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Inventory and Analysis of the Downtown Boston Parking Freeze

An Interactive Qualifying Project (IQP) Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the Requirements for the Degree of Bachelor of Science
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Submitted to:

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Causeway Street entrance to the North End Garage (Ian Smith, 2016).

Sponsoring Agencies:
City of Boston
Boston Environment Department
Boston Air Pollution Control Commission

Boston Project Center
Worcester Polytechnic Institute

Abstract

Millions of Americans live in urban areas where air pollution presents serious health concerns. Under the regulations of the Clean Air Act, the City of Boston established a plan to reduce local air pollution by implementing a parking freeze that capped the number of public off-street parking spaces in the downtown area. The goal of our project was to assist the Boston Environment Department improve parking freeze regulations designed to combat vehicular emissions while supporting the transportation needs of businesses, residents and commuters. Our team completed a comprehensive inventory of the downtown freeze zone, created a geographic information system layer of the collected data on BostonMaps and proposed a set of recommendations for parking freeze and data management strategies.

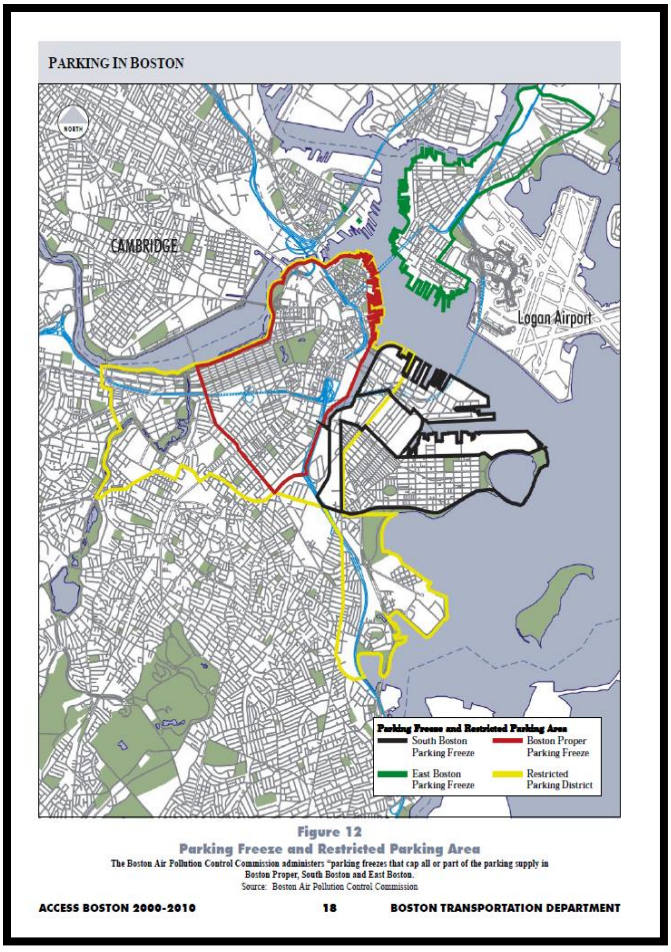
Acknowledgements

We would like to extend our sincerest gratitude to those who helped us complete this project. Many thanks go to Ms. Haidee Janak, Mr. Carl Spector and the entire staff at the Boston Environment Department (BED) for providing invaluable guidance during our seven weeks at City Hall. We would also like to thank Mr. William Toussaint of the Department of Innovation and Technology (DoIT), who generously assisted us with BostonMaps. Thank you to A Better City and Nelson/Nygaard for providing key information for our investigation. The team would also like to thank the parking attendants who participated in our inventory of the downtown freeze zone. Finally, thank you to our advisors, Professor Melissa Belz and Professor Seth Tuler, for providing tremendous direction, feedback, and support throughout our project.

Executive Summary

Millions of Americans live in urban areas where air pollution presents serious health concerns (World Health Organization, 2010). Urban smog irritates the eyes, nose, and throat while particle pollution induces wheezing, coughing, and breathing difficulties (MassDEP, 2015a). Toxic pollutants such as ground-level ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide make existing heart and lung problems worse (World Health Organization, 2010). In a 2008 case study of the Southern California metropolitan area, 29% of deaths resulting from coronary heart disease were attributable to near-roadway air pollution within cities (Ghosh et al., 2016). Furthermore, urban air pollution poses a variety of environmental threats including acid rain, eutrophication, haze, crop damage, and climate change (MassDEP, 2015a).

Under the regulations of the Clean Air Act, the City of Boston established parking freeze zones with the aim of decreasing greenhouse gas emissions via the reduction of vehicle miles traveled (VMT) within the city. The Boston Air Pollution Control Commission (BAPCC), which is part of the Boston Environment Department (BED), was created to manage a parking freeze program by reviewing and maintaining permit applications. The parking freeze also works in conjunction with the Transportation Access Plan Agreements (TAPAs) to regulate the number parking spaces being created in new developments. There are three parking freeze zones in downtown Boston, as shown in the Figure. However, due to parcel-level city redevelopment and unreported changes in parking facilities, the BAPCC has lost track of the number of spaces available within the downtown freeze zone (outlined in red). The City of Boston is conducting its first-ever Parking Policy Study that will reassess the viability of the parking freeze as an inhibitor of VMT within the zone.



The goal of our project was to assist the Boston Air Pollution Control Commission in improving parking freeze regulations that must balance the transportation needs of businesses, residents and commuters. Our project team accomplished this goal by:

1. Creating a GIS database layer for inventory data storage and analysis purposes.
2. Inventorying off-street parking spaces in the downtown parking freeze zone to understand the reality of parking facility practices.
3. Analyzing trends in parking facility management in relation to VMT and urban space use.

Methodology

Before the inventory process, we developed a system to store and represent the data collected about each parking facility. The system consisted of a GIS layer with the locations of parking facilities and information we collected about them. This GIS layer can be

opened on both BostonMaps and the desktop platform, ArcMap. By uploading the GIS layer to BostonMaps, the layer can be accessed with a cellphone application called Collector. Collector enabled us to collect and update data in the field while logging our locations.

To gather information about each parking facility we talked to the attendants. The information we recorded included the number of total existing spaces, numbers of each type of parking space, number of electrical car and bicycle parking and similar features (see Appendix A for details). We also took notes of undocumented parking facilities we found. For parking facilities that we could not access or were not able to collect data, we recorded contact information and reached out to their managers.

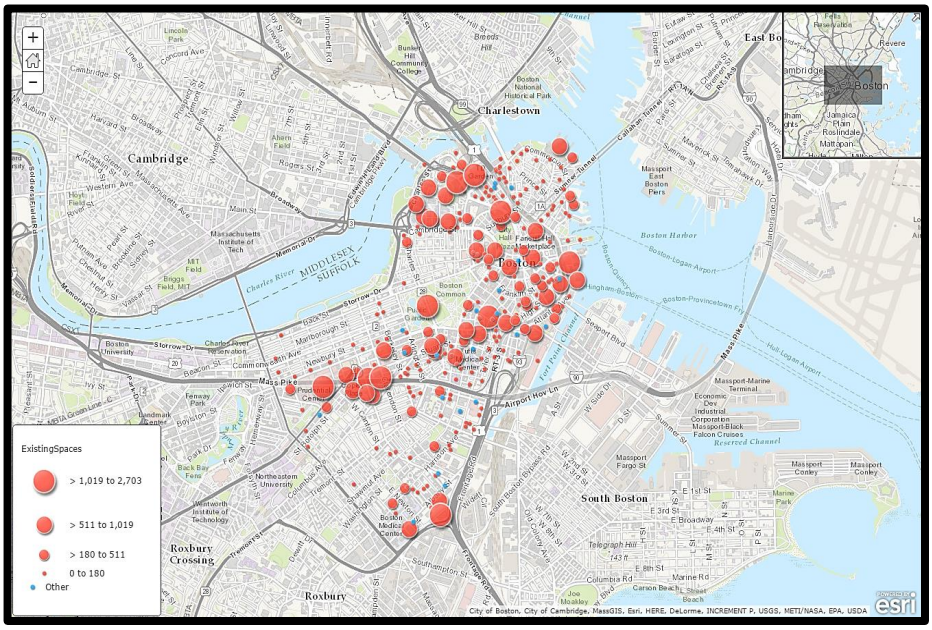
After completing the inventory, we examined the distribution of parking facilities relating to city development and compared the collected data with old permit records. Additionally, we considered multiple data sets related to Boston downtown neighborhoods along with our inventory data to identify the effects of urban development on parking management. We exported our data set from BostonMaps to provide the BED with an updated parking freeze permit database in the form of an Excel spreadsheet.

Findings

From our field observations and an analysis of the parking freeze inventory data, we uncovered the complications of maintaining the downtown parking freeze.

Discrepancies in the Parking Freeze Permit Records

A set of findings focused on the multiple inaccuracies in the parking freeze permit records. First, during the inventory process, we identified ten facilities not listed in the parking freeze permit records. For most of the facilities without permit data, their locations were nearby facilities that were listed in the parking freeze permit records but could not be found. Second, we found that subtle redevelopments amongst parcel tenants and construction projects shifted some parking facilities several blocks away from their permitted addresses. Third, most of the garages in the downtown freeze zone contain fewer parking spaces than their permitted capacity. According to our data, 78% of the downtown neighborhoods (7 of 9) contained fewer existing garage spaces than permitted garage spaces, the exceptions being in the West End and the Leather District (which contained only 2 facilities, both garages). Fourth, our data showed that a majority of the open air lots (OALs) in the Back Bay, Bay Village, and North End neighborhoods contained more parking spaces than their permits allow. During our inventory, the counts provided by some OAL attendants were noticeably lower than the number of vehicles parked at the time of our



visit. On the other hand, most garage facilities were operated by professional parking management companies with capacity data immediately available upon request.

