Promoting the Use of Green Roofs on Street-Level Surfaces to Improve Public Awareness about Stormwater Management in Boston

An Interdisciplinary Qualifying Project Report by:
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Sponsor: U.S. Environmental Protection Agency, Region 1, Assistance and Pollution Prevention Office

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Due to the government shutdown of October 2013, our sponsor at the Environmental Protection Agency, Region 1, was unable to review this report before it was submitted for academic credit. Any errors are those of the authors.

Abstract

Stormwater runoff is a problem in the City of Boston due to the urbanization of the area. The goal of our project was to determine the technical and financial feasibility of installing green roofs on street-level surfaces in the City of Boston with the purpose of raising public awareness and encouraging a change in the public’s behavior with respect to stormwater runoff. We conducted interviews with representatives from similar projects in other cities and performed an observational study to determine the possibility of installing green roofs on bus stops for the purpose of raising public awareness. Our research led to a set of recommendations involving the technical, financial, informational, and visual aspects for the design of street-level green roofs on bus stops.

Acknowledgements

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Executive Summary

As cities develop and urbanize, they provide people with added benefits such as employment opportunities, rich cultural exchanges, lively downtowns, and numerous businesses. However, this growth also results in negative effects on the environment, including air pollution, the urban heat island effect (UHIE), and stormwater runoff. Among these problems, stormwater runoff is of particular concern for cities near bodies of water. The abundance of impervious surfaces in urbanized cities prevents stormwater, which results from precipitation, from being naturally absorbed by soil and plants (VanWoert, 2007), leading to an increased risk of urban flooding. Furthermore, pollution accumulated on impervious surfaces due to human activities is washed off and carried by stormwater into bodies of water when precipitation events occur. This pollution includes bacteria, pathogens, sediments, heavy metals, toxic substances, and nutrients, which originate from factory emissions, vehicle emissions, building erosion, and the use of fertilizers (Calvet, 1989; VanWoert, 2007). Due to contaminated stormwater runoff, marine ecosystems near urbanized areas could become damaged, drinking water could become contaminated, and bodies of water may become unsuitable for recreational activities (Gaffield, 2003; Krishnayya, 1994).

Gray infrastructure is used to manage stormwater via the use of pipes and other impervious surfaces (University of Wisconsin, n.d). Gray infrastructure redirects stormwater rather than infiltrating it as natural ground cover would. Although this strategy is the most commonly used stormwater management method by cities, it is often insufficient. The reliance on gray infrastructure can be complemented by the use of green infrastructure, including rain barrels, rain gardens, and pervious pavements (University of Wisconsin, n.d). This could provide a series of benefits over gray infrastructure, such as the capture of pollutants, ground water infiltration, and the beautification of urban areas (EPA, 2013c).

Our project focused on investigating the implementation of street-level green roofs, which are green spaces consisting of a combination of layers that allow for the installation of vegetation on surfaces such as subway entrances, information kiosks, and bus shelters. One of the factors hindering the adoption of green infrastructure is the lack of public awareness about the importance of dealing with stormwater runoff and the benefits that these structures provide (National Environmental Education & Training Foundation [NEETF], 2005; Anonymous, 2008).

Therefore, the goal of our project was to determine the technical and financial feasibility of installing green roofs on street-level surfaces in the City of Boston with the purpose of raising public awareness and encouraging a change in the public's behavior with respect to stormwater runoff.

To complete our goal, we accomplished three objectives:

(1) We determined the technical and financial feasibility of installing green roofs on street-level surfaces and assessed the public outreach opportunities.

(2) We identified possible locations in Downtown Boston for the implementation of street-level green roofs.

(3) We identified possible stakeholders for the implementation of street-level green roofs in the City of Boston.

We completed the first objective by conducting interviews with companies and organizations involved in previous projects of a similar nature. This allowed us to identify important characteristics with respect to the technical and financial considerations, as well as the public outreach opportunities, of this kind of project. Based on these interviews, we determined that bus stops were the most suitable street-level surfaces for the installation of green roofs, and identified a set of characteristics they should have. To complete our second objective, we visited some possible locations for the installation of street-level green roofs in the City of Boston in order to determine whether they met the identified characteristics and allowed for the successful installation of a green roof. Finally, we interviewed possible stakeholders in Boston in order to obtain local opinions and recommendations about the installation of street-level green roofs.

After completing our objectives, we developed findings with respect to the benefits of street-level green roofs, their financial feasibility, their technical feasibility, and the public outreach opportunities that they provide:

(1) The installation of street-level green roofs is widely perceived as an environmentally conscious effort undertaken by cities and municipalities to raise public awareness about environmental concerns such as stormwater runoff.

(2) Among all other street-level surfaces, bus stops provide great opportunity for the installation of green roofs due to their standard design and high pedestrian traffic.

(3) Bus stops can be designed to support green roofs with moderate financial costs.

(4) There are mechanisms available to achieve funding and lessen the costs for projects involving the installation of green roofs on bus stops.

(5) The installation of a green roof is replicable if a standard bus stop design is selected for the pilot bus stop.

(6) Standard bus stops can be retrofitted for the installation of street-level green roofs with modest structural changes.

(7) There are two main green roof systems that can be installed on bus stops; one consisting of pre-grown trays and the other consisting of rolled mats of vegetation planted into the soil media. The key aspects when comparing these systems are cost, weight, and initial maintenance.

(8) As bus stops provide a limited opportunity to convey information, existing efforts and projects have implemented multiple methods of providing the public with information.

(9) There is minimal systematic evaluation of how effective street-level green roofs are at educating the public about stormwater runoff.

Based on the findings, we derived the following set of recommendations for the implementation of green roofs on bus stops with the purpose of raising public awareness about stormwater runoff:

(1) An outreach program should be created in the City of Boston with the purpose of raising public awareness about the problem of stormwater runoff through the use of street-level green roofs on bus stops.

(2) Standard bus stops should be selected for the installation of street-level green roofs to ensure that the project can be replicated at reduced cost. While other street-level surfaces, such as information kiosks and subway entrances, can be considered for the installation of a green roof, we recommend focusing on bus stops since most of these structures in the City of Boston have a standard design according to the MBTA’s guidelines.

(3) Long-term plans for carrying out the project should be completed through working in conjunction with the owner and manager of the bus stops in the City of Boston, namely the MBTA, Wall USA, and JCDecaux.

(4) Local engineers and contractors should be employed to design the structure and retrofit the bus stops in order to reduce the costs of the project. These local companies may be able to provide lower costs when compared to companies outside of the Boston area due to the fact that materials and workers won’t need to be transported long distances.

(5) The maintenance responsibilities of the green roofs should be relayed to volunteers or the city’s landscaping associations. This includes watering for the first few growing season and occasional weeding.

(6) Advertisements should be used on bus stops where green roofs have been installed in order to fund subsequent green roofs.

(7) Outreach materials, supplemented with the incorporation of social media, should be presented on the bus stops where the green roofs are installed to help raise public awareness about stormwater runoff and the benefits that green roofs provide. We also suggest incorporating an online website with detailed information about the problem of stormwater runoff and the best management practices available into the outreach campaign.

(8) Additional types of social media and online communities should be explored in order to make outreach programs of this nature accessible to the largest amount of people possible.

(9) The success of environmental outreach programs involving the use of social media and online websites should be evaluated. By completing research on this topic, future projects of this nature will have a solid foundation from which to base their work, allowing them to focus their efforts on exploring the relevant topics in their field of study.

As human activities are one of the major contributors to the pollution found in stormwater runoff, it is important for the public to be informed about the problem and what they can do to mitigate its effects. Installing these green roofs alongside the public outreach materials that we have suggested will provide the public with the opportunity of learning about stormwater runoff, its causes and consequences, and what they can do in order to reduce its effects and alleviate the burden of daily human activities on the environment.

Authorship

Abstract	Kevin & Oliver
Executive Summary	Kevin & Oliver
Introduction	Victor
Background	Victor, Kevin, & Oliver
Methodology	Victor & Kevin
Findings	Victor, Kevin, & Oliver
Conclusions & Recommendations	Victor & Oliver

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1. Introduction

As cities develop and urbanize, they provide people with added benefits such as employment opportunities, rich cultural exchanges, lively downtowns, and numerous businesses. However, this growth also results in negative effects on the environment, including air pollution, the urban heat island effect (UHIE), and stormwater runoff. Among these problems, stormwater runoff is of particular concern for cities near bodies of water. The abundance of impervious surfaces in urbanized cities prevents stormwater, which results from precipitation, from being naturally absorbed by soil and plants (VanWoert, 2007), leading to an increased risk of urban flooding. Furthermore, pollution accumulated on impervious surfaces due to human activities flows into bodies of water when precipitation events occur. This pollution includes bacteria, pathogens, sediments, heavy metals, toxic substances, and nutrients, which originate from factory emissions, vehicle emissions, building erosion, and the use of fertilizers (Calvet, 1989; VanWoert, 2007). Due to contaminated stormwater runoff, marine ecosystems near urbanized areas could become damaged, drinking water could become contaminated, and bodies of water may become unsuitable for recreational activities (Gaffield, 2003; Krishnayya, 1994).

Boston is an example of a large metropolitan city that has to deal with stormwater runoff as a result of urbanization. Boston is very densely populated, with 625,000 people living in less than fifty square miles of land (United States Census Bureau, 2013). In addition, as many as 4.6 million people live in the Greater Boston area, which comprises 4,674 square miles of land surrounding the City of Boston. Many of the people in the Greater Boston area travel to the city on a regular basis (Boston Redevelopment Authority, 2002). This large amount of people visiting and living in the city has contributed to the growth of businesses and to the urbanization of the city itself. However, the growth of the city has also led to an increase of impermeable surfaces, which in turn has led to serious problems concerning stormwater runoff. In fact, impervious surfaces cover as many as 175,000 acres of the Metropolitan Boston area (Metropolitan Area Planning Council [MAPC], 2005). From these surfaces, 29,000 acres have been developed over the past twenty years (MAPC, 2005).

Cities manage stormwater runoff in several different ways. The oldest and most common stormwater management technique is gray infrastructure, which uses drains and pipes to transport stormwater to a wastewater sewer system (University of Wisconsin, n.d.). This system redirects stormwater to various discharge locations, such as lakes and rivers, resulting in the pollution of the environment due to the presence of the aforementioned contaminates in the runoff. Another way to manage stormwater runoff is by promoting infiltration of rainwater into the ground. This management strategy benefits the environment by filtering stormwater and reducing the amount of urban runoff. In addition, infiltration reduces the risk of flooding and the associated damages to the environment. One way of promoting infiltration is by increasing the amount of pervious surfaces in urban areas through the installation of green infrastructure such as green roofs, rain gardens, rain barrels, and pervious pavements. Among these structures, green roofs are particularly useful due to the amount of stormwater runoff that they retain. In fact, green roofs can retain as much as 90% of precipitation during summer months and 40% during winter months (Green Roofs for Healthy Cities, n.d.). However, one of the main factors hindering the adoption of green infrastructure is the lack of public awareness about the importance of dealing with stormwater runoff and the benefits that these structures provide (NEETF, 2005; Anonymous, 2008).

Various efforts have been taken to educate the public about environmental issues. Among them, a great emphasis has been placed on teaching the public about the consequences of stormwater runoff and the benefits of green infrastructure. For example, Region 1 of the Environmental Protection Agency (EPA) created the Soak Up the Rain campaign. Through this campaign, the EPA is seeking to make the public aware of the problem of stormwater runoff so that they can help prevent the pollution of local bodies of water (EPA, 2012a). This campaign builds upon the best management practices (BMPs) proposed by the EPA (EPA, 2012a). Among these practices, the installation of green roofs stands out as providing a great educational opportunity. Another effort was conducted by the Philadelphia Water Department (PWD) as part of the Green City, Clean Waters campaign with the purpose of raising public awareness about stormwater runoff (PWD, n.d.-a). As part of this campaign, the PWD managed a project in which a green roof was installed on a bus stop in front of City Hall (PWD, n.d.-b). Other cities, including Boston, Buffalo, Austin, San Francisco, and East Lansing, Michigan, have also completed initiatives of a similar nature (California Academy of Sciences, n.d.; Michigan State University, n.d.; Neville, 2012; Welch, 2012). Still, more has to be done in order for the public to be properly informed about stormwater runoff and achieve a change in behavior with respect to the installation of green infrastructure. In order to contribute to this effort, this project explores how Boston can adopt a program involving the installation of street-level green roofs to raise public awareness about stormwater runoff.

The goal of our project was to determine the technical and financial feasibility of installing green roofs on street-level surfaces in the City of Boston with the purpose of raising public awareness and encouraging a change in the public's behavior with respect to stormwater runoff. To complete our goal, we accomplished the following objectives:

(1) Determined the technical and financial feasibility of installing green roofs on street-level surfaces and assessed the public outreach opportunities.
(2) Identified possible locations in Downtown Boston for the implementation of street-level green roofs.
(3) Identified possible stakeholders for the implementation of street-level green roofs in the City of Boston.

We completed the first objective by conducting interviews with companies and organizations involved in previous projects of a similar nature. This allowed us to identify important characteristics with respect to the technical and financial considerations, as well as the public outreach opportunities, of this kind of project. Based on these interviews, we determined that bus stops were the most suitable street-level surfaces for the installation of green roofs, and identified a set of characteristics they should have. To complete our second objective, we visited some possible locations for the installation of street-level green roofs in the City of Boston in order to determine whether they met the identified characteristics and allowed for the successful installation of a green roof. Finally, we interviewed possible stakeholders in Boston in order to obtain local opinions and recommendations about the installation of street-level green roofs. By completing these tasks, we were able to present our sponsor with recommendations concerning the technical feasibility of installing green roofs on street-level surfaces, the financial considerations that must be taken, and the outreach opportunities that could be created by the successful execution of this project. We also provided our sponsor with a prototype of the poster that could be used as part of the outreach campaign. Overall, these recommendations are aimed at helping the City of Boston to manage the pressing problem of stormwater runoff by teaching the public and encouraging a change in behavior with respect to this problem and the benefits that green infrastructure provides.

2. Background

Urbanized areas have to deal with environmental issues as a result of their growth and urbanization. Among these issues, air pollution, the urban heat island effect, and stormwater runoff greatly affect the environment of cities and the surrounding areas. Air pollution, caused by the combustion of fossil fuels and factory emissions, pose serious health concerns to humans (Cohen, 2004). The UHIE causes an urbanized area to be significantly warmer than the surrounding rural area due to the development of the area and materials used in construction (Peng, 2012). Finally, the abundance of impervious surfaces in cities prevents stormwater from being naturally absorbed by soil and plants, leading to an increased risk of urban flooding (VanWoert, 2007). Stormwater may also be contaminated with sediments, heavy metals, and other toxins that contribute to water pollution (VanWoert, 2007). In this chapter, we will describe the three aforementioned environmental consequences of urbanization. Moreover, we will discuss in detail the causes and consequences of stormwater runoff as well as gray and green management practices, with a detailed analysis of green roofs. We will also analyze the effectiveness of outreach programs in teaching the public about environmental issues and encouraging a change in behavior with the aim of reducing the effects of environmental issues. Finally, we will study the implementation of green roofs on street-level surfaces as a means for raising public awareness about stormwater runoff and encouraging a change in behavior with respect to the implementation of green infrastructure.

2.1 Environmental Consequences of Urbanization

Urbanization results in a number of environmental issues. Three of the most significant ones are air pollution, the urban heat island effect, and stormwater runoff.

2.1.1 Air Pollution

Air pollution in urban areas is primarily caused by emissions from manufacturing, the burning of fossil fuels, and the use of household chemicals and fertilizers (Cohen, 2004). First, the incomplete combustion of fossil fuels used for transportation and power generation is one of the largest contributors of chemical air pollutants, as this process can produce carbon monoxide (Cohen, 2004). Second, factories, mills, and petroleum refineries contribute to air pollution by expelling pollutants such as nitrogen oxides, sulfur oxides, and toxic metals (Cohen, 2004). Third, pesticides and fertilizers expose ammonia to the surrounding environment and atmosphere, lowering air quality and contributing to air pollution (Cohen, 2004).

People living in areas with high indices of air pollution face a number of serious health problems (Cohen, 2004). A recent study conducted in the City of Boston identified a significant association between carbon monoxide, nitrogen dioxide, black carbon, and fine particulate air pollution exposure to the risk of pneumonia hospitalization and heart attack (Zanobetti et al., 2006). Another study concluded that air pollution, caused by motorized traffic, accounts for 12% of all heart attacks on a global scale (Kotz, 2011). Finally, a study in 2002 revealed that 30% of all childhood asthma results from environmental exposure and suggests that air pollution contributes to the development of asthma in healthy individuals (Natural Resources Defense Council, 2005).

Several strategies have been implemented to reduce air pollution in urbanized areas. First, recycling paper, cardboard, plastic, glass bottles, and aluminum containers help to conserve energy and reduce emissions during the production of these materials (EPA, 2012c). Second, individuals can use public transportation, carpool, or purchase more efficient motor vehicles to help reduce the emissions from vehicles (EPA, 2012c). Third, planting trees and vegetation can have positive effects on air pollution by removing pollutants from the environment, absorbing carbon dioxide, and producing oxygen (Maryland Department of Natural Resources Forest Service, n.d.). Fourth, governments at local, state, and federal levels have approved regulations to reduce the amount of air pollution and contaminants in the environment. For example, the Boston Air Pollution Control Commission (APCC) regulates the concentration and quantity of allowable air contaminants that cause harm to humans, animals, plant life, or property (City of Boston, n.d.-a). Additionally, the United States government implemented the Clean Air Act to reduce factory and vehicle emissions in order to improve air quality throughout the country (EPA, 2013a).

2.1.2 The Urban Heat Island Effect

The urban heat island effect is a second environmental problem originating from the urbanization of cities. Urbanized areas that are affected by the UHIE have a higher temperature than that of the surrounding rural areas (Peng, 2012), as seen in Figure 1. This is caused by heat absorption due to the presence of large infrastructure. Large buildings made of concrete, asphalt, and steel retain heat and prevent the surface heat from moving into the cooler night air (Peng, 2012). These materials also possess properties influencing solar reflectance and thermal emissivity, influencing how the sun's energy is reflected and absorbed by the structure. In addition, these surfaces and structures replace vegetation that would otherwise cool the air via evapotranspiration, whereby plants release water into the air, thus removing ambient heat. Finally, the UHIE can be caused by the presence of humans and their daily activities including transportation, heating, cooling, and industrial processes (EPA, 2013d).

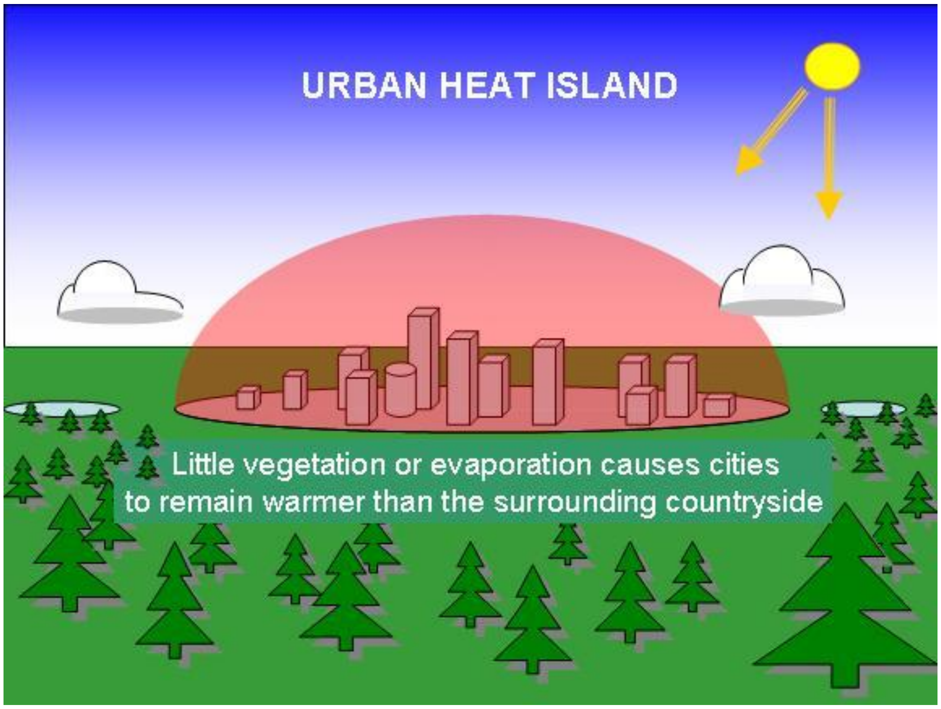
URBAN HEAT ISLAND
Little vegetation or evaporation causes cities
to remain warmer than the surrounding countryside

Figure 1: The Urban Heat Island Effect

(From: http://www.weatherquestions.com/urban_heat_island.jpg)

A recent study documented the effects of the UHIE in the New England area via the measurement of the surface urban heat island intensity (SUHII), a measure of the variance of temperature in rural versus urban areas (Peng, 2012). The overall daytime SUHII ranged from 3 to 4°C, and the nighttime SUHII ranged from 1 to 2°C. The study also revealed that SUHII variance is larger in summer months in comparison to winter months due to the presence of vegetation. The daytime SUHII difference in summer versus winter months ranged from 3 to 4°C and the nighttime difference ranged from 0 to 2°C (Peng, 2012).

