Improving Nantucket's Parking

An Interactive Qualifying Project
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For more information regarding our project see:
https://wp.wpi.edu/nantucket/projects/2018-projects/npo/

Abstract

Nantucket is a small island with a historic charm that attracts numerous tourists during the summer months. This influx of tourists combined with the historic, narrow, cobblestone roads and a limited parking supply leads to a multitude of parking problems. The goals of our project were to improve traffic flow in the downtown area, and to improve parking management. To achieve these goals our team analyzed current on-street conditions, evaluated new parking management systems, and proposed solutions to common problems, then solicit feedback from various SME's and stakeholders. Some of the results of this project are a list of potential street redesigns with photoshopped concept pictures, an improved parking inventory process, and a decision matrix for evaluating parking management technology systems.

Acknowledgements

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Executive Summary

Most drivers have experienced trying to find parking when the only option is on-street parking in crowded downtown areas. This experience mostly consists of driving in circles up and down the same streets trying to find that one open space or waiting for a car to leave its space. This repetitive action of circling around streets can account for roughly 30 percent of downtown traffic congestion on average across cities (Oregon Department of Tansportation, 2015).

From early June to late August increased traffic congestion is prevalent on the island of Nantucket and is stressed by the problems created from a downtown historic district that is 0.3 square miles with narrow cobblestone roads. Being a primarily seasonal location for tourists, Nantucket experiences a large population increase from about 17,200 to as many as 46,000 visitors and residents combined over the peak summer months. Since the primary way to travel to the island is by ferry, many visitors are able to bring their cars over as a means of transportation once they arrive on the island. This sizeable influx of visitors and residents coming to the island, and inevitably bringing their cars with them, can lead to the downtown area being extremely congested.

Figure 1: Traffic Congestion on South Water St

Although there are no delineated parking spaces on most streets, there are an estimated 1,390 on-street parking spaces in Nantucket's downtown area. The summer season renders the on-street parking supply near downtown inadequate, as many drivers searching for an open space add to the overall traffic that exists from vehicles driving through the downtown (Edmondson, 2017).

Project Statement

The first goal of the project was to improve traffic flow in the downtown area of Nantucket. We accomplished this goal by evaluating whether prohibiting on-street parking or reconfiguring selected streets, would benefit the overall Nantucket central district parking situation and improve traffic flow. The second goal was to propose improved downtown parking management strategies by analyzing available parking management systems and assessing their applicability on island. To achieve these goals, we proposed four specific objectives:

1. Determine current on-street parking conditions
2. Propose on-street parking changes to improve traffic flow of vehicles, pedestrian access, and promote alternative modes of transportation
3. Evaluate new parking management systems
4. Analyze stakeholder opinions regarding parking management solutions

To complete these objectives, our team developed a process to document the observed parking conditions on selected streets. The data was then transferred to a GIS program and spreadsheet to display and analyze it. Our team noted the problems on the selected streets in the downtown area and then provided street reconfigurations, along with multiple parking management system solutions. We presented solutions to local stakeholders to learn their opinions and made changes to recommendations accordingly.

Results and Recommendations

The results of this project entailed a range of solutions centered around street reconfigurations, an improved manual parking inventory process, and a decision matrix. This project includes a streamlined version of a manual parking data inventory process and a decision matrix for analyzing parking management solutions. Both products were deliverables given to the town to aid anyone continuing our work. The decision matrix has a list of categories and attributes deemed critical to analyzing the feasibility of a parking management technology system on Nantucket. The improved parking inventory system focuses on using map techniques and software tools to make the process more efficient. The process involves converting data from paper maps to an ArcGIS layer, and then summarizing the data in an Excel table. With our process of data collection and input one person originally input data at a rate of 32 vehicles an hour while recording a day's data set of about 600 inventoried vehicles. After improving the system, the process increased to a rate of 174 vehicles an hour for the team complete a day's data set of over 2000 inventoried vehicles. The process improved by allowing multiple people to be both collecting and inputting data simultaneously. Although it is an improved process our team had limited resources and therefore made recommendations on how to improve upon the process even further. These involve using the GPS from phones to record the exact location while filling out the information need on the field through the phone.