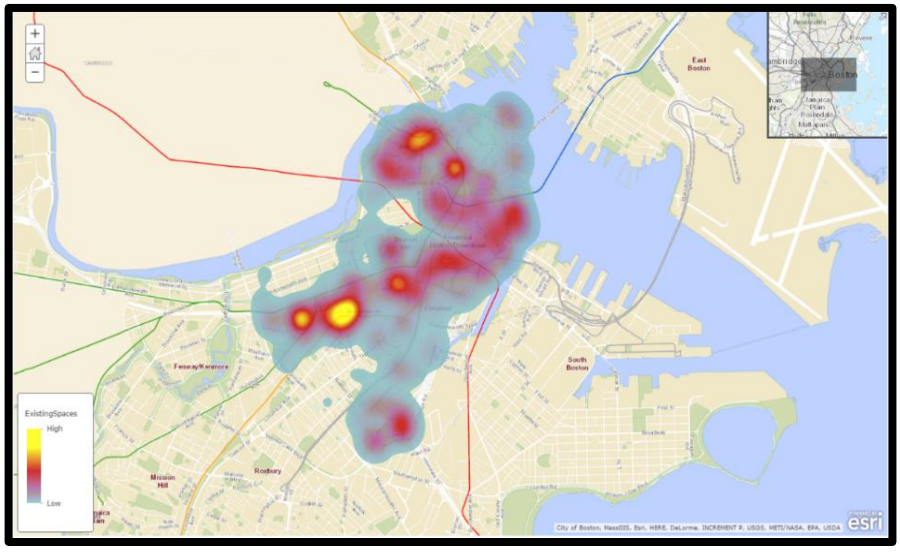
Innovations in Parking Technologies

Our second set of findings focused on the application of technology in parking facilities. Technologies currently in use at parking facilities assist with reductions in VMT, the primary goal of the freeze.

- Vacancy indicators, which were noted in the observations of several garages, are signs on the outward facades of facilities that indicate the availability of spaces within. These signs or indicators have the potential to allow individuals seeking parking to spend less time idling in their vehicles as they avoid circling the garage to determine if a facility is full. This simple method of communicating about the availability of spaces could help to reduce VMT, which is the rationale for the parking freeze.
- Automated garages, which are used at some facilities, have the added benefit of keeping track of what types of parkers are entering and leaving a mixed-used facility at a given time. This information allows facilities to adjust the supply of different type of parking spaces (residential, public or business parking) to use limited parking spaces more efficiently.
- Vehicle lifts, able to raise one car so that another car can be parked beneath it, double the capacity of a single space. Vehicle elevators, used in specially designed garages, stacked several cars on top of each other. VMT could be decreased when parking capacity is increased because drivers do not need to circle the block looking for the next lot with available spaces. Minimizing the spatial requirements of individual parking spaces conserve land resources for other purposes, such as affordable housing.

The Variability of Facility Capacity

A final set of findings were related to the variability of parking facility capacity. First, according to the inventory data, the average parking facility capacity was lowest in the North End neighborhood of the downtown freeze zone. 70% of parking facilities in the North End neighborhood were open-air lots. The distribution of parking facilities in the North End may increase VMT by forcing potential parkers to drive longer distances searching for available parking spaces since small open-air lots were scattered throughout the North End and filled up quicker than large open-air lots or garages. Second, we found that many parking facilities near event locations allowed event parking with higher rates and extended business hours. Some facilities that were only permitted for business or residential



parking opened specifically for the public during events. The extra event parking magnified off-street parking availability, creating a swell in supply during event hours.

Recommendations

We proposed five recommendations for our sponsor. These recommendations were organized to guide the BED in making amendments to parking freeze policies and to streamline future inventory processes.

1. Extend the South Boston annual renewal system to the downtown freeze zone.

    - The discrepancies in parking permit records demonstrate that more enforcement or periodic facility updates are necessary.
    - Funds generated from annual renewal fees could be used to hire a parking freeze manager to more evenly distribute the duties of current BED staff.
    - Inventory 30% of facilities annually to verify accuracy of the information submitted by parking facilities to the BED.

2. Reconcile parking freeze permits with Transportation Access Plan Agreements (TAPAs) to minimize the number of spaces granted for new developments.

    - The fact that many parking facilities provided counts lower than their permit totals suggested that too many permitted spaces were allocated during the building planning of new developments.
    - Could be caused by TAPAs mandating an inappropriate amount of parking during new building development.
    - Eliminate oversupply of parking spaces to reduce VMT by discouraging drivers to park at new developments and prevent the construction of unused spaces.

3. Utilize the Collector application in field surveys of parking facilities.

    - Eliminates the inefficiency of entering paper field survey forms into a digital database after completing a survey.
    - Allows the tracking of surveyor routes which is useful in keeping track of the area covered during field inventories to know if they have been surveyed for unpermitted facilities.
    - Enables the real-time creation of new data points in the field if unpermitted facilities are located.

4. Publish the inventory data online by making the BostonMaps database public.

    - Promote public access to detailed parking information, which is useful for locating parking availability and developing parking-related software for the city (such as ParkBoston).
    - Could be useful for legal matters, such as the selling of land containing parking, and ensuring permit compliance within the BED.

5. Implement BostonMaps as the primary database for parking freeze management until the currently used city-wide database becomes fully integrated.

- Can be accessed by all departments in City Hall.
- Simple, user-friendly interface is ideal for temporary workers who may be hired seasonally to update inventories.
- Compatible with the desktop version of ArcMap, which was commonly used in the BED already.

Conclusion

Effective urban parking management relies on the routine interfacing of environmental regulators, city planners, business leaders, and residents to prioritize competing agendas. Environmental regulators favor policies that tackle the dangers of climate change, city planners desire policies that maximize spatial utility, business leaders push for policies that stimulate economic activity, and residents yearn for policies that promote neighborhood livability. Our inventory of the downtown freeze zone uncovered trends in transportation demand management techniques that provide further nuance of the varying viewpoints of those who maintain a vested interest in Boston's parking management.

The collaboration of the City of Boston, Nelson/Nygaard, and A Better City on the most comprehensive Policy Study yet completed marks a pointed shift towards community engagement to interpret Boston's parking needs. The Study's report, due for release in Fall 2016, will outline the future of parking in Boston as it relates to the City's environmentally-sustainable GoBoston 2030 transportation plan. Our ground-truthing of the parking freeze permit data provided the City of Boston with the evidence necessary to impose parking policy changes that emphasize the intersectionality of stakeholder values, with air pollution control at the core.

List of Authors

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Chapter 1: Introduction

Millions of Americans live in urban areas where air pollution presents serious health concerns (World Health Organization, 2010). Urban smog irritates the eyes, nose, and throat while particle pollution induces wheezing, coughing, and breathing difficulties (MassDEP, 2015a). Toxic pollutants such as ground-level ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide are linked with "worsening of existing heart and lung problems" (World Health Organization, 2010). In a 2008 case study of the Southern California metropolitan area, 29% of deaths resulting from coronary heart disease were attributable to near-roadway air pollution within cities (Ghosh et al., 2016). Furthermore, urban air pollution poses a variety of environmental threats including acid rain, eutrophication, haze, crop damage, and climate change (MassDEP, 2015a).

Vehicular exhaust is a primary contributor to urban air pollution. Due to the increased concentration of cars in urban areas, vehicular emissions contribute to 97% of carbon monoxide, 75% of nitrogen dioxide, 77% of particulates, and 53% of volatile organic compounds found in cities (World Health Organization, 2010). The enactment of the federal Clean Air Act Extension in 1970 mandated states develop comprehensive regulations for mobile sources of air pollution, such as vehicles, through State Implementation Plans (SIPs). To comply with the Massachusetts SIP, the Department of Environmental Protection (MassDEP) issued general regulations for a parking freeze that imposed a cap on the number of off-street parking spaces in downtown Boston, South Boston, and East Boston. The freeze, which excludes residential spaces and employee parking, was intended to reduce emissions by decreasing vehicle miles traveled (VMT) within Boston. Although not all of the reductions in greenhouse gas emissions in Boston since the establishment of the freeze in 1978 have been linked specifically to the program, carbon monoxide levels in the city have decreased from 6.0 parts per million to nearly 0.5 parts per million while monitored levels of ground-level ozone, nitrogen dioxide, and sulfur dioxide “have been steadily decreasing” (MassDEP, 2015b).

The Boston Air Pollution Control Commission (BAPCC), tasked with the administration of the parking freeze, performed an initial inventory of off-street spaces in downtown and developed procedures for the issuance of permits to property owners (BAPCC, 2014). Since the success of the freeze depends on accurate space counts to properly allocate parking to developers, the City of Boston sponsors periodic inventories of the freeze zones to update the BAPCC’s off-street parking records. Previous inventory reports have highlighted the challenges of implementing and maintaining the parking freeze, including interdepartmental coordination within a decentralized management structure and commercial development that impacts the categories of parking available (Allard, Armato, Barber & Couture, 2001; Cormier, Liang, Vial & Zuniga, 2007). Survey data collected by the Central Transportation Planning Staff (CTPS) in 2001 interpreted construction project proposals to anticipate city development in downtown, estimating a 7% increase in total off-street parking spaces in the coming decade (BTD, 2001).

In September 2015, the City of Boston released a Vision Report outlining goals and targets for Go Boston 2030, a multi-year initiative "to envision a bold transportation future" (Walsh, 2015). One of the goals specified by the Vision Report was a decrease in greenhouse gas emissions through a further reduction in the "number of miles driven per person" (Walsh, 2015). To accomplish this goal, the City of Boston is conducting its first-ever Parking Policy Study that will reassess the viability of the parking freeze as an inhibitor of VMT within the zone. As part of this study, the BAPCC has requested on-foot verification of the parking freeze permit records and an analysis of changes in parking trends as revealed by the inventory.