In order to reduce the effects of the urban heat island effect, several strategies have been proposed. For example, cool roofs, which have a low solar reflectance, can be used to reflect sunlight away from a building, thus reducing the roof's temperature (EPA, 2013e). Similarly, cool pavements reflect a greater amount of solar energy than traditional pavements and increase water evaporation to reduce the temperature of the pavement surface (EPA, 2013e). Finally, trees and vegetation can also be used to lower surface and air temperatures through evapotranspiration and by providing shading.

2.1.3 Stormwater Runoff

Stormwater runoff is another environmental issue that affects big cities. As an area urbanizes, impervious surfaces, such as roads and sidewalks, replace vegetation and soil that would otherwise be able to retain and filter rainwater. As illustrated in Figure 2, in an area with natural ground cover only 10% of stormwater becomes runoff, while in urban areas with 75% to 100% impervious cover as much as 55% of rainwater becomes runoff. VanWoert (2007) estimates that an urban area generates more than five times the amount of stormwater runoff than a vegetated area of the same size. The consequences of stormwater runoff are particularly evident in cities that are near bodies of water. As seen in Figure 3, as much as 45% of estuaries and ocean shorelines, 20% of lakes, and 14% of rivers and streams in the United States have been impaired by stormwater runoff. The City of Boston, bordered by nearly fifty square miles of water, is vulnerable to the effects of stormwater runoff (Massachusetts Water Resource Authority [MWRA], 2011). As seen in Figure 4, the high amount of impervious surfaces throughout the city intensifies the consequences of stormwater runoff. In fact, the Department of Environmental Protection (DEP) has identified the Boston Harbor as an impaired body of water due to the effects of improper stormwater management (University of Massachusetts Boston, n.d.).

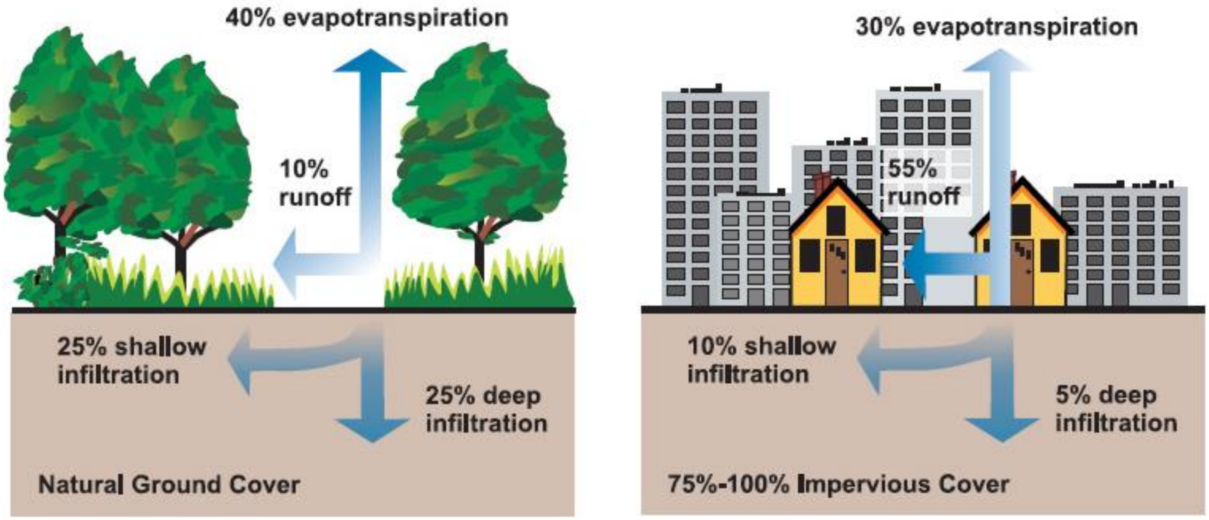

Figure 2: Stormwater Runoff

(From:

http://commons.wikimedia.org/wiki/File:Natural_&_impervious_cover_diagrams_EPA.jpg)

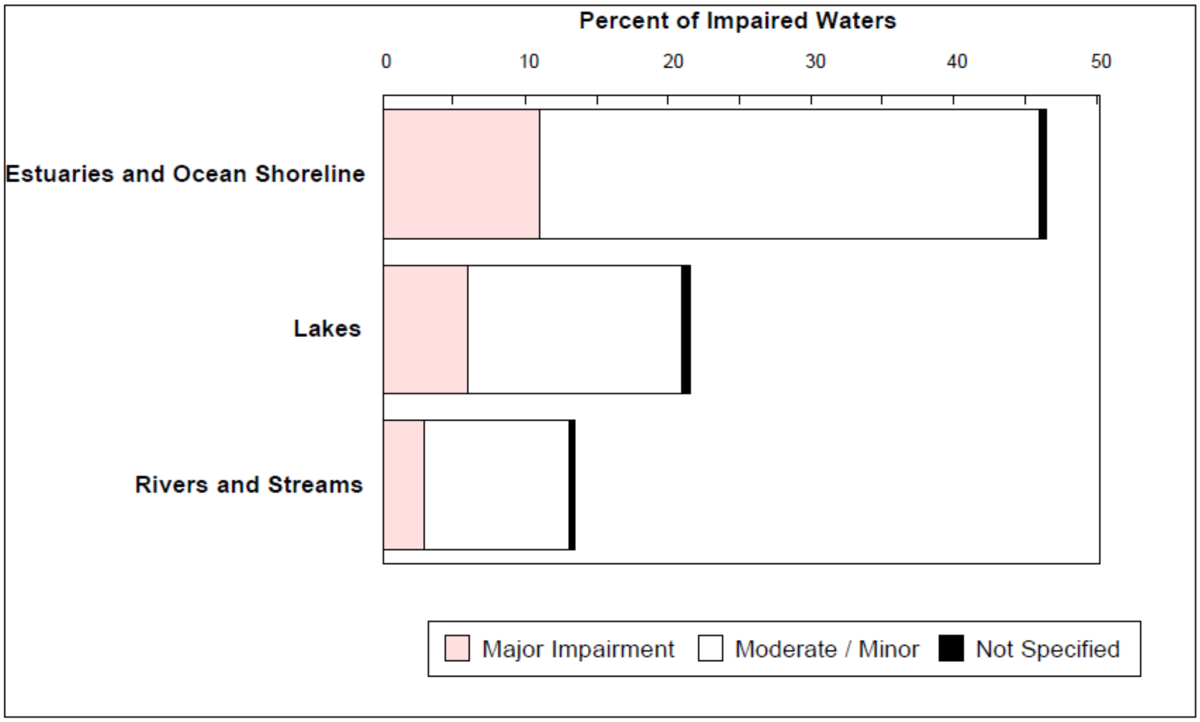

Figure 3: Proportions of Impaired Water Bodies Attributed to Urban Runoff

(From: http://water.epa.gov/scitech/wastetech/guide/stormwater/upload/2006_10_31_guide_stormwater_usw_b.pdf)

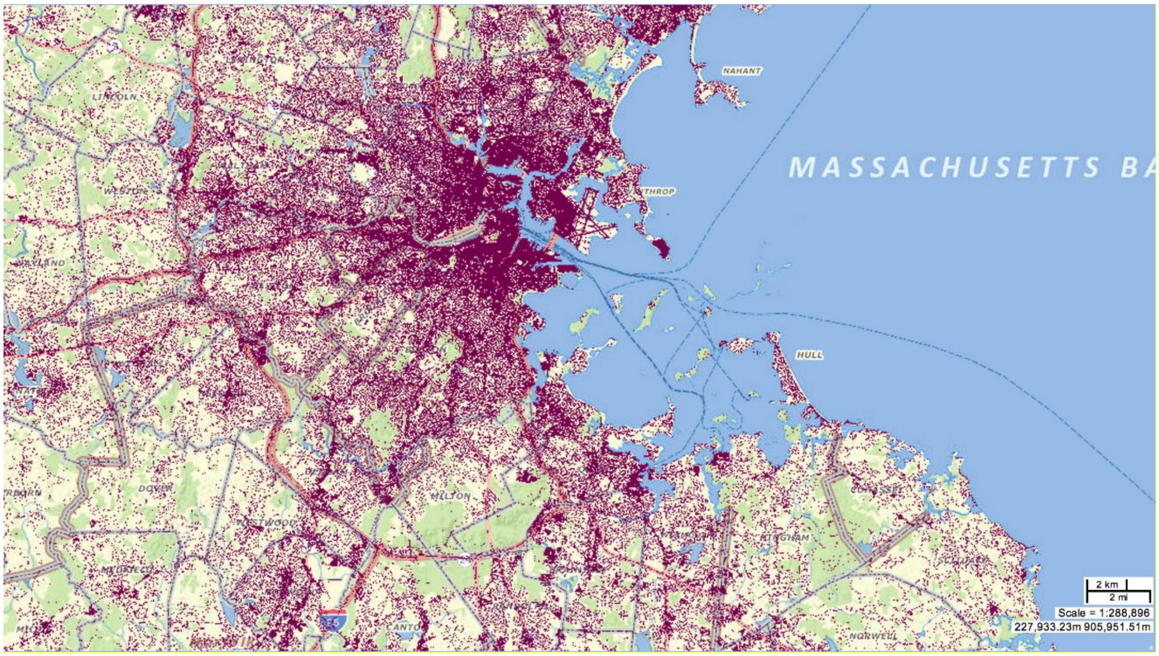

Figure 4: The Area of Impervious Surfaces in the City Of Boston

(From: http://maps.massgis.state.ma.us/map_ol/oliver.php)

Stormwater runoff is a significant environmental and health issue for two main reasons (Calvet, 1989). First, in a vegetated area, stormwater is infiltrated into the ground, intercepted by plants, or is evaporated. However, in areas with large amounts of impervious surfaces, direct runoff occurs into lakes, rivers, and oceans (Calvet, 1989). Stormwater runoff may be polluted by human activities, posing a great threat to the environment. The main sources of these threats are factory emissions, vehicle emissions, building erosion, and soil or fertilizer transported to rooftops via the wind and weather, as identified in Table 1 (EPA, 2006). Once the toxins and pollutants enter a body of water, they can be adsorbed by soil or sediment (Calvet, 1989). This process, known as adsorption, exposes the environment to the risks associated with these pollutants (Krishnayya, 1994). In addition, the sediments can become suspended and can reduce the amount of light entering the aquatic ecosystem, thus diminishing the activity and growth of photosynthetic organisms (Aryal, 2010).

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

Table 1: Sources of Contaminants in Urban Storm Water Runoff

Second, contaminants of multiple types that are often in stormwater runoff can present dangerous threats to the environment. As seen in Table 2, these contaminants include heavy metals, such as copper, lead, and zinc, resulting from fire emissions, oil dumping, and the erosion of roofing materials, which can pose especially dangerous threats to an aquatic ecosystem’s plant and animal life due to their toxicity and concentrations in urban areas (California Department of Transportation, 2003). For example, nutrients in stormwater runoff, which may originate from the use of fertilizers and chemicals applied to gardens or other agricultural areas, contain inorganic phosphates or nitrates. These can have a detrimental effect on bodies of water through eutrophication, whereby nutrients promote the growth of algae and aquatic plants. This can lead to the depletion of oxygen, thus reducing aquatic populations (Aryal, 2010).

Contaminant	Source
Aluminum	Natural and anthropogenic sources such as aluminum works industries
Cadmium	Tire wear, brake pads, combustion of oils, insecticides
Chromium	Corrosion of welded metal plating, moving engine parts, brake lining wear
Cobalt	Wastes from tire and vehicle appliance manufacturing
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides, insecticides
Iron	Auto body rust, steel roadway structures, moving engine parts, corrosion of vehicular bodies
Lead	Leaded gasoline, tire wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Zinc	Tire wear, motor oil, grease

Table 2: Sources of Contaminants Often Found in Stormwater Runoff

Besides damaging the environment, the pollution of bodies of water due to stormwater runoff can lead to a number of health risks and waterborne illnesses (Gaffield, 2003). For example, nitrates increase the risk of methemoglobinemia, causing shortness of breath, and have also been linked to an increase in miscarriage risk (Gaffield, 2003). In addition, fecal coliform bacteria lead to skin rashes and gastrointestinal problems. Furthermore, heavy metals and insecticides can have carcinogenic effects on both human health and aquatic ecosystems (Gaffield, 2003).

2.2 Management Strategies for Stormwater Runoff

Although air pollution and the urban heat island effect are prevalent consequences of urbanization, stormwater runoff is of particular concern for big cities due to the vast consequences that it presents. As a result, cities have implemented several methods to manage stormwater runoff. The installation of gray infrastructure and green infrastructure are among these methods. In this section, we will discuss how these two types of structures help reduce the effects of stormwater runoff.

First, gray infrastructure is used to manage stormwater via the use of pipes and other impervious surfaces (University of Wisconsin, n.d). Through gray infrastructure, stormwater is redirected into storm drains and flows into nearby bodies of water, many times without being treated by wastewater sewer systems (University of Wisconsin, n.d). The Boston Water and Sewer Commission manages stormwater by using 424 miles of storm drain, 201 storm drain outfalls, and 31,752 catch basins (Boston Water and Sewer Commission, 2013). Almost half of the city is served by combined sewers, sanitary sewers only, or is open space without sewers or drains (Boston Water and Sewer Commission, 2013). Gray infrastructure systems are the most commonly used stormwater management strategy by cities. Still, they are not enough in most cities because of the varying effectiveness of treating quality and quantity of stormwater runoff (University of Wisconsin, n.d).

A second way of managing stormwater runoff is through the implementation of green infrastructure. This type of structure uses soil and vegetation to infiltrate stormwater, avoiding urban runoff into nearby bodies of water and providing a series of benefits including the capture of pollutants, ground water infiltration, and the beautification of urban areas (EPA, 2013c). Individuals can install their own green infrastructures at home in the form of rain barrels, green roofs, rain gardens, pervious pavements, and redirected downspouts. These techniques help infiltrate rainwater, collect runoff from rooftops and gutters from homes, and reduce the overall amount of stormwater runoff. Municipalities can implement larger scale green infrastructure to manage stormwater. These include pervious parking surfaces, large green roofs, and urban parks and green spaces. For our project, we will focus on the implementation of green roofs as a method for managing stormwater runoff.

2.2.1 Definition and Technology of Green Roofs

Green roofs are green spaces consisting of a combination of layers that provide structural support, insulation, a growing medium, and plants. Green roofs are placed on top of traditional roofs and provide several benefits to the environment (Kuhn & Peck, n.d.). The layers of a green roof are commonly arranged in the following way, as seen in Figure 5, and require the following considerations (EPA, 2000; Kuhn & Peck, n.d.; Philadelphia Water Department [PWD], n.d.-b; Roofmeadow, n.d.):

1. The lowest layer of a green roof comprises the roof structure itself, which has to be robust enough to hold the combined weight of the green roof layers. In order to verify the strength of the roof, a structural engineer is hired to conduct a structural analysis. If the analysis yields positive results, the installation of the green roof may continue.
2. A second protection layer may also be added depending on the characteristics of the structure where the roof will be built. This layer protects the roof from any surface damage that the green roof may cause.
3. The third layer waterproofs the roof from the surface where the green roof is installed, and stops plants from expanding their roots downwards with a root repellent medium. The surface of the waterproofing system is first washed, and then plywood and particleboard is laid down between the waterproofing material and polystyrene. A qualified inspector then completes a waterproofing inspection and submits a written report to the contractor specifying what type of conditions the green roof can withstand. The root barrier is then installed, with a minimum of two inches of slack to accommodate for expansion.
4. An optional fourth insulation layer may be added to prevent water stored in the green roof from extracting heat in the winter and cold in the summer from the building. In turn, this can help reduce the cost to maintain the temperature of the building.
5. The fifth layer comes on top of the waterproofing membrane and provides drainage to the whole structure by managing the runoff of the green roof. This layer may also contain water reservoirs to reduce runoff from the roof and improve insulation.
6. The sixth layer consists of a filter cloth that sits on top of the drainage layer. This cloth holds the roots of the plants and the growing medium, and allows for the infiltration of water to the lower layers.

7. A seventh layer of a specially engineered growing medium is set to allow for the growth and maintenance of the plants that come on the top-most layer of the roof.
8. The eighth and final layer supports a variety of different vegetation that can be planted depending on the climate of the region where the green roof is installed. The installation of this layer usually involves unrolling pre-grown vegetation on top of the growing medium, soaking the vegetation, and providing maintenance for the first 4 weeks after the installation. After the initial maintenance period, the green roof becomes mostly self-sustainable, requiring only occasional watering and hand weeding.

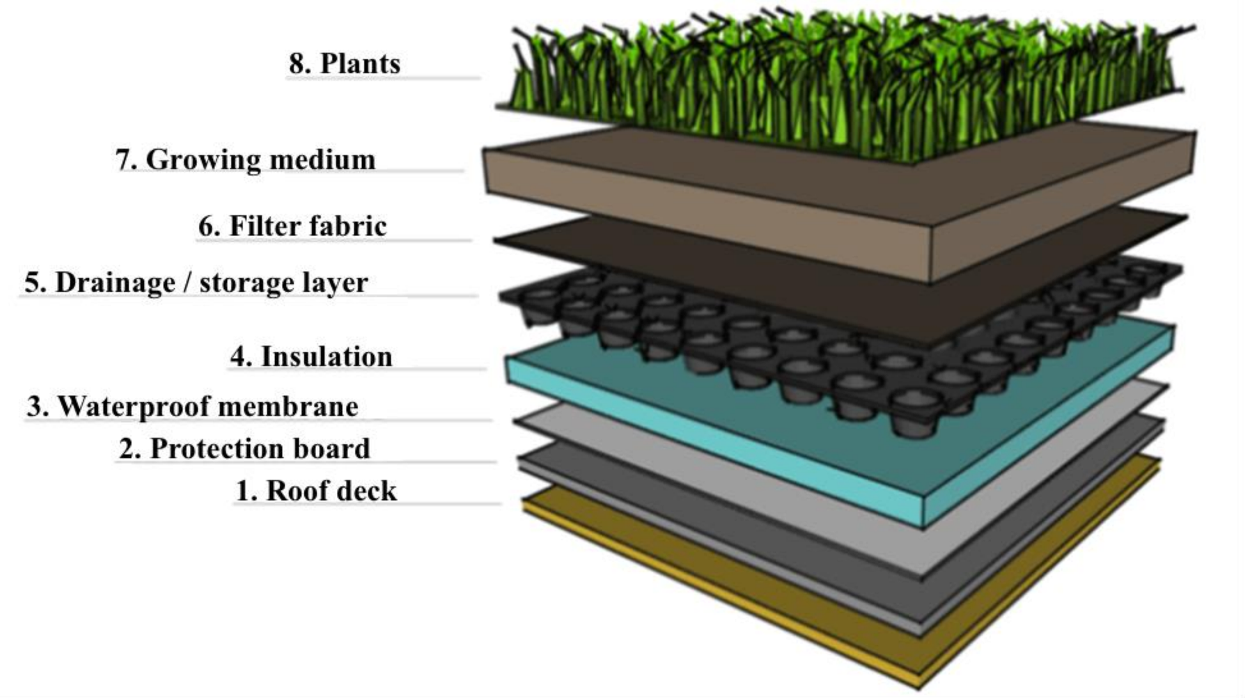

Figure 5: Layers of a Green Roof

(From: http://greengarage.ca)

The degree of effectiveness of a green roof depends on a number of design choices, including the depth of media used on the green roof, the slope of the rooftop, and the vegetation that is planted on the green roof system. A study conducted by the EPA concluded that a greater depth of media with a lesser slope could retain more stormwater, where a media depth of 4 centimeters and a 2% slope retained 70.7% of the annual rainfall (VanWoert, 2005). In addition, the media and soil influence the green roof’s susceptibility to freezing, as mineral-based media can be used to resist damage from freezing and thawing. Likewise, the depth of media used affects the survivability of vegetation from freezing injury, as a thicker depth results in less damage. The structure of the green roof can be designed to withstand thermal contraction and expansion if required by the climate of the area where the green roof is installed (Boivin, 2001). Furthermore, the species of plant used on the green roof can have an effect on the water retention (VanWoert, 2005). While water retention is a desirable characteristic for the plants of a green roof, transpiration is a more important factor since it affects the moisture of the soil and ultimately the amount of water held by the green roofs (Wolf, 2008). To this effect, green roof designers must carefully consider the different options available and make decisions based on the specific requirements of each project.

