fundamental Commissioning of the Buildings Energy Systems (1 point)**
    - Hire an engineer to monitor the buildings energy systems during and after the project
- **Construction Waste Management (1 point)**
    - Create and enforce a construction waste management plan so that 50% of construction debris is diverted from landfills

- **Environmental Tobacco and Smoke (ETS) Control (1 point)**
    - Post six signs per floor banning smoking within the parking structure
- **Construction Activity Pollution Prevention (1 point)**
    - Reduce erosion control dust
    - Install silt bags in the catch basin covers and erosion control barriers around the site
    - Install silt fence, silt traps and dust mats for entrances
    - Hire a street sweeper to clean up dirt tracked off site by vehicles. The cost for these may be significant.

The team recommends that the project obtain full LEED certification at a total cost of $297,547.[23] The total cost for this job was previously $21.5 million which makes the LEED certification an increase of only 1.26% over the initial cost of the project. Since it is uncommon for parking garages to become LEED certified, it is recommended that the city of Worcester spend the additional 1.26% of the total project cost to obtain a LEED certificate. This certificate would be valuable to the city of Worcester because it would show that the city is dedicated to green building and environmental awareness. Worcester would then be on par with cities like Boston, who already mandate LEED certification for public buildings.

6.2 Green Roof

- ✓ **Install the specified retrofitted green roof onto the garage (8 points)**

A major part of transforming the Union Station Parking Garage into a LEED certificate-worthy project is adding the retrofitted green roof that was designed and explained in chapter 4. It is

[23] A LEED certification guide for renovations is currently in the works and is in the pilot programs phase and a copy was not available for use in this project. LEED New Construction Version 2.2 was used as this was the best guide available at the time. The actual certification of a renovation will depend on the release of the new version.

recommended that this green roof be installed on the structure before it begins to be used. The addition of this green roof accounts for 8 of the 29 points that were achieved in our plan. The major effects of the green roof will be to cool the building, reduce storm-water runoff, and create more green open space on the project.

6.3 Green Building in Worcester

- ✓ **Mandate LEED certification for all new buildings**
- ✓ **Encourage LEED certification for renovations by giving tax incentives**

A green roof on top of a LEED certified parking garage owned by the city of Worcester will be a visible reminder that the project is environmentally sensitive, another public relations statement for the city of Worcester. Many cities such as Boston (MA), Chicago (IL), Dallas (TX), Houston (TX), Los Angeles (CA), and Phoenix (AZ) require LEED certification on all new municipal buildings.[24] It is recommended that the city of Worcester mandate at least a LEED certificate on all new buildings, which would put it into a group with some of the most environmentally conscious cities in the country.

6.4 The Future of Green Building

Green engineering is a positive growing trend and a good indicator of how up-to-date a city is on its environmental policies. The adoption of green engineering can add environmental, social, and economical benefits including reduction of the heat island effect, and decreased stress on a city's inhabitants and infrastructure. With the growing population, there will be a larger need for sustainable development to conserve space and resources. As people become more

[24] http://files.harc.edu/Sites/GulfCoastCHP/Publications/CitiesRequiringLEEDList.pdf

environmentally conscious they are going to look to their local government to implement policies that are consistent with these views.

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Appendix A: LEED Spreadsheet

Point Description	Criteria Met?		Point Value	Points Earned		What would have to be done to meet it
	AS IS	W/GR		AS IS	W/GR	
Construction Activity Pollution Prevention	YES	YES	Required	0	0	
Site Selection	YES	YES	1	1	1	
Development Density & Community Connectivity	YES	YES	1	1	1	see supporting evidence
Brownfield Redevelopment	NO	NO	1	0	0	used to be a post office
Alternative Transportation, Public Transportation Access	YES	YES	1	1	1	mbta
Alternative Transportation, Bicycle Storage & Changing Rooms	NO	YES	1	0	1	Have to include 2 or 3 bike racks or shower and changing facilities
Alternative Transportation, Low-Emitting & Fuel-Efficient Vehicles	NO	YES	1	0	1	Provide 25 preferred spots for low emission and fuel efficient cars
Alternative Transportation, Parking Capacity	NO	NO	1	0	0	Could be done, just not realistic
Site Development, Protect or Restore Habitat	NO	YES	1	0	1	Green Roof
Site Development, Maximize Open Space	NO	YES	1	0	1	Green Roof
Stormwater Design, Quantity Control	NO	YES	1	0	1	Green Roof
Stormwater Design, Quality Control	NO	YES	1	0	1	Green Roof

Heat Island Effect, Non-Roof	NO	YES	1	0	1	Green Roof
Heat Island Effect, Roof	NO	YES	1	0	1	Green Roof
Light Pollution Reduction	NO	NO	1	0	0	Interior Lighting
Water Efficient Landscaping, Reduce by 50%	YES	YES	1	1	1	Cannot use potable water for landscaping, just rain water
Water Efficient Landscaping, No Potable Use or No Irrigation	YES	YES	1	1	1	Cannot use potable water for landscaping, just rain water
Innovative Wastewater Technologies	NO	NO	1	0	0	
Water Use Reduction, 20% Reduction	NO	NO	1	0	0	attainable but very unrealistic
Water Use Reduction, 30% Reduction	NO	NO	1	0	0	attainable but very unrealistic
Fundamental Commissioning of the Building Energy Systems	NO	YES	Required	0	0	talk to architect, seems like hiring a 3rd party is necessary
Minimum Energy Performance	NO	YES	Required	0	0	talk to architect, seems like hiring a 3rd party is necessary
Fundamental Refrigerant Management	NO	YES	Required	0	0	talk to architect, seems like hiring a 3rd party is necessary
Optimize Energy Performance	NO	NO	1	0	0	This is a parking garage, these points apply to enclosed buildings
10.5% New Buildings or 3.5% Existing Building Renovations	NO	NO	1	0	0	
14% New Buildings or 7% Existing Building Renovations	NO	NO	1	0	0	

17.5% New Buildings or 10.5% Existing Building Renovations	NO	NO	1	0	0	
21% New Buildings or 14% Existing Building Renovations	NO	NO	1	0	0	
24.5% New Buildings or 17.5% Existing Building Renovations	NO	NO	1	0	0	
28% New Buildings or 21% Existing Building Renovations	NO	NO	1	0	0	
31.5% New Buildings or 24.5% Existing Building Renovations	NO	NO	1	0	0	
35% New Buildings or 28% Existing Building Renovations	NO	NO	1	0	0	
38.5% New Buildings or 31.5% Existing Building Renovations	NO	NO	1	0	0	
42% New Buildings or 35% Existing Building Renovations	NO	NO	1	0	0	
On-Site Renewable Energy	NO	NO	1	0	0	
2.5% Renewable Energy	NO	NO	1	0	0	
7.5% Renewable Energy	NO	NO	1	0	0	
12.5% Renewable Energy	NO	NO	1	0	0	
Enhanced Commissioning	NO	NO	1	0	0	
Enhanced Refrigerant Management	YES	YES	1	1	1	
Measurement & Verification	NO	NO	1	0	0	
Green Power	NO	NO	1	0	0	
Storage & Collection of Recyclables	NO	YES	Required	0	0	

Building Reuse, Maintain 75% of Existing Walls, Floors & Roof	NO	NO	1	0	0	
Building Reuse, Maintain 100% of Existing Walls, Floors & Roof	NO	NO	1	0	0	
Building Reuse, Maintain 50% of Interior Non-Structural Elements	NO	NO	1	0	0	
Construction Waste Management, Divert 50% from Disposal	NO	YES	1	0	1	They are not currently meeting these, but due to the nature of precast concrete pieces, there is little waste, and with planning, these points could be met
Construction Waste Management, Divert 75% from Disposal	NO	YES	1	0	1	
Materials Reuse, 5%	NO	YES	1	0	1	
Materials Reuse,10%	NO	YES	1	0	1	
Recycled Content, 10% (post-consumer + ½ pre-consumer)	NO	YES	1	0	1	
Recycled Content, 20% (post-consumer + ½ pre-consumer)	NO	NO	1	0	0	
Regional Materials, 10% Extracted, Processed & Manufactured Regionally	YES	YES	1	1	1	
Regional Materials, 20% Extracted, Processed & Manufactured Regionally	YES	YES	1	1	1	
Rapidly Renewable Materials	NO	YES	1	0	1	
Certified Wood	NO	YES	1	0	1	
Minimum IAQ Performance	YES	YES	Required	0	0	
Environmental Tobacco Smoke (ETS) **Control**	NO	YES	Required	0	0	

Outdoor Air Delivery Monitoring	NO	NO	1	0	0	
Increased Ventilation	NO	NO	1	0	0	
Construction IAQ Management Plan, During Construction	NO	YES	1	0	1	
Construction IAQ Management Plan, Before Occupancy	NO	YES	1	0	1	
Low-Emitting Materials, Adhesives & Sealants	NO	YES	1	0	1	
Low-Emitting Materials, Paints & Coatings	NO	YES	1	0	1	
Low-Emitting Materials, Carpet Systems	NO	NO	1	0	0	
Low-Emitting Materials, Composite Wood & Agrifiber Products	NO	YES	1	0	1	
Indoor Chemical & Pollutant Source Control	NO	NO	1	0	0	
Controllability of Systems, Lighting	NO	NO	1	0	0	
Controllability of Systems, Thermal Comfort	NO	NO	1	0	0	
Thermal Comfort, Design	NO	NO	1	0	0	
Thermal Comfort, Verification	NO	NO	1	0	0	
Daylight & Views, Daylight 75% of Spaces	NO	NO	1	0	0	
Daylight & Views, Views for 90% of Spaces	NO	NO	1	0	0	
Innovation in Design: Provide Specific Title	NO	NO	1	0	0	
Innovation in Design: Provide Specific Title	NO	NO	1	0	0	

Innovation in Design: Provide Specific Title	NO	NO	1	0	0	
Innovation in Design: Provide Specific Title	NO	NO	1	0	0	
LEED® Accredited Professional	NO	YES	1	0	1	
			PROJECT POINTS	8		Not Certified
					29	Certificate

Appendix B: LEED Review Packet

SS Prerequisite 1: Construction Activity Pollution Prevention

Required

Intent:

The intent of this requirement is to reduce and try to eliminate the effects that construction activities have on the environment and the inhabitants of the environment.