The goal of our investigation was to evaluate the downtown parking freeze as part of the City of Boston’s first comprehensive Parking Policy Study. We first developed the methodology for an on-foot inventory that ground-truthed the outdated parking freeze permit records. Next, we developed a

geospatial representation of the inventory data through the generation of GIS layers on BostonMaps. We then analyzed the inventory data by comparing trends in our updated count with patterns in historic off-street parking data. Analysis of the comprehensive database, in combination with our field observations, revealed trends in transportation demand management techniques that underlie the City's struggle to maintain accurate parking freeze permit records. Our data and analysis provided the City of Boston with the evidence necessary to support the parking policy changes outlined in Go Boston 2030.

Chapter 2: Background

In the early twentieth century, the dense smog that enveloped many of the nation's cities and industrial centers—such as Los Angeles and New York City—brought attention to the health risks of urban air pollution (Gardner, 2014).

2.1 The Transition of Air Quality Responsibility from the Federal Government to the States

To reduce air pollution, the federal government passed the Clean Air Act (CAA) in 1963. The federal government has since made several amendments to the CAA to improve national air quality, including amendments in 1970 that created the Environmental Protection Agency (EPA) to enforce the CAA. The CAA requires the EPA to establish National Ambient Air Quality Standards (NAAQS) for certain common and widespread pollutants such as particulate matter, ozone, nitrogen dioxide, and carbon monoxide (Environmental Protection Agency, 2007). NAAQS sets the general limit on the amount of pollutants in the air anywhere in the United States.

However, it has been impossible for the EPA to develop a general solution to achieve the standards nationwide. Without specific plans designed for local conditions, the federal effort for controlling air pollution would be ineffective. Therefore, each state was required to develop and implement its own State Implementation Plans (SIPs) to prevent further air pollution for areas to meet NAAQS. States that violate NAAQs were also required to submit a plan to reduce criteria pollutants emitted to levels that are compliant with the NAAQS.

One of the main targets of the SIPs is the air pollution caused by vehicles. Twenty-six percent of air pollution is caused by the transportation industry in the United States (Environmental Protection Agency). Vehicle exhaust chemicals are harmful for asthmatics- affecting lung functions and may advance allergic reactions and airway constriction. All vehicles, especially diesel engines, release particles that puncture lungs and inflame the circulatory system, damaging cells and causing respiratory problems. Even short-term exposure to vehicle exhaust may harm asthmatics. In spite of the manufacturers' efforts to increase mile per gallon and to reduce emissions, automobiles have become one of the major sources for air pollution due to increasing vehicle ownership over time (Environmental Protection Agency, 2010). The number of registered vehicles in the U.S. has increased from 74 million in 1960 to 260 million in 2014 (Bureau of Transportation Statistics, 2016).

In order to reduce automobile emissions, many of the nation's major cities passed laws to regulate city traffic and to reduce vehicle miles traveled (VMT). Along with the City of Boston, several cities—including Cambridge and Somerville, MA and Portland, Oregon—adopted the policy of a parking maximum limit to increase use of public transit and reduce VMT. However, each of these cities, other than Boston, changed their air pollution control tactic. Currently, Boston is the only city where a parking freeze is implemented.

2.2 The Boston Parking Freeze

The Boston parking freeze is intended to reduce vehicle-caused air pollution by capping the amount of commercial off-street parking spaces in the Boston area (Air Pollution Control Commission, 2006). The freeze is enforced in three areas as shown in Figure 1—Downtown Boston, South Boston, and East Boston.

The Boston Air Pollution Control Commission (BAPCC) administers the parking freeze by enforcing regulations, granting permits, holding public hearings, and cooperating with other local, regional, state, and federal agencies on managing parking facilities. Table 1 outlines types of parking in the freeze zones and how they are managed.

The BAPCC conducted an inventory of existing commercial spaces, created the "parking freeze bank," and established procedures and criteria for the issuance of permits as a part of the parking freeze. The "parking freeze bank" records the number of parking spaces available for building parking facilities. If the "bank" is empty, no application for parking facility permit will be approved unless old parking facilities close (Air Pollution Control Commission, 2006). In order for the freeze to be successfully enforced, an accurate and complete count of commercial off-street parking spaces is needed.

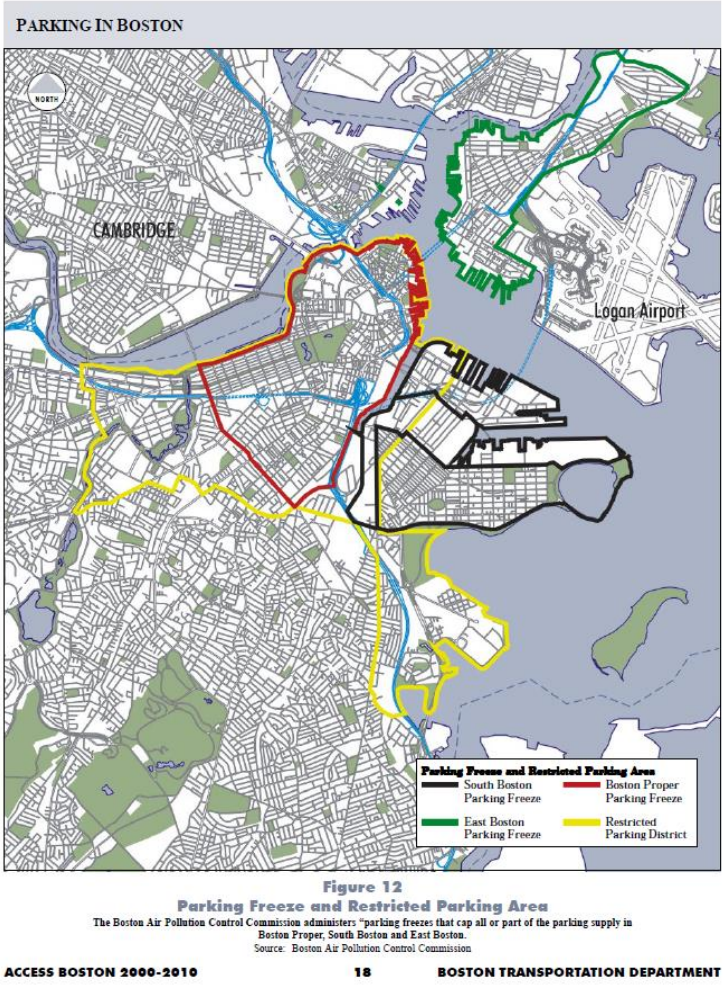

FIGURE 1. Boston Parking Freeze Zones (Air Pollution Control Commission, 2006).

TABLE 1. Types of parking designated under freeze regulations.

Type	Users	Management
Commercial	Public/Visitors	Permitted and Count Towards Freeze
Exempt	Employees	Permitted
Excluded	Residents	Not Permitted or Managed

The downtown Boston freeze zone, our focus for the inventory, is outlined in red in Figure 1, ranging from the North End neighborhood to the South End neighborhood. The freeze allows a maximum of 35,556 public parking spaces in commercial parking facilities in downtown. The number has not been changed since the freeze was established. As of December 31, 2013 there were no spaces in the parking freeze bank (Air Pollution Control Commission, 2006).

TABLE 2. Change in air pollution from the 1900s to 2014.

Pollutant	Amount of Pollutant in 1900's	Amount of Pollutant in 2014
Ozone (O_3)	30 days exceeding standard	No days exceeding standard
Nitrogen Dioxide (NO_2)	120 (ppb)	50 ppb
Carbon Monoxide (CO)	6 (ppm)	0.5 ppm
Particulate matter under 10 micrometers in diameter (PM 10)	25 mg/m^3	15 mg/m^3

One method to evaluate the success of the freeze is an examination of air pollutants before and after its implementation. Even though the freeze is only one factor that contributes to air quality changes, the data in the 2014 Massachusetts Air Quality Report shows an association between the improvement of air quality in Boston and the enforcement of the SIP. As shown in TABLE 2, the amount of pollutants has decreased significantly since the implementation of the parking freeze.

2.3 Challenges in Maintaining an Updated Inventory

The BAPCC has partnered with the Central Transportation Planning Staff (CTPS), Worcester Polytechnic Institute, and Nelson\Nygaard on various occasions to assist in performing inventories on parking freezes in the city (Allard, Armato, Barber, & Couture, 2001; Cormier, Liang, Vial & Zuniga, 2007). In each case, the teams faced challenges and, ultimately, an updated inventory has not been kept.

2.3.1 The Impact of Commercial Development on Types of Parking Available in Downtown

The Boston Transportation Department (BTD) set the framework for off-street parking policy in the 2001 report Parking in Boston (Allard, Armato, Barber, & Couture, 2001). The report included a 1997/1998 inventory of Boston's parking supply conducted by the CTPS (Allard, Armato, Barber, & Couture, 2001). The study identified buildings under construction to have an estimate (or overestimate) of to-be-developed parking spaces, most of which would contribute to exempted parking spaces and would not count towards the freeze cap (Allard, Armato, Barber, & Couture, 2001). In Figure 2, the

increase in exempt parking spaces in downtown (26%) accounts for nearly all of the net change in off-street parking in the freeze zone; the number of public parking spaces remained relatively stagnant during the same period (Allard, Armato, Barber, & Couture, 2001). This shift in type of parking development is an inherent challenge with the setup of the freeze because the legislation only limits the development of commercial parking spaces. Although this development is not in violation of the freeze, it allows for an increased number of individual vehicles to operate within the city, ultimately increasing VMT.