Some of the options for reconfiguring select roads involved manipulating the sidewalks to allow an increase in driving lane space and parking area. An example of this approach is reducing the width of the sidewalk while keeping it ADA compliant. To meet the standards of the Americans with Disabilities Act the sidewalks must be at least three feet wide. This solution involves removing a certain width of the sidewalk and rebuilding the curb at the new edge. This allows vehicles to have enough space to park on-street without ramping over the curb and damaging the sidewalk. Another solution that our team proposed is delineating parking spaces as shown in Figure 2. This process simply defines the space allocated for a vehicle to park with painted marks and does not alter the current road infrastructure in any major way. This solution would reduce instances of some negative driver habits such as sandwiching a car in between two vehicles so that it cannot move or parking in a way that uses two spaces instead of one. Along

Figure 2: Comparison Between Non-Delineated Spaces and Delineated Spaces

with these options our team recommends conducting a traffic flow study on selected streets, evaluating all the options presented in the report for reconfiguring the streets and then evaluating the impact of the chosen reconfiguration option. Then to test one of the options and see the effects of it and whether another option should be considered.

To improve the parking management on Nantucket our team recommends implementing a system of parking management technologies in the downtown region. This way parking utilization can be monitored in real time throughout the day. For a management system to be implemented, it is necessary that the current cellular network on the island be upgraded, so that these technological systems can communicate effectively in the downtown. Currently, the network connection and capabilities in downtown are not sufficient as there are reports of dropped calls and other data transfer problems during the summer season. The signal strength and connection on the island is poor overall as some homeowners must purchase their own personal microcells to guarantee a strong, reliable signal throughout the year. This will also have other positive effects, such as helping communication between first responders not get interrupted thus increasing the safety of the island. After, using the decision matrix provided, it is recommended to find the most feasible parking management technology for the town and then conduct a pilot program with it. The pilot program will tell if the technology runs the way that is desired by the town and whether to continue with that system. If the system works, the data collection for parking then will be able to be sent to the operator without any problems so that the town can have more time on managing parking rather than data collection.

1.0 Introduction

Most drivers have experienced trying to find parking when the only option is on-street parking in crowded downtown areas. This experience mostly consists of driving in circles up and down the same streets trying to find that one open space or waiting for a car to leave its space. This repetitive action of circling around streets has been attributed by studies to account for roughly 30 percent of downtown traffic congestion on average across cities. A rise in traffic congestion leads to the obvious slowing of vehicle traffic, but there are also unforeseen consequences such as increasing car emissions and creating anxiety for all drivers in the affected area (Oregon Department of Tansportation, 2015). From early June to late August increased traffic congestion is prevalent on the island of Nantucket and is exasperated by the problems created from a downtown historic district that is 0.3 square miles with narrow cobblestone roads.

Being a primarily seasonal location for tourists, Nantucket experiences a large population increase from about 17,200 to as many as 46,000 visitors and residents combined over the peak summer months (Edmondson, 2017). Since the primary way to travel to the island is by ferry, many visitors are able to bring their cars over as a means of transportation once they arrive on the island. This sizeable influx of visitors and residents coming to the island, and inevitably bringing their cars with them, can lead to the downtown area being extremely congested as shown in Figure 3 below.

Figure 3:Traffic Congestion on Main St in the Summer

While many more cars are being driven and parked on the streets in the historical district over the summer months, the parking supply unfortunately stays the same year-round. Although there are no delineated parking spaces on most streets, there are an estimated 1,390 on-street parking spaces in Nantucket’s downtown area. The summer season makes the on-street parking supply near the downtown appear inadequate, as the many drivers searching for an open space add to the overall traffic that exists from vehicles driving through the downtown. The number of drivers looking for a parking space in the downtown can also increase in the case of poor weather conditions because people simply do not want to walk to and from an open parking space that may be only a few blocks from the downtown area. The combination of vehicles coming off the ferries, driving through the downtown, and driving into downtown in search of parking, leads to a large number of vehicles in a small area. This resulting congestion in downtown Nantucket during the summer months not only creates frustration for people looking for parking, it can also significantly impact emergency vehicle response times when they must get to a downtown location.