Cost Implications:

To keep the erosion and dust control to a minimum, Gilbane will have to hire laborers specifically for this task. They will be required to put silt bags in the catch basin covers and erosion control barriers around the site. Since this is maintenance work, and only minimal time per day will be dedicated to it, this task does not require a significant amount of time or money. The contractor will need to buy silt fence, silt traps, dust mats for the entrances and may have to hire a street sweeper to clean up dirt tracked off site by vehicles. The cost for these may be significant.

Estimated Labor Cost: $386.00

Estimated Material Cost: $678.00

Estimated Time: 17.3 Hours

Total Cost including O& P: $1367.00

Recommendations:

Since this is a requirement to meet LEED certification, and Gilbane is already cleaning the site, we recommend taking the extra steps to fulfill these tasks. By doing this, the site becomes a cleaner and healthier place, both for the environment and the people working on it.

SS Credit 1: Site Selection

1 Point

Intent:

To choose a site where development will not have as much of an adverse environmental impact and to not develop inappropriate sites.

Cost Implication:

This point will cost nothing since the site has already been chosen and it is in the downtown Worcester area.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

The job site sits next to Union Station and is the only undeveloped lot around. Development will not change the face of the surrounding area or have any environmental implications.

SS Credit 2: Development Density & Community Connectivity

1 Point

Intent:

The intent of this point is to build on a previously developed site, or a brown field to protect the natural resources and green space.

Cost Implications:

This is not going to cost the City of Worcester anything, since the site has already been selected. If this was in the design phase, and the property had to be purchased, it would most likely be realized that urban developed areas will cost more than an open space in an undeveloped area. Since the site has already been chosen, we evaluated the surrounding area and determined that the site is within a half mile of at least ten of these basic services defined in the LEED criteria.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Since this point has been met for the duration of the project, there are no recommended adjustments.

SS Credit 3: Brownfield Redevelopment

1 Point

Intent:

To clean up Brownfield sites which relieves pressure on underdeveloped land by promoting the clean-up of polluted sites.

Cost Implications: N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

There is no way that this point can be earned because the site is not a Brownfield site. The site previously accommodated a post office.

SS Credit 4.1: Alternative Transportation: Public Transportation Access

1 Point

Intent:

The intent of this point is to minimize the effects automobiles have on the environment by locating the development within range of public transportation.

Cost Implications:

This parking garage is being built to provide parking for the MBTA Commuter Rail, there is no extra cost to achieve this point.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Since this point has been met for the duration of the project, there are no recommended adjustments.

SS Credit 4.2: Alternative Transportation: Bicycle Storage & Changing Rooms

1 Point

Intent:

To reduce the use of automobiles by providing other modes of transportation.

Cost Implications:

The cost will be providing secure bicycle storage indoors for 15% of the buildings full-time occupants or outdoor secure bicycle storage for 5% of the full time occupants and changing/shower facilities. Probably the first choice is more realistic to satisfy the requirement. In order to make space for 15% of the building's occupants there would have to be space to store 75 bicycles. This would probably mean giving up 2-5 parking spaces to allow for storage. This could be a significant cost if there is not currently a place inside the garage to add this.

Estimated Labor Cost: $141.00

Estimated Material Cost: $1170.00

Estimated Time: 6 Hours

Total Cost including O & P: $1515.00

Recommendations:

There should be indoor storage for bicycles that accommodate 15% of the buildings occupants or 75 bicycles. This may be able to be incorporated into the current structure without too much money being spent. The plans will have to be further reviewed.

SS Credit 4.3: Alternative Transportation: Low Emitting & Fuel Efficient Vehicles

1 Point

Intent:

The intent of this point is to reduce pollution from vehicle emissions by promoting the use of low emitting and fuel efficient vehicles with the incentive of preferred parking spots.

Cost Implications:

The primary cost associated with this task is not one of monetary value, but rather one of convenience. With the exception of paying for the signs to indicate these spots and the labor costs associated with installing them, the main cost is giving up 25 preferred parking spots. Since the City of Worcester already has to designate preferred parking spots for the handicapped, it depends on how many more spots they would be willing to lose. On a day the normal spots were full, would the garage open up the fuel efficient spots to regular cars to increase profits?

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

One of the recommendations that the US Green Building Council gives is to provide an alternative refueling station on the site, or in a neighboring parcel. Since the Washington Square area is already developed, the more realistic way to meet this point is assigning the preferred spots. Our team recommends looking at the drawings and evaluating which spots would have to be given up, and if the sacrifice was reasonable, then the point should be met.

SS Credit 4.4: Alternative Transportation: Parking Capacity

1 Point

Intent:

To reduce pollution and land impacts from single vehicle use. To minimize parking lot/garage size.

Cost Implications: N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

The nature of this project is to provide single vehicle storage so there is no way to obtain this point. The only thing that could be done would be to promote shuttles to the station from other locations around the city. This would have to be done by Union Station itself and not the parking garage. The whole purpose of constructing this garage is so people can leave their cars there while they ride the commuter rail or the bus.

SS Credit 5.1: Site Development: Protect or Restore Habitat

1 Point

Intent:

The intent of this point is to restore natural environment by reintroducing local habitat, and promoting biodiversity.

Cost Implications:

The idea of this point is to introduce local greenery back into a developed setting. In this case, it would be a onetime cost of building the green roof, since the plants require minimal or no irrigation, and require no active maintenance such as mowing or fertilizing. The real costs would become relevant when the steel and decking material had to be purchased to build the green roof itself. The labor costs would be intense, and a crane would be necessary as well. There are excavation and trucking costs for the environmental material, and multiple species of plants would be necessary to avoid monoculture planting.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Since we recommend building the green roof, the only necessary steps from this point is to research what types of plants will be going on the roof. They have to be plants native to the area, of more than one species, and relatively maintenance free. Our recommendation is to find a medley of grasses that will not get out of control and can survive off the expected rainfall of the Worcester area.

SS Credit 5.2: Site Development: Maximize Open Space

1 Point

Intent:

To provide a lot of open space and create room for biodiversity.

Cost Implications:

The city of Worcester zoning codes for this site say that 5% of the gross area of the project has to be dedicated to open space. A vegetated green roof can be applied to this percentage so the point will definitely be earned with a green roof on the structure. The cost of the green roof will directly earn this point.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We recommend that the station adds a green roof on top of the structure.

SS Credit 6.1: Storm water Design: Quantity Control

1 Point

Intent:

The intent of this point is to prevent the disruption of natural water hydrology by reducing impervious surfaces, promoting on site infiltration, and preventing pollution from contaminated runoff.

Cost Implications:

This is another point that relies on the green roof. Currently this site is more than 50% impervious so the best way to eliminate the runoff is to introduce this vegetated roof to soak up the rainwater. There is no extra cost in this other than the cost of building the green roof. A study might be necessary to make sure there would be no runoff from the 2 year, 24 hour storm.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This point reinforces our recommendation to retrofit the Union Station Parking Garage with a green roof. Without the roof, it would be impossible for this project to reach any level of LEED certification. We believe that the prevention of contaminated runoff is one of the most important benefits to the Parking Garage, since the water that would be running through the building would most certainly pickup contaminants from the vehicles parked in it.

SS Credit 6.2: Storm water Design: Quality Control

1 Point

Intent:

To limit the pollution of water flowing from the site.

Cost Implications:

The green roof will be satisfying this condition so there will be no additional cost past that. The green roof, to meet this implication must capture and treat 90% of the rainwater. What this actually means is not known at this time, but it will need to be part of the final green roof design.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We recommend that the station adds a green roof on top of the structure.

SS Credit 7.1: Heat Island Effect: Non-Roof

1 Point

Intent:

The intent of this point is to reduce heat produced from developed areas to imbalance climates in undeveloped areas.

Cost Implications:

As a result of concrete and asphalt covering a majority of urbanized areas, it has been proven that the temperature is higher than in undeveloped regions. It is because of this, the LEED rating system has a point for buildings that make attempts to reduce these impervious heat absorbing surfaces. The Union Station Parking Garage is currently designed with no roof, and just the pre-cast concrete slabs of the top floor being exposed. The green roof that we proposed will eliminate the heat, and actually reduce the surrounding heat produced. Because we are providing a lump sum cost for the roof, this point is met with no further cost implications.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This point requires 50% of the parking area to be covered by a material with a SRI rating of at least 29. A vegetated roof would meet this requirement, and our garage is designed to cover the entire parking area with vegetated material. It is therefore previously met with no extra cost, or need for a recommendation besides the designed green roof addition.

SS Credit 7.2: Heat Island Effect: Roof

1 Point

Intent:

To reduce heat island effect from the roof to reduce the impact on the climate.

Cost Implications:

A green roof is needed to cover at least 50% of the structure.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We recommend that the station adds a green roof on top of the structure.

SS Credit 8: Light Pollution Reduction

1 Point

Intent:

The intent of this point is to reduce the effect that the light coming from a development has on its surrounding environment. This can accomplish better nighttime visibility, less glare, and less of an impact on the nocturnal environment.