2.2.2 Environmental Benefits of Green Roofs

Installing green roofs in urban areas can have positive effects on the environmental issues of air pollution, the urban heat island effect, and stormwater runoff. First, green roofs can help reduce air pollution and its effects through the filtration of toxins and carbon dioxide from the atmosphere through processes known as carbon sequestration and dry deposition (EPA, 2013c). In addition, green roofs can also cool down buildings, which in turn can lower the demand for air conditioning and reduce the amount of air pollution originated through the production of electricity (EPA, 2013c). Second, green roofs help reduce the effects of the urban heat island effect by reducing the city’s temperature via evapotranspiration, which prevents heat from being absorbed by the large buildings in cities made of concrete, asphalt, and steel (EPA, n.d.). In fact, during the summer, green roofs can reduce the temperature of rooftops by almost ninety degrees Fahrenheit when compared to traditional tar roofs (EPA, 2013c). Third, green roofs greatly reduce the effects of stormwater runoff by retaining and filtering stormwater. The water absorbed by green roofs is eventually released into the atmosphere though evapotranspiration, reducing the amount of stormwater flowing to sewer systems (EPA, 2008). Finally, green roofs can still filter stormwater when they become saturated to reduce the pollution and toxins entering nearby bodies of water (EPA, 2008).

The amount of area spanned by a green roof can also influence its beneficial effects on the environment. For example, in Washington DC, there are over one hundred green roofs throughout the city, covering nearly one million square feet (Kalousdian, 2010). The Washington

D.C. District Department of the Environment (DDOE) estimates that these green roofs will total in fifteen million gallons of stormwater retention every year (Kalousdian, 2010). In addition, Chicago has installed over five million square feet of green roof coverage in order to help reduce the effects of stormwater runoff (De Melker, 2012). One of the most significant green roofs in the city is the 23,000 square foot roof on City Hall, as seen in Figure 6. The city estimates that this particular green roof reduces annual heating and cooling expenses by over $3,500 (De Melker, 2012). Furthermore, Development Management Associates, a company that has been active in the installation of green roofs throughout Chicago, estimates that $100 million in energy could be saved every year if all rooftops in the city had green roofs installed (De Melker, 2012).

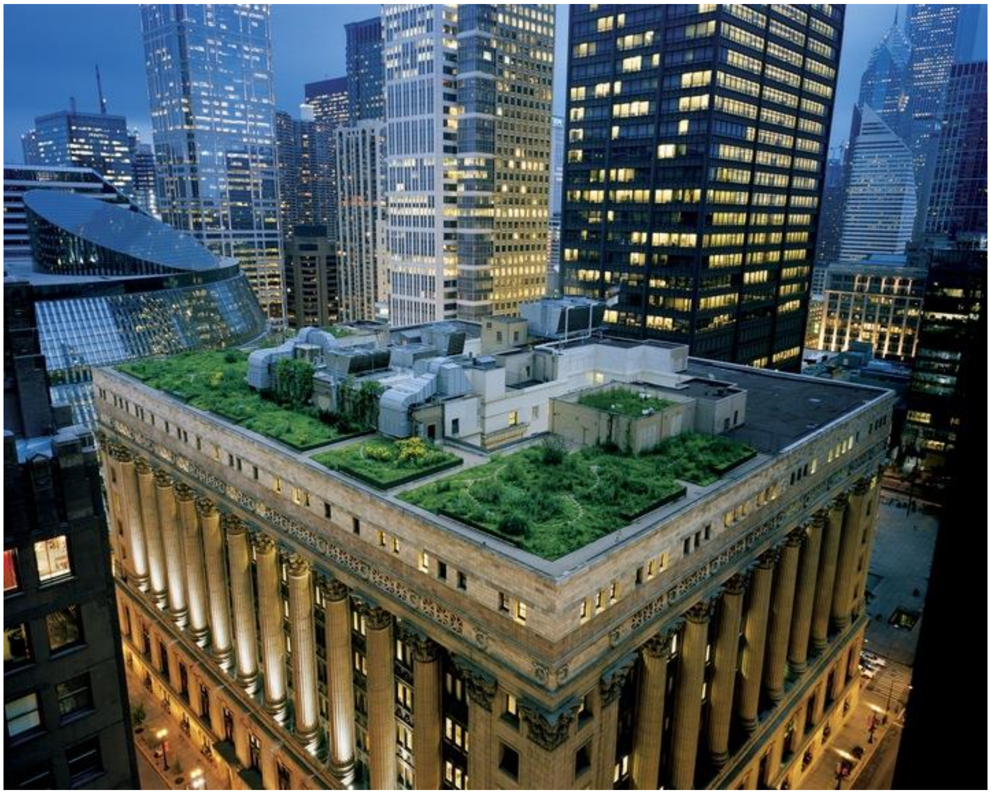

Figure 6: Green Roof on City Hall in Chicago

(From: http://www.pbs.org/newshour/multimedia/chicago/index.html)

2.2.3 Public Outreach Opportunities Created by the Implementation of Green Roofs

In addition to the environmental benefits provided by green roofs, street-level green roofs can be used as educational tools to teach the public about the problem of stormwater runoff and the benefits that green infrastructure provides as seen in the projects executed by the Philadelphia Water Department, Michigan State University, and the Bus Roots program. First, the Philadelphia Water Department developed the Green City, Clean Waters program to make Philadelphia a greener city and reduce the impact of stormwater runoff (PWD, n.d.-a). In approaching this goal, the PWD has managed the installation of green roofs on bus stops to inform the public of the actions they can take to help mitigate the effect of stormwater runoff. Specifically, the project was carried out on Market Street near City Hall. Roofmeadow, a green-roofing company based in Philadelphia, was in charge of the design and retrofitting of the bus stop. The green roof itself was composed of 3 inches of lightweight growing media, both to lessen the strain on the bus stop and help the plants strive (Roofmeadow, 2011). Pre-grown mats of drought tolerant succulents were used for vegetation on the green roof, as seen in Figure 7, in order to diminish the amount of maintenance required (Roofmeadow, 2011). In order to improve water retention and to manage overflow, the structure was installed with a subtle slope, as can also be seen in Figure 7 (VanWoert, 2005; Roofmeadow, 2011).

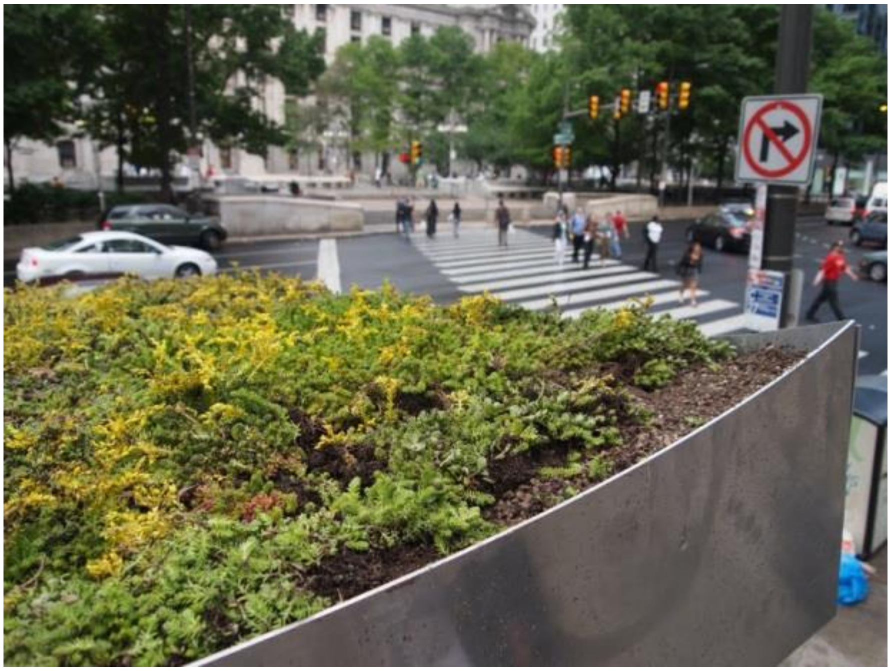

Figure 7: Green Roof on Bus Stop at the Corner of 15th and Market in Philadelphia, PA (From: http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2011/07/Philly-Bus-Green-Roof-8-537x402.jpg)

Second, Michigan State University is in the process of installing a green roof on a bus stop with the purpose of raising public awareness about stormwater runoff (MSU, n.d.). This bus stop will feature an informational poster with Quick Response (QR) codes, which look similar to barcodes and can be scanned with a smartphone in order to direct the user to a website, social media page, or other online outlet. The QR code will bring users to the Michigan State Green Roof Research Program website, where they will be able to find information about stormwater runoff and the best management practices available.

Finally, the Bus Roots initiative involved the installation of a green roof on a moving bus (Castro, n.d.). This project also involved surveying individuals to determine the current public knowledge about certain environmental issues, as well as a website that provided information about the benefits of green infrastructure. By using a moving green roof, Castro (personal communication, September 19, 2013) hopes to increase the public's awareness about stormwater runoff and the benefits of green infrastructure.

2.2.4 Disadvantages of Green Roofs

Green roofs may present a number of financial disadvantages when compared to traditional roofs:

- First, compared to traditional roofing systems, green roofs have a higher initial cost because of their installation and the materials required. The average price of a green roof is $15, compared traditional tar and gravel roofs that cost approximately $3 per square foot (EPA, 2013c; Homewyse, 2013). However, the price of green roofs generally decreases when installed on roofs with a greater area (United States General Services Administration, 2013).
- Second, some types of green roofs require a greater amount of maintenance when compared to traditional roofs as the plants require care for the first two years until they are fully established (Blackhurst, 2010).
- Finally, green roofs can cause serious damage to the building if leaks occur due to drainage backups or holes in the waterproofing membrane system from root puncture, which may result in heavy economic losses (Greenroofs, n.d.).

In addition, the public's perception about green roofs may also be an obstacle for their implementation. A survey conducted in 2008 among visitors at the EcoBuild trade show in London demonstrated that while green roofs are understood to be a sustainable technology, many people focus too heavily on the disadvantages rather than on the benefits that they provide (Anonymous, 2008).

Those surveyed stressed that green roofs have an increased cost versus traditional rooftops, are more difficult to install, and do not provide enough benefits in the long term to make up for the initial costs (Anonymous, 2008).

Despite these disadvantages, green roofs have shown great potential to help reduce the effects of stormwater runoff. However, for cities to take advantage of this potential, it is important for the public to be aware of the problem of stormwater runoff and the benefits that green roofs provide.

2.3 Educating the Public to Reduce the Effects of Stormwater Runoff

Previous research suggests that education and outreach components are crucial to any successful environmental program, especially stormwater management programs (Barnes, 2012; EPA, 2012b; Maddox et al., 2011; A. Taylor et al., 2007). As previously stated, green infrastructure should be implemented as part of stormwater management programs in cities to help reduce the effects of stormwater runoff. Therefore, the public must become aware of the problem of stormwater runoff so that they can help mitigate its effects by supporting and implementing green infrastructure (EPA, 2012b). Due to the importance of public education, there has been ample research done about the different techniques for developing outreach campaigns. In this section, we will discuss how public education plays a role in reducing the effects of environmental issues, the best practices for carrying out public education programs, and one of the theories behind these practices.

Effective outreach programs provide the public with valuable and relatable information about the problem of concern and the specific ways in which they can help reduce its effects, as illustrated by Table 3 (A. Taylor et al., 2007; EPA, 2005).

First, previous research suggests that in order for outreach programs to promote effective action, it is crucial for the public to have an ample understanding of the problem of concern (Dilling & Moser, 2007/2008). For example, a study comparing different explanations of the process of global warming determined that participants who viewed a heat-trapping diagram with clear and easy-to-understand information were more likely to state relevant concepts when asked to describe global warming in comparison to those who received no explanation, a scientific explanation, or an explanation with a focus on the impacts of this environmental problem rather than on the (Dilling & Moser, 2007/2008). In addition, the participants who were shown the heat-trapping diagram were able to acknowledge the causes and consequences of global warming and the techniques available for reducing its effects (Dilling & Moser, 2007/2008).

Second, the information conveyed by outreach programs must be presented in a relevant and significant way so that it catches the public's interest (Dilling & Moser, 2007/2008); McKenzie, n.d.). The knowledge-attitude-action theory suggests that in order to achieve a change in behavior about a specific environmental problem, the knowledge and attitude of the public with respect to a concern must be positively reinforced (McKenzie, n.d.). This process, which is illustrated in Figure 8, can be accomplished through the following series of steps:

- Assess the existing knowledge, attitude, and behavior of the public with regards to the issue of concern (McKenzie, n.d.). This is achieved by asking the public what they know about the environmental problems, how they feel about specific aspects of the problems, and what actions, if any, they think they should take with regard to these aspects.
- Determine the knowledge the public has to have and what changes in behavior are expected to result from the outreach campaign (McKenzie, n.d.).
- Compare the state of the public's knowledge, attitude, and action with respect to the environmental problem of concern.
- Identify the information that must be conveyed for the public to understand the subject in greater detail and encourage a positive change in attitudes and behavior (McKenzie, n.d.).

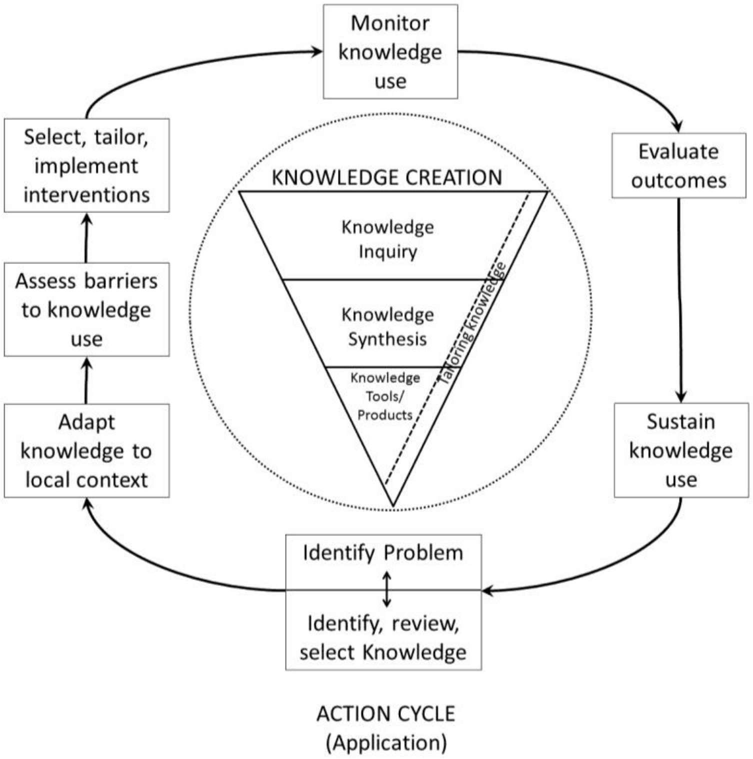

Figure 8: The Knowledge-Attitude-Action Theory

Third, in order to be successful, outreach campaigns must provide the public with direct actions that they can take in order to help reduce the effects of environmental problems (Dilling & Moser, 2007/2008). Providing information without a direct action can create a sense of futility among the public, resulting in the absence of education and, ultimately, in the lack of a positive change in behavior (Dilling & Moser, 2007/2008).

Aspect missing from an outreach campaign	**Consequences**
Comprehensive information about the issue of concern is not provided	If the public is not provided with ample information about the environmental problem of concern, they will not be able to properly understand the causes and consequences of the issue. In addition, it will not be apparent why it is important to deal with said issue.
The information is not given in a relevant and significant way	If the public cannot relate to the information provided, they will not feel the need to learn about the environmental problem and take action to reduce its effects since they will not realize how the issue affects them personally.
The information is not accompanied by specific actions that the public can take to help reduce the effects of the issue of concern	If specific actions to reduce the effects of the environmental problem are not given, the public will feel a sense of futility and frustration with respect to the campaign. This will result in the lack of involvement and subsequently in the lack of behavior change.

Table 3: Consequences of Not Having Three of the Key Components of Outreach Programs

As previously stated, several studies and educational campaigns have been conducted with the goal of increasing community participation in efforts to reduce the impact of environmental issues. Some of these studies focus on conveying information by using passive techniques, such as handing out brochures and posting banners in public places. One such study occurred at the Fountaindale Public Library in Bolingbrook, Illinois in which direct contact techniques were used to raise public awareness about energy management (Barnes, 2012). The director of the library approved the installation of digital monitors to display the benefits that were obtained from the green infrastructure implemented in the building and the resources that were saved in the process. These monitors were made visible to the public and provided them with a relation between the green infrastructure installed in the building and the money saved by the library. This study suggests that places with high traffic, such as public libraries and university campuses, can be used to provide access to green infrastructure to the public so that they will receive first-hand knowledge of green infrastructure and the benefits that it brings (Barnes, 2012).

Evidence from past studies and programs also suggests that the public needs to be constantly reminded about the environmental issue of concern so that they remain involved in reducing its impact (Barnes, 2012; Maddox et al., 2011; A. Taylor et al., 2007). An educational program has the potential of raising public awareness about stormwater runoff, but if the knowledge provided to the community is not properly reinforced throughout time, it will fail to achieve a long-lasting effect. Taylor et al. (2007) implemented a program in Australia with the purpose of teaching the public about their role in reducing stormwater pollution in commercial areas. The study concluded that the use of active educational strategies, such as public speeches and first-hand interaction with the educational material, was necessary for raising public awareness (Taylor et al., 2007). Furthermore, the study suggested that the constant use of these strategies greatly increases the success of outreach campaigns (Taylor et al., 2007).

Past research also indicates that providing the public with information through printed material can contribute to the success of outreach programs (A. Taylor et al, 2007, Eureka Recycling, 2002). A recycling program study completed by Eureka Recycling in Saint Paul, Minnesota determined the ways in which residents preferred to receive outreach (Eureka Recycling, 2002). During this study, five different recycling collection methods varying by frequency of pick up, separation of recyclables, and recycling containers were measured. Through this program, the researchers determined that most residents preferred information delivered via the mail and delivered to the door, followed by discussions with staff members and calls to the informational hotline (Eureka Recycling, 2002).

In addition, public speeches and the use of public websites can also contribute to a successful project (Barnes, 2012). The EPA’s Soak Up the Rain project involved the creation of a comprehensive website concerning the problem of stormwater runoff (EPA, 2012a). The website provides the user with information about the causes and consequences of stormwater runoff, the techniques available for reducing its impacts, and information on how the public can implement green infrastructure in their communities and at their homes (EPA, 2012a). This type of project targets a wider audience by providing a reference web address where users can get information about stormwater runoff in any place where there is Internet access and at any time. In addition, a study involving multifamily recycling completed by Eureka Recycling revealed the outreach methods that were successful through a focus group with residents (Eureka Recycling, 2004). They determined that public speeches, such as council meetings, were important for raising public involvement, and concluded that recognizing differences in audiences and monitoring the successes of the program were critical to the outcomes of the campaign (Eureka Recycling, 2004). After presentations were given to the residents of buildings involved in the recycling program, the weight of recyclables collected increased by 31% to 187% in three months when compared to the three months prior to the presentations, giving a clear indication of the success of public speeches (Eureka Recycling, 2004).

Previous research also suggests that encouraging those who acquire knowledge from outreach campaigns to share the information with those who cannot access them has the potential of increasing the range of educational programs (Maddox et al., 2011). Maddox et al. (2011), while working on a project in the United Kingdom, concluded that besides engaging the primary audience of an educational program, developing methods for these individuals to share information with their relatives and communities is important for raising public awareness. One way of encouraging the conveying of information is through the use of social media. Through social media, individuals can share their experiences, advice, and photographs related to outreach programs providing others with the knowledge that they gained from hands-on practices. Over the past years, social media has become a very effective technique for spreading information in a fast and creative way (Viglianasi, 2011). Sites such as Facebook and Twitter can significantly reduce the time that it takes to influence a substantial amount of people, which is important for an environmental educational campaign (Viglianasi, 2011). In addition, online video communities such as Vine and YouTube allow for the publication of interesting and informative videos that create the opportunity of reaching an even broader audience (Nonprofit Network, 2013). The importance of social media will continue to increase as computers and smartphones continue to gain popularity, making the use of the aforementioned online communities an even greater asset for public outreach campaigns (Viglianasi, 2011).

There have been several environmental outreach campaigns involving the use of social media and online websites.