Multiple transportation firms and other research teams have investigated and proposed various solutions to Nantucket's parking problems over the past decade. For example, Tetra Tech Rizzo did a study on Nantucket's overall parking in hopes of identifying problems with the island's parking system by focusing on the current supply and demand. However, very little action was taken based on the results of the study (Tetra Tech Rizzo, 2010). Fortunately, because of the work done by Tetra Tech Rizzo, a detailed parking inventory of Nantucket was created that gave exact on-street space totals of each type of parking restriction in their study area (i.e. time-limited, handicapped, loading zones, etc.). Afterwards, a transportation planning firm by the name of Nelson/Nygaard constructed a matrix of possible parking management improvements for Nantucket. In their study, Nelson/Nygaard divided the solutions they considered into four categories based on what aspect of parking management the solution related to the most. Unfortunately, the parking management devices on the market in 2010 that the firm took into consideration were seen as too bulky and too intrusive for the historical look of Nantucket's downtown district and were not implemented. Most recently in 2017, a WPI team (Alvarez, Hosea, Lanotte, & Macleod, 2017) worked on a similar project to that of Nelson/Nygaard's. In the WPI team's report, a few additional solution systems were proposed, but the report primarily focused on defining what the public's opinion on implementing these systems on Nantucket. The student team's research showed that the public's opinion on parking management solutions was divided on whether or not they were in favor of integrating the systems into the downtown community. While there has been significant groundwork done in analyzing parking management strategies' applicability on Nantucket, there were still multiple solutions that had not been covered in previous studies.

Project Statement

The first goal of this project was to improve traffic flow in the downtown area of Nantucket. We planned on accomplishing this goal by evaluating whether prohibiting on-street parking or reconfiguring selected streets, would benefit the overall Nantucket central district parking situation and improve traffic flow. The second goal of this project was to improve parking management as a whole in the downtown by providing the town an analysis of parking management systems. To achieve these goals, we created the following objectives:

1. Determine current on-street parking conditions
2. Propose on-street parking restrictions to improve traffic flow

3. Evaluate new parking management systems
4. Analyze stakeholder opinions regarding parking management solutions

To meet these objectives, we proposed combining the data collected from recent surveys and previous parking management studies, with parking utilization data we collected, to understand the on-street parking conditions and issues on streets throughout the historic district. To gather information on various parking management technologies and systems we planned to reach out to parking management vendors and determine their technology's capabilities along with discussing the feasibility of their implementation on the island. After gathering information on the parking management systems, we planned to construct a decision matrix that compared the effectiveness of the parking management solutions we analyzed.

2.0 Background

This section presents background information that is essential to understand for this parking management study. The topics covered include the current problems with on-street parking, different aspects of parking management on Nantucket, and a collection of parking management technologies and strategies.

2.1 Nantucket's Parking Problem

Nantucket's historic downtown district is vital to its tourist industry's success and sees a large increase in vehicle traffic over the peak summer months due to the large increase in population. The island experiences issues managing this steep increase of vehicles brought by visitors, due to the island's historic road design and limited parking supply. Nantucket does not have an off-street parking structure, so the on-street supply is primarily the option when looking for a parking space in the downtown. Additionally, many roads in the downtown are made of cobblestones and some roads can be so narrow that vehicles are forced to drive up on the curb to navigate past parked cars.

Currently there are city traffic laws that allow parking practices in the downtown Nantucket area that are generally not allowed on the mainland. For example, streets that are exceptionally narrow generally allow drivers to park on the sidewalks to create a wide enough driving lane for vehicles to pass as seen in Figure 4 below. This parking behavior narrows pedestrian walkways and damages the historic brick sidewalks overtime. Sidewalk parking also has significant consequences for pedestrians with disabilities. Title II of the American Disability Act states that public entities must cover access to all programs and services offered by the entity (Legal Information Institute, 2014). In 2004 Barden v. Sacramento set a precedent across the nation requiring that all public sidewalks be made accessible. The court ruled that public entities must "address barriers such as missing or unsafe curb cuts throughout the public sidewalk system, as well as barriers that block access along the length of the sidewalks," (Disability Rights Advocates, 2007). This ruling applies to parked cars taking up a significant portion of the width of a sidewalk.

Figure 4: Sidewalk Parking Obstructing Pedestrian Access

2.2 Parking Management on Nantucket

The increased traffic congestion due to a limited parking supply has been a known issue on Nantucket for over a decade. Multiple firms and teams have investigated the downtown area of Nantucket and proposed solutions to improve both parking management and traffic flow. In 2009, Tetra Tech Rizzo did a study that focused on accurately surveying the supply and demand for parking in downtown Nantucket. In 2010, Nelson\Nygaard categorized solutions into four broad categories based on what aspect of parking management the solution dealt with. This section will cover the aspects of parking management that these two studies focused on.