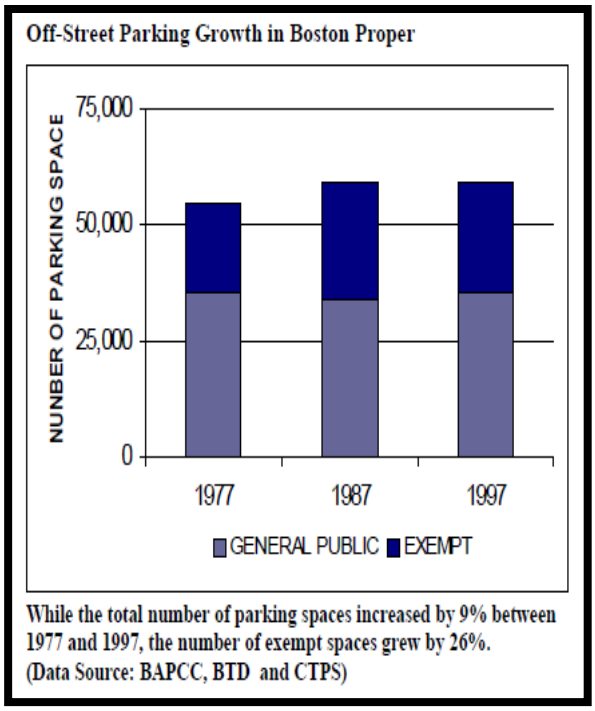

FIGURE 2. Changes in types of off-street parking available from 1977 to 1997 (Allard, Armato, Barber, & Couture, 2001).

2.3.2 Interdepartmental Coordination Challenges Decentralize Boston Parking Management

The BED has sponsored two WPI Interactive Qualifying Projects (IQPs) concerning the parking freeze: a 2001 study about off-street parking in downtown and a 2007 evaluation of the South Boston freeze zone (Allard, M. et al, 2001; Cormier, R. et al, 2007). The 2007 project recommended improved communication with the Boston Assessing Department since 39% of the data supplied by the Boston Redevelopment Authority (BRA) did not match the BAPCC parking freeze permit (PFP) records. In 2001, four separate entities were responsible for parking data collection, leading the downtown team to suggest that the City form a committee dedicated to parking management. Both teams recognized Boston's decentralized parking management as a cause of inefficiencies in tracking spaces, citing interdepartmental coordination challenges as the primary inhibitor of maintaining updated off-street parking records. This challenge, although not inherent to the freeze, limits accurate and complete data collection management required to enforce the freeze and determine its success.

2.3.3 *Go Boston 2030*: The Impact of the Preliminary Inventory on Greenhouse Gas Emissions

In a recent effort to overcome the challenges previously faced, the BED and the BTD collaborated with a nonprofit urban planning organization, A Better City (ABC), on a Boston citywide Parking Policy Study. In a memorandum with the ABC, BED, and BTD, Nelson\Nygaard (the transportation consulting firm hired by the City of Boston) described the study as a "comprehensive multi-modal, off-street parking policy" (Nelson/Nygaard, personal communication, March 31, 2016). The City of Boston plans to incorporate the parking management solutions generated by the Policy Study into a citywide transportation plan: *Go Boston 2030*. The transportation plan is part of *Imagine Boston 2030*, the City's multi-year initiative to capitalize on Boston's 6% population growth since 2010 (*Imagine Boston 2030*, 2015). One of the four goals of *Imagine Boston 2030* is to "promote a healthy environment and adapt to climate change" (*Imagine Boston 2030*, 2015). Based on the feedback of Boston residents collected for *Go Boston 2030*, the City plans to invest in mobility infrastructure—such as parking facilities—and "continue to be a global leader in reducing greenhouse gas emissions in…the transit sector" (*Imagine Boston 2030*, 2015).

In order to understand the current parking situation, Nelson\Nygaard completed a digital inventory of off-street parking in downtown Boston by drawing information from the following data sources:

1. Detailed records of permitted off-street parking spaces maintained by the BAPCC for the freeze zones.
2. Data recorded by the Boston Fire Department (BFD) concerning combustible material storage within buildings.
3. Data from the Transportation Access Plan Agreement (TAPA) detailing permitted parking spaces for "large developments citywide."
4. "Parcel-level" data from the Boston Redevelopment Authority (BRA).
5. Aerial data maintained by Google maps that outlines Open Lot Data, excluding open-air lots with less than 1000 square feet (the equivalent of approximately three parking spaces) (Nelson/Nygaard, personal communication, March 31, 2016).

The first four sources include information from governmental departments. The third data source, the TAPAs, are negotiated during the permitting of new developments. They determine several details about new buildings, including the number of parking spaces allocated to the facility based on state-wide building regulations. The last source only approximated available land that could potentially be used as open air lots. Although many data sources were used, Nelson/Nygaard did not include a ground-truthed inventory to ensure the accuracy of these numbers. An accurate count is needed as the city completes it parking policy study.

The Parking Policy Study conducted by the City of Boston in collaboration with Nelson/Nygaard and A Better City will culminate in a report due for release to the public in fall 2016. As the most comprehensive transportation plan released for *Go Boston 2030* thus far, the report will outline parking policy changes that may significantly affect parking space owners, such as an extension of the annual renewal fee from the South Boston parking freeze to the downtown zone. This extension would require parking management companies to annually renew their parking permits with the BED in addition to paying a fee for each parking space housed at the facility. In anticipation of heavy public scrutiny, the City of Boston has requested that we complete on-foot verification of a digital inventory completed by Nelson\Nygaard so they can present the data in conjunction with the report to increase the legitimacy of their parking policy recommendations. (A Better City, personal communication, August 30, 2016).

Chapter 3: Methodology

The goal of this project was to complete an on-foot inventory and analysis of off-street parking in downtown to help the City of Boston understand the significance of vehicle emissions in urban air pollution. The three primary objectives were to:

1. Create a GIS database layer for inventory data storage and analysis purposes.
2. Inventory off-street parking spaces in the downtown parking freeze zone to understand the reality of parking facility practices.
3. Analyze trends in parking facility management in relation to VMT and urban space use.

3.1 Objective 1: Created a Database for Our Inventory of Downtown Off-street Parking Spaces

One of the main objectives of the project was to store, represent, and analyze the data collected about each facility with geographic information systems (GIS). It was a useful tool to recognize patterns and relationships in data. We used GIS to display each parking facility as a point on a map of downtown Boston. Each of these points contained specific information about the parking facilities. This would allow our sponsors to see, analyze, update, and distribute the data in a user friendly manner.

3.1.1 Developed a GIS Layer Comprised of Inventory Data

We used a cloud-based version of ArcMap called BostonMaps, which allows users to explore data within a data set, symbolize features accordingly, and create maps. BostonMaps has the added benefits of being viewable without specialty software and is similar to other commonly-used web based mapping platforms such as Google Maps, making it accessible to a wider audience than ArcMap. Another advantage of BostonMaps is that it could work in conjunction with a cellphone application called Collector. Collector enabled us to create digital survey sheets, collect and update data in the field, log our current location, and put the data captured in a visual space so we could make more informed and timely decisions about routes between facilities. It was also able to record user's location to generate user's walking route. With the combination of Collector and BostonMaps, we were able to increase efficiency of our fieldwork with mobile entry.

With the permit records from the BED and help of William Toussaint at the Department of Innovation and Technology (DoIT), we created a GIS layer with the locations of parking facilities as a database for inventory data. On the layer, each of 286 parking facilities were represented as a point that stored information from the specific parking facility's survey.

Because the system was set up and prefilled with the data from our inventory, the BAPCC would be able to update the map with new information they obtained at any time with ease. This will allow them to focus on reviewing and enforcing the freeze cap instead of managing data.

3.2 Objective 2: Inventoried Off-Street Parking Spaces in the Downtown Freeze Zone

Prior to our project, Nelson/Nygaard had already estimated the current number of off-street parking spaces in different areas of Boston. To complete an accurate inventory, we needed to obtain basic information and precise numbers of different kinds of parking space for each parking facility. To accomplish this task, we visited each downtown parking facility personally and conducted field surveys.

3.2.1 Conducted a Field Survey of Off-Street Parking Spaces

We completed a systematic inventory of downtown off-street parking facilities by dividing the process into three stages. The first stage was to develop the plan and get familiar with this process by ourselves.

At first, the GIS database layer and Collector were not set up, therefore we allocated parking facilities to be inventoried to pairs of group members, tracked our walking route with Google Maps, and used paper survey sheets developed with our sponsor to record information. The data we collected included number of existing spaces in the facility, number of spaces for each type of parking (public, residential, exempt), price, operation hours, contact information, and other facility information. The full paper survey can be seen in Appendix A. We went out with our sponsor to visit a couple facilities, in order to see how we should have talked and approached facility attendants or managers. Then we split into groups of two with assigned lists of about 15 facilities for each pair to visit every day. We decided to start from the Boston City Hall area and work successively through the following neighborhoods: North End, West End, Water Front, Back Bay and South End. During the inventory process, if we spotted any undocumented parking facilities, we took note of them on BostonMaps. For each parking facility, we would first introduce ourselves to the managers or attendants and state the purpose of our visit. We would then use the survey sheet as a guide to ask questions about the parking facility. If there was no attendant or they refused to give any information, we would at least try to obtain contact information or take notes of the interaction for the third stage of our inventory.

When the GIS database layer and Collector were ready, we moved into the second stage. The second stage was similar to the process of the first stage, however, with the GIS layer on BostonMaps and Collector we did not need survey sheets or Google Maps tracking anymore. We imported all the data collected during the first stage to the GIS layer. We decided to conduct inventories individually to maximize efficiency. Each team member was assigned a list of 15 facilities within a small area every day. By the end of second stage, we visited all 271 parking facilities including 10 unpermitted facilities that we discovered during the inventory process.