- The Florida Department of Environmental Protection launched an interactive blog and Twitter account to aid their Easy As One campaign, which has the goal of educating individuals about easy ways to live a more sustainable lifestyle (Lock, 2012). The blog and Twitter account provide people with facts and green tips on sustainability. In addition, the Florida DEP uses the Twitter account to provide information about the environmental programs that are going on throughout the whole state (Lock, 2012).
- The City of Vancouver has displayed posters across the city with the purpose of getting the public's attention to topics of environmental concern (BeQRious, 2008). The QR codes in the posters displayed across Vancouver bring users to a website with a special petition against construction efforts in the Flathead River Valley. With this strategy, the City of Vancouver seeks to get enough signatures to prevent the construction, and the associated environmental damages, from taking place (BeQRious, 2008).
- Amnesty International, the Everglades Foundation, and Diabetes UK are among the many nonprofit organizations that have used Vine videos to promote their work (Nonprofit Network, 2013). With over thirteen million users, Vine provides outreach campaigns the opportunity of creating six-second videos to convey their message in a creative and interesting way (Nonprofit Network, 2013). Videos posted on this site can be oriented towards a large audience or targeted to specific Vine users to create a connection between users and the publisher of the videos. For example, Amnesty International published a Vine video to ask for general support for an arms treaty, while Diabetes UK used the social media site to thank one of their volunteers for raising ninety British Pounds for the foundation (Nonprofit Network, 2013).
- The Air Pollution Control Commission has placed advertisements on several bus stops throughout the City of Boston with the purpose of making the public aware about the consequences of vehicle idling, as seen in Figure 9 (City of Boston, 2013). These advertisements include QR Codes that link the public to the APCC's website, where information about the issue of vehicle idling is provided (City of Boston, 2013).
- UMass Lowell, in conjunction with UMass Boston, Hofstra University, the MBTA, the Museum of Science, and the National Science Foundation, created the Science to Go

campaign in the City of Boston with the purpose of educating the public about climate change (Science to Go, 2013). As part of the campaign, advertisements have been placed across the city with QR codes linking to the campaign's website, as seen in Figure 10 (Science to Go, 2013). On the website, users can find information on climate change, surveys about this environmental problem, and links to the campaign's Twitter and Facebook pages. As part of this effort, periodic surveys will be conducted to measure whether the campaign is successful at increasing the public's knowledge with respect to climate change (Science to Go, 2013).

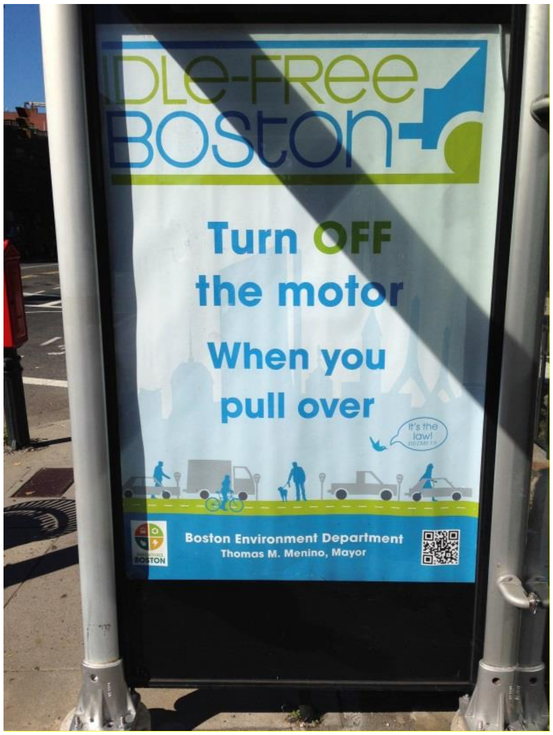

Figure 9: Idle-Free Boston Campaign Advertisement

(Picture taken by: Victor Andreoni)

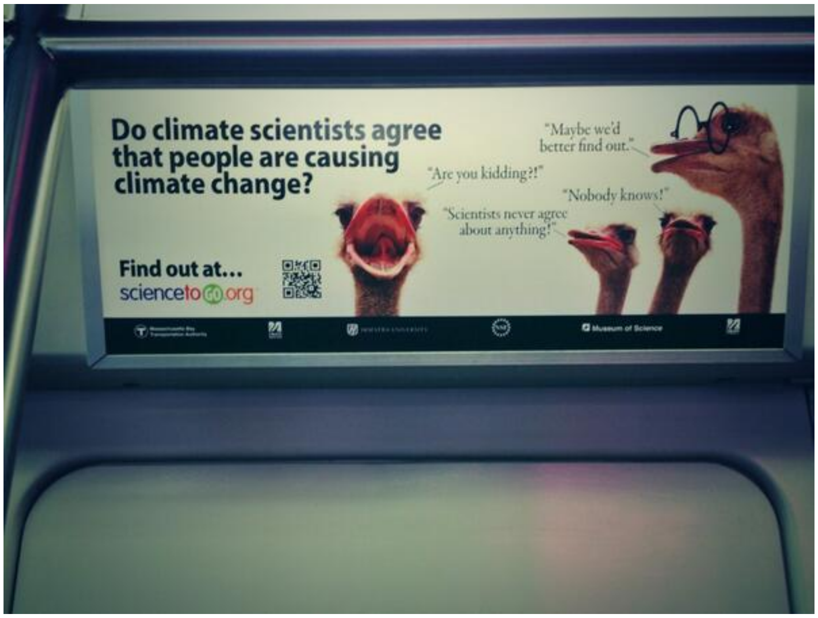
Do climate scientists agree that people are causing climate change?
"Are you kidding?!"
"Scientists never agree about anything!"
"Nobody knows!"
"Maybe we'd better find out."
Find out at...
sciencetogo.org
Museum of Science

Figure 10: Science to Go Climate Change Advertisement
(From: https://twitter.com/BostonOstrich)

In summary, as illustrated in Table 4, successful outreach programs provide the public with information about the environmental problem of concern and the techniques available for reducing its effects, create outlets for the public to share information gathered from the outreach campaign, and reinforce the information given even after the outreach campaign has ended.

Key Aspects of Successful Outreach Campaigns	Methods for Implementing Key Aspects	Examples
Provide the public with information about the environmental problem of concern and the techniques available for reducing its effects	Incorporate public speeches into the outreach campaign	• Invite experts on the relevant field of study to give public speeches • Organize council meetings to discuss the environmental problem of concern
	Incorporate the use of printed materials into the outreach campaign	• Display informational posters in the areas where the outreach campaign is implemented
	Incorporate the use of online websites into the outreach campaign	• Create a webpage with information about the causes and consequences of the environmental issue of concern • Create a webpage with information about the techniques for reducing the effects of the environmental issue of concern
Encourage the public to share information related to the environmental problem of concern	Incorporate social media into the outreach campaign	• Use Facebook accounts to encourage the public to share pictures related to the outreach campaign • Use Twitter accounts to encourage the public to post information gained from the outreach campaign
Remind the public about the environmental problem of concern	Reinforce the information provided by the outreach campaign	• Send brochures with information about the outreach campaign via email or mail • Create information hotlines for the public to ask questions and gain information relevant to the outreach campaign

Table 4: Key Aspects of Successful Outreach Campaigns

2.4 Using Green Roofs as a Means to Educate the Public about the Problem of Stormwater Runoff

As previously mentioned, the promotion of stormwater infiltration through the use of green infrastructure can be an effective and environmentally conscious strategy for dealing with stormwater runoff. Moreover, educating the public about stormwater runoff increases the chance for positive public action, which can lead to a wider implementation of green infrastructure. The implementation of green infrastructure, such as green roofs, on street-level surfaces provides a great opportunity for educating the public about the problem of stormwater runoff and the benefits that green infrastructure provides for several reasons (Barnes, 2012; Clark 2008; McKenzie, 2006; Taylor et al., 2007).

First, the visibility of street-level green roofs makes them of great interest for educational campaigns. Most green roofs are installed on buildings, making it difficult for people to access them and learn about the benefits that they provide. However, green roofs can be installed on street-level surfaces, making them a great candidate for an outreach program. The Philadelphia Water Department utilized the versatility of green roofs to their advantage in the Green City, Clean Waters program (PWD, n.d.-b). As seen in Figure 11, a green roof was installed on Market Street in Philadelphia. Bringing a green roof to the public’s view allowed the PWD to reach the pedestrians in the area and the riders of public buses (PWD, n.d.-a).

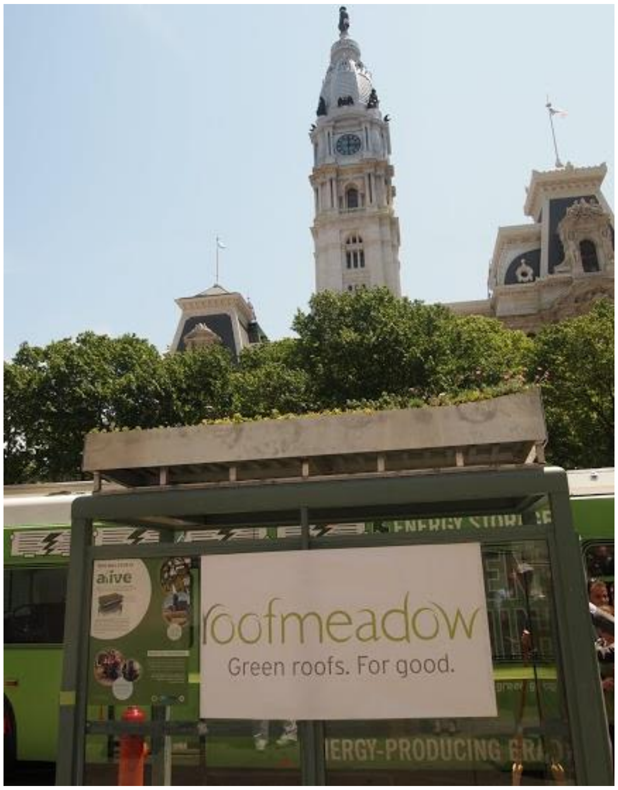

Figure 11: Green Roof on a Bus Stop in Philadelphia
(From: https://lh6.googleusercontent.com/-aCaHo3VIt_s/TgtvzVnlVwI/AAAAAAAACSs/gtbuHKme9eo/w433-h577-no/P6150471.JPG)

The Bus Roots initiative is another example of the implementation of green roofs on street-level surfaces (Castro, n.d.). As part of a graduate thesis from a student at New York University, a green roof was installed on a BioBus that travels across the Northeastern United States (Castro, n.d.). The green roof complements the educational material inside the bus, and gives the public the opportunity of learning about the benefits of green roofs in an accessible way. By using a moving vehicle, the green roof becomes visible to a very wide audience.

Researchers at Michigan State University have also studied the benefits of street-level green roofs to educate the public about stormwater runoff (Michigan State University [MSU], n.d.). According to their study, the greatest barrier for the wide implementation of green infrastructure is the lack of public knowledge about the benefits that they provide (MSU, n.d.). In order to inform the public about the benefits of green infrastructure, the research team proposed the installation of green roofs on bus stops across campus. According to their research, making green roofs visible to the public will result in an increase of public awareness about stormwater runoff and the benefits that green roofs provide (MSU, n.d.).

Second, street-level green roofs may be seen by a large amount of people from diverse audiences. Choosing a public location with high pedestrian traffic will increase the number of people that an educational program may influence. Due to their versatility, green roofs can be installed on highly trafficked street-level surfaces, such as bus stops, and become visible to a large number of people. In addition, by installing green roofs on bus stops in different locations, a diverse audience may be reached by the educational program. For example, the green roof installed in Philadelphia as part of the Green City, Clean Waters program is located near City Hall in order to reach a high amount of pedestrians as well as to make it visible to city officials working in the City Hall building (Tiffany Groll, personal communication, October 8, 2013). Moreover, the green roof installed in Austin, Texas, is visible to homeowners and commuters that travel near the Pecan Spring Commons area (Welch, 2012). Finally, the project being carried out at Michigan State University will involve the installation of street-level green roofs across the University’s campus (MSU, n.d.). Through the installation of street-level green roofs in these diverse locations, these projects were able to target city officials, homeowners, and university students. In a similar way, outreach programs can be designed to target specific audiences through the use of street-level green roofs in diverse areas.

Third, green roofs are visually appealing and interesting to the public, which makes them great subjects of discussion. Compared to traditional rooftops, green roofs beautify the structures on which they are installed, improving the overall look of cities (Moss Acres, n.d.). In addition, green roofs have increased the value of property by as much as 9%, which suggests that both residents and building owners appreciate this type of green infrastructure (Komorowski, 2010). Furthermore, research suggests that the green color has a soothing effect on the human eye and helps alleviate stress (Human and Health, 2013), making green roofs particularly appealing in places with little vegetation. Drawing upon these facts, the PWD used the visual appearance of green roofs to help promote their implementation on the bus stop in front of City Hall (PWD, 2011). Tiffany Groll (personal communication, October 8, 2013), member of the Green City, Clean Waters program, commented that the green roof on Market Street stands out amidst the concrete of the city and catches the attention of the people walking by the structure or waiting for the bus. Likewise, people living and walking near Pecan Springs Commons in Texas have shown a positive response to the green roof installed on a bus shelter in the area (Welch, 2012). After completing the installation, Christa Noland, Green Doors' deputy director, reported that members of the community were pleased with the project, and showed great interest in the idea of having green roofs on bus stops (Welch, 2012). Finally, Marco Castro, creator of the Bus Roots initiative, commented that he repeatedly received positive feedback about his project due to the attractiveness and innovativeness of the moving green roof that he installed (Marco Castro, personal communication, September 19, 2013).

Fourth, installing street-level green roofs on bus stops serves the purpose of reinforcing the public's knowledge about stormwater runoff. As previously discussed, providing a constant reinforcement of information is a key factor for the long-term success of outreach programs (Taylor et al., 2007). To this end, the public must be constantly reminded about the problems associated with stormwater runoff and the best management practices available in order for a positive change in behavior to occur. Bus stops are ideal locations for this purpose since commuters visit the same stops on almost a daily basis. In fact, Boston's public urban transportation service had a weekly average ridership of 1,093,973 passengers during 2010 (Massachusetts Bay Transportation Authority [MBTA], 2010a). Throughout the whole year of 2010, the average ridership of the urban transportation service was of 334,360,150 passengers (MBTA, 2010a). Although these numbers include every time that each individual boarded a transportation vehicle, they suggest the existence of a high pedestrian traffic in bus stops and train stations across the city.

Finally, street-level green roofs can be widely implemented as part of public outreach campaigns due to the low maintenance that they require. An outreach campaign involving the use of various street surfaces throughout a large region could present maintenance difficulties due to the distance between the different locations. In addition, some locations may be under different jurisdictions, which may make the development of a large-scale maintenance program difficult. However, green roofs can be designed to be self-sustainable and to require little to no maintenance after the first few growing seasons. Draught and winter resistant vegetation, such as sedum, can be installed on street-level green roofs to reduce the maintenance required (Roofmeadow, 2011). By choosing this type of vegetation, it would only be necessary to water the green roof for the first few growing seasons and to hand-weed the vegetation layer occasionally (Roofmeadow, 2011).

2.5 Summary

The City of Boston is affected by various environmental issues including stormwater runoff. Previous research suggests that teaching the public about the environmental issues, discussing the techniques available for reducing their impact, and encouraging individuals to share their knowledge with their communities has the potential to modify attitudes and behaviors. As such, it is possible that implementing green roofs on highly trafficked street-level surfaces, such as bus stops, may be instrumental in creating a positive change in the attitudes and behaviors of those targeted by the project, and that the effects of stormwater runoff will diminish as the community gets involved in dealing with the issue.

3. Methodology

The goal of our project was to determine the technical and financial feasibility of installing green roofs on street-level surfaces in the City of Boston with the purpose of raising public awareness and encouraging a change in the public's behavior with respect to stormwater runoff. To complete our goal, we accomplished the following objectives:

(1) Determined the technical and financial feasibility of installing green roofs on street-level surfaces and assessed the public outreach opportunities.

(2) Identified possible locations in Downtown Boston for the implementation of street-level green roofs.

(3) Identified possible stakeholders for the implementation of street-level green roofs in the City of Boston.

In this chapter, we discuss the methods we used to accomplish the objectives, including gathering and analyzing input from representatives of past projects involving stormwater management and green infrastructure, which enabled us to provide our sponsor with recommendations for the use of street-level green roofs as tools for public outreach. Through completing these objectives, we also provided our sponsor with a prototype of the informational poster that can be displayed on bus stops, our interview minutes, a summary of our observational study, and the full contact list of organizations that we contacted to obtain information relevant to our project.

3.1 Objective One: Determined the technical and financial feasibility of installing green roofs on street-level surfaces and assessed the public outreach opportunities.

The first step in our project was to carry out interviews with representatives and stakeholders from organizations involved in past projects of a similar nature in order to determine the technical and financial requirements of installing green roofs on street-level surfaces.

Based on the information obtained during our literature review and discussion with our sponsor, we created a list of companies and organizations in the fields of interest to our project. We chose to contact experts and organizations to compliment the information that we found on their websites and in various publications. In addition, we wanted to ask questions related to our project with the purpose of reaching our goal of determining the feasibility of installing green roofs on street-level surfaces in the City of Boston. We then evaluated the contact list with our sponsor to determine additional company representatives that we should interview. The full list of the companies and organizations that we contacted can be found in Appendix A: Interview Contact List.

The purpose of completing these interviews was to learn about the projects that these organizations completed, including the technical and financial requirements for carrying out such a project and the outreach opportunities that they provided. Specially, we sought to answer the following questions while conducting our interviews:

- How were the street-level surfaces retrofitted for the installation of green roofs?
- What specific qualifications were required for installing green roofs?
- What setbacks were encountered during the installation process?
- How have the green roofs endured extreme weather conditions?
- How were the street-level surfaces selected for the project?
- What were the overall costs associated with the project?
- What were the incentives behind the project?
- What forms of public outreach, if any, were implemented to complement the project?
- How successful was the public outreach campaign associated with the project?

From these questions, we created specific interview guides for each member of our contact list based on their specific field of knowledge. We gathered information about each organization through online research to ensure that we were knowledgeable about the projects in which they were involved. In addition, we selected the questions for each interview guide to ensure that they were relevant to the interviewees' work. This allowed us to take advantage of the allotted interview time. While completing our interview guides, we also initiated contact with the organizations with whom we wanted to interview to set up a time and date for the conference to take place.

We completed the interviews from our sponsor's conference rooms, using their phone lines, where one team member conducted the interview and the other two took notes. We decided to conduct phone interviews because of the time and cost benefits associated when compared to visiting the offices of the organizations and experts. By having two team members take notes during the meeting, we were able to compare our notes from each interview to ensure that we accurately recorded the responses. During each of our interviews, we created a list of preliminary recommendations derived from our conversations for implementing an educational campaign in Boston.

Once these interviews were completed, we analyzed the interviewees' responses. We organized these responses into three categories based on technical feasibility, financial feasibility, and public outreach opportunities, and further sorted the interview answers by the specific question asked within each category. We were then able to compare the information that we received and identify patterns in the responses that allowed us to make conclusions about the technical, financial, and educational aspects of installing green roofs on street-level surfaces. Based on our data analysis, we determined if we needed to perform follow-up interviews with any specific companies based on whether or not all of the desired questions were answered during the first interview and if other questions arose after the interview.

As with all research techniques, there were setbacks associated with conducting phone interviews. For instance, we were unable to see firsthand the results of the different projects implemented by these organizations. Therefore we had to rely on pictures and videos of the project sites, as well as on the conversations that we had, to assess the results of the project and the final green infrastructure. In addition, we were not able to conduct interviews and obtain information from every representative and organization that we identified as they either did not return our calls or were unable to put us in contact with someone who would be able to answer our interview questions. Therefore, we had to rely solely on online research and our literature review to obtain information about certain aspects of some projects. The detailed results from contacting each representative can be found in Appendix A: Interview Contact List. In addition, the minutes from these interviews can be found in Appendix B: Interview Minutes.