2.2.1 Parking Supply

In 2009, Tetra Tech Rizzo quantified the supply of parking spaces in downtown Nantucket. They counted approximately 1,390 total spaces within their study area as seen by the yellow outline in Figure 5. Of those spaces, 1,054 were located on-street and 336 were considered off-street. Of the supply inventoried, six percent (equal to 66 spaces) of the on-street parking spaces are designated for handicap, taxi, loading, or town usage. Nearly all on-street parking spaces in the study area are time regulated with 1/2, 1, or 2 hour limits (Tetra Tech Rizzo, 2010).

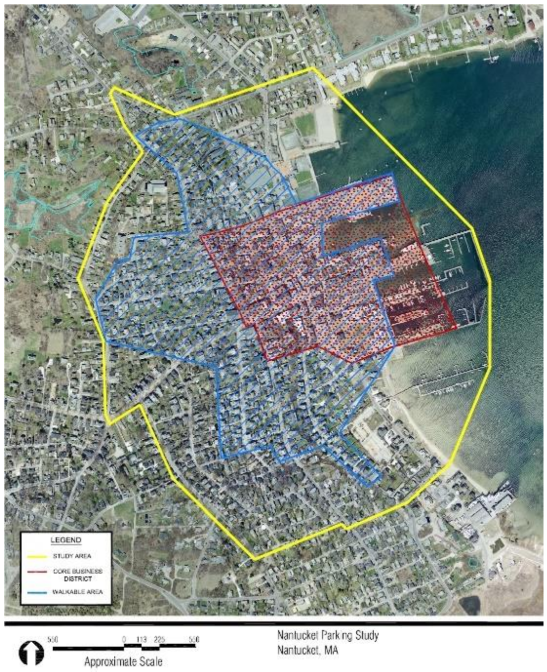

Figure 5: Study Area Map from Tetra Tech Rizzo

2.2.2 Parking Demand

Tetra Tech Rizzo also determined the demand for the downtown Nantucket parking spaces using three different methods. One of these methods was a parking utilization study and according to Nelson\Nygaard, "Parking utilization looks at the number of parking spaces that are occupied versus those available at certain points of the day…. The on-street parking optimal utilization rate is 85-percent," (Nelson\Nygaard, 2010). The data Tetra Tech Rizzo collected shows that the utilization percentage for the whole parking supply on a street was typically over 85% and in some cases during the day, over 100% due to illegally parked cars on the street. Nelson\Nygaard's transportation study that examined parking on Nantucket also showed in their parking utilization analysis that most roads, during peak times, were considered fully utilized or over utilized. This is evident by the pink and red sections in one of Nelson\Nygaard's utilization maps shown in Figure 6 below.