In the last stage, we sorted out the facilities we could not obtain information from and tried to contact them through phone calls or emails. For the facilities that we could not even obtain contact information for, our sponsor suggested to send letters (see Appendix B) to the owners of these facilities with the addresses from permit records available to the public. These parking facilities would either provide updated information within a certain period of time, or their permits would be revoked.

3.2.2 Obtained Credentials to Access Parking Facilities

Since the business owners own commercial off-street parking facilities, we needed documentation to prove our sponsorship by a government agency to collect data inside the facilities. Our team adopted a similar strategy to the one from a previous study and obtained an official letter from our sponsor as a credential (Cormier, Liang, Vial & Zuniga, 2007). The letter could be showed to the facility managers if they refused to provide information or questioned the legitimacy of our work.

3.3 Objective 3: Analyzed Updated Off-Street Parking Data

We started to look for patterns in the collected data by using the analysis tools on BostonMaps. As each facility has several fields recording information on the GIS database layer, we filtered out the fields we wanted to compare and generated visual representations like heat maps to reveal the trends. We also had other data layers owned by the City of Boston available on BostonMaps. These included a residential and commercial parcel data layer as well as a transportation facility data layer. By

overlapping these layers on our inventory data, we were able to identify the effects of urban development in parking facilities.

In addition to an analysis of our inventory data, we compared the data we collected with the permit records collected by Nelson/Nygaard. The data files provided by them included historic parking data for the downtown freeze zone that specified the category of parking available at each facility. By comparing two data sets, we learned more about shifts in parking usage. In the next chapter we present our results and explain findings that provide evidence for the recommendations and outcomes of our research.

Chapter 4: Findings

We inventoried 271 facilities in the downtown parking freeze zone, identifying 60,103 total off-street parking spaces: 5,689 residential, 18,228 exempted, and 35,799 public. Since only public parking counts are included in the freeze, these numbers indicate that the downtown zone exceeds the cap by 243 spaces. However, the count of residential spaces obtained by our inventory does not equal the total number of residential parking spaces in downtown as our data derives solely from facilities that were once permitted by the BAPCC. The BAPCC only keeps track of the residential spaces associated with public parking facilities. Figure 3 presents the locations of the 271 downtown parking facilities in a data layer generated by BostonMaps. In this chapter, our findings are organized into themes interpreted from our inventory data and qualitative observations. The findings mainly focus on the differences between the permit records and the data we collected, applications of technology in parking management, and the variability of parking facility capacity.

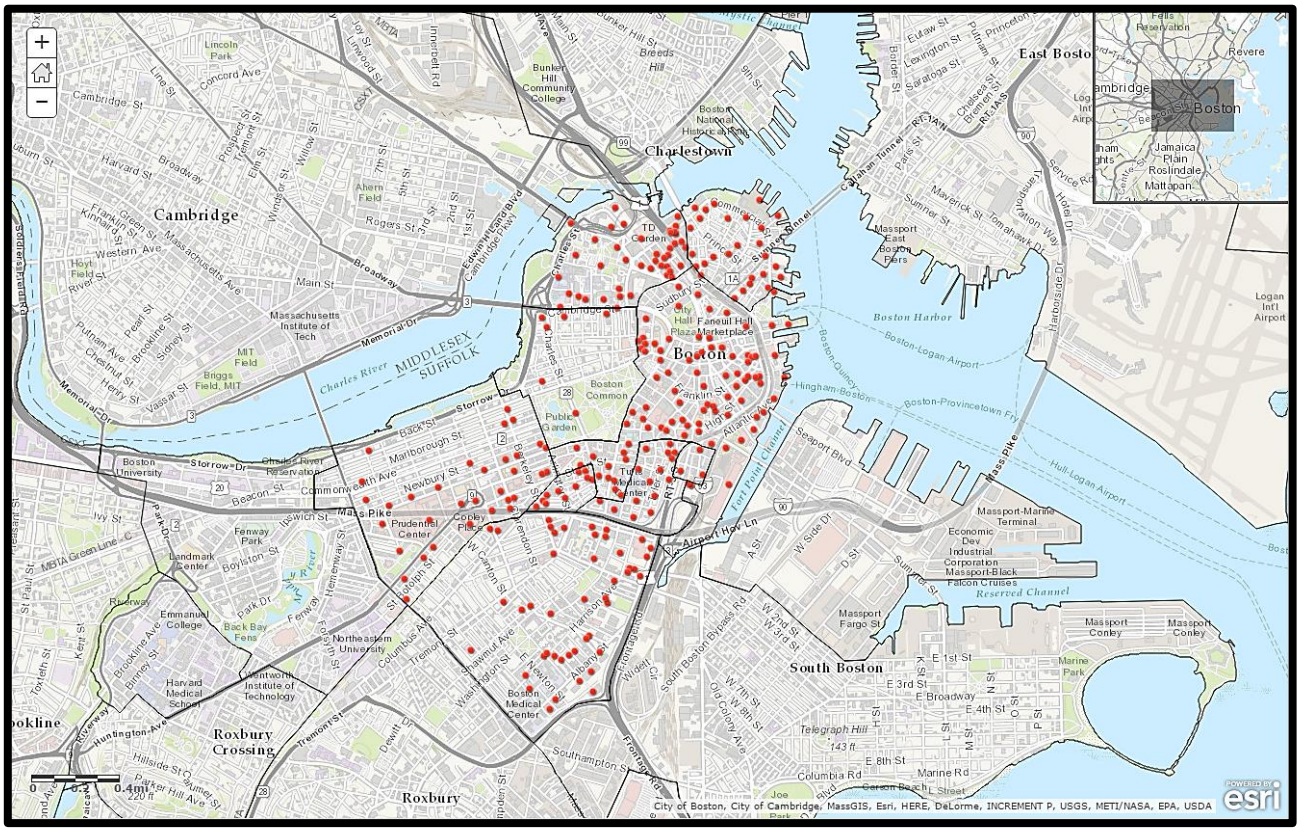

FIGURE 3. Map of 271 Boston downtown parking facilities (BostonMaps, 2016).

4.1 Discrepancies in the Parking Freeze Permit Records

We discovered that the parking freeze permit records are not accurate with respect to the current state of off-street parking in the downtown freeze zone. The data provided by facility attendants during our inventory often did not match the data contained in the permit records. In this section, we present our findings on the discrepancies in the parking freeze permit records.

Finding 1. The BAPCC does not have permits recorded for every off-street parking facility in the downtown freeze zone.

During our time in the field, we collected data for ten facilities not listed in the parking freeze permit records. These facilities, listed in Table 3, each have 0 permitted spaces for all categories of parking type: public, exempted, and residential. To incorporate these counts into BostonMaps and ultimately into the parking freeze permit records (pending formal site visits from the BED staff), each team member created data points via Collector as undocumented facilities were discovered in the field. For most of the facilities without permit data, their locations were nearby facilities that were listed in the parking freeze permit records but could not be found. For example, the Merrimac Street Lot is

TABLE 3. Undocumented parking facilities found during the inventory.

Facility Name	Facility Address	Number of Public Spaces	Number of Exempted Spaces	Number of Residential Spaces	Total Number of Existing Spaces
Hurley Building Lot	25 Staniford Street	169	16	0	185
Merrimac Street Lot	37 Friend Street	75	0	0	75
Dartmouth Street Lot	278 Dartmouth St	71	0	0	71
Columbus Avenue Lot	38 Isabella Street	52	0	0	52
Tip O'Neil Federal Building Lot	10 Causeway Street	50	0	0	50
200-204 Friend Street Lot	200-204 Friend Street	41	0	0	41
251-267 Friend Street Lot	251-267 Friend Street	35	0	0	35
Canal Street Lot	120-126 Canal Street	0	15	0	15
45 Seaman's House Lot	45 Church Street	0	0	12	12
44 Prince Street Lot	44 Prince Street	0	10	0	10
TOTAL		**493**	**41**	**12**	**546**

located at 37 Friend Street directly adjacent to the Green Charge and Park Lot at 150 Friend Street. The Merrimac Street Lot, attended independently from the Green Charge and Park Lot, absorbed some of the spaces from its neighboring parcel and expanded upon them by valeting in vehicles. These subtle redevelopments amongst parcel tenants and relocations of some exempted parking lots, such as the Canal Street Lot and Prince Street Lot, contribute less than 1% to the total 60,103 parking spaces counted in our inventory.