Cost Implications:

If this project was still in the design phase, the cost associated with this point might even save money by cutting down on the necessary lights for the job. However the lighting has already been planned out for this site and the specifications for the materials is laid out, meaning the cost would involve another study to plan the new lighting scheme around the LEED requirements. It may not even be possible to meet this since the lights are required to have an automatic shut off for when the building is closed. It is in the nature of the parking garage to leave lights on 24 hours a day to prevent theft or other crime since it is visible to anyone passing by.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Since there was already a study done on the site for the necessary lights without the LEED checklist in mind, it would be redundant to go back and do another evaluation on the necessary lights, and find the right equipment, as well as economically inefficient. It is for this reason that our team does not recommend going back and reevaluating the layout of the lighting on the site. There are already conduits for the electrical lines to follow, and other obstacles due to the project being as far along as it is. There is planned retail in the first level that does not have such plans, and for this area it may be beneficial to follow the LEED requirements.

WE Credit 1.1: Water Efficient Landscaping: Reduce by 50%

1 Point

Intent:

To reduce or eliminate the use of potable water for irrigation.

Cost Implications:

The object is to reduce potable water consumption by for irrigation by 50%. A soil/climate analysis would have to be done to study to learn what types of native or adapted plants would survive on the site without needing much irrigation. Any irrigation that is done should be rainwater or treated wastewater.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Any plants on site or on top of the green roof need to be able to survive from the rainwater that exists in Worcester. Any irrigation that must be done should be done using high efficiency equipment or climate based controllers.

WE Credit 1.2: Water Efficient Landscaping: No Potable Water Use or No Irrigation

1 Point in addition to WE Credit 1.1

Intent:

The intent of this point is to totally eliminate the use of potable water for landscape irrigation.

Cost Implications:

The Union Station Parking Garage has very minimal plantings on the site, and they do not require permanent irrigation. It is because of this the project meets the requirement. With the addition of the green roof, the parking garage still does not need to use potable water for landscape irrigation. The species chosen for the green roof must be of a variety of local plants that are able to survive off rainwater alone. It is because of all of this, there is no implied cost for this.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We recommend building the green roof, and with that, this point, and other points will be met. It would be impossible for the Union Station Parking Garage project to be LEED certified without it and some other necessary changes.

WE Credit 2: Innovative Wastewater Technologies

1 Point

Intent:

Reduce the amount of potable water and wastewater demand while maximizing aquifer recharge.

Cost Implications:

The two options to obtain this point are to treat water on site, or install water conserving fixtures so that total potable water consumption is decreased by 50%. Non potable water fixtures can also be used such as rainwater, recycled greywater, or on-site municipally treated wastewater. The best option here seems to be to use water saving fixtures, but getting the amount of water down by 50% could be challenging. The major amount of water used will be in the retail spaces and it is hard to tell at this juncture who is going to be filling those spaces. As far as the garage is concerned this point would probably work, but if we include retail space, it is probably unattainable.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Any water fixture put into the garage should use non-potable water if possible. The retail spaces could use water saving fixtures, but it may be difficult to get the use of potable water down to a level that is 50%. High efficiency filters, non water using urinals, and recycled greywater would probably all have to be enacted to meet this point.

WE Credit 3.1: Water Use Reduction: 20% Reduction

1 Point

Intent:

The intent of this point is to maximize the water efficiency to reduce the burden on the public water supply.

Cost Implications:

The cost associated with accomplishing this goal would be a multiple part goal. One aspect that would increase initial cost would be the refurbishing of all of the plumbing fixtures to meet the high efficiency standards. Also, there would be a design cost involved in the planning of the systems to ensure they are meeting 20% water use less than the calculated water baseline. The parking garage will have plumbing needs, but the majority of the water usage will come from the retail that is expected in the future. Presently the retail space is not designed, so future modifications will not be as costly.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This point could be met; however our group does not recommend pursuing it since we currently have enough points to meet the basic LEED certification. Also this point is more relevant to the interior finishes so it will be more appropriate to the future finishes for the first floor retail.

WE Credit 3.2: Water Use Reduction: 30% Reduction

1 Point in addition to WE Credit 3.1

Intent:

To maximize water efficiency and reduce the burden on public water supply.

Cost Implications:

Same as WE Credit 3.1 but must be a 30% reduction.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Same as WE Credit 3.1 but must be a 30% reduction.

EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems

Required

Intent:

The intent of this point is to make sure the installation, calibration, and performance of all energy related systems are according to the contractual documents.

Cost Implications:

To accomplish these goals, the owner (the City of Worcester) will have to hire an individual to work on the commissioning process and act as the Commissioning Authority throughout the review of all the activities involved. Since the commissioning processes could take months, this poses as a significant cost especially since the individual responsible for this review must have experience in this area with two previous projects. It could also imply costs applied to contractors and subcontractors having to fix their work according to the contractual documents.

Estimated Labor Cost: $21,500.00

Estimated Material Cost: $0

Estimated Time: Duration of the Project

Recommendations:

There are no recommendations necessary for this point. It is a requirement so it must be completed to the approval of the Commissioner's Authority. We do recommend using the resources from the Green Roundtable, the resource from the Boston area since they will be the most familiar with the Worcester area. We also recommend to the City of Worcester to look into providing benefits and resources for municipal as well as private building projects to enhance the atmosphere of the city.

EA Prerequisite 2: Minimum Energy Performance

Required

Intent:

Establish a minimum level of energy efficiency for the project.

Cost Implications:

ASHRAE needs to be consulted to determine whether the building meets the minimum level of efficiency. The cost here would be the time for the company to research this and then the implementation of any changes that need to be made.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

The review of ASHRAE to determine specifications for HVAC, lighting, and building envelope. We would recommend using the hired LEED Professional to determine whether this is met or not.

EA Prerequisite 3: Fundamental Refrigerant Management

Required

Intent:

The intent of this point is to reduce ozone depletion as a result of refrigerant and HVAC systems in new building construction.

Cost Implications:

This would require the architect and contractor to make sure the new HVAC for a building that uses no CFC refrigerants. This could cost more money in a building that needed an HVAC system; however a garage is open and naturally ventilated. Fans are used when necessary to remove car gas fumes, especially when garages go below ground level.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Since this is required, we suggest applying for this point. This is a point that is reevaluated after the project is over, so even though the garage meets the point now, it will have to be verified in the future that there is still no cooling system. This should not be a problem because economically it would make no sense to cool an open building.

EA Credit 1: Optimize Energy Performance

1–10 Points

Intent:

Improve energy performance above the ASHRAE baseline minimum. For each percentage level above the minimum, another point is given.

Cost Implications:

Increasing energy performance will increase cost but also add long-term value to the project.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

A computer based simulation model should be constructed to assess the best cost effective methods for reducing energy waste in the building. These new levels energy efficiency should be compared with the ASHRAE baseline minimum. This also should be done by the hired LEED Professional.

EA Credit 2: On-Site Renewable Energy

1–3 Points

Intent:

The intent of this point is to promote on site production of renewable energy with the intent of minimizing the effects of burning fossil fuels to the environment.

Cost Implications:

This point requires producing at least 2.5% of the total money spent on energy to come from an onsite renewable resource, such as wind, hydro, thermal, or solar power. The cost implications for such a task could be astronomical. If the city of Worcester could put up a wind turbine or solar panels on the garage, the price would be in the thousands of dollars to purchase, and more money to transport and construct. The options for renewable energy generation in the heart of Worcester are very limited, and not practical for this application.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

The zoning for the city would certainly prohibit the construction of any wind tower, since they can be hundreds of feet tall. Our group does not recommend meeting this point since the money that would have to be spent is truly not worth it. If this was on the ocean, and the wind was always very strong, it would make sense to put up a wind farm, or if it was being built in a wide open rural setting where the sun was very prevalent, then solar would make sense. However, on this small parcel of land in the center of Worcester, investing that kind of money, and paying for the extra construction costs, does not make sense economically.

EA Credit 3: Enhanced Commissioning

1 Point

Intent:

To begin the commissioning process early and involve the commissioning party after the project is complete.

Cost Implications:

This would mean getting a third party involved in a consultants role early in the project and having them stay with the project 10 months into the buildings operation. This would present an additional cost to the project. This person would basically have to be a LEED specialist.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

This would be beneficial to the green building of this project but it would also be a significant cost. The person cannot be related to the contractor at all and may be only hired through the design firm or the owner.

EA Credit 4: Enhanced Refrigerant Management

1 Point

Intent:

The intent of this point is to reduce ozone pollution by minimizing the effects of refrigerants to global warming.

Cost Implications:

This point will cost less if you simply remove the refrigerant, however in most building construction you cannot just get rid of the cooling systems or else the occupants will be uncomfortable. In the case of a parking garage, without a complete outer shell, there are no cooling systems. It is in this case that this point does not change the cost of the project at all.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

The recommendation that the LEED packet gives is to eliminate the use of refrigerant. Since the project is not using it to start with, there are no recommendations to be given.

EA Credit 5: Measurement & Verification

1 Point

Intent:

Provide the ongoing accountability of energy consumption over time.

Cost Implications:

The cost implications here would be the engineering or the energy analysis that would have to accompany the measurement and tracking of the energy consumption of the building, according to the International Performance Measurement & Verification Protocol (IPMVP) Volume III: Concepts and Options for Determining Energy Savings in New Construction, April, 2003.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Equipment would have to be installed in order to monitor the energy use and compare it with projected or baseline energy use.

EA Credit 6: Green Power

1 Point

Intent:

The intent of this point is to promote the use of green power to reduce the effects that burning fossil fuels has on the environment.

Cost Implications:

There is a power company called Shrewsbury Electric and Cable Operations that supplies power to 12,000 Massachusetts residents. The company has an option for customers to purchase green power, which is generated by wind. This is geared more toward residential but can also support commercial, and the calculated premium is 6.67¢/kWh.[25] Since the average price of regular electricity which is 9.46¢/kWh already, this would bring 35% of the energy costs from 9.46¢/kWh to 16.13¢/kWh and add a significant amount of cost to the already pricey parking garage.[26]

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Our team does not recommend meeting this point due to the inconvenience of getting the green power to the site and the dramatic increase of electricity costs. Typically if the project is very close to a level higher of certification, this is an option the owner has of simply spending more money to get another point. So if our final points had come out to a number just below the silver certificate, we would have suggested meeting this, however this is not the case.