3.2 Objective Two: Identified possible locations in Downtown Boston for the implementation of street-level green roofs.

After assessing the technical and financial requirements for the installation of green roofs on street-level surfaces, as well as the public outreach opportunities, as part of Objective 1, we determined that bus stops were ideal structures based on their standard design, visibility by the public, and based on the fact that there have been successful projects involving the installation of a green roof on a bus stop. Our sponsor then requested that we identify specific bus stops for the implementation of green roofs in the City of Boston. We first identified the bus stops that we wanted to visit by looking at the Massachusetts Bay Transportation Authority (MBTA) website. We then chose a few stops throughout the city that we believed would be candidates based on what we learned from our research conducted in Objective 1 and the feedback from our sponsor. We then visited the identified locations as part of our observational study. From our research in Objective 1 and our literature review, we were able to create the following list of characteristics that we wanted to assess on each bus stop:

- Ridership demand and average number of pedestrians in the area
- Technical suitability for the installation of a green roof
- The design of the bus stop so that the green roof design can be replicable
- Financial as well as public outreach opportunities such as advertisement space
- Nearby plazas, parks, or other public gathering locations

We created an observational guide to ensure that we collected all the information required from each bus stop in a structured and consistent way. We identified the number of riders that visited each stop during a period of ten minutes and the duration of time that they stayed near the stop. While this study only provided us with limited data about each stop, we decided that a ten-minute observational period would give us sufficient information upon which to base our recommendations with the time constraints we were under. We measured the distance to the nearest storm drain to the bus stop. We noted objects that could be potential causes of concern in the surrounding area such as nearby transformers and fire hydrants. We observed and recorded information about public gathering locations near the stops and identified the number of people that frequented these areas in the ten minutes that we were there. Furthermore, we identified the physical characteristics of the stops and the advertising opportunities available. This involved measuring the height, length, and depth of the bus stop. We noted if the roof was flat or curved, as well as an estimated slope. In addition, we looked for existing advertisements on the bus stop and for potential spots for the installation of new advertisements. We collected this information on our observational guides while sitting a distance away from the stop such that we would not affect the public's behavior.

We analyzed the data collected by comparing the notes of each team member to ensure consistency in the findings. We then created a summary for each bus stop, which included all of our combined findings. From these summaries, and based on the findings of Objective 1, we identified bus stops that we deemed suitable for the installation of green roofs.

We chose to conduct an observational study for several reasons. First, we wanted to gain first-hand knowledge about the features of each bus stop and whether they could be retrofitted to support a green roof. Second, we wanted to observe the amount of people that transited the areas surrounding the bus stops and the average time that they spent there in order to get an idea of the outreach opportunity of each location. However, we faced a few challenges when conducting our study. It took us more time to visit all the bus stops of interest than if we had done interviews or online research. Furthermore, we did not visit each stop multiple times and at different times of the day to ensure that our results were consistent throughout different timeframes. Therefore, the observational study summaries should be acknowledged as a preliminary basis which must be further developed in order to determine which specific bus stops in the City of Boston are ideal for the implementation of a green roof.

3.3 Objective Three: Identified possible stakeholders for the implementation of street-level green roofs in the City of Boston.

In order to gain an insight into the requirements and implications of installing green roofs on street-level surfaces in the City of Boston, we decided to conduct interviews with potential stakeholders for this type of project. First, our interviews with the Philadelphia Water Department and Roofmeadow gave us a clear indication about the importance of discussing this type of project with owners and managers of bus stops in the City. As a result, we contacted the MBTA to inquire about the ownership of the bus shelters in the City of Boston. Through our conversation, we identified Wall USA and JCDecaux as co-managers of bus shelters in Boston, which led us to include them in the list of organizations with whom we wanted to interview. Second, interviews with representatives from the green roof program at Michigan State University and Brasco International revealed that working with local green-roofing companies and contractors would make the project more manageable in both technical and financial terms.

As a result, we contacted Recover Green Roofs, a local green-roofing company based in Somerville, Massachusetts. Our conversation provided us with insights into the regulations behind the installation of green roofs in the Greater Boston area. In addition, we received estimates about the cost and labor required for completing this type of project in Boston. We identified Recover Green Roofs as a company of interest for our project from our literature review and from the interview held as part of Objective 1 with representatives from Roofmeadow. Third, our research and interviews from objective one indicated that getting the opinion of local organizations experienced in outreach programs would serve to develop an outreach campaign tailored to the people of Boston. As a result, we contacted the Air Pollution Control Commission to inquire about their Idle-Free Boston campaign. We also contacted Greenovate Boston to learn about other green projects going on in the City, including the Science to Go campaign. These conversations resulted in a broader understanding about the benefits of using online websites and social media as part of an educational campaign in the City of Boston.

The process through which we completed this objective was similar to that of Objective 1. We first identified a preliminary list of organizations that we wanted to interview with by conducting a literature review. We searched online for information about the owners of bus shelters in the City of Boston, green-roofing companies in the Greater Boston area, and organizations involved in outreach campaigns involving the use of social media and online websites. Then, as was the case with Wall USA and JCDecaux, we gathered additional contacts from the interviews that we conducted. Before calling representatives from each company and organization, we created an interview guide containing the questions that we wanted to answer. These questions were drawn from the global list of questions and from our interviews that were completed as part of Objective 1. While conducting each interview, one member of our team was in charge of moderating the conversation while the two other members took notes. This approach allowed our conversations to be fluid since the designated speaker did not have to pause in order to take notes. After conducting each interview, we discussed the information that we were given and organized it to be analyzed. We analyzed the information by looking at the original questions that we had and synthesizing the information that we got from each interviewee with respect to each specific question. Then, we compared the notes that we gathered from each conversation and identified the questions that the interviewee had not answered so that we would ask them in follow-up interviews.

We decided to conduct phone interviews for several reasons. First, the Federal Government shutdown that occurred in October of 2013 directly affected the execution of this objective. Our original plan involved meeting in person with possible stakeholders in the City of Boston. Our sponsor was to organize these meetings in order to connect us with stakeholders relevant to our project who would be able to provide us with feedback and further contacts to interview with. However, since the EPA is a federal agency, the government shutdown prevented them from organizing and carrying out these meetings. In fact, the government shutdown prevented us from meeting with our sponsors during the last two weeks of our project. As a result, we had to identify alternative organizations to interview with in order to obtain the information that we were hoping to get from the originally planned meetings. Second, we decided to use phone interviews since we had gained experience with interviewing through the completion of our first objective. During this objective, we were able to gather all the information that we were looking for without major setbacks. In addition, despite having to reschedule many of our interviews due to the interviewees' unavailability, we were able to conduct our interviews in a short period of time.

The fact that we had to conduct phone interviews instead of having face-to-face meetings resulted in a number of consequences. First, we were not able to get feedback about our preliminary findings from some of the stakeholders that our sponsor wanted us to meet with. Even though we were able to revise our work from the phone interviews that we conducted, we were not able to get feedback from the stakeholders with whom our sponsor originally wanted to work, which would have made our recommendations more specific and practical for our sponsor. Second, we were not able to interview with some of the contacts that we had originally planned. Due to the shutdown, we missed the opportunity of meeting with various stakeholders at the same time to engage in a discussion that we think would have greatly benefited our project. Finally, some of the organizations that we wanted to interview with were not reachable. For example, despite our many efforts and phone calls, we were not able to speak with representatives from either JCDecaux or Wall USA. We feel that if our sponsor had been able to work with us during the last two weeks of the project, they would have been able to facilitate interviews with these and other organizations.

3.4 Summary

The goal of our project was to determine the technical and financial feasibility of installing green roofs on street-level surfaces in the City of Boston with the purpose of raising public awareness and encouraging a change in the public's behavior with respect to stormwater runoff. In order to achieve this goal, we performed online research about previous projects of a similar nature, interviewed with representatives of past projects involving stormwater management and green infrastructure, identified locations in Downtown Boston for the implementation of street-level green roofs. This allowed us to provide our sponsor with recommendations for the use of street-level green roofs as tools for public outreach, a prototype of the informational poster that can be displayed on bus stops, our interview minutes, a summary of our observational study, and the full contact list of organizations that we contacted to obtain information relevant to our project. These methods concluded in the findings that we will present in the next chapter.

4. Findings

This chapter presents findings concerning the installation of street-level green roofs and the outcomes of previous projects of a similar nature executed across the United States. We organized our findings in the following way: benefits of street-level green roofs, financial aspects of street-level green roofs, technical aspects of street-level green roofs, and methods for building public awareness.

4.1 Benefits of Street-Level Green Roofs

Finding #1: The installation of street-level green roofs is widely perceived as an environmentally conscious effort undertaken by cities and municipalities to raise public awareness about environmental concerns such as stormwater runoff.

Many of the interviewees that we spoke to believed that the installation of green roofs on street-level surfaces provides a great opportunity for raising public awareness about stormwater runoff and encouraging a change in public behavior with respect to stormwater management. The Philadelphia Water Department, Michigan State University, and the Bus Roots initiative were executed with the purpose of using green roofs to educate the public about stormwater runoff.

The green roof installed in front of City Hall in Philadelphia had the goal of increasing public awareness about stormwater runoff and the use of green infrastructure to alleviate the consequences of this environmental concern. In addition to the installation of the green roof, the water department organized an inaugural event of the retrofitted bus shelter. As part of the inaugural event, representatives from Roofmeadow, the company in charge of the design and installation of the green roof, and the PWD reviewed the importance of taking action to reduce the effects of stormwater runoff and the benefits that green roofs provide. Furthermore, the PWD installed informational posters on the bus shelter where the green roof was installed. These posters provided the public with information concerning the effects of stormwater runoff and the best management practices available for reducing its effects. However, due to the advertising company’s interest in the bus stop as a means of collecting revenue, the sign only stayed up for a few months.

Researchers at Michigan State University are also researching the installation of green roofs on bus stops near the university campus with the purpose of educating the public about stormwater runoff. Dr. Brad Rowe, one of the lead researchers involved in the university's green roof research program, stated that bus stops are great locations for a public educational program due to their high pedestrian traffic and visibility, and that the versatility and self-sufficiency of green roofs make them ideal for a project of this nature. Furthermore, Dr. Rowe commented that using street-level green roofs as part of educational campaigns provide a great opportunity for raising awareness about stormwater runoff. He also told us that the installation of the green roofs at Michigan State University will be accompanied by the use of social media and QR codes in order to encourage the public to visit a website with information about stormwater runoff and the techniques available for reducing its effects (Brad Rowe, personal communication, September 26, 2013). In order to display the QR codes and the links to the social media sites, informational posters will be displayed on the bus shelters where the green roofs are installed.

Finding #2: Among all other street-level surfaces, bus stops provide great opportunity for the installation of green roofs due to their standard design and high pedestrian traffic.

Based on our interviews with Roofmeadow and Michigan State, we determined that bus stops provide an ideal location for the implementation of street-level green roofs to raise public awareness about stormwater runoff. Compared to other street-level surfaces such as subway entrances and information kiosks that can vary in structure, most bus stops have a standard design, making the green roof installed on them replicable. (Lauren Mandel, personal communication, September 23, 2013). In addition, bus stops are located in highly trafficked areas, making them an ideal location for a public outreach campaign (Brad Rowe, personal communication, September 26, 2013).

4.2 Financial Aspects of Street-Level Green Roofs

Finding #3: Bus stops can be designed to support green roofs with moderate financial costs.

When designing and constructing a green roof that will be installed on a bus stop, there are several associated costs. These include costs associated with the design of the green roof, the retrofitting process, and the materials used for the green roof itself. Overall, the most critical costs associated with prior bus stop green roof projects have been the initial design of the structure and the retrofitting process (Sean Loewe, personal communication, September 26, 2013; Lauren Mandel, personal communication, September 23, 2013). In contrast, the expenses associated with the green roofs themselves were very minimal in the projects that we studied since only a small amount of green roofing material was needed to cover the area of the bus stops.

Through a series of interviews with Lauren Mandel, a project manager from Roofmeadow, we were able to obtain information about the financial aspects of the project carried out in Philadelphia. Although the first green roof that was installed on the bus stop in front of City Hall was a donation by Roofmeadow to the city, the company stated that the total cost of the project was between $10,000 and $12,000, including the design of retrofitting the bus stop, the design of the green roof, the materials used, and the labor involved. Lauren Mendel was able to identify the costs of the materials alone to be $6,000 of the total cost, with the most critical cost being the materials used in the retrofitting process.

We also conducted interviews with stakeholders from the project taking place at Michigan State University. Professor Brad Rowe referred us to Sean Loewe of Brasco International, a company involved with the design and manufacturing of bus shelters. Through our phone conference, we discovered that from the $5,000 budget provided by the university's sustainability program for the project, $3,000 to $4,000 were allotted to retrofitting the ten foot by five foot bus shelter. Of the funds reserved for the retrofitting process, half were allocated to the engineers designing the structure and half were put towards the materials used, including tubed rafters and aluminum sheeting (Sean Loewe, personal communication, September 26, 2013).

The bus stop green roof development in Austin, Texas involved building a completely new bus stop. The majority of the $20,000 budget for this project was put towards the design and construction of the bus stop itself. The green roof expenses only involved the epoxy-based paint used as the membrane for the roof as well as $100 to $200 for the soil, while the plants used were a donation from a local landscaping company.

Through email correspondence with Ian Smith of Recover Green Roofs, a green roofing company based in Somerville, Massachusetts, we were able to obtain information about the associated expenses if the project were to be carried out in the City of Boston. The approval of the retrofitting process by a structural engineer is required, which costs $2,500 for each visit per structural analysis. Although Ian Smith was unable to provide an estimate for the cost of a street-level green roof in the city, he stated that the price depends on economies of scale, whereby a larger roof will cost less per square foot. However, the information that Ian was able to provide was based on larger scale projects, rather than on the installation of smaller green roofs on street-level surfaces.

Finding #4: There are mechanisms available to achieve funding and lessen the costs for projects involving the installation of green roofs on bus stops.

While conducting interviews with Roofmeadow, we were able to learn about a system for funding future projects in the form of a green premium for advertisements. Through the green premium, companies pay an additional fee to advertise on the bus stops where green roofs are installed to promote themselves as an environmentally conscientious company or to achieve their sustainability goals. In turn, the additional money collected from the advertisements will serve to fund the future installation of green roofs on additional bus stops in the city.

We were also able to identify methods for reducing the costs of advertisements posted as part of outreach programs. Haidee Janak, a program manager from the Environmental Department for the City of Boston, works on the Idle-Free Boston campaign with the Air Pollution Control Commission. Haidee spoke with JCDecaux, one of the companies that manages the bus shelters in the City of Boston, in order to learn about the contract that the company has with the City of Boston to allocate 15% of the available advertisement spaces for public service announcements (Haidee Janak, personal communication, October 3, 2013). JCDecaux gave Haidee and Idle-Free Boston the specifications for sizing and material for the advertisement. Then, the APCC put out a bid to have the posters made. One-hundred posters were made, for $36 each, which were posted on the unsold advertisement spaces.

Trevor Smith, of the Ecological Landscaping Association, provided us with suggestions to reduce the costs of projects involving the installation of green roofs. During our interview, Trevor Smith stated that by hiring local contractors and engineers, the price of the project could be significantly less when compared to hiring companies that specialize in or have experience with the installation of green roofs on bus stops. Trevor Smith also specified that having students and volunteers involved with installation and maintenance of the green roof would not only lessen the associated costs, but would also provide an opportunity for the community to become involved in the project. Similarly, the PWD enlisted volunteers to maintain the green roof after it was installed, in terms of hand weeding and watering the vegetation.

Finding #5: The installation of a green roof is replicable if a standard bus stop design is selected for the pilot bus stop.

Our interview with Lauren Mendel revealed that subsequent projects in Philadelphia would not cost as much as the pilot one because a standard bus stop design was selected for the preliminary green roof. By choosing a standard bus stop design, the green roof could be replicated on multiple bus stops in a cost-effective way because new designs would not be needed due to the standard features of the stops (Lauren Mandel, personal communication, September 23, 2013).

4.3 Technical Aspects of Street-Level Green Roofs

Finding #6: Standard bus stops can be retrofitted for the installation of street-level green roofs with modest structural changes.

After interviewing representatives from Roofmeadow and Brasco International, we determined the requirements involved with retrofitting a bus stop. Our interview with Lauren Mandel from Roofmeadow provided us with information about the selection process of the bus stop and the retrofitting that took place. Lauren told us that the Philadelphia Water Department wanted to be able to replicate the installation of green roofs on many bus stops across the city (Lauren Mandel, personal communication, September 23, 2013). In order to achieve this, Roofmeadow and the PWD chose a bus stop with a standard design for the pilot green roof. Lauren also told us that the retrofitting of the bus stop required so few materials that all of the parts required for completing the process were transported in the back of a minivan. Furthermore, the whole retrofitting process was completed within a day, requiring the labor of less than ten workers. Sean Loewe from Brasco International told us that almost any type of bus stop could be retrofitted to accommodate for a green roof. During our conversation, Sean pointed out that cost and time were the major variables affected by the characteristics of the bus stop to be retrofitted (Sean Loewe, personal communication, September 26, 2013). Besides these two aspects, the technical specifications of the bus stop do not typically hinder the possibility of retrofitting the bus stop. As an example, Sean told us that one of the bus stops that will be retrofitted as part of the Michigan State University green roof project has a curved roof. This will result in a longer design process and a higher cost, but will still result in a bus stop capable of supporting a street-level green roof.

Finding #7: There are two main green roof systems that can be installed on bus stops; one consisting of pre-grown trays and the other consisting of rolled mats of vegetation planted into the soil media. The key aspects when comparing these systems are cost, weight, and initial maintenance.

There is a remarkable difference in the design of these two types of green roof systems. As the name implies, the rolled mat green roof system is formed by a continuous strip of vegetation, usually sedum, with the length required to fill the structure where the green roof is to be installed. In contrast, the pre-grown tray system consists of eighteen-inch by eighteen-inch biodegradable plastic trays containing pre-grown sedum. In this system, several trays are installed in order to completely cover the underlying structure. Furthermore, the rolled mat system uses the eight-layer design discussed in section 2.2.1, with every layer spanning the whole roof, whereas the pre-grown tray system contains the eight layers in each individual tray. The rolled mat system has been widely used in projects involving the installation of street-level green roofs, with installation times being as short as four hours (Lauren Mandel, personal communication, September 23, 2013). However, the pre-grown tray system has not been implemented in a wide scale, which results in a lack of reliable and unbiased information about the installation process.

The cost of these two green roof systems varies significantly. While pre-grown mats of sedum cost an average of $4 per square foot, the pre-grown tray system has an average cost of fifteen to $16 per square foot. For example, without accounting for the retrofitting of the bus stop itself, the sixty-square foot green roof installed in Philadelphia by Roofmeadow using the rolled mat system cost a total of $240 (Lauren Mandel, personal communication, September 23, 2013), whereas the fifty-square foot green roof that will be installed at Michigan State University using the pre-grown tray system will cost a total of $750 to $800 (Ian Smith, personal communication, October 3, 2013).

The weight of these different systems also varies to some degree. For a growing medium with a depth of four inches, the weight of the rolled mat system is twenty-eight pounds per square foot (Lauren Mandel, personal communication, September 23, 2013), while the pre-grown tray system weights thirty pounds per square foot (Ian Smith, personal communication, October 3, 2013). As a result, the green roof installed in Philadelphia weighted a total of 1680 pounds, whereas the green roof that will be installed at Michigan State University will weigh

1500 pounds. Even though these numbers seem to indicate that the pre-grown tray system is lighter, it is worth noticing that the green roof installed in Philadelphia is ten square feet larger than the one being installed at Michigan State. In addition, the depth of the growing medium, and subsequently the weight of the whole system, can be easily modified in rolled mat systems, while tray systems do not provide as much versatility. The weight of these different systems is particularly important because the amount of money and work required to retrofit a bus stop is related to the weight that the stop has to withstand. Thus, the lighter the green roof system, the less work involved in retrofitting the structure.

Maintenance requirements are different depending of which green roof system is installed. Rolled mat systems require watering for the first few growing seasons in order to properly settle (Tiffany Groll, personal communication, October 8, 2013; Lauren Mandel, personal communication, September 23, 2013), while pre-grown tray systems do not require watering as the vegetation is fully developed when the system is installed (Ian Smith, personal communication, October 3, 2013). In addition, the tray system allows for individual trays to be removed for maintenance and replaced if necessary, while the rolled mat system is fixed on the roof. Both types of green roof systems require occasional hand weeding to remove unwanted weeds. A summary of the characteristics of each green roof system is provided in Table 5.

	Pre-Grown Tray System	Rolled Mat System
Key Design Characteristics	• Individual 18x18-inch trays • Each tray has its own green roof layers • Individual trays may be removed or replaced • New system, not widely used	• Mat extends for the length of the underlying structure • All green roof layers extend across the length of the green roof • The green roof is fixed and cannot be removed by sections • System has been widely used in previous street-level green roofs
Cost Per Square Foot	\$15 - \$16	\$4
Weight Per Square Foot	30 lbs./ft^2	28 lbs./ft^2
Overall Maintenance Requirements	• No initial watering • Occasional hand weeding	• Watering for the first few growing seasons • Occasional hand weeding

Table 5: Differences Between Rolled Mat and Pre-Grown Tray Green Roof Systems

4.4 Methods for Building Public Awareness

Finding #8: As bus stops provide a limited opportunity to convey information, existing efforts and projects have implemented multiple methods of providing the public with information.