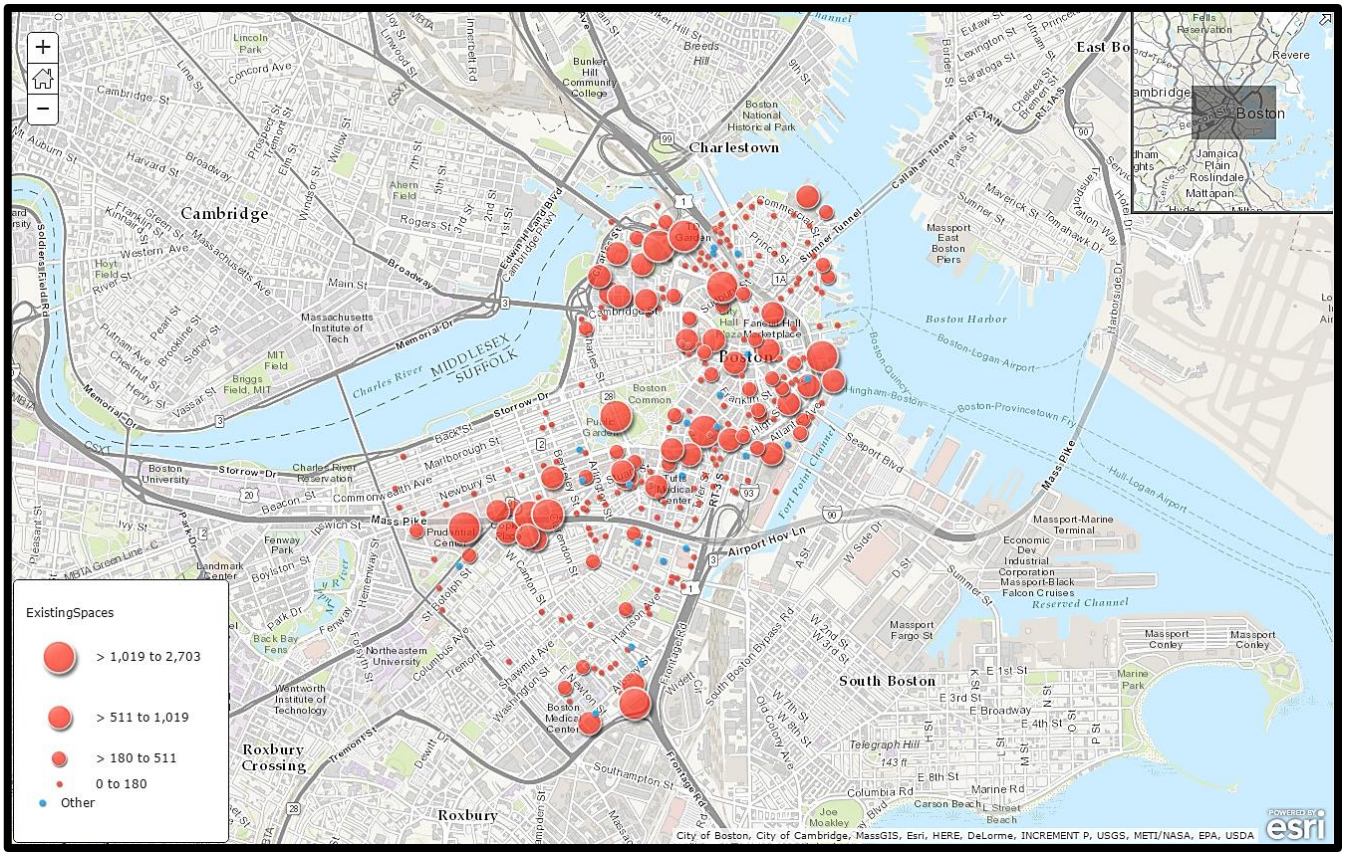

FIGURE 4. Distribution of existing off-street parking spaces in the downtown Boston freeze zone (BostonMaps, 2016).

In addition to documenting facilities without records in the permit data, we were not granted access to some of the more secure sites with residential and exempted parking spaces, such as the U.S. Coast Guard Station in the North End. As requested by the BED, we used the permitted data to fill in the blank of inventory data for these facilities. Figure 4 provides a visual representation of the locations of the aforementioned undocumented and inaccessible parking facilities highlighted by blue markers.

We obtained counts for existing spaces, with their respective number of permitted spaces, at 250 parking facilities in the downtown freeze zone. Figure 5 presents the relationship between the total number of existing spaces and the total number of permitted spaces identified for each facility in our inventory. According to how many the number of existing spaces falls behind or exceeds the number of permitted spaces for each facility, the color of the corresponding marker varies from green to red. The map indicates that facility compliance rates are relatively high in the North End, Chinatown, Back Bay, and Bay Village. The West End and Financial District each contain numerous sites where the number of verified existing spaces exceeds the number of permitted spaces, relative to facilities in other neighborhoods.

FIGURE 5. Visual representation of the ratio of existing spaces to permitted spaces for each parking facility in downtown (BostonMaps, 2016).

Finding 2. Most of the garages in the downtown freeze zone contain fewer parking spaces than their permits allow.

Garages, commonly built underneath the building for which they supply parking (especially in the Financial District), contained significantly more parking spaces than open-air lots (OAL) but were consistently below their permitted capacity. For our inventory, covered facilities not categorized OALs were considered garages.

Table 4 demonstrates the prevalence of garage facilities containing fewer than their permitted spaces across the downtown freeze zone; 78% of the neighborhoods (7 of 9) contained fewer existing garage spaces than permitted garage spaces, the exceptions being in the West End and the Leather District (which contained only 2 facilities, both garages). During our inventory, we found most garage facilities to be operated by professional parking management companies—namely LAZ Parking, ProPark America, Sp+ Parking, and VPNE Parking Solutions—with capacity data immediately available upon request. Garages often mark spaces with numbers to facilitate valet services and gauge facility occupancy. The awareness of garage managers of their permitted capacities throughout the freeze zone is evident in the low ratio of total existing garage spaces to total permitted garage spaces. Even though many garages had capacities well below their permitted spaces, the number of public parking spaces still exceeded the downtown parking freeze cap. This is because many garages provide parking for residents and business employees, while only public parking spaces counts toward the freeze cap.

TABLE 4. Comparison of existing garage spaces with permitted garage spaces in different neighborhoods.

Downtown Boston Neighborhoods	Number of Existing Garage Spaces	Number of Permitted Garage Spaces	Ratio of Existing Spaces to Permitted Spaces
Chinatown	781	3533	0.221
North End	808	1437	0.562
Back Bay	11885	14896	0.797
Financial District	23146	25455	0.909
Beacon Hill	1641	1766	0.929
Bay Village	765	792	0.965
South End	5872	5898	0.995
West End	8663	8205	1.055
Leather District	310	210	1.476
TOTAL	**53871**	**62192**	**0.866**

Finding 3. The majority of the OALs in the Back Bay, Bay Village, and North End neighborhoods contain more parking spaces than their permits allow.

OALs throughout the downtown parking freeze area consistently contained more existing spaces than permitted spaces. During our inventory, the counts provided by some OAL attendants were noticeably lower than the number of vehicles parked at the time of our visit. Table 5 demonstrates the increased frequency of OAL exceeding their number of permitted spaces found in our inventory. The Back Bay, Bay Village, and North End neighborhoods (representative of 33% of the total neighborhoods) were found to exceed their number of permitted OAL spaces. However, the total number of existing OAL spaces did not exceed the total number of permitted OAL spaces in the downtown area, indicating that the discrepancy between number of existing spaces and number of permitted spaces of the Back Bay,

Bay Village, and North End neighborhoods (together contributing only 1,968 spaces to the 60,103 total) may not significantly affect net VMT within Boston.

TABLE 5. Comparison of existing OAL spaces with permitted OAL spaces in different neighborhoods.

Downtown Boston Neighborhoods	Number of Existing OAL Spaces	Number of Permitted OAL Spaces	Ratio of Existing Spaces to Permitted Spaces
Bay Village	296	240	1.233
Back Bay	175	160	1.094
North End	1497	1387	1.079
West End	1010	1025	0.985
Financial District	751	897	0.837
Chinatown	462	611	0.756
South End	2016	2822	0.714
Beacon Hill	25	40	0.625
Leather District	0	0	0
TOTAL	**6232**	**7182**	**0.877**

4.2 Innovations in Parking Technologies

During the inventory, our team observed improvements in the technology used to manage parking facilities that were not prevalent at the time of the parking freeze's enactment in 1976. The advent of parking technologies that allow facility managers to monitor space availability in real-time may be related to changes in traffic patterns around lots and garages. These shifts in traffic affect the net VMT within the downtown freeze zone and therefore must be considered when developing city-wide parking regulations.

Furthermore, the incorporation of space-saving technologies may have increased facility capacities without affecting permitted capacities, as no renewal system is currently in place to prevent undocumented installation of car-stacking machines or increases in parking-type fluidity. The significance of decreasing the spatial requirements of parking in cities lies in construction costs and the

value of real estate in dense urban areas. A standard parking spot (200 square feet) occupies double the average space of a bedroom in downtown Boston (99 square feet), causing areas with an abundance of parking to experience rent hikes for all tenants, including businesses (A Better City, 2016). Although the goal of the parking freeze is to improve air quality by reducing VMT, one of the key initiatives of the City of Boston's larger transportation plan is to "improve residential neighborhoods" by adding 53,000 affordable housing units before 2030 (A Better City, 2016). Thus, technology-induced changes in facility capacities must also be considered when amending parking regulations for the City of Boston.

Finding 4. Facility vacancy signs may reduce VMT within the downtown freeze zone by relieving traffic near multi-level parking garages.

Several facilities have installed signs on their outward facades that light up indicating if the lot is full. These vacancy indicator signs may allow individuals seeking parking to spend less time idling in their vehicles as they avoid circling the block to figure out if a facility is full. By eliminating unnecessary vehicular travel in the immediate vicinity of facility entrances, vacancy indicator signs could decrease traffic congestion around major parking lots and garages. This simple method of communication ultimately reduces VMT. Figure 6 depicts two examples of outwardly-visible signs that inform drivers about the parking availability within.

The signs are able to light up because of computerized systems keeping track of the number of vehicles in a given garage or lot. There are several systems being used including weight sensors in parking spaces and automated entrance and exit gate machines. Automated gates have the added benefit of keeping track of what types of parkers are entering and leaving a mixed-use facility at a given time. This information allows for the creation of algorithms specific to individual facilities so they may use space more efficiently. For example, a facility that once held a certain number of spaces for residents indefinitely could now rent out some of those spaces during daytime hours when a few of the residents drive to work. By allowing parking type to be fluid in a facility, the number of unused spaces can be reduced and the total capacity can be increased.

FIGURE 6. Examples of vacancy indicator signs at Government Center Garage (left) and Fruit Street Garage (right) (Ian Smith, 2016).

Finding 5. Vehicle stacking-machines may increase the capacity of parking facilities without increasing permitted capacity or facility area.