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[25] http://www.eere.energy.gov/greenpower/markets/pricing.shtml?page=1

[26] http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html

MR Prerequisite 1: Storage & Collection of Recyclables

Required

Intent:

To reduce the amount of waste from the building that is taken to landfills.

Cost Implications:

There would need to be an area created in the parking garage that is dedicated to the recycling of materials such as paper, corrugated cardboard, glass, plastics, and metals.

Estimated Labor Cost: $0

Estimated Material Cost:

There could be a cost here related to lost space in the parking garage but it is probably reasonable to find a spot where trash cans are to be placed that could also incorporate places for recyclable materials.

Estimated Time: 0

Recommendations:

An area needs to be created to recycle, at a minimum, materials such as paper, corrugated cardboard, glass, plastics, and metals. This area would not have to be big because of the nature of the parking garage, meaning that not a lot of people would have large amounts of waste to dispose of.

MR Credit 1.1: Building Reuse: Maintain 75% of Existing Walls, Floors & Roof

1 Point

Intent:

The intent of this point is to save on resources, reduce waste and the effect on the surrounding environment, maintain cultural resources, and minimize production of new materials, and the costs involved in transporting them.

Cost Implications:

This point saves money on material costs; however, it may increase the costs of design and construction. This is because the architect and engineer must deal with the evaluation of existing structure whereas in new building construction, they will know based on common knowledge what they are dealing with. In terms of the expectations of the contractor, they may not be able to follow the normal steps in the erection of a building because they have to preserve and work around existing material.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

The Union Station Parking Garage did not have the option of using any of the previous structure that stood on this parcel. There was no part that would have been adequate for the load this garage is designed to take. Also the City of Worcester was very particular about the way they wanted this building to look, which is why they spent almost twice as much as similar capacity garages in the area.

MR Credit 1.2: Building Reuse - Maintain 95% of Existing Walls, Floors & Roof

1 Point

Intent:

To re-use as much of the existing structure as possible.

Cost Implications:

This is not possible since the Union Station Parking Garage is new construction.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

N/A

MR Credit 1.3: Building Reuse: Maintain 50% of Interior Non-Structural Elements

1 Point

Intent:

The intent of this point is to reduce the amount of material produced, and also to promote the preservation of interior finishes.

Cost Implications:

Again, the cost would initially be less, since the interior components would be preserved, however there would be new labor costs in refurbishing and cleaning these pieces. The incentive, other than meeting this LEED point, probably lies in receiving a federal grant for historical purposes.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This is another point that the City of Worcester did not even have the option of meeting. The building that was on the site before the garage was a post office, and for the same reasons the exterior of the building could not be reused, the interior also cannot be used. The design of the garage is strictly concrete pre-cast panels designed to carry significant loads from vehicles, and nothing in the previous building was able to do this.

MR Credit 2.1: Construction Waste Management: Divert 50% from Disposal

1 Point

Intent:

To divert construction and demolition debris away from landfills and incinerators and toward recyclable methods.

Cost Implications:

50% of non-hazardous construction and demolition debris must be recycled and/or salvaged. This cost must be evaluated based on how much debris is actually being created and what methods could be used to recycle or re-use.

Estimated Labor Cost: 0

Estimated Material Cost: $5120

Estimated Time: 0

Recommendations:

A construction waste management plan must be created and implemented that identifies the materials that are to be diverted from disposal and whether the materials will be sorted on site or not. The contractor must establish a diversion plan for keeping materials out of landfills. This may include the donation of materials to charitable organizations or the re-use of some materials on site. The cost implied is assumed to be an extra 30 cubic yard container onsite for the recyclable material for 8 weeks.

MR Credit 2.2: Construction Waste Management: Divert 75% from Disposal

1 Point in addition to MR Credit 2.1

Intent:

The intent of this point is to divert construction materials and waste from landfills, and promote recycling reusable materials.

Cost Implications:

The added cost to this point could be very minimal, especially since it is only an increase in 25% recycling rate from the last point. The extra labor cost will be minimal since it is maintenance work, and as long as every time a laborer goes to throw away materials, he or she makes sure it is in the correct dumpster, there should be no extra cost. In terms of materials and shipping, there will be fees for extra dumpsters and trips to empty them at recycling facilities. However, due to the nature of the pre-cast panels, there will be less waste material produced than in something such as wood construction. With the remaining material, the cost of hauling the debris away may be offset by the value of scrap metal. When on a site in Connecticut, the project managers explained that they haul out the scrap metal for free since the scrap is worth money.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Our team recommends meeting this qualification. Currently Gilbane is not diverting 75% of the waste products; however, we have located a recycling facility in North Grafton, Millbury, and Sterling all willing to take brick, concrete, wood, and asphalt. There is also recycling centers right here in Worcester that can take the scrap metal. This is a very reasonable point in the LEED process in which the Green Building Council is trying to prevent landfills from becoming full of construction materials that could easily be reused with a little prevention. On a site where a majority of the building material is pre-cast panels, it would be an attainable goal to divert 75% of construction waste to be recycled.[27]

[27] http://massachusetts.earth911.org/usa/master.asp?s=lib&a=brrc/default.asp

MR Credit 3.1: Materials Reuse: 5%

1 Point

Intent:

To reuse at least 5% of materials in order to decrease waste and decrease the demand for virgin materials on-site.

Cost Implications:

Five percent of the total cost of materials must be reused, refurbished, or recycled materials. This will probably cost a little bit more, but not a significant amount.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Identify opportunities to incorporate recycled materials into the design of the building. Since only 5% of materials must be recycled, it will be crucial to spot where they can most easily be incorporated.

MR Credit 3.2: Materials Reuse: 10%

1 Point in addition to MR Credit 3.1

Intent:

The intent of this point is to reduce the need to use virgin materials by reusing left over materials rather than discarding them.

Cost Implications:

This point promotes using materials already purchased but never used, therefore promoting the use of free materials. Even though there would be no added material cost, there would be some sacrifice by the contractor however. The contractor would have to coordinate buying material in such quantities that there would be no waste, or at least waste that could be reused later. Also, the contractor would have to store this left over material on site most likely, unless they had access to storage somewhere else.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Our group recommends meeting this point. It is not difficult on a site using precast concrete panels to eliminate waste. We recommend looking for salvaged furniture, doors and frames, cabinetry and masonry blocks. Currently the project is too far ahead to meet this point; however, if we could implement our recommendations at the beginning of the project, Gilbane could reuse 10% of the materials. The 10% is to be calculated by cost, so if the materials on the job cost $1,000,000, they would be expected to reuse at least $100,000 worth of materials.

MR Credit 4.1: Recycled Content: 10% (post-consumer + 1/2 pre-consumer)

1 Point

Intent:

Increase demand for building products that incorporate recycled content materials, reducing impacts resulting from production of virgin materials.

Cost Implications:

The cost may be significantly higher for materials that contain both post-consumer and pre-consumer recycled content. Post-consumer recycled content means materials that can no longer be used for their intended purpose. (I.e. ripped jeans may be used as insulation) Pre-consumer recycled content means using materials that are created in the manufacturing process, but are not capable of being reclaimed in the same process that generated it. This could contribute a high cost to the materials of the garage since 10% of the weight of all materials must be post-consumer + half pre-consumer.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Identify opportunities to incorporate recycled materials into the design of the building. This will take a fair amount of research and may mean that some materials will cost more than originally intended. A broad range of different types of materials will have to be considered.

MR Credit 4.2: Recycled Content: 20% (post-consumer + 1/2 pre-consumer)

1 Point in addition to MR Credit 4.1

Intent:

The intent of this point is to promote the use of recycled materials to decrease the need for creating new materials.

Cost Implications:

This is an extension of the last credit, and requires an extra 10% of recycled material to be purchased and used. Concrete is able to be recycled, mostly as crushed rock, but in this case, our site needs the actual concrete to make precast panels. Even though concrete can be crushed and used as the dry aggregate in the concrete mix, it is most often not allowed due to a significant loss in strength at this point. In terms of material costs involved with this site, it is very possible the precast panels will be the majority of the cost.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Due to the lack of strength that is associated with recycled concrete, it seems in the best interest for both the owner and the contractor to avoid this point. It was previously thought that recycled concrete had the same compressive strength. This would mean the contractor only needed to find a distributor that would include enough recycled content in the mix to meet the point without compromising the integrity of the panels. Unless we can be assured that the panels will be acceptable, we do not recommend attempting to meet this point.

MR Credit 5.1: Regional Materials: 10% Extracted, Processed & Manufactured Regionally

1 Point

Intent:

Increase demand for building products that are manufactured within the region that the construction is being completed. This means that the process will rely more on indigenous resources and will reduce pollution created from material transport.

Cost Implications:

The cost for this point varies with how much of the pre-cast concrete is extracted and process and manufactured within 500 miles of Worcester. Although the company is from New Jersey, which is within acceptable limits, the actual product may not come from there.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Use at least 10% (based on cost) of materials that come from local sources. The pre-cast concrete, as well as the cast in place concrete will be the first materials that need to be investigated. Bricks, insulation and interior materials will also be applicable. Interior fixtures are not applicable to this point.

MR Credit 5.2: Regional Materials: 20% Extracted, Processed & Manufactured Regionally

1 Point in addition to MR Credit 5.1

Intent:

The intent of this point is to promote the use of materials extracted, processed, and manufactured regionally, thereby supporting the use of indigenous resources, and minimizing the effects of transportation on the environment.