One of the main aspects of our project involved the use of outreach materials to increase public awareness about stormwater runoff. In particular, we were interested in exploring the use of social media and online webpages to convey information to a vast number of people without having to account for geographical barriers. Through our literature review and interviews with representatives from the PWD, Michigan State University, the Bus Roots initiative, the Air Pollution Control Commission, and Greenovate Boston we learned about the several methods that these organizations have used to provide outreach materials to the public.

As part of the effort to raise public awareness about stormwater runoff, the PWD displayed an informational poster on the bus stop where a green roof was installed to promote the Green City, Clean Waters website (Tiffany Groll, personal communication, October 8, 2013). This website is dedicated to provide the public with information about watershed protection techniques involving the proper management of stormwater runoff through the use of green infrastructure. In addition, the website explains to the reader what the Philadelphia Water Department is doing to help reduce the effects of stormwater runoff, and describes what individuals can do to help them in the effort to protect the watersheds.

Researchers at Michigan State University are also using posters as part of their green roof program to provide the public with access to online information about stormwater runoff. By maintaining a website with information about the problem of stormwater runoff and the benefits associated with green roofs, the researchers rely on a centralized source of information that can be distributed to the public with ease. In the case of the street-level green roofs project, a poster with a QR code will be displayed on the bus stops where green roofs are installed (Brad Rowe, personal communication, September 26, 2013). This will allow people with smartphones to scan the QR codes and be redirected to the website where they can learn more about stormwater runoff and the green roofs installed on the bus stops.

Marco Castro, the creator of the Bus Roots initiative, used social media to promote his graduate thesis at New York University, which involved the installation of green roofs on moving vehicles. In order to educate the public about the benefits of his work, Castro used Facebook and Twitter accounts to share information about the project. The updates posted from these accounts provided the public with information about the progress of the construction of the green roofs and the ways in which they could help fund the completion of the project. In addition, Castro commented that he will use these social media accounts to update the public about the location of the moving vehicles as well as to provide them with facts about the vehicles and the green roofs installed once the construction phase is completed (Marco Castro, personal communication, September 19, 2013).

Organizations in the City of Boston are also using social media and online webpages to raise public awareness about various environmental concerns. One such organization is the Air Pollution Control Commission. While conducting our observational study in the city Boston, we came across an advertisement from the APCC promoting the Idle-Free Boston campaign. This campaign seeks to stop drivers from leaving their cars idle in order to reduce air pollution in the city. The advertisement on the bus stop displayed a QR code in the bottom right corner, which directs people to the APCC website where they can find information about the consequences of idling and the penalties that they could face. Another example in the City of Boston of the use of social media to raise awareness about environmental concerns is the Science to Go campaign. As a collaboration between UMASS Lowell, UMASS Boston, Hofstra University, the MBTA, the Museum of Science, and the National Science Foundation, this campaign seeks to educate the public about climate change. In order to do so, informational posters will be displayed on trains and train stops with links to the campaign's Facebook and Twitter profiles. By following these links, the public will receive updates on the locations of new advertisements and information concerning climate control. Through this approach, the campaign seeks to raise public awareness about climate change in an entertaining way with the purpose of getting people involved.

Finding #9: There is minimal systematic evaluation of how effective street-level green roofs are at educating the public about stormwater runoff.

The representatives that we spoke to concurred on the argument that measuring the effectiveness of these types of outreach strategies is very difficult. They also acknowledged that the aforementioned techniques allowed them to reach a vast amount of people and convey information in an attractive and innovative way. While they were unable to provide statistical data or concrete evidence that their outreach programs were effective, Tiffany Groll from the PWD, Brad Rowe of Michigan State University, and Marco Castro claimed that their projects were able to raise public awareness about environmental concerns because they believed that the techniques used allowed them to reach a vast amount of people and convey information in an attractive and innovative way.

When conducting our interview with Tiffany Groll of the PWD, she stated that the Green City, Clean Waters website received many more visitors after the green roof was installed on the bus stop and poster was placed. Additionally, she stated that the project received a lot of attention through the media and from their launch event once the green roof was installed. Furthermore, although the project at Michigan State University is an ongoing effort, Professor Brad Rowe believes that the use of QR codes and online webpages is an effective method to convey information to the public. He explained that a study is currently taking place at the university to determine the most effective outreach methods to promote stormwater runoff, although the study has yet to be completed. Finally, when asked about the effectiveness of social media, Marco Castro claimed that he had a great response from his friends and those who saw his posts.

4.5 Conclusion

Based on our research, interviews, and observational study, we were able to synthesize the aforementioned findings. These findings concerned the incentives behind projects involving the use of street-level green infrastructure, the technical and financial aspects of the installation of street-level green roofs on bus stops, the flexibility of the structural requirements of a bus stop to be considered for the installation of a green roof, the two different types of green roofs that can be installed on street-level surfaces such as bus stops, and the use of outreach materials, social media, and online websites to raise awareness about environmental concerns such as stormwater runoff. In the next chapter, we will present a set of recommendations for the completion of a project involving the installation of green roofs on bus stops in the City of Boston with the purpose of raising public awareness about stormwater runoff.

5. Conclusions & Recommendations

Based on our research, interviews, and observational study, we have determined that it is technically and financially feasible to install green roofs on street-level surfaces in the City of Boston. In addition, we concluded that green roofs are an effective way to raise public awareness about stormwater runoff and the benefits that green infrastructure provides. Based on these conclusions, we are confident that a program involving the installation of green roofs on bus stops in the City of Boston will provide an opportunity to raise public awareness about stormwater runoff and to encourage a change in the public's behavior with respect to the installation of green infrastructure. In this chapter, we will provide specific recommendations for the successful implementation of such an outreach program.

5.1 Recommendations for Implementing Street-Level Green Roofs in the City of Boston

Recommendation #1: An outreach program should be created in the City of Boston with the purpose of raising public awareness about the problem of stormwater runoff through the use of street-level green roofs on bus stops.

Stormwater runoff is a problem of major concern for the City of Boston. As a result, an outreach program should be implemented to make the public aware of the causes and consequences of this environmental concern. Finding #1 and section 2.4 suggest that this can be done by implementing street-level green roofs and using them as educational tools. The interviews conducted with representatives from the PWD and Michigan State University as part of Objective 1 further indicate that green roofs can be used to promote stormwater runoff mitigation practices.

Recommendation #2: Standard bus stops should be selected for the installation of street-level green roofs to ensure that the project can be replicated at reduced cost.

While other street-level surfaces, such as information kiosks and subway entrances, can be considered for the installation of a green roof, we recommend focusing on bus stops since most of these structures in the City of Boston have a standard design according to the MBTA's guidelines. As a result, once a preliminary green roof is installed on the first bus stop, it becomes easier for subsequent projects to take place. As discussed in Finding #2 and #3 concerning the associated financial costs of such a project and the process of retrofitting a bus stop, our interviews with Roofmeadow indicated that choosing a standard bus stop for the implementation of a green roof has the potential to save money for future projects. By doing so, the project can be replicated without further engineering required, thus saving money in future projects as the designs for the structure and the specifications used for the first bus stop can be used on subsequent ones. In addition, this will greatly reduce the time needed for the project to be completed, as Roofmeadow indicated that the six to eight weeks that it takes to create the plans for the retrofitting of the green roof and the green roof designs will not be required.

After speaking with representatives from these previous projects, we conducted an observational study in the City of Boston to identify possible locations for the installation of street-level green roofs. As part of our study, we visited six bus stops throughout Boston, including two in the Downtown area, three in the Back Bay area, and one in Chinatown. We found that five of the six bus stops that we visited had a standard design according to the MBTA’s guidelines. These bus stops had a flat roof and very similar dimensions in terms of height, length, and depth. The last bus stop that we visited was shorter and narrower, and had a rounded roof. The full results from our observational study can be found in Appendix C: Observational Study Summaries.

Recommendation #3: Long-term plans for carrying out the project should be completed through working in conjunction with the owner and manager of the bus stops in the City of Boston, namely the MBTA, Wall USA, and JCDecaux.

This recommendation is based upon the interviews conducted with Roofmeadow and the Philadelphia Water Department as part of Objective 1. After speaking with representatives from these organizations, we discovered that they originally had plans to install green roofs on bus stops throughout the whole city. However, the PWD did not discuss the project with the department that manages the bus stops in the city. As a result, the project was put on hold since all bus stops in the city are being replaced. In order to avoid a similar situation from happening in Boston, we recommend that the stakeholders of the project work together with the MBTA, Wall USA, and JCDecaux to prepare long-term plans for the completion of this project. Besides making long-term plans, working with these companies will also provide different advertising opportunities such as the public service spaces provided by JCDecaux discussed in Finding #2.

Recommendation #4: Local engineers and contractors should be employed to design the structure and retrofit the bus stops in order to reduce the costs of the project.

Based on Finding #2 involving the financial expenses associated with a project of this nature, we were able to create a set of methods to lessen the costs of installing a green roof on a bus stop. Our research and interviews suggest that hiring a company with experience with the installation of green roofs on street-level surfaces, such as Roofmeadow, is not necessary for the successful execution of this project. In fact, Finding #5 indicates that local green roofing companies can be hired to complete the retrofitting of the bus stops. Furthermore, these local companies may be able to provide lower costs when compared to companies outside of the Boston area due to the fact that materials and workers won't need to be transported long distances. For this purpose, local companies should be surveyed to get an estimate of the costs of the project. Trevor Smith from the Ecological Landscaping Association stated that local engineers and contractors can be hired to retrofit the existing bus stops in Boston, likely at a much lower price.

Recommendation #5: The maintenance responsibilities of the green roofs should be relayed to volunteers or the city's landscaping associations.

Another method of reducing the costs of the project involves relaying the maintenance responsibilities of the green roofs, mostly watering for the first few growing season and occasional weeding, to volunteering groups in the city. For example, as discussed in Finding #3, Trevor Smith suggested that students and workers in need of experience could be offered the opportunity of being involved in the maintenance and installation of these green roofs. In addition, Greenovate Boston suggested that the Downtown Boston Business Improvement District, an organization involved with the enhancement of the area, could maintain the green roofs. Furthermore, as discussed in Finding #3, the Philadelphia Water Department enlisted the help of volunteers for the maintenance of the green roof installed near City Hall, a strategy that can be used in Boston to delegate the maintenance of the green roofs.

Recommendation #6: Advertisements should be used on bus stops where green roofs have been installed in order to fund subsequent green roofs.

Finding #3 indicates that funding for subsequent green roofs can be obtained by implementing a green premium for advertisements. Through the green premium, companies would pay an additional fee to advertise on bus stops where green roofs are installed. The extra funds that are collected from this program would then be used to pay for future implementations of this project.

5.2 Recommendations for the General Implementation of Street-Level Green Roofs as a Means for Educating the Public about Stormwater Runoff

Recommendation #7: Outreach materials, supplemented with the incorporation of social media, should be presented on the bus stops where the green roofs are installed to help raise public awareness about stormwater runoff and the benefits that green roofs provide.

Based on Finding #5, we recommend the creation of a public outreach campaign to accompany the installation of street-level green roofs. Specifically, we suggest incorporating an online website with detailed information about the problem of stormwater runoff and the best management practices available into the campaign, as suggested by representatives from the aforementioned organizations. This webpage could be integrated with existing efforts, such as the EPA's Soak Up the Rain website.

We also recommend creating accounts on social media sites, such as Facebook and Twitter, in order to reach a wider audience. As discussed in Finding #7, using these accounts will increase the amount of people influenced by the outreach campaign. In addition, as discussed in section 2.3, these accounts can be used to encourage the public to share pictures and information that they have learned from the street-level green roof program. By doing so, more people are likely to learn about the program and the chances for the creation of public awareness will increase.

Furthermore, we advise displaying posters with concise information about stormwater runoff and the street-level green roof program on every bus stop where green roofs are installed. As discussed in section 2.3, 2.4 and Finding #7, a picture showcasing how green roofs work should be included in these posters to make them more interesting and visually appealing. In addition, as suggested in Finding #7 and the interviews conducted with Michigan State

University, a QR code linking to the aforementioned website should be displayed on the posters so that the public can easily access the social media accounts of the project and obtain detailed information about stormwater runoff and the benefits that green roofs provide. A prototype of the possible design of this poster can be seen in Appendix D: Prototype of Informational Poster.

5.3 Recommendations for Future Research

Recommendation #8: Additional types of social media and online communities should be explored in order to make outreach programs of this nature accessible to the largest amount of people possible.

Based on section 2.3 and Finding #7, we identified Vine and YouTube videos to be very effective for bringing outreach campaigns to the public's attention. However, more research needs to be completed involving their use in public outreach campaigns focused on raising public awareness about environmental problems and creating a change in behavior. As such, the inclusion of these online communities in future outreach programs of this nature should be studied.

Recommendation #9: The success of environmental outreach programs involving the use of social media and online websites should be evaluated.

As indicated in Finding #8, we had a difficult time finding assessments about the success of the use of social media, online websites, and other modern outlets for public outreach as part of environmental outreach campaigns, which hindered our ability to systematically evaluate the effectiveness of these different outreach techniques. As a result, we had to invest a considerable amount of time investigating potential practices for creating an effective outreach program, which limited the scope of our project due to time constraints. By completing research on this topic, future projects of this nature will have a solid foundation from which to base their work, allowing them to focus their efforts on exploring the relevant topics in their field of study.

5.4 Summary

Stormwater runoff is a problem of great concern for urbanized cities, such as Boston, due to the vast consequences that it brings. As impervious surfaces in cities increase, rainwater cannot be infiltrated into the ground, making stormwater runoff a common occurrence (VanWoert, 2007). As a result, urban runoff may catch harmful particles on city surfaces originated from pollution from human activities, such as vehicle emissions and the use of fertilizers, which may result in the contamination of nearby bodies of water (California Department of Transportation, 2003). Furthermore, the increase of annual precipitation across the United States makes urban areas highly vulnerable to urban flooding and the associated economic damages.

In order to deal with stormwater runoff, cities can implement two basic stormwater management systems involving the use of either gray infrastructure or green infrastructure. Gray infrastructure is used to manage stormwater via the use of pipes and other impervious surfaces (University of Wisconsin, n.d). Through gray infrastructure, stormwater is redirected rather than infiltrated. In contrast, green infrastructure allows for the infiltration of rainwater into the ground through the implementation of pervious surfaces such as rain gardens, pervious pavements, and green roofs. Green infrastructure benefits the environment by reducing the pollution of aquatic ecosystems while also reducing the risk of urban flooding (EPA, 2013c).

Among the different types of green infrastructure, green roofs stand out due to their qualities for reducing the effects of stormwater runoff and providing an opportunity for public outreach. Green roofs can retain as much as 90% of the precipitation during summer months and 40% during winter months (Green Roofs for Healthy Cities, n.d.). Green roofs also provide a series of benefits over gray infrastructure such as the capture of pollutants, ground water infiltration, and the beautification of urban areas (EPA, 2013c). In addition, due to their versatility and aesthetic appeal, street-level green roofs can be installed in cities as part of public outreach campaigns to raise public awareness about stormwater runoff and encourage a change in behavior with respect to the implementation of green infrastructure.

Through the installation of street-level green roofs and the use of public outreach materials, the public may gain the opportunity of learning about stormwater runoff, its causes and consequences, and what they can do in order to reduce its effects and alleviate the burden of daily human activities on the environment. Even though small-scale projects such as the one proposed in this report will not result in a perceivable reduction of the effects of stormwater runoff in a short term, they serve as a stepping-stone for making the public aware about this environmental problem and the need for the City of Boston, and other cities in the greater metropolitan area, to take action in dealing with this problem.

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Appendix A: Interview Contact List

Organization / Company	Contact Information	Date of Contact	Was Interview Conducted?
Philadelphia Water Department	ledesmagrolltd@cdm.com 267.625.0589	October 3rd and 8th, 2013	Yes
Roofmeadow	info@roofmeadow.com 215.247.8784	September 23rd, 2013	Yes
Roofmeadow	info@roofmeadow.com 215.247.8784	October 10th, 2013	Yes
Onondaga County Department of Water Environment Protection	315.435.2260	October 7th, 10th, and 11th, 2013	No – Did not answer phone
Stanley Studios and Growers	512.445.0444	September 16th, 2013	Yes
Bus Roots	-	September 19th and 26th, 2013	Yes
Niagara Frontier Transportation Authority	716.855.7300	October 7th, 10th, and 11th, 2013	No – Did not answer phone
California Academy of Sciences	415.379.8000	September 16th, 23rd, 26th 2013	Yes- Did not get back to us
Hazel Landscaping and Edibles	-	September 23rd, 2013	Yes
Michigan State University	rowed@msu.edu 517.355.5191	September 23rd, 25th, and 26th, 2013	Yes
Michigan State University	westphal@msu.edu 517.355.5191	September 23rd, 25th, and 26th, 2013	No – Did not get back to us
Advanced Green Roof	810.516.0849	September 26th, 2013	Yes
Wall USA	617.757.8500	October 2nd and 3rd 2013	No – Did not answer phone
Massachusetts Bay Transportation Authority	617.222.3200	October 2nd and 3rd, 2013	Yes

Brasco International	800.893.3665	September 26th, 2013	Yes
JCDecaux	646.834.1200	October 2nd, 4th, and 7th, 2013	No – Did not answer phone
Recover Green Roofs	617-764-1310	October 3rd, 2013	Yes
Air Pollution Control Commission	617.635.2516	October 3rd and 8th, 2013	Yes
Greenovate Boston	617.635.3425	October 3rd, 2013	Yes

Appendix B: Interview Minutes

Boston Green Roof & Bus Stop Initiative
Meeting Minutes with Roofmeadow
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Lauren Mandel

Summary

Roofmeadow is a green roof design and installing company based out of Philadelphia. They are the company that designed and installed the green roof on a bus stop in Philadelphia. We spoke to Lauren Mandel, a project manager at Roofmeadow, and found out about the technical, financial, and public outreach aspects of their green roof bus stop project.

- Lauren emphasized how important it is to understand the organization of the public transit company. The reason for this is to install a green roof on a standard bus stop, and this project can be replicable.
- Roofmeadow wanted to replicate these green roofs across the city, however the project has been put on hold because the bus shelters are going to be reconstructed.
- She estimated the project cost around $6,000 total. The material and labor are inexpensive, the corrugated steel frame was the most expensive item.
- It took about 4 hours to install the new roof, she estimated that it would be quicker if there was a next time due to experience.
- She advised to run a gutter system by the back leg of the bus stop to deal with stormwater overflow.
- This roof in particular was at an angle.
- The project first had to be approved by the city’s engineering department, this included making sure the roof could hold snow.
- The roof requires minimal maintenance, they watered for the first growing period, not much after that.
- Volunteers from the Green City, Clean Waters program do the maintenance when required. The Green City, Clean Waters program is the one who did the public outreach part of the project/
- There was a sign on the glass on the bus stop for the purpose of public education, she did not think people noticed it all too much.
- This project was a gift to the city, in hopes that they would be able to be hired to put roofs up all over the city later.
- Future funding would be done by advertisers, a “Green Premium” program where companies pay a certain amount of money to be recognized as a “Green-Conscientious” Company and help fund the green roof.

We had a follow up with another representative from Roofmeadow

- We received an estimate that the green roof system would weight somewhere between 28 and 42 pounds/ square foot. This is calculated by the 4-6 inches of soil depth times 6.75 pounds.

- A pre-grown mat, which was used in this green roof, roughly costs around $4/square foot. It was an estimate that the cost of the project was around 10-12 thousand, a lot different from what Lauren told us.
- He estimated that the bus stop was probably around 10 feet long by 5 feet wide.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Philadelphia
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Tiffany Ledesma Groll – Philadelphia Water Department

Summary

The Philadelphia Water Department created the Green City, Clean Waters program. They were the organization who approached Roofmeadow for the installation of a green roof on a bus stop near City Hall in Philadelphia.

- The bus shelters are going to be changed out in the near future; this has put a halt to the project.
- She emphasized it is important to make long term plans with the owner/manager of the bus stop to avoid that sort of situation. In their case, the city transportation department owns the bus stop.
- Tiffany said it was necessary to look at every bus stop from a unique advertising perspective, in order to convince the advertisement company.
- Their hope is that companies with sustainability goals will want to advertise on bus stops
- They had a sign on the bus stop, it explained what the Philadelphia water Department is, what a green roof is, and suggestions for what the public can do to become greener.
- Their project got a large amount of attention in the media; they had a large launch event that helped gain a lot of publicity. The project even made it to become the cover of a Philadelphia magazine.
- A webpage was created for the Green City, Clean Waters program; they found that this was their “most visited” webpage once this project began.
- The bus stop is right across the street from the mayors and city officials offices, it’s hopeful that this will constantly remind them of the project.
- There were Facebook updates about the project, as well as blog posts.
- The sign was only kept up on the bus stop for a few months; the advertisement company didn’t want it blocking chances for new advertisements.
- There is no longer any maintenance; the first few months required watering.