Vehicle stacking machines were not as commonly employed by facilities when the downtown parking freeze was enacted in 1976. The capacities of permitted parking facilities changed with the advent of vehicle lifts and elevators; however, these capacity expansions were only incorporated into

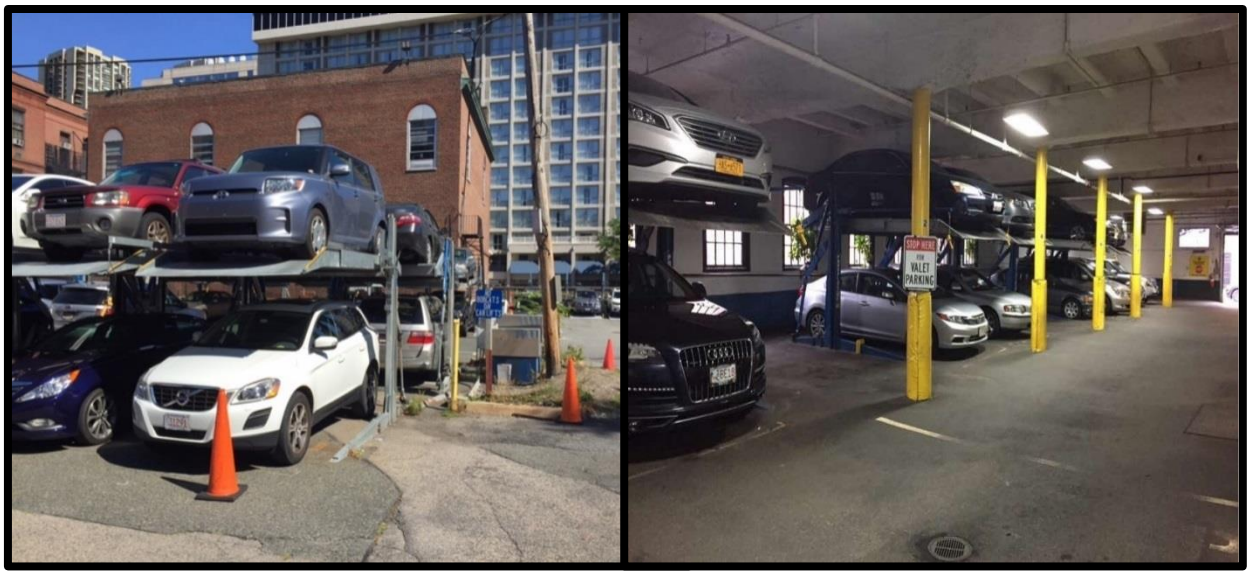

FIGURE 7. Vehicle lifts in the North Anderson Street Lot servicing the Wang Ambulatory Care Center (left). Car stacking machines in use at the Brimmer Street Garage, a single-level residential parking facility (right) (Ian Smith, 2016).

the parking freeze permit records upon inspection. Vehicle lifts are able to raise one car with an automated lift so another can drive under it and are employed in both OALs and parking garages. Figure 7 shows an example of vehicle lifts in the North Anderson Street Lot. This lot services the Wang Ambulatory Care Center at Mass General Hospital through an extensive valet system. Vehicle lifts at the North Anderson Street Lot eliminated the need for a second parking facility nearby by increasing the number of vehicles that could be parked per unit area. Similarly, Brimmer Street Garage in Beacon Hill, the largest parking facility in the neighborhood, utilizes car lifts for every space to accommodate more residential parkers than the spatial constraints of the building would otherwise allow.

5.3 The Variability of Facility Capacity

Undocumented changes in parking facility capacity may affect the transportation pattern around the downtown neighborhoods and, ultimately, compromise one of the primary goals of the parking freeze: to reduce VMT by promoting public transportation. During our inventory, we found the parking capacity of individual facilities to vary according to neighborhood location and the time of day.

Finding 6. The average parking facility capacity is lowest in the North End neighborhood of the downtown freeze zone.

During our inventory process, we noticed that different neighborhoods in downtown Boston had different types of parking facility distribution. As shown in Table 6, majority of the parking facilities in the North End, Bay Village, Chinatown and South End were OALs. Among these neighborhoods, North End had the fifth fewest number of parking facilities, but lowest average parking facility capacity of 88 parking spaces per facility. This suggests that parking facilities in the North End were mostly small OALs scattered around the neighborhood. This pattern of parking facility distribution may increase VMT. Potential parkers are forced to drive around to look for parking spaces because small OALs are not close to each other and fill up quicker than large OALs or garages.

TABLE 6. Average parking facility capacity and percentage of OAL in different neighborhoods.

Downtown Boston Neighborhoods	Number of Parking Facilities	Total Parking Spaces	Average Parking Facility Capacity	Number of OAL	Percentage of Parking Facilities Existing as OAL
North End	26	2305	88	18	70%
West End	40	9673	241	16	40%
Beacon Hill	6	1666	278	2	33%
Back Bay	30	12060	402	7	23%
Financial District	83	23897	288	19	23%
Bay Village	10	1061	106	8	80%
Leather District	2	310	155	0	0%
Chinatown	14	1243	89	9	64%
South End	39	7888	202	25	64%
TOTAL	**250**	**60103**	**205**	**104**	**42%**

Finding 7. Event parking incentivizes parking facility attendants to valet cars beyond their parking freeze permit allowances.

After talking to many parking facility attendants and managers, we noticed that many parking facilities near event locations allow event parking with higher rates. These facilities, sometimes including private or business parking facilities, would extend their business hours and open to public with hiked rates during special events. With such high profit, the attendants of these parking facilities would valet in more cars than their permit allowances to make more money. The LAZ Parking facility located at 588 Commercial Street is an automated public OAL with a capacity of 49 parking spaces. However, according to the attendant, there are approximately 10 additional valet spaces for event parking. The event rate is the same as the maximum rate no matter how long the car is parked, as seen in Figure 8. Another example of hiked event parking rates

FIGURE 8. Example of parking price sign with event parking rates (Xinyuan Zhang, 2016).

is the garage for Marriott Boston Long Wharf, which is exclusively for hotel guests according to the manager. During events, the garage is opened to the public with 38 additional valet spaces.

The extra valet spaces for event parking, and even during regular hours, makes the capacities of parking facilities unclear. The number of vehicles that can be fitt into unlined spaces depends on the sizes of the cars. This flexibility of facility capacity may become a problem for future freeze policy enforcement. The extra event parking also magnifies off-street parking availability, creating a swell in supply during event hours. Because of this, people attending events may be encouraged to drive instead of using alternative transportation, which increases VMT. Figure 9 highlights the proximity of parking facilities to the green line, red line, and blue line corridors (public transit lines) as well as event locations, particularly TD Garden and the Theater District. This pattern indicates that the influx of drivers within the city during events could be mitigated by increased public transit usage without sacrificing convenience for visitors.

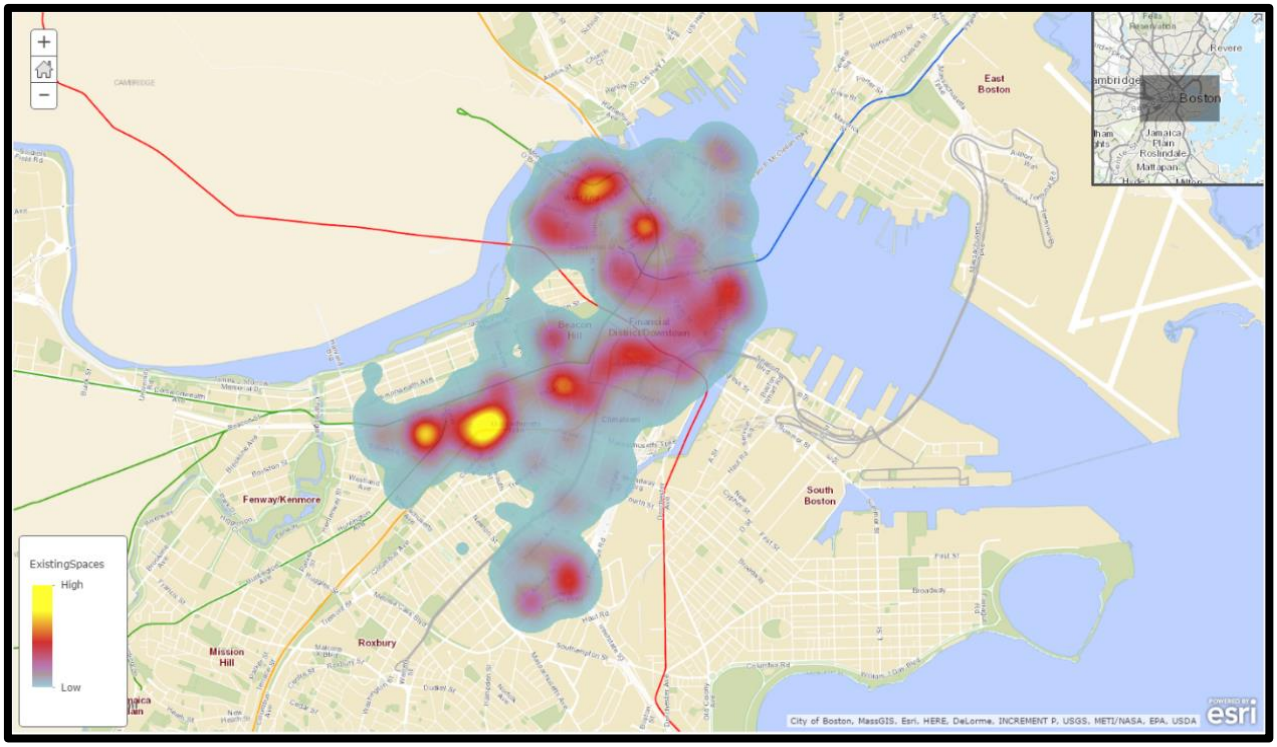

FIGURE 9. Proximity of parking facilities to public transit lines and event locations (BostonMaps, 2016).