Cost Implications:

The cost of this will be nothing for the Union Station Parking Garage site. Since the precast panels are coming from New Jersey, which is within 500 miles of the jobsite, the project meets the point. The precast panels are a majority of the components of the whole building and therefore Gilbane shouldn't need any other materials to come from within 500 miles; however it is most likely more materials will.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We do not have to recommend anything since this point has been met the duration of the project. It just happened to be the supplier that was chosen for this project was within the allotted 500 miles. If it were proven that the precast panels were not at least 20% of the materials for some reason, it could be proven that the cast in place concrete came from within 500 miles as well, since it is coming from Aggregate in Massachusetts.

MR Credit 6: Rapidly Renewable Materials

1 Point

Intent:

Reduce the use of finite raw materials and long-term renewing materials in favor of more rapidly renewing materials.

Cost Implications:

2.5% of all materials (by cost) must be harvested in a process that is completely renewable in 10 years. This means that there will be a slightly higher cost of seeking out and replacing such materials. It will also have to be considered is the maintenance of these materials having a higher cost then less renewable resources.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Consider rapidly renewable materials such as bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard and cork for use in the construction of Union Station. In order to find an exact cost, the material necessary would have to be determined. This could only be done when the city finds tenants for the retail areas.

MR Credit 7: Certified Wood

1 Point

Intent:

The intent of this point is to encourage safe and environmentally friendly forestry management practices.

Cost Implications:

Certified wood is proven to be up to 15% more expensive than normal wood. On a large project built mainly of wood construction, this would imply a huge price increase. From a contractor's point of view it is also more inconvenient to have to actively seek out this unusual wood and any paperwork that might come with it. Another difficulty lies in the fact that there are many organizations who can sign off on acceptable forest management, so the contractor would have to make sure with the LEED AP that the source was in fact acceptable.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Our team recommends meeting the minimum 50% certified wood for the project. Since the materials used for this project are mostly precast concrete for the core, and masonry and steel studs for the interior, wood is a minimal cost and should not affect the price of the project in any serious manner. This minor sacrifice by the City of Worcester would be worth meeting one extra point. Since most Home Depots are even carrying certified wood now, it shouldn't be that arduous of a task to get this wood from any major distributor.

EQ Prerequisite 1: Minimum IAQ Performance

Required

Intent:

Establish minimum Indoor Air Quality (IAQ) performance standards to improve air quality and contribute to the well-being of occupants.

Cost Implications:

Since this is a naturally ventilated building, it needs to comply with ASHRAE 62.1-2004, paragraph 5.1. This hopefully will not present an extra cost as the building is open to the air in lots of places and is extremely well ventilated.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Review the section of ASHRAE to ensure that these standards are met. This can be done by the engineer that we hired for the duration of the project to oversee these tasks.

EQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Required

Intent:

The intent of this point is to minimize the occupants' exposure to tobacco smoke as well as the contents of the building.

Cost Implications:

This point directly does not increase costs in the case of a parking garage. If this were an office building, there would be no smoking allowed in it, so they might have to designate an area for smoking. In the case of a parking garage, there is constant natural ventilation so having smoke linger in the air for extended periods of time is unlikely, especially since the parking garage does not go underground. In this case, to prevent people from smoking in or around this garage, signs would be necessary, and some sort of enforcement would have to be arranged.

Estimated Labor Cost: $62.00

Estimated Material Cost: $94.80

Estimated Time: 4.8 Hours

Total Cost including O & P: $200.00

Recommendations:

The point behind creating an area for smokers is because these people are occupying a building for the entire workday, whereas in a parking garage people park their cars and leave for extended periods of time. It is in this sense that smoking in the garage should not be a serious threat. We recommend posting 6 signs per floor in the most visible areas to defer people from smoking inside. With the natural ventilation, tobacco smoke should not be a problem. This is also a requirement, so the site must meet this point in order to be LEED certified.

EQ Credit 1: Outdoor Air Delivery Monitoring

1 Point

Intent:

Provide ventilation system monitoring for occupant safety and well-being.

Cost Implications:

The cost for this point could be very high since the building is both naturally and mechanically ventilated, meaning solutions for outdoor air delivery monitoring would not be cost effective.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Carbon dioxide and airflow measurements would have to be fed to the HVAC system and or the building automation system to be corrected. Alarms would have to alert system managers and building occupants if the air quality deviated more than 10% from the set level. We do not recommend that Union Station meet this point at this time.

EQ Credit 2: Increased Ventilation

1 Point

Intent:

The intent of this point is to provide more outdoor air so the occupants are not breathing stale air.

Cost Implications:

In a building with an outer shell this would cost more money in the ventilation systems. Since a parking garage is naturally ventilated there is a different set of requirements. Independent sets of tests must be performed to verify that these natural ventilation systems meet the recommendations set forth in the CIBSE Applications Manual 10: 2005 for naturally ventilated buildings. To meet this requirement it would require hiring a professional to follow a carefully laid out procedure to ensure this is being met.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:
We do not recommend meeting this point since the project is currently certified and this would be a very unlikely outcome for the parking garage. Due to the nature of having cars parked in it all day, and no source of cleaning the spots, it is likely there will be unacceptable levels of carbons in the air. Also, this point is intended to increase the mental health, alertness, and productivity of the occupants, and since people are not in parking garages for any extended period of time, this goal would be useless.

EQ Credit 3.1: Construction IAQ Management Plan: During Construction

1 Point

Intent:

Reduce Indoor Air Quality (IAQ) problems resulting from the construction/renovation process for the well being of occupants and construction workers.

Cost Implications:

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

Develop and implement and IAQ management plans to control pollutants and interrupt contamination pathways. The installation of absorptive materials should be sequenced so that they do not come in contact with contaminative substances.

EQ Credit 3.2: Construction IAQ Management Plan: Before Occupancy

1 Point

Intent:

The intent of this point is to reduce the effect that the construction process has on the air quality before occupancy.

Cost Implications:

There are multiple ways to ensure this point is met. The first way to meet this would be to completely flush out the majority of the air in the building before occupancy. The second way is to perform a test on the air quality in the building to prove that it is safe as it is. When the tests are completed according to the procedure laid out in the LEED requirements, there must be acceptable levels of 5 different contaminants. The cost associated with flushing the air out simply requires the bringing in of some commercial size fans and running them for a couple days. This cost is minimal, however, the cost for performing the test are most likely in the hundreds of dollars.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

We recommend meeting this point since we feel that it will be fairly easy to get any contaminated air out of the building with relative ease. If the contractor uses low emitting materials, this task will even be easier, and the harmful contaminants will be less likely to reappear after the flush out. It is likely Gilbane has fans already on the site. This is another point that helps the project become LEED certified, and comes with minimal effort by the contractor.

EQ Credit 4.1: Low-Emitting Materials: Adhesives & Sealants

1 Point

Intent:

Reduce the quantity of indoor air contaminants that are odorous, irritating, and/or harmful to the comfort and well-being of installers and occupants.

Cost Implications:

Most low-emitting adhesives and sealants can be purchased for a reasonable price so this point would be cost-effective.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Specify VOC limits and makes sure they are clearly defined in the plans of the building. Make clear to all sub-contractors the VOC limits on adhesives and sealants. This is another area that the hired engineer would have to oversee throughout the project.

EQ Credit 4.2: Low-Emitting Materials: Paints & Coatings

1 Point

Intent:

The intent of this point is to reduce the indoor contaminants that are odorous, irritating, and/or harmful to the comfort and health of the occupants.

Cost Implications:

In the past, these low VOC paints and coatings were unusual, since there was no concern about the health risks involved with these airborne contaminants. However, since the LEED system and sustainable development has increased in popularity, these low VOC products are now becoming relatively available and affordable to the public. Right now they are slightly more expensive than the harmful paints, but it is a reasonable price difference.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We provided a list of acceptable low emitting paints as a reference at the bottom of this page.[28] We recommend using these paints for the interior to better the quality of air and meet this LEED point. Not only does this point help the health of the occupants of the building, but it also immediately improves the environment by preventing these harmful contaminants to become airborne. The more the LEED process pushes contractors in this direction, the better off our environment will be, which in essence is what the USGBC is headed to do.

[28] http://www.chps.net/manual/lem_table.htm#paint

EQ Credit 4.3: Low-Emitting Materials: Carpet Systems

1 Point

Intent:

Reduce the quantity of indoor air contaminants that are odorous, irritating, and/or harmful to the comfort and well-being of installers and occupants.

Cost Implications:

There is no carpet in the Union Station Parking Garage.

Estimated Labor Cost: N/A

Estimated Material Cost: N/A

Estimated Time: N/A

Recommendations:

None

EQ Credit 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products

1 Point

Intent:

The intent of this point is to reduce the indoor contaminants that are odorous, irritating, and/or harmful to the comfort and health of the occupants.

Cost Implications:

Similar to the low VOC paints, these low emitting wood products were once uncommon to find, especially to a low bidding contractor. As green building becomes more and more popular, these products are becoming more mainstream and readily available to these contractors. The cost will be higher for these products. Unlike the low emitting paints, it does not seem that these products can be found at Home Depot, so the contractor will have to look for acceptable composite woods that are within 500 miles.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

We would recommend meeting this requirement if the building contained more wood, such as cabinetry or benches, however this is not the case. We do not feel we can meet this point since there really is no basis to claim we have low emitting wood.

EQ Credit 5: Indoor Chemical & Pollutant Source Control

1 Point

Intent:

Minimize the exposure of building occupants to potentially hazardous particulates and chemical pollutants.

Cost Implications:

This could be a huge cost to the building, especially since so many people will come and go from the garage. A system that will clean and maintain could be very costly.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

Design cleaning and maintenance areas with isolated exhaust systems for contaminants. These areas should be physically isolated from the rest of the building to avoid cross contamination. Permanent architectural entryway systems with grates should be installed to eliminate occupant-borne contaminants. High level air filtration systems should also be installed in air handling units to catch any air pollution. This would be a lot for Union Station to install and would probably not be a cost-effective point. We do not recommend pursuing this point at this time.