Tiffany forwarded some of our questions to an engineer from the Philadelphia green roof project. The following is a Q & A with their engineer.

General Questions

What were the incentives behind installing a green roof on a bus stop?

- Inspiring residents of Philadelphia to install green stormwater infrastructure on their properties and in their communities

Why did you decide to install the green roof on a bus stop? Did you consider any other street-level surfaces?

- Bus stop is visible, unlike tall buildings.

Are there any design plans or specifications for the green roof installed in front of City Hall that we could study as reference?

- Ask Roofmeadow. They did the work pro-bono. Feel free to let Melissa Muroff know that I sent you.

Most online reports about this project state that the bus stop retrofitted near City Hall was the first of many; have any other green roofs been installed on bus stops in the city? If not, are there any plans for the future installation of street-level green roofs?

- We would like to do more after the city replaces the current ones.

What would you say were the key lessons learned during the execution of this project? We are looking to do a similar project in Boston, so we are very interested in any suggestions that you may have.

- See the above from matt.

<u>Financial and Technical Questions</u>

How was funding for the project achieved? Were advertisements used to fund future green roofs?

- PWD partially paid for it, along with a coastal nonpoint pollution program grant from NOAA (administered through the Pennsylvania Department of Environmental Protection).

What was the approximate cost of the green roof installed?

- Off the top of my head, I believe the total was about $10,000, but I would have to verify.

What type of maintenance does the green roof require? What is the approximate cost of maintenance?

- Minimal. Hardly anything.

How well have the green roofs endured winters and long periods without precipitation?

- Very well.

How was the bus stop selected for this project? What characteristics were most important in the selection process?

- Highly visible location.

Were any environmental groups involved in the project?

- Mayor's office of sustainability.

<u>Public Outreach Questions</u>

What is the public opinion about the project?

- Lots of positive press. People seem to like it. There are always naysayers though.

Was the installation of green roofs in these sites accompanied by an education campaign?

- The launch was co-hosted with the mayor's office of sustainability. They were promoting their sustainability plan (annual report). This was helpful in getting more people to our event. The education took place at the event and in the media and on the signage.

What outreach techniques were used?

- Web page, signage, press, Facebook, blog, interviews, etc.

Were there any outreach materials installed on the bus stop itself?

- Signage

Was social media involved in the project?

- Facebook and blog

What were the results of the public outreach program? Was the success of the campaign measured?

- Yes, lots of press and lots of web hits.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Michigan State University
September 25rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Brad Rowe

Summary
Brad Rowe is a professor at Michigan State University in the Green Roof Research Department. Their program at MSU is working on installing a green roof on a bus stop on campus, for the purpose of raising public awareness.

- The CATA (the equivalent of our MBTA) is the one that owns the bus stop that is located on campus.
- The selected bus stop is nearby the football field, it was chosen because of the amount of people that will walk by it on a regular basis.
- The bus stop by the football stadium is curved, there is a second one that they plan on making a roof for as well. This roof will be at a 1% slope.
- The retrofitting company will build trays, and put retainers around the trays. The company that is charge of this is Brasco International. We were put in contact with Sean Loewe, who is currently working on the design on this project.
- Advanced Green Roofs will install the green roof on the bus stop, we were put in contact with a former MSU graduate student is also working on this project, Erik Cronk.
- It is their plan to put up Quick Response codes that provide information about green roofs and their department.
- The funding will be through the campus sustainability program, they will pay for the retrofitting of the bus stop. The green roof itself will not cost much.
- For maintenance, they will need watering to start out, and they do not expect to require maintenance after.
- The soil will be 6” deep to hold water, but this could promote weeds.
- The vegetation used will be sedum and allium, and considering experimenting with others.
- Professor Rowe hopes that this will be the start of a large project, he hopes they will start with one roof, and potentially more depending on the results.
- He stressed the point that public awareness is important because “People will not consider a behavior change if they don’t know what the issue is first.”

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Michigan State University
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Sean Loewe – Brasco International

Summary

Sean Loewe works for Brasco International, the company that is retrofitting the bus stop for the Michigan State University green roof project. We were put in contact with Sean by Professor Brad Rowe of Michigan State.

- Brasco has done similar work in the past to this, they usually construct bus stops, and they made special bus stops that could support green roofs for Buffalo, NY.
- Claims you "can retrofit almost any bus stop, just need to know what size to determine what mats to use.
- The current bus stop can support the necessary snow requirements at the moment, but needs to be retrofitted to support the green roof.
- He gave us a brief overview of the process of retrofitting a bus stop. You basically start the roof from scratch.
    - A barrel shaped tube every two feet is first installed, this is about 1" x 2"
    - Next is a tray around the roof, 3-6", with an extending lip.
    - They change the polycarbonate to aluminum sheet, much stronger material.
    - It is about a 6-8 week process, a 5' x 10' roof could cost $3000-$4000, and the price can go up exponentially. He said he can "make a $5000 budget work"
- The critical costs to consider are the engineering, the materials, the coating, the installation, the cost of packaging the bus stop, and the cost of shipping it.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Michigan State University
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Erik Cronk – Advanced Green Roof

Summary

Erik Cronk works for Advanced Green Roof, the company that is designing and installing the green roof on the bus stop for the Michigan State University green roof project. We were put in contact with Erik by Professor Brad Rowe of Michigan State.

- Erik told us that this particular project is going to involve a tray system green roof.
- The 1.8” x 1.8” plastic trays are filled with pre grown medium and fully grown plants, about 2.5 sq. ft. / tray.
- The trays sit on the roof structure, provide drainage.
- The trays cost $16/square foot, there will be 25 trays on this project.
- This project is flat, there may be a future curved barrel styled roof, which will require a custom design.
- Each bus stop is roughly 50 square feet.
- A slip sheet is used for waterproofing for green roofs, but this may not be required on a bus stop.
- The trays are easy to install, the plants are already grown. The modular is easy to remove and replace sections.
- Less maintenance is required because the plants are fully grown, there is a less chance of weeds, and hardly any watering is required due to the fact that sedum is used.
- Maintenance could be weeding (if needed) once a year on a bus stop.
- A standard tray weighs about 30 lbs. /sqft with 4” of soil.
- The tray system normally has a biodegradable side wall, and they can do a carpet system as well.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Austin & Growers Organization
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Lauren Stanley

Summary

Lauren Stanley is a co-founder of the Growers Organization, a landscaping company based out of Austin, Texas. Her company was involved in the construction of a brand new bus stop, and the installation of a green roof on top of it.

- There were multiple companies involved, they were approached by the ACDDC who do the design work for community development.
- They also worked with Stanley Studio, CapMetro Buses, and Green Doors.
- Lauren said that the installation of this green roof could hopefully create potential for more to come, it was the hope that this green roof could inspire people.
- There was no outreach or social media involved in the project, they were however featured in the Austin Newsletter.
- She claimed it was very hard to measure the successfulness of the project.
- The total cost of the entire project was around $20,000. Capital Metro normally pays $7,000 for a bus stop, that offer was matched. However the green roof itself was a minimal cost.
- The soil cost about $100-$200.
- The creation of the bus stop required a welding inspection, as well as double extra strength pipe. There is no membrane, they instead use a steel plate and epoxy based paint.
- It took about a half day to install the green roof, then they continued planting when the weather was more comfortable
- The maintenance contractor for a nearby apartment complex waters the bus stop once per month.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – Bus Roots
September 23rd 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Phone interview with Marco Castro

Summary

Marco Castro installed a green roof on a bus as part of his graduate thesis at New York University. He prototyped the installation of green roofs in other moving vehicles such as trucks and school buses.

- The reason Marco Castro started this project was to make cities and other spaces more interactive, he feels that cities have a responsibility to reduce stormwater runoff.
- He has also done green roof work done at the Brooklyn Navy yard
- Believes "you can turn everything into a plant surface, bus roof tops are not used, so why not create a green roof?"
- Currently it is difficult to access any green roofs in New York City, not many are there for the public.
- He has done fundraising through an online cloud source, where people can donate any amount of money to support him.
- He installed the green roof himself, it took him around 3 days.
- He thought it was important to design the green roof to require the lowest amount of maintenance possible.
- He used his own Facebook and Twitter pages to post about the project, and said he had some success and good feedback.
- There was no intervention with the city, he received advice from the busing company in New York.
- Funding for the project has been the largest obstacle.

Boston Green Roof & Bus Stop Initiative
Meeting Minutes – City of Boston
October 8th, 2013
Present: Oliver Sullivan, Kevin Payne, Victor Andreoni
Email correspondence with Haidee Janak – Air Pollution Control Commission

Summary

Haidee Janak works for the City of Boston, and is a program manager in the Environmental Department. After our observational study, we came across an advertisement for the Air Pollution Control Commission on a bus stop, for the purpose of raising public awareness about leaving cars idling.

- Haidee spoke about some ongoing efforts that are being carried out in Boston right now, such as Greenovate Boston.
- For Idle-Free Boston, Haidee spoke with JCDecaux, the company that owns the bus shelters.
- JC Decaux has a contract with the city to allocate 15% of the available advertisement spaces for public service announcements for free.
- JC Decaux gave Idle-Free Boston the specs for sizing and material for the advertisement, then the APCC put out a bid to have the posters made.
- 100 posters were made, for $36 each, then the vendor sent them to JC Decaux, who put the advertisements up in the unsold locations.

Appendix C: Observational Study Summaries

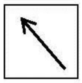
1. State Street Bus Stop

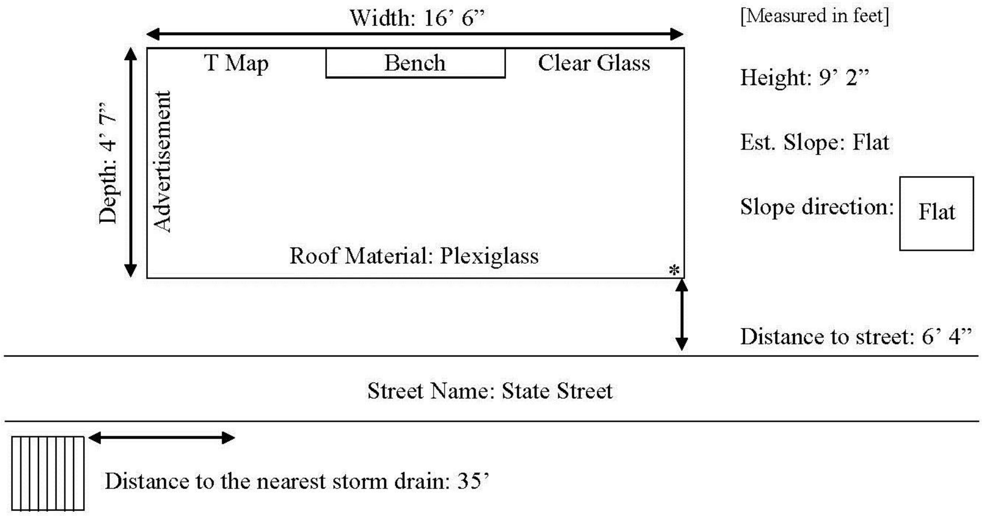
Location: State Street

Latitude: 42° 21’ 32” N

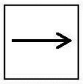
Longitude: 71° 3’ 26” W

North Arrow:





Direction from center of Bus stop:



Down Spout (Y/N – possible location): N, possible location at *

Seating: (Y/N): Y, indicated above

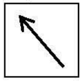
Warmer or cooler than usual (subjective estimation): Same temperature; protects from wind

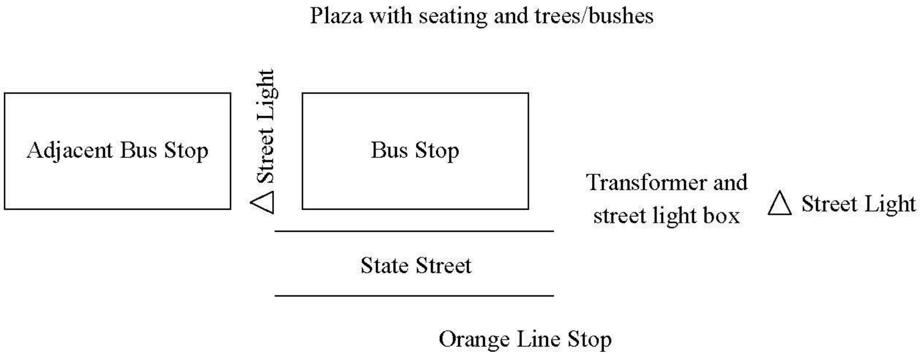
Advertisement Company: JCDecaux

Pros:	**Cons:**
• Trolley stop & on Duck Boat route • High pedestrian traffic • Hubway bike station nearby • Tourist spot • On the Freedom Train • Many buildings around so people can look down at it • Stop on inclined street	• Some greenery in nearby plaza • May be expensive to put up information about the green roof • No MBTA riders in the amount of time that we observed the stop

Time spent observing bus stop (target of 10 minutes):
9/27/2013, 1:17 P.M. – 1:27 P.M. →10 min 25 sec

Sketch of nearby area:

North Arrow: 



Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): Y

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):
N, roof is flat

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study: 10, waiting for trolley

Total number of people getting off of bus at station observed during study: 0

Total number of people visiting nearby public spaces observed during study:
20 in plaza, 500 + pedestrians

Nearby T Station (Y/N – station name): Y, Orange Line

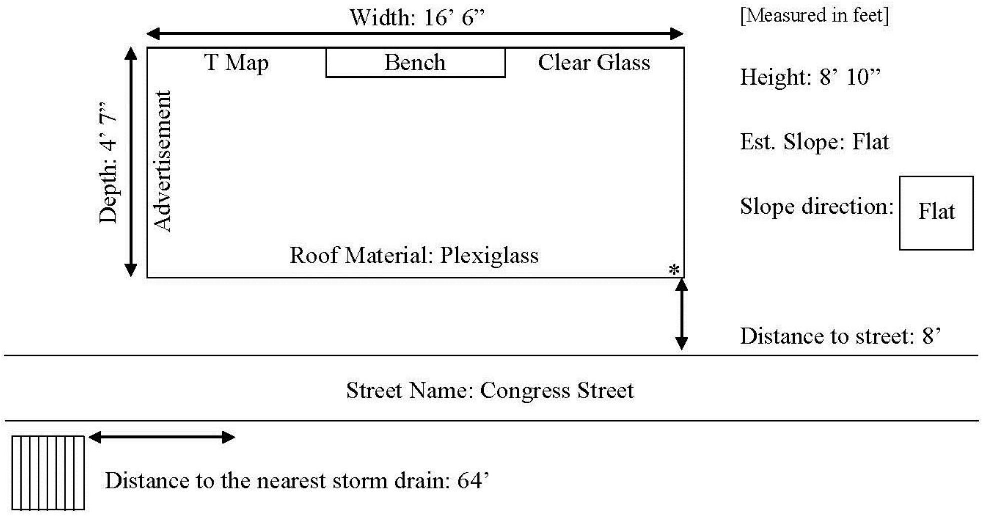
Total number of people exiting/entering nearby T Station observed during study: 21

2. Congress Street Bus Stop

Location: Congress Street

Latitude: 42° 21’ 40” N
Longitude: 71° 3’ 28” W

North Arrow: →



[Measured in feet]

Height: 8’ 10”

Est. Slope: Flat

Slope direction: Flat

Distance to street: 8’

Distance to the nearest storm drain: 64’

Direction from center of Bus stop: →

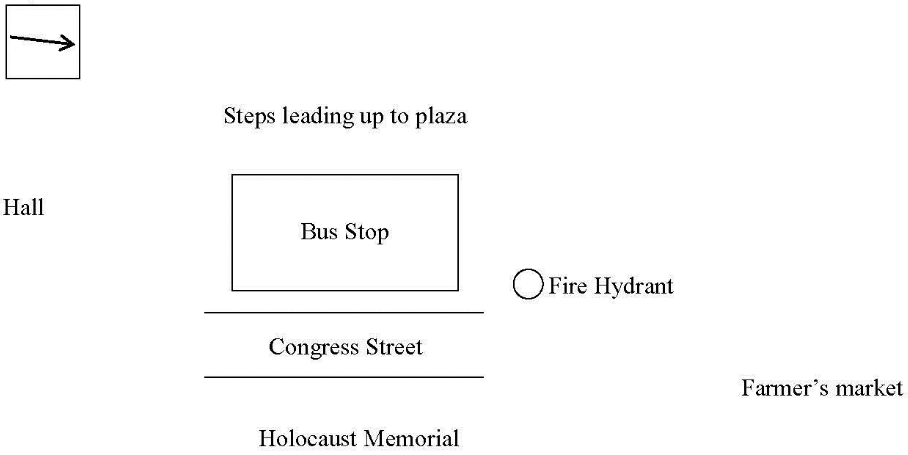
Down Spout (Y/N – possible location): N, possible location at *
Seating: (Y/N): Y, indicated above
Warmer or cooler than usual (subjective estimation): Warmer from direct sunlight
Advertisement Company: JCDecaux

Pros:	**Cons:**
• Some MBTA bus activity • Farmers market nearby • Free newspaper stand next to shelter • Restaurants across the street • Holocaust Memorial across the street • Plaza in back of bus stop	• Not as heavily trafficked as other Downtown bus stops • Trees nearby

Time spent observing bus stop (target of 10 minutes):
9/27/2013, 2:01 P.M. – 2:11 P.M. →10 min 52 sec

Sketch of nearby area:

North Arrow:



Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): Y

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):
N, roof is flat

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study: 0

Total number of people getting off of bus at station observed during study: 4

Total number of people visiting nearby public spaces observed during study: 245

Nearby T Station (Y/N – station name): None nearby

Total number of people exiting/entering nearby T Station observed during study: N/A

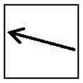
3. Massachusetts Avenue (East) Bus Stop

Location: Massachusetts Ave. & Commonwealth (East)

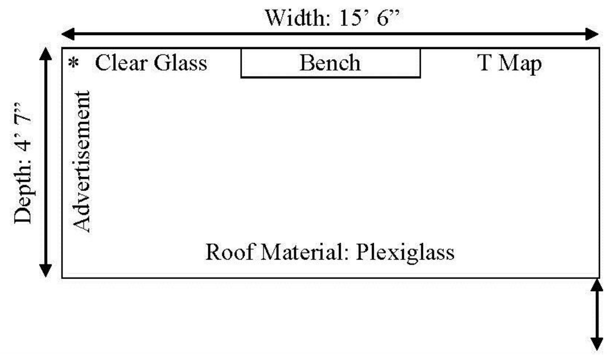
Latitude: 42° 20’ 56” N

Longitude: 71° 5’ 19” W

North Arrow:



[Measured in feet]



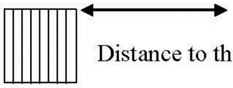
Height: 9’

Est. Slope: Flat

Slope direction: Flat

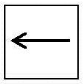
Distance to street: 8’ 9”

Street Name: Massachusetts Avenue



Distance to the nearest storm drain: 214’

Direction from center of Bus stop:



Down Spout (Y/N – possible location): N, possible location at *

Seating: (Y/N): Y, indicated above

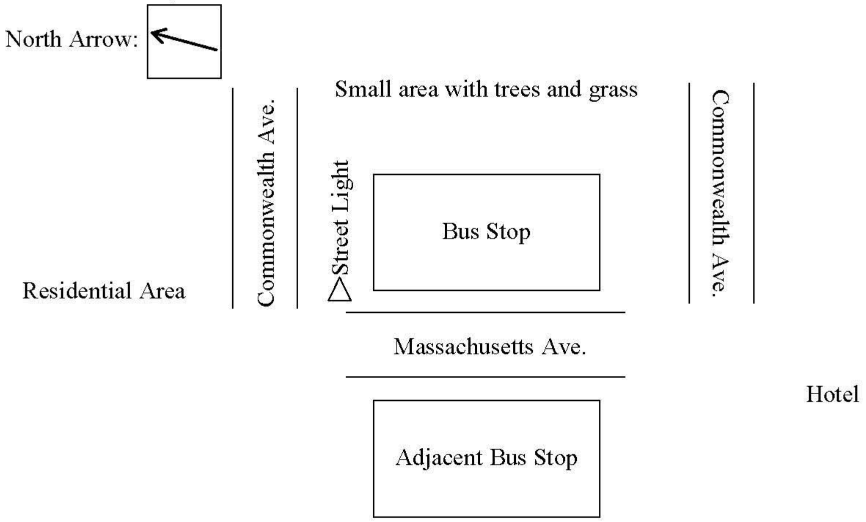
Warmer or cooler than usual (subjective estimation): Same temperature; no direct sun at the time