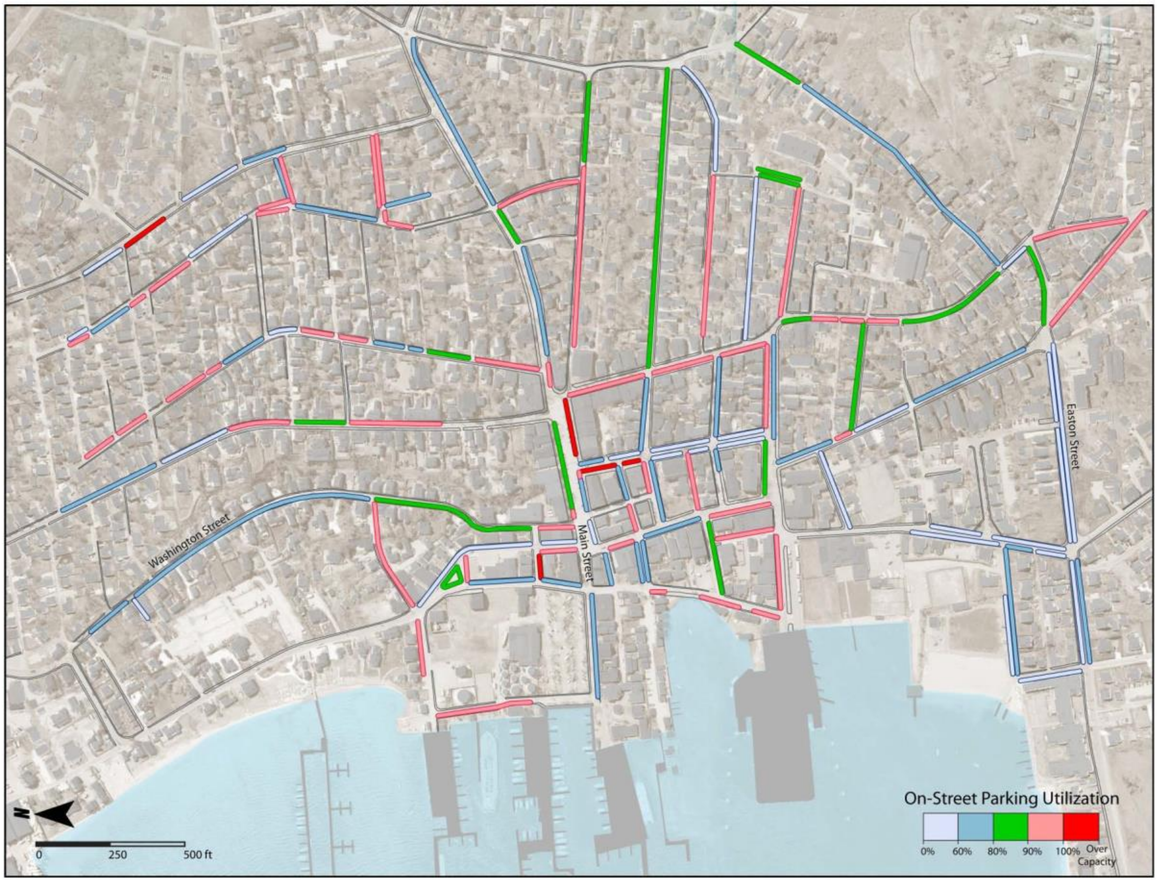

Figure 6: Friday 5:00pm Utilization Map from Nelson\Nygaard

2.2.3 Supply Enhancement

Supply enhancement focuses on reducing the need for parking, redesigning parking layouts to be more efficient, or increasing the total supply of parking (CMAP, 2013). In 2010, Nelson\Nygaard explored the feasibility of five options. Here we discussed one of the options, which is reverse angle on-street parking. The premise of this solution is to angle parking spaces at either 45, 60 or 90 degrees opposite to the flow of traffic and have drivers back into the spaces. This way when the driver is pulling out of a space, they are facing the flow of traffic and are less likely to get into an accident as a result. By taking parking spaces parallel to the curb and angling them, the supply of parking spaces in an area would increase by anywhere from 20 to 70 percent depending on both the angle, and if the street is wide enough to accommodate for the spaces extending out farther from the curb.

2.2.4 Improved Parking Regulation Enforcement

Improved enforcement solutions are referred to as "technologies that simplify or streamline the enforcement procedures in some way, either tools that enhance the enforcement officers ability or automating monitoring procedures" (Nelson\Nygaard, 2010). A critical element to improving the flow of traffic and utilization of parking spaces is the efficient enforcement of parking regulations. One of the main problems Nantucket faces with parking is that people often leave their car in a time limited space all day and paying any ticket received as a minor inconvenience (a flat $25 ticket for overstaying the time limit) (personal communication, Mike Burns and Peter Morrison, September 17, 2018). This problem exists because of the difficulties that come with enforcing time limited parking and the relatively low cost of tickets.

Some methods recommended in the previous studies for improved parking regulation enforcement included tracking a vehicle's time spent in a parking space using handheld units, curbside or in-ground sensors, and automatic license plate readers. Such methods improve the efficiency of enforcing time-related parking laws which in turn, improves the turnover rate of parking spaces. With efficient turnover rates, parking spaces can be occupied by more drivers throughout the day rather than having one or two vehicles sitting there for hours. These parking enforcement improvements would lay the ground work for a redesigned parking fee structure that can effectively punish drivers who leave their car parked in a space longer than allowed.

2.2.5 Demand Management

As described by Nelson\Nygaard, "Demand management strategies focus on influencing behavior of those traveling to the