EQ Credit 6.1: Controllability of Systems: Lighting

1 Point

Intent:

The intent of this point is to provide individual controls for the lighting in a building for all of the occupants to be comfortable, productive, and happy.

Cost Implications:

This would require more switches to be installed in an office building to make sure everyone could have their own personal light on when they were in their office. This is not a significant cost, especially because the building will use less electricity whenever anyone is not in their office, in essence, saving money. However, this is a parking garage, and this point is not relevant since the lights stay on nearly all the time.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This point is not possible for a parking garage. There are no individual areas that can have their own separate lighting switches to promote comfort and electricity conservation. In a parking garage, there are bright lights to ensure safety of the people in the garage, and to protect cars from being stolen. It is for this reason; the lights remain on all the time, in and around the building. In an office building, people have offices and having their own controls in each office makes complete sense for comfort, increased productivity, and personal well being. This is one good example of the differences in the LEED certification of a building versus the LEED certification of a parking garage.

EQ Credit 6.2: Controllability of Systems: Thermal Comfort

1 Point

Intent:

Provide a high level thermal comfort system to be controlled by different individuals throughout the building to maximize comfort and productivity.

Cost Implications:

N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

A thermal comfort system would have to be installed in the building that different people could regulate and maintain for their own area of the building. This would not be possible since there are really no different areas of the Union Station Parking Garage. We do not recommend pursuing this point.

EQ Credit 7.1: Thermal Comfort: Design

1 Point

Intent:

The intent of this point is to provide a comfortable thermal environment in a building that promotes the productivity and well being of the occupants.

Cost Implications:

In a building, this point would cost an engineer's time to do a study and verify that the thermal controls and systems are designed to meet the requirements of ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy. Chances are this would not be a significant extra since the building would most likely have been designed to meet such standards. However this is another point that is based on the fact that a building would have occupants, which a parking garage does not.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

If this was a building we would certainly recommend applying for this point since it is an important point, yet fairly easy to meet. We do not have this option however, since technically parking garages do not have occupants. This is going to be difficult for any points that base their results on this number, and hopefully in the future, the USGBC will adopt a system that will be just for parking garages. Right now, the new building design is for enclosed buildings that people work in for extended periods of time, not an open place where someone parks their car and leaves within minutes.

EQ Credit 7.2: Thermal Comfort: Verification

1 Point

Intent:

Monitor the thermal comfort of the building over time.

Cost Implications:

N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This point requires maintaining the thermal comfort system, which is really not possible or practical in the scenario of Union Station Parking Garage. Since we recommend that no system be installed, we do not recommend the long term verification of one.

EQ Credit 8.1: Daylight & Views: Daylight 75% of Spaces

1 Point

Intent:

The intent of this point is to connect the occupants of a building to the outdoors through the use of natural light and views into the regularly occupied areas of the building.

Cost Implications:

This is a point that must be planned and designed for before the construction or even the bidding process begins. A good example of how this point could be met would be a long narrow building that is located in a rural setting. If the corridor rand down the middle, and the offices were along the windows, it would encourage a maximum amount of natural daylight and provide a view. The implications in regards to cost could be higher real estate prices and a fee for specialty design by the architect. The contractor would know about these unusual arrangements before bidding so no extra costs would be incurred later.

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

This garage is located in the center of Worcester, and does not have any impressive views. Much of the parking garage is going to let in natural lighting, and there are no windows. However, this building was not designed to meet this point, and by not having any windows, it is not meant to pass the point. So, for now we will recommend looking into whether or not this point is met, but for now, since we are not even relying on it, we will not count it.

EQ Credit 8.2: Daylight & Views: Views for 90% of Spaces

1 Point

Intent:

Connect the occupants of the building to the outdoors by providing daylight and views into regularly occupied areas of the building.

Cost Implications:

N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: $0

Recommendations:

There would have to be daylight views between 2'6 and 7'6 for 90% of areas in the parking garage. This is probably not going to happen just because of the nature of the building.

ID Credit 2: LEED Accredited Professional

1 Point

Intent:

At least one member of the team shall be a LEED Accredited Professional (AP).

Cost Implications:

N/A

Estimated Labor Cost: $0

Estimated Material Cost: $0

Estimated Time: 0

Recommendations:

The LEED AP can guide the rest of the project team through the process of becoming LEED certified. The AP will be able to identify plans and practices that can be used in the facilitation of green building.

Appendix C: Green Roof Spreadsheets

Slab Thickness (L/31.5)

L (10' span)	120
Thickness (inches)	4

L (12' span)	**144**
Thickness (inches)	**5**

L (15' span)	180
Thickness (inches)	6

Roof Beams

Dead Loads (psf)	decking	concrete	roof material	suspended services	total (psf)	total (plf)
	2.00	60.42	50.00	5.00	117.42	1409.00

Live Loads (psf)	Snow	total (psf)	total (plf)
	35.00	35.00	420.00

Tributary Width (ft)	12.00

Load Combinations (plf)	1.4D	0.00
	1.2D+1.6L	**2362.80**

Member Length (ft)	60.00

Design Moment (ft-k) (M_u=W_u*L^2)	**1063.26**

Yield Strength (F_y) (ksi)	50.00

Req'd Z_x (in^3) (M_u*12)/(.9*F_y)	**283.54**

Trial Member Size	Z_x (in^3)	$b_f/2t_f \leq 9.2$	$h/t_w \leq 90.5$
W24x105	**289.00**	**8.50**	**43.10**

Check

(ΦM_p= (.9*Z_x*F_y)> M_u	**1083.75**
	OK!
$b_f/2t_f \leq 9.2$	OK!
$h/t_w \leq 90.5$	OK!

Beam Deflection Checks

Live Loads	
$\Delta_{max}=(wL^4)/(384EI)$	
w_{LL} (lb/in)	35
L (in)	720
E (psi)	29000000
I (in^4)	3100
Δ_{max}	0.27

Dead Loads	
$\Delta_{max}=(wL^4)/(384EI)$	
w_{DL} (lb/in)	117.42
L (in)	720
E (psi)	29000000
I (in^4)	3100
Δ_{max}	0.91

Allowable Deflection	
L (in)	720
$\Delta_{allowable}$=L/360 (inches)	2
Δ_{LL}	OK!
Δ_{DL}	OK!

Roof Girders (inside)

Dead Loads (psf)	decking	concrete	roof material	suspended services	total (psf)	total (plf)
	2.00	54.38	50.00	5.00	111.38	6767.30

Live Loads (psf)	Snow	total (psf)	total (plf)
	35.00	35.00	2100.00

Beam weight (plf)	106.00

Effect of Adjacent beams on girders	84.80

Tributary Width (ft)	60.00

Load Combinations (plf)	1.4D	9474.22
	1.2D+1.6L	**11480.76**

Member Length (ft)	48.00

Design Moment (ft-k) (M_u=W_u*L^2)	**2204.31**

Yield Strength (F_y) (ksi)	50.00

Req'd Z_x (in^3) (M_u*12)/(.9*F_y)	**587.81**

Trial Member Size W36x160	Z_x (in^3)	$b_f/2t_f \leq 9.2$	$h/t_w \leq 90.5$
	624.00	**4.14**	**24.80**

Check	
(ΦM_p= (.9*Z_x*F_y)> M_u	**2340.00**
	OK!
$b_f/2t_f \leq 9.2$	OK!
$h/t_w \leq 90.5$	OK!

Roof Girders (outside)

Dead Loads (psf)	decking	concrete	roof material	suspended services	total (psf)	total (plf)
	2.00	54.38	50.00	5.00	111.38	3510.85

Live Loads (psf)	Snow	total (psf)	total (plf)
	35.00	35.00	1050.00

Beam weight (plf)	106.00

Effect of Adjacent beams	169.60

Tributary Width (ft)	30.00

Load Combinations (plf)	1.4D	4915.19
	1.2D+1.6L	**5893.02**

Member Length (ft)	48.00

Design Moment (ft-k) (M_u=W_u*L^2)	**1131.46**

Yield Strength (F_y) (ksi)	50.00

Req'd Z_x (in^3) (M_u*12)/(.9*F_y)	**301.72**

Trial Member Size	Zx (in^3)	$b_f/2t_f \leq 9.2$	$h/t_w \leq 90.5$
W21x122	**307.00**	**6.45**	**31.30**

Check	
(ΦM_p= (.9*Z_x*F_y)> M_u	**1151.25**
	OK!
$b_f/2t_f \leq 9.2$	OK!
$h/t_w \leq 90.5$	OK!

Roof Columns

Dead Loads	decking	concrete	roof material	suspended services	total (psf)	W24x104 beam (plf)	W24x207 girder (plf)	total (kips)
	2.00	54.38	50.00	5.00	111.38	12.48	9.94	343.18

Snow Loads	Snow	total (psf)	total (kips)
	35.00	35.00	100.80

Wind Loads $q_{30}=.0027(v_{30}^2)$	wind(psf)	total (kips)
	17.28	4.79

LOAD	1.2D+1.6S+.8W	576.92

TRIBUTARY AREA (ft^2)	2880
TRIBUTARY WIDTH (ft,y)	60
TRIBUTARY WIDTH (ft,x)	48
LENGTH (ft)	10.67

GROSS AREA CALCULATIONS	
$A_g \geq (w_u)/(\Phi_c F_{cr})$	
r_y	2
L/r	64
E	29000
$F_e=(\pi^2 * E)/(L/r)^2$	69.88
F_y (ksi)	50
F_y/F_e	0.72
$F_{cr}=(.658)^{Fy/Fe} * F_y$	37.06
$A_g \geq (w_u)/(\Phi_c F_{cr})$ (in^2)	17.30

SECTION TRAITS	Area	r_x	r_y	r_y/r_x
W12x58	**17.0**	**5.28**	**2.51**	**0.48**
W10x68	20.0	4.44	2.59	0.58
W14x61	17.9	5.98	2.45	0.41

CHECKING	
L/r_y	51.00
$F_e=(\pi^2 * E)/(L/r)^3$	110.06
F_y/F_e	0.45
$F_{cr}=(.658)^{Fy/Fe} * F_y$	41.34

CAPACITY OF	
W10x60	
$\Phi * A_g * F_{cr}$	632.53
Capacity>w_u	OK!

Baseplate

Req'd Area	
$A_{req'd}=(P_u/\Phi_c)(.85f'_c)\sqrt{(A_2/A_1)}$	
P_u (kips)	576.92
Φ_c	0.6
$.85f'_c$	2.55
$\sqrt{(A_2/A_1)}$ (assumed)	2
$A_{req'd}$ (A_1)	188.54
$\sqrt{A_{req'd}}$	13.73
A_2	196
CHECK $\sqrt{(A_2/A_1)}<2$	1.02
	OK!

Baseplate Dimensions	
W10 x60	
d	10.2
b_f	10.1
A	17.6
F_y	50
$\Delta=(.95d-.8b_f)/2$	0.805
$N=\sqrt{A_1}+\Delta$	14.54
Whole Number N	15
$B=A_1/N$	12.57
Whole Number B	13
$n=(B-.8b_f)/2$	2.46
$m=(N-.95d)/2$	2.66
CHECK	
$\Phi_cP_p=.6(.85f'_c)A_1(\sqrt{(A_2/A_1)})>592.39$	596.7
	OK!

Baseplate Thickness	
$x=(4d*b_f)/((d+b_f)^2)$	1.00
$\lambda=(2*\sqrt{(x)})/(1+\sqrt{(1-x)})$	1.99
USE	1.0
$\lambda n'=\lambda\sqrt{(d*b_f)}/4$	2.54
$t_{req'd}=l\sqrt{((2*p_u)/.9F_y*B*N)}$	0.99

BASEPLATE
1"x1'1"x1'3"

Beam to Girder

Beam	
w_u (plf)	2362.8
L (ft)	60
V_u=(w_u*L)/2 (kips)	70.88
h/t_w	27.2
$\sqrt{(E/F_y)}$	58.99
d (inches)	18.34
t_w (inches)	0.56
ΦV=.9*50*d*t_w (kips)	462.17
	OK!

Girder	
wu (plf)	11480.76
L (ft)	48
V_u=(w_u*L)/2 (lb)	275.54
h/t_w	24.8
$\sqrt{(E/F_y)}$	58.99
d (inches)	25.7
t_w (inches)	0.87
ΦV=.9*50*d*t_w (kips)	1006.16
	OK!

Angles	
V_u	70.88
F_n	48
d_b	1/2
A_b	0.196
$\Phi R_n=F_n*A_b$	7.07
V_u/R_n	10.03
# Bolts	10
Spacing	1 1/2
Edge	3/4
Length (inches)	7.5
Width	3
USE 3x3x7.5 long angles	

For Strength (thickness)	
$t_1 = \Phi F_u t_1 L \leq V_u$	**0.301**
$t_2 = \Phi(F_y*A_{nv})$	0.263
$t_3 = \Phi(F_y*A_{gv})$	0.164
USE	**0.25**

Weld	
Inside Girder	W36x160
d	36
t_f	1.02
b_f	12
Beam	W24x104
d	24.1
t_f	0.75
b_f	12.8

Moment	
$(wL^2)/12$	
w	2362.8
L	48
	453.7
C=T=M/(d-t_f)	155.6
Weld Area Req'd= (C or T)/(ΦF_y)	3.5
Weld width Req'd= (Weld Area Req'd)/t_f	3.4

Girder to Column

Girder	
w_u (plf)	11480.76
L (ft)	48
V_u=(w_u*L)/2 (lb)	275.54
h/t_w	24.8
?(E/F_y)	58.99
d (inches)	25.7
t_w (inches)	0.87
? V=.9*50*d*t_w (kips)	1006.16
	OK!

Angles	
V_u	275.54
F_n	48
d_b	1
A_b	0.79
? R_n=F_n*A_b	28.26
V_u/R_n	9.75
# Bolts	10
Spacing	3
Edge	1 3/4
Length (inches)	15 1/2
Width	6 1/2
USE 6.5x6.5x15.5 long angles	

For Strength (thickness)	
t_1 = ? $F_u t_1$L? V_u	1.17
t_2 = ? (F_y*A_{nv})	1.02
t_3 = ? (F_y*A_{gv})	0.64
USE	**0.75**

Weld	
Inside Girder	W36x160
d	36
t_f	1.02
b_f	12
Column	W12x58
d	12.2
t_f	0.64
b_f	10

Moment	
$(wL^2)/12$	
w	11480.8
L	48
	2204.3
C=T=M/(d-t_f)	756.2
Weld A Req'd= (C or T)/(? F_y)	16.8
Weld width Req'd= (Weld Area Req'd)/t_f	16.5

Member Costs
Trial 1 (10' beam spacing)

	Size	Quantity	Total Length (ft)	Total Tonnage	Labor hours	Cost/ft	Total Hours	Total Cost
Outside Girders	W21x122	17	464.81	28.35	0.08	$85.00	6.8	39,508.85
Inside Girders	W36x160	9	227.00	18.16	0.069	$108.50	7.5	24,629.50
Beams	**W18x106**	**46**	**2,783.87**	**147.55**	**0.089**	**$75.00**	**6.7**	**208,790.25**
Columns	W12x58	17	181.39	5.26	0.075	$45.00	3.4	8,162.55
Totals							24.3	281,091.15
Greenroof Material	125x250		31,250.00			$8-20/sf		250,000.00
							Total Roof Cost	$531,091.15

Appendix D: Structural Proposal

Union Station Parking Garage

Structural Proposal for Retrofit Green Roof

Project Objective

The objective of this project is to improve the sustainability and the environmental compatibility of the Union Station Parking Garage through a plan that involves improving the existing design to comply with more LEED standards and integrating a green roof into the project. The addition of a green roof will reduce storm water runoff, reduce the urban heat island effect (i.e., reducing temperature differences between urban and rural areas), increase the aesthetic appeal of the garage, and visually promote sustainable building practices in Worcester.

Structural Objective

A subsection of this project is to design a structure that will add another story to the existing parking garage, allowing a green roof to be constructed.

Background

The addition of a green roof to a building is a particularly effective method of achieving multiple LEED points; yielding up to six points on the LEED checklist. A green roof addresses such LEED points as the reduction of the urban heat island effect, storm water mitigation, restoration of natural habitat, and maximization of open space, as well as several social benefits such as increased aesthetic value and acting as a visual symbol of a building's commitment to environmental sustainability. Because a green roof addresses multiple LEED points and enhances an area aesthetically, it is an advantageous way to increase a building's environmental sustainability.

Currently, the City of Worcester is not employing green construction and design practices with the Union Station Parking Garage. This means that any green building standards will have to be applied in a retrofit fashion, including the green roof and its supporting structure. Construction of the Union Station parking garage will be completed by December 2007. The green roof structure would potentially be installed a few months after the completion of the garage.

The Union Station Parking Garage is a roofless garage, meaning that the uppermost deck has no overhead covering. For a green roof to be added to the existing design configuration, a frame structure must first be designed to surmount the existing open deck, allowing vehicles to maneuver underneath. The structure will be designed with a minimal number of strategically placed columns so that vehicle travel will be uninterrupted. Adequate clearance between the upper deck and the green roof will be determined using the deck-to-ceiling distance of the lower levels.

Structural Design

The structural design will focus on the balance between weight of the roof structure and its ability to resist all possible loadings, i.e., weight vs. strength. Weight is a paramount aspect to consider, not only for cost (discussed in the subsequent Cost/Benefit section), but for the integrity of the underlying parking garage. If the weight of the added green roof structure exceeds the limits for the parking garage, supplementary design measures may need to be taken, such as redesign of the green roof structure or reinforcement of the parking garage. The goal however is to design a roof structure that, when installed, will be light enough to not exceed the garage's structural limits, but strong enough to resist all applied loadings.

Since the integrity of the underlying garage is important, a structural analysis of the underlying garage will be performed to ensure that it can hold the retrofit roof. To do this, a trial version of the green roof structure will be designed. For simplicity's sake, the trial structure will be designed as a steel structure (then redesigned later with other possible materials). The weight of this structure will then be applied to the top of the garage as an additional load. The underlying garage will then be analyzed to ensure that this added weight will not impede the garage's structural integrity. As stated above: if the added weight of the green roof structure exceeds the limits of the garage, structural reinforcements for the garage will be designed.

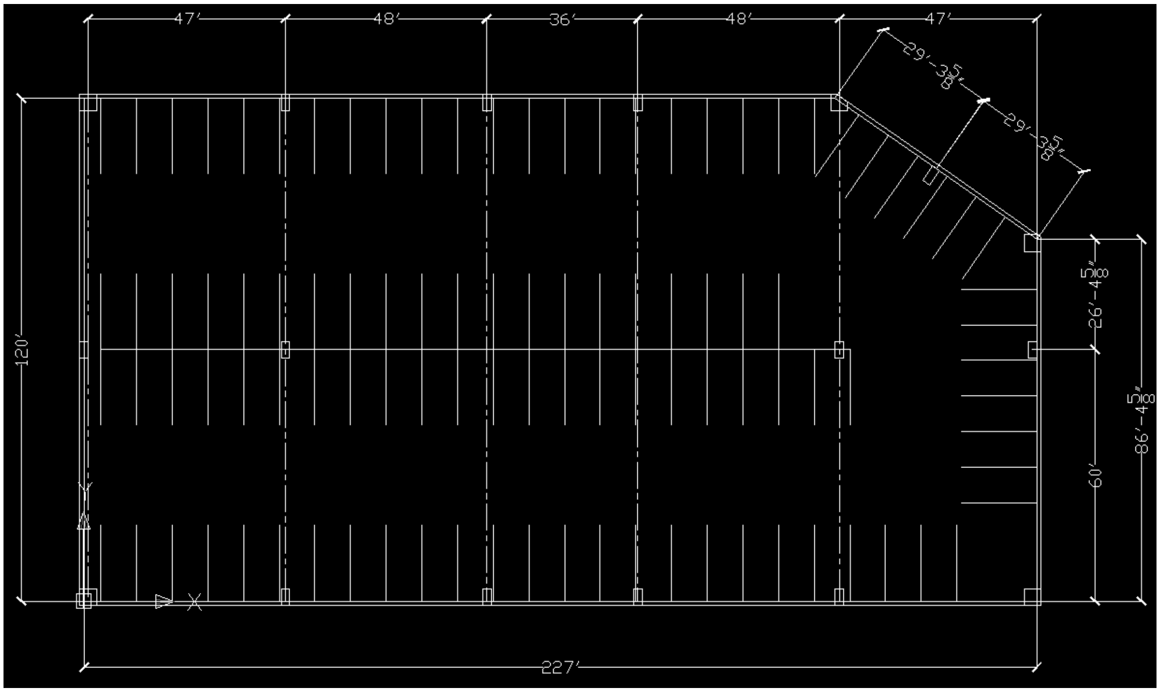
To begin the design process, the team will determine what dead and live loadings the retrofit roof will be subject to (see step 1 of the design process below). Then, the possible locations of columns will be assessed; columns for the roof structure will initially be placed directly over columns in the underlying garage, allowing loads from the roof structure to travel directly to the foundation of the garage without creating unnecessary moments in the garage's beams. This also eliminates the possibility of columns interfering with vehicular traffic. The locations of these columns will then define the span of each girder and beam. Once the loadings and layout have been determined, a preliminary steel design including columns, girders, beams, and slab can be created using hand calculations and up-to-date software, most likely RISA 3D, which can perform comprehensive analysis of the entire frame structure. It will also be possible to rapidly redesign member properties, materials, and locations if necessary. The design of the structure will adhere to the Massachusetts State Building Codes, AISC standards, and current best practices of green roof construction.

Cost/Benefit Analysis

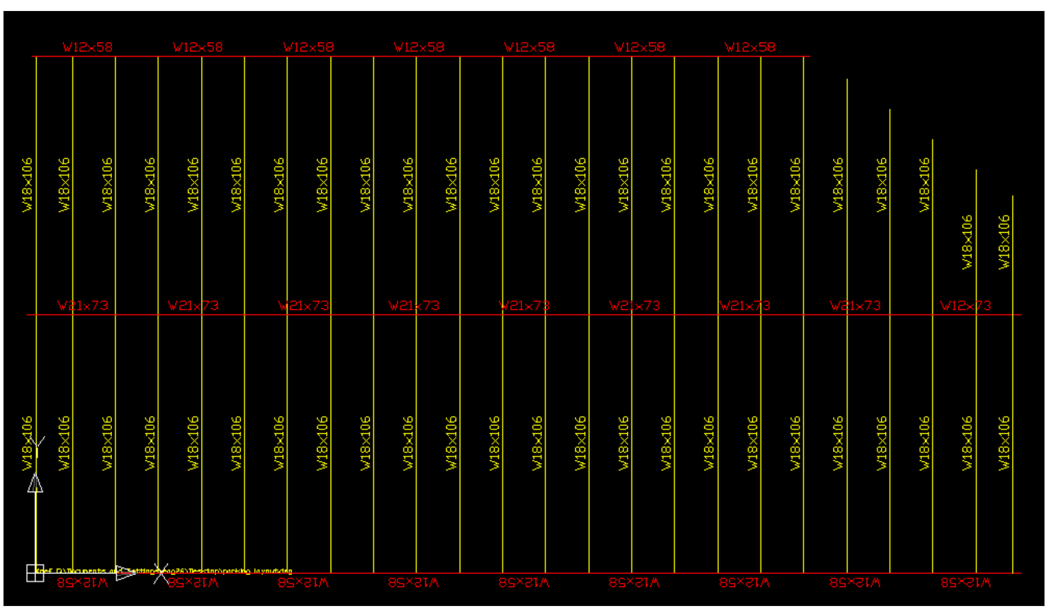
The construction feasibility of a green roof and support structure is based on the premise that the benefits will outweigh the cost. The benefits are environmental, social, and aesthetic. Environmental benefits include reduction of the urban heat island effect, storm water mitigation, and restoration of natural habitat. These environmental benefits culminate in a possible LEED certification, which then adds to such social benefits as increased environmental consciousness and increasing Worcester's commitment to sustainable building, making Worcester a more desirable city. Finally, aesthetic benefits include the maximization of open space and beautification of a once industrialized area.

The cost of the green roof and support structure will be based on materials, which will be dictated by the design, as well as labor and equipment costs. Some redesign of the structure may be necessary if the construction cost of one particular type of material is too high. For example, it may cost less to purchase steel columns than the raw cost of cast in place concrete columns, but the cost of erecting the steel with a crane may be more expensive than pouring the concrete, or vice versa. The cost of the structure and its installation will be based on R.S. Means construction averages.

Existing Upper Deck Scheme



Tentative Girder and Beam Placement



Tentative Design Process

10. Determine design material
    a. In the interest of economics and weight, the preliminary design will be steel
11. Determine loadings (given in plans)
    a. Dead
        i. Beams
        ii. Slab
        iii. Green roof material
    b. Live
        i. Snow/rain/wind
        ii. Roof Live Load
12. Determine column grid and beam and girder spans
    a. Using existing top deck plan
    b. Consider parking space layout
13. Design green roof components (all members and green roof material)
14. Determine weight of structure
15. Analyze parking garage to ensure structural integrity
    a. If added weight exceeds garage and foundation limits, then:
        i. Redesign green roof structure, or
        ii. Design reinforcements for parking garage
    b. If added weight does not exceed garage limits, proceed with design
16. Analyze preliminary design
    a. Use structural software for entire structure
        i. Demo version of RISA 3D is available
    b. Check by hand calculation
17. Redesign members and connections
18. Determine weight of green roof
19. Review capacity of existing structure
    a. Check to make sure the existing garage will be able to withstand the green roof weight
20. Determine total cost of green roof

Note: The term green roof refers to the vegetated roof and the structure that supports the vegetation

Appendix E: Lunch and LEED

Summary from Lunch and LEED information seminar:

Lunch and LEED

12/3/2007

The four of us attended the Lunch and LEED question and answer session in Boston on Monday. The hour was very beneficial and we were able to clear up many of our questions about the project. For the first half, the LEED representative explained how the rating system works, and announced any recent updates. She also told us how much it could cost to certify a building. The prices are different based on the size of the project and whether or not the applicant is a member of the USGBC. There are many steps involved to certify a building, and all of these steps require paperwork and money. She told us about a book that we can purchase for $200 that is a reference guide and contains explanations of each point, and even past cases of whether or not a situation met points or not. We are going to look into if the school has a copy of that, or if we could receive funding to purchase one.

For the rest of the session, she answered questions from anyone who had them, so we asked many about our project. She confirmed that parking garages can be LEED certified, but admitted it would be difficult, and she had only heard of one example ever being done. She explained that there are incentives for private projects, like Paul Moosey said, and she also said that state buildings have to be LEED certifiable in many big cities. This is raising the bar, and taking away the "bragging rights" for any companies that voluntarily became certified in the past.

This was a great seminar, and we were even able to look around the Green Roundtable and write down the names of some books we are going to request from the library.

Appendix F: Interview with Paul Moosey

Worcester's Position on LEED Certification - 10/17/2007

Paul Moosey, the Assistant Commissioner of Engineering and Architectural Services for Worcester was interviewed and explained the city's involvement and stance on LEED Certification. The officials in Worcester are aware that Green Building has significant benefits to the environment, however there are no financial incentives set up for municipal projects. Right now there is a high school being built by the city that is following green guidelines; however city advisors came to the conclusion that paying for the LEED Certification title would not be profitable. Despite not having the LEED certification, the school is eligible for federal grants by taking such guidelines into account during design, construction, and use. Moosey says there are benefits set up for private owners on the federal level for LEED certified buildings, however since it doesn't help city owned buildings, the city of Worcester currently does not own any. Worcester currently does not have any regulations for buildings to be environmentally friendly, however there are guidelines set up to make sure that it is taken into account.
The site of the Union Station Parking Garage was formerly a Postal Building, located next to the tracks for easy access to process mail. It was not previously a brown field, and the excess soil was disposed of in a landfill.

Appendix G: LEED Point Cost

LEED POINT	SS Prerequisite 1										
					BARE COSTS						
R.S. Means Ref #	Construction Activity	Crew	Daily Output (L F)	Labor Hours	Material	Labor	Equip.	Total	Total w/ O&P	Units Needed	Price
02300-550-1100	Erosion Control, Silt Fence, polypropylene, 3' High, Adverse Conditions	2 Laborers	950	0.017	0.3	0.38	0	0.68	0.93	900	$ 837.00
02300-550-1200	Hay bales	A-2	2500	0.01	2.04	0.22	0.06	2.32	2.65	200	$ 530.00
				Material	$ 678						
	A-2 Crew 2 Laborers 1 Truck Driver (Light) 1 Light Truck, 1.5 Ton			Labor	$ 386						
				Time (hours)	17.30						
										Total Cost incl O&P	$ 1,367.00

[redacted]

[redacted]

[redacted]

[redacted]