Chapter 5: Recommendations

Upon the completion of our field survey and data analysis, we created a set of recommendations for the City of Boston to consider when creating future parking management policies and techniques.

5.1 Freeze Management Recommendations

Recommendation 1. Extend the South Boston annual renewal system to the downtown freeze zone.

According to Finding 1, some of the parking facilities in Downtown Boston were not permitted, some parked more cars than permits allowed, and some were allowed access by the public even though they were permitted as residential or business parking only. All these violations indicate that there is not enough enforcement of the downtown parking freeze policy. There is no requirement for facility owners to update the BED on changes in parking types at their facilities on a periodic basis. This is most likely due to the fact that the BED does not have dedicated staff for parking freeze zone management.

Therefore, we recommended extending the South Boston annual renewal system to the downtown freeze zone. Under the downtown freeze annual renewal system, the parking facility owners would be required to submit basic information needed to update the parking freeze database every year. They would also be charged with an annual fee dependent on the capacity of the parking facility. The funds generated by the renewal system could be used to hire a parking freeze manager responsible solely for maintaining the database, decreasing the workload of current BED staff. This system would also prevent the need to frequently inventory every facility in the freeze zone.

With the annual renewal system, the database could be kept up to date. However, it would be an honor system without verifying the information the facility owners submitted. Therefore, we also recommend to inventory about 30% of facilities in the database annually to ensure compliance. The selection of these 30% would be partially based on the past record of violations and partially based on random selection depending on the number of uncompliant facilities. Every year, the parking freeze manager would make a list of selected parking facilities and visit them personally to verify submitted information. The first list for selected inventory could be generated from the database we created by comparing the existing spaces with permitted spaces for each facility.

Recommendation 2. Reconcile parking freeze permits with TAPAs to minimize the number of spaces granted for new developments.

Since many of the parking facilities we inventoried provided counts significantly lower than their permit totals, we believe that too many permitted spaces were allocated initially. This “oversupply” of permitted spaces may be caused by the TAPAs mandating an unnecessary or inappropriate amount of parking. This could also be due to the breakdown in parking demands referenced in Finding 1. In either case, we recommend the TAPAs be revisited due to inconsistencies between what assessors believe to be the parking needs of a particular facility and the actual parking demand or use experienced by the facility. Eliminating this “oversupply” of parking would reduce VMT in the same manner that the freeze itself reduces VMT by limiting parking availability. Further, less building space and construction costs dedicated to parking facilities would allocate more real estate for building owners—the City of Boston is constantly seeking to find ways to use space more efficiently, especially in downtown.

5.2 Data Management Recommendations

Recommendation 3. Utilize the Collector application in field surveys of parking facilities.

We were the first project team to use the Collector application in the BED and recommend that it be utilized in field surveys of parking facilities for several reasons:

- Eliminates the inefficiencies of paper field survey forms
- Allows for route tracking
- Enables real-time creation of new data points in the field

With the increased need for digitized data as the City of Boston switches to computerized systems, gathered data should be collected and stored electronically. In our experience, Collector was an excellent application to be used when inventorying as it enables real-time data input. This allows no information to get lost and the processing time decreases since paper field surveys do not need to be manually input into BostonMaps after the information is collected. We were able to easily create fields needed for gaining information about parking facilities in Collector and fill them out when inventorying.

As Boston's skyline continues to change, many new developments are built or redesigned. Because of this development, the BAPCC does not have permits recorded for every off-street parking facility in the downtown freeze zone. During the on-foot survey of our project, we were able to find some undocumented facilities. When inventorying with paper sheets, our team had a list of addresses to go through, and we did not have a map that showed us all the facility locations that were documented nearby or route tracking methods to know where other team members had travelled and checked for undocumented facilities. However, Collector offered all of these, and it enabled us to input information about new parking facilities that were not on the record. Moreoverthe application allowed us to take picture of the facilities and input them into BostonMaps immediately.

Recommendation 4. Publish the inventory data online by making the BostonMaps database public.

As technology evolves, parking demands are being satisfied in new ways such as grassroots mobile applications that offer drivers a map of parking locations based off of proximity or price. It would be useful to make the BostonMaps database public so the information could help people find facilities to park through apps similar to ParkBoston—an easy and convenient way to find and pay for metered parking in Boston using a mobile phone or web browser. Making new applications that have more and new functionalities would simplify the ways people find convenient parking spots. This would cause a reduction in VMT by reducing the amount of time spent in vehicles searching for parking spaces.

This information also could be useful in legal matters such as the selling of land and ensuring permit compliance. Companies or individuals who want to buy or sell land with parking spaces currently have to directly contact the BED to gain information about the parking permit compliance of specific facilities. If the information were available online, it would be easier for buyers and lawyers to access information pertinent to their business transactions.

Recommendation 5. Implement BostonMaps as the primary database for parking freeze management until other city-wide systems becomes fully integrated.

Hanson is a city-wide database used by the Boston government. The BED has not adopted it for parking freeze data management due to difficulties in initial implementation, data input, and information sharing. Until the Hanson database becomes fully integrated, we recommend the BED use

BostonMaps as the primary database for parking freeze management. BostonMaps can be accessed by all departments and has a clean and user-friendly interface. Even GIS novices like us were able to easily navigate through BostonMaps with limited interaction. BostonMaps works in conjunction with the full desktop version of ArcGIS to create and edit data layers. Since ArcGIS is very commonly used in the BED, employees could integrate BostonMaps into their projects with little training.

5.3 Conclusion

These recommendations are aimed at improving data and parking freeze management at the BED. Our on-foot inventory uncovered trends in transportation demand management techniques in the downtown Boston freeze zone. The process by which we collected data uncovered simplified ways of collecting, organizing, and distributing information. By following these recommendations, the BED would have the tools necessary to enforce the freeze more strictly. This enforcement could improve the effects of the freeze by discouraging commuting, reducing VMT, consolidating the land area devoted to parking, and improving air quality, which is the ultimate goal of the freeze. The recommendations we put forth could also assist in validating the legitimacy of the freeze's effectiveness by examining inventory data and quantitative measurements of air pollution. This could lead to the evidence needed to make policy changes in the future to improve current freeze legislation.

The collaboration of the City of Boston, Nelson/Nygaard, and A Better City on the first comprehensive Parking Policy Study will culminate in a report due for release in Fall 2016. It will outline the future of parking in Boston as it relates to the City's environmentally-sustainable *Go Boston 2030* transportation plan. Our ground-truthing of the parking freeze permit data provided the City of Boston with the evidence necessary to justify parking policy changes that emphasize the intersectionality of stakeholder values, with air pollution control at the core.

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Appendix A: Boston Downtown Freeze Inventory Survey Sheet

BOSTON OFF-STREET PARKING INVENTORY – FIELD SURVEY

Project Information

Project Name _____

Project Address _____

Entrance Location _____

Company Name _____

Manager _____

Contact Information _____

Parking Information

Existing Spaces _____

Additional Valet Spaces_____

Public/Commercial _____

Residential _____

Exempted _____

Permitted Spaces _____

Parking Method (Valet, Self Park, Etc) _____

Hours of Operation _____

Rates _____

Others

Electric Vehicle Spaces _____

Electric Vehicle Outlets Locations _____

Number of Bicycle Spaces _____

Location_____

Car Sharing Program _____

Notes:

Project Information

Project Name _____

Project Address _____

Entrance Location _____

Company Name _____

Manager _____

Contact Information _____

Parking Information

Existing Spaces _____

Additional Valet Spaces_____

Public/Commercial _____

Residential _____

Exempted _____

Permitted Spaces _____

Parking Method (Valet, Self Park, Etc) _____

Hours of Operation _____

Rates _____

Others

Electric Vehicle Spaces _____

Electric Vehicle Outlets Locations _____

Number of Bicycle Spaces _____

Location_____

Car Sharing Program _____

Notes:

Appendix B: Parking Facility Inquiry Letter

City of Boston Environment Department
One City Hall Plaza, Room 709 Boston, MA 02201
www.cityofboston.gov/environment/
617-635-3850

October 4, 2016

Dear (parking facility),

We are a team of students at Worcester Polytechnic Institute working with the Boston Environment Department to conduct a survey of parking availability in Downtown Boston. For some reason we were not able to collect the data we needed when we visited this facility in person, and we would really appreciate it if you could answer the following questions. This survey is related to the parking freeze permit held by this facility and overseen by the Air Pollution Control Commission.

Please respond to this letter, preferably by email, with the following information:

1. How many total parking spaces are located in this facility?
    a. Lined?
    b. Unmarked (i.e. valeted into available space)?
2. How many of these spaces are available to the public?
3. How many of these spaces are available to employees or patrons only?
4. How many of these spaces are available to residents only?
5. How are cars parked at this facility (e.g. valet, self-park, etc.)
6. How are the number and types of parkers (e.g. residential, general public, etc.) tracked?
7. What are the hours of operation?
8. What are the facility rates?
9. On what streets are the entrances and exits?
10. How many electric vehicle charging stations or regular outlets used by electric cars are on the premises? Please specify how many of which.
11. How many bicycle spaces are on the premises? Where are they located?
12. Is there a car share available at this facility such as Zipcar or Enterprise? If so, how many are available?

Thank you for time,
Boston Off Street Parking Team
Storie Nivers
Ian Smith
Nata Vacheishvili
Simon Zhang

Email Survey to:
bos16parking@wpi.edu
cc: haidee.janak@boston.gov