Advertisement Company: JCDecaux

Pros:	**Cons:**
• A lot of car traffic (CO_2 sequestration) • On bus route 1 (busy) • Near another stop across the street • High bike traffic • One trolley came by • On the MIT shuttle route • Near a residential area and hotel so people can look down at it • The downspout can lead to an area with grass behind the stop	• Not a lot of pedestrian traffic compared to others in the area • Trees behind stop and to the sides

Time spent observing bus stop (target of 10 minutes):
10/1/2013, 2:08 P.M. – 2:18 P.M. →10 min 5 sec

Sketch of nearby area:



Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): Y

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):
N, roof is flat

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study:
3; 1 got on the bus, 2 left before a bus came

Total number of people getting off of bus at station observed during study: 0

Total number of people visiting nearby public spaces observed during study: 38

Nearby T Station (Y/N – station name): Y, Hynes Convention Center Station

Total number of people exiting/entering nearby T Station observed during study:
Not close enough to be within viewable distance of bus stop

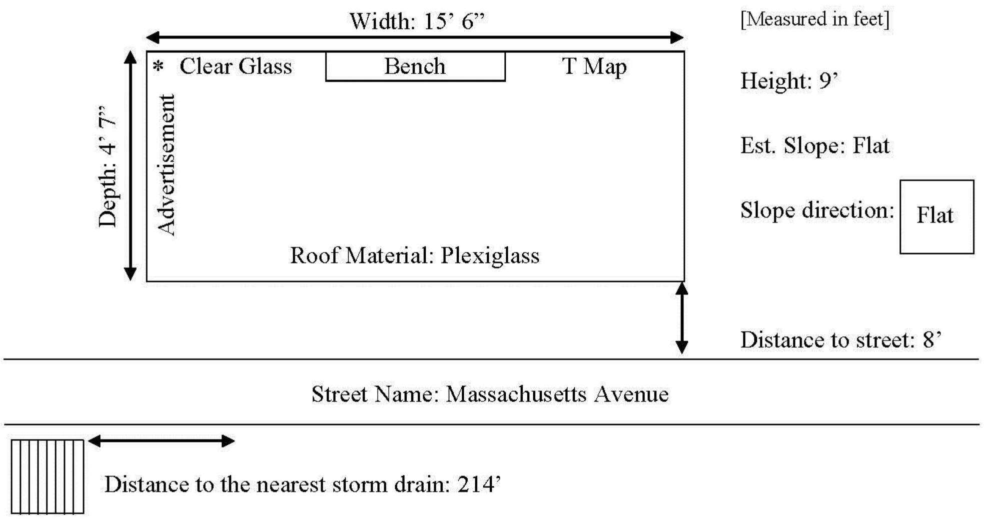
4. Massachusetts Avenue (West) Bus Stop

Location: Massachusetts Ave. & Commonwealth (West)

Latitude: 42° 20’ 60” N

Longitude: 71° 5’ 38” W

North Arrow: ↘



Width: 15’ 6”

[Measured in feet]

Depth: 4’ 7”

Height: 9’

Est. Slope: Flat

Slope direction: Flat

Roof Material: Plexiglass

Distance to street: 8’

Street Name: Massachusetts Avenue

Distance to the nearest storm drain: 214’

Direction from center of Bus stop: →

Down Spout (Y/N – possible location): N, possible location at *

Seating: (Y/N): Y, indicated above

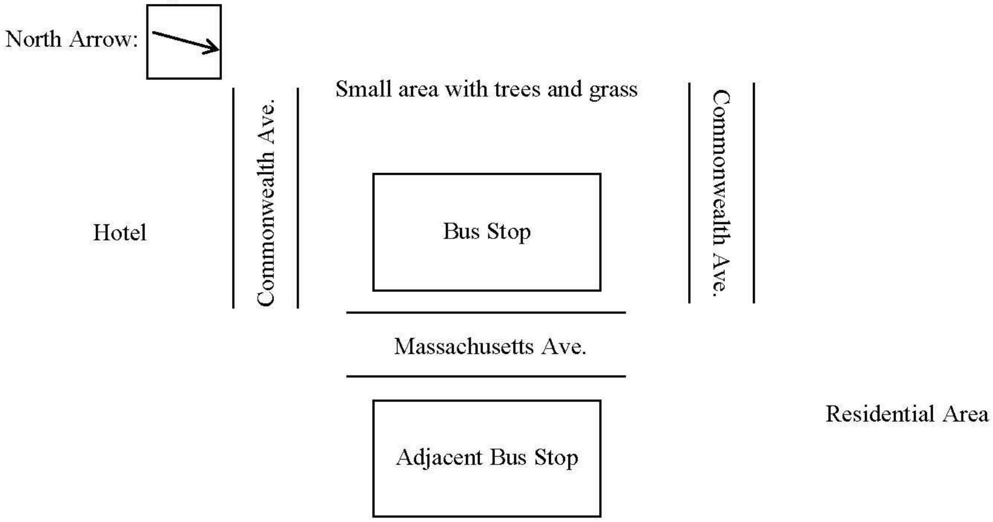
Warmer or cooler than usual (subjective estimation): Same temperature; no direct sun at the time

Advertisement Company: JCDecaux

Pros:	**Cons:**
• A lot of car traffic (CO_2 sequestration) • On bus route 1 (busy) • Near another stop across the street • High bike traffic • Near a residential area and hotel so people can look down at it • The downspout can lead to an area with grass behind the stop	• Not a lot of pedestrian traffic compared to others in the area • Trees behind stop and to the sides

Time spent observing bus stop (target of 10 minutes):
10/1/2013, 2:21 P.M. – 2:31 P.M. →10 min 0 sec

Sketch of nearby area:



Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): Y

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):
N, roof is flat

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study: 0

Total number of people getting off of bus at station observed during study: 0

Total number of people visiting nearby public spaces observed during study: 26

Nearby T Station (Y/N – station name): Y, Hynes Convention Center Station

Total number of people exiting/entering nearby T Station observed during study:
Not close enough to be within viewable distance of bus stop

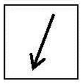
5. Boylston Street Bus Stop

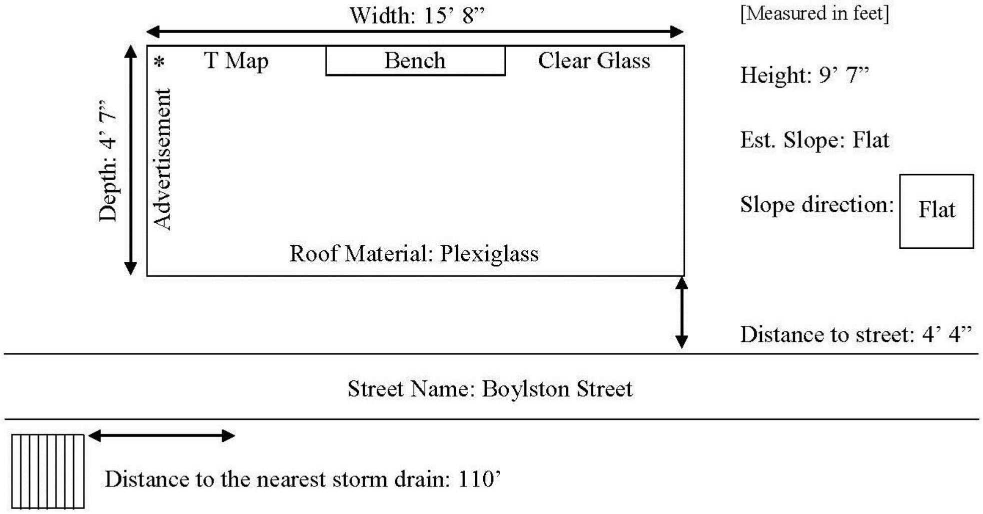
Location: Boylston Street in front of Berklee College of Music

Latitude: 42° 20’ 50” N

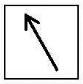
Longitude: 71° 5’ 13” W

North Arrow:





Direction from center of Bus stop:



Down Spout (Y/N – possible location): N, possible location at *

Seating: (Y/N): Y, indicated above

Warmer or cooler than usual (subjective estimation): Warmer from direct sunlight

Advertisement Company: JCDecaux

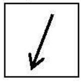
Pros:	**Cons:**
• Three times more pedestrians than other stops in the area • Near Berklee College of Music • Slope near the bus stop to lead excess runoff to drain • On Boylston Street and near Massachusetts Ave. (busy area)	• Not on a direct sidewalk (on an island in the road) • Trash dumpsters nearby

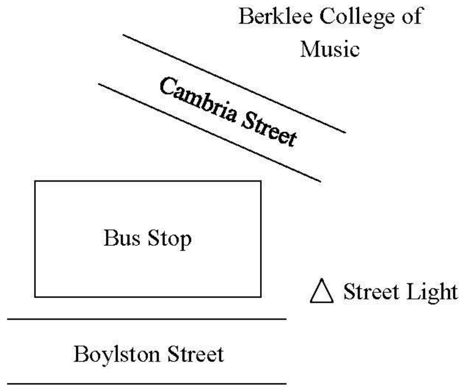
Time spent observing bus stop (target of 10 minutes):

10/1/2013, 2:45 P.M. – 2:55 P.M. →10 min 0 sec

Sketch of nearby area:

North Arrow:





Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): Y

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):

N, roof is flat

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study: 1

Total number of people getting off of bus at station observed during study: 0

Total number of people visiting nearby public spaces observed during study: 84

Nearby T Station (Y/N – station name): Y, Hynes Convention Center Station

Total number of people exiting/entering nearby T Station observed during study:

Not close enough to be within viewable distance of bus stop

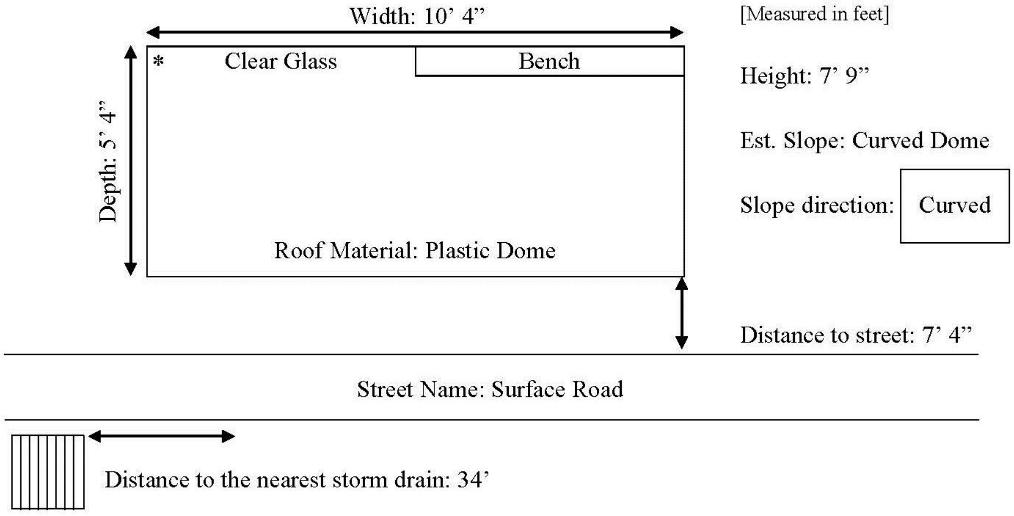
6. Surface Road (West) Bus Stop

Location: Surface Road (Near Chinatown)

Latitude: 42° 21’ 2” N

Longitude: 71° 3’ 35” W

North Arrow: ↗



[Measured in feet]

Height: 7’ 9”

Est. Slope: Curved Dome

Slope direction: Curved

Distance to street: 7’ 4”

Distance to the nearest storm drain: 34’

Direction from center of Bus stop: ←

Down Spout (Y/N – possible location): N, possible location at *

Seating: (Y/N): Y, indicated above

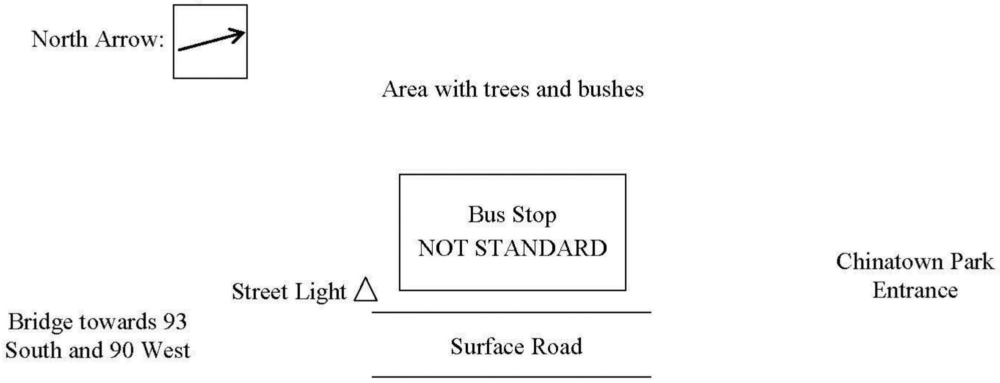
Warmer or cooler than usual (subjective estimation): Same temperature; no direct sun at the time

Advertisement Company: JCDecaux

Pros:	**Cons:**
• A lot of car traffic (CO_2 sequestration) • A lot of people waiting for the bus • Near Chinatown Park • Near South Station • The downspout can lead to an area with grass behind the stop	• Not a standard bus stop • Has a curved roof • Not as much pedestrian traffic compared to others in the area • Trees and bushes behind stop and to the sides

Time spent observing bus stop (target of 10 minutes):
10/1/2013, 3:53 P.M. – 4:03 P.M. →10 min 20 sec

Sketch of nearby area:



Technical Aspects:

Is the bus stop a standard design according to the MBTA's guidelines (Y/N): N

Is there something on the roof of the stop that would hinder installation (Y/N - Describe):
Y, the roof is curved

Outreach Aspects (Potential number of people targeted by green roofs)

Total number of people waiting for bus observed during study: 7; 5 got on the bus

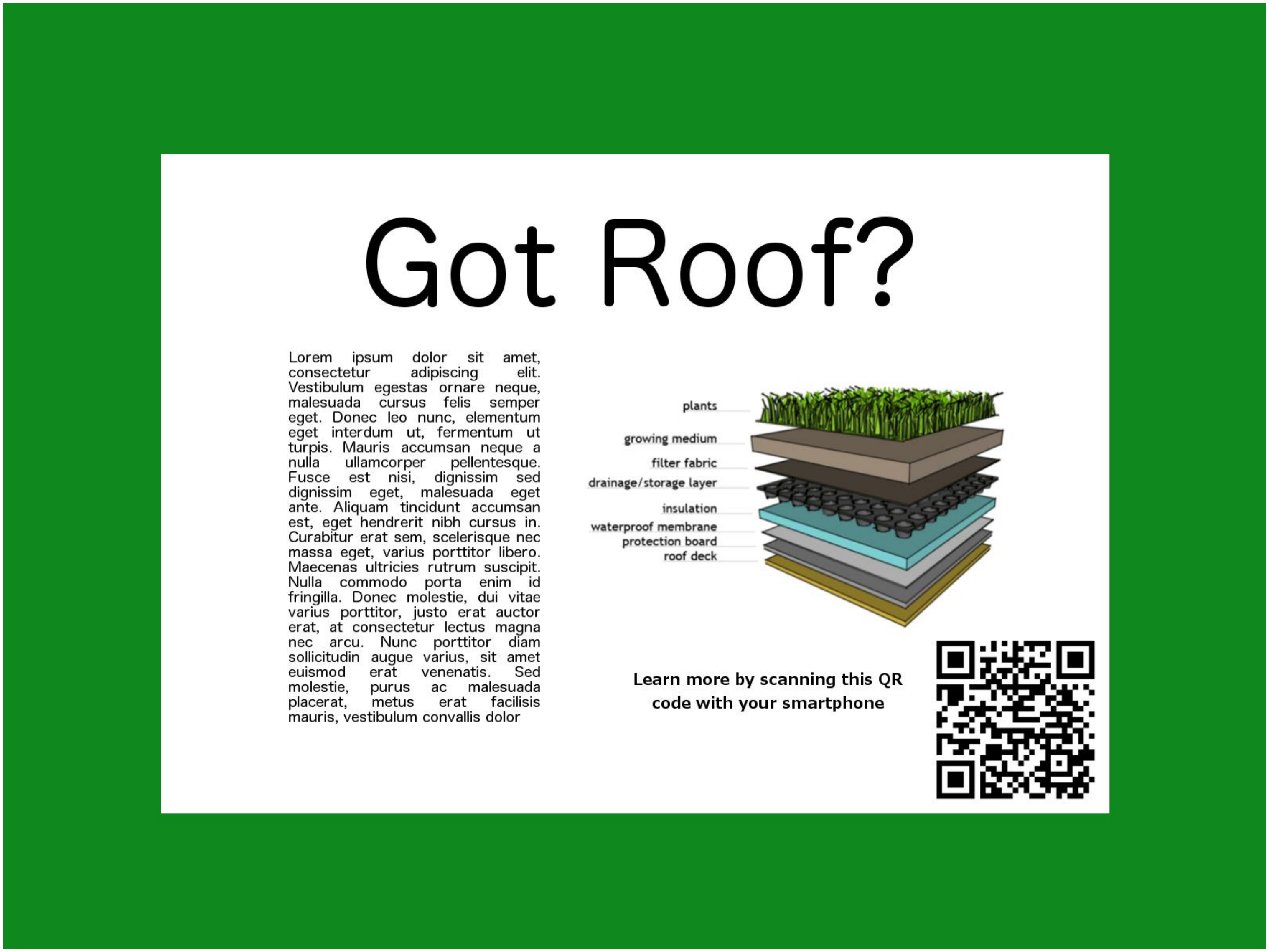
Total number of people getting off of bus at station observed during study: 0

Total number of people visiting nearby public spaces observed during study: 62

Nearby T Station (Y/N – station name): Y, South Station

Total number of people exiting/entering nearby T Station observed during study:
Not close enough to be within viewable distance of bus stop

Appendix D: Prototype of Informational Poster



Got Roof?

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Vestibulum egestas ornare neque, malesuada cursus felis semper eget. Donec leo nunc, elementum eget interdum ut, fermentum ut turpis. Mauris accumsan neque a nulla ullamcorper pellentesque. Fusce est nisi, dignissim sed dignissim eget, malesuada eget ante. Aliquam tincidunt accumsan est, eget hendrerit nibh cursus in. Curabitur erat sem, scelerisque nec massa eget, varius porttitor libero. Maecenas ultricies rutrum suscipit. Nulla commodo porta enim id fringilla. Donec molestie, dui vitae varius porttitor, justo erat auctor erat, at consectetur lectus magna nec arcu. Nunc porttitor diam sollicitudin augue varius, sit amet euismod erat venenatis. Sed molestie, purus ac malesuada placerat, metus erat facilisis mauris, vestibulum convallis dolor

Learn more by scanning this QR code with your smartphone

Appendix E: Summative Team Assessment

Through completing this project, we have learned a lot about ourselves and are able to reflect on our team process. We were able to successfully monitor ourselves such that we worked effectively together as a team. For example, we successfully designed roles for each team member based on their strengths during our interviews. Oliver led the team through this process, calling each organization or company and conducting the interviews. He was able to effectively communicate and portray the team's ideas and opinions. During these interviews, Kevin and Victor took detailed notes on the responses from each interviewee. Furthermore, we evaluated where we were on a daily basis to ensure that our tasks were completed. This was an effective strategy and we are glad to have done it since the beginning of the project. Based on the experience gained from this project, we will improve on estimating how long each task will take to complete in future projects such that we can better plan our schedule.

When the team process was not as effective as it could be, we evaluated ourselves and found ways to improve. For example, during our first assessment, we realized that we were not being as effective as we could have been since we were writing our drafts together instead of splitting up the work. Based on this evaluation, we created an effective method to complete the writing associated with our report. When writing content for each chapter of the report, we split up each section so that each team member wrote what they felt they could most effectively complete. Before presenting our assignment to our advisor and after receiving feedback, we met as a group to edit the document and assess our writing. During the process of editing, we were open and respectful to each team member's input and ideas, allowing us to create writing that reflected all of our opinions. As suggested by our advisor, we also went to a writing tutor when we faced difficulty in organizing our paragraph structure. We also found where our individual weaknesses were and improved them. Victor shared the leadership role with others in the group, allowing Kevin to become more vocal and lead team meetings. Oliver also spoke up more and gave additional input during writing sessions. Furthermore, we were able to take our advisor's input well. When receiving feedback and comments for each chapter draft, we evaluated what was said and determined how to best incorporate the suggested changes. After receiving an email from our advisor, we also discovered that we needed to be more open about our project and share the details associated with our research and completion of objectives, even if some aspects might not be finalized. Thanks to our IQP experience, we feel that we have developed social and technical abilities that will help us in future projects and throughout our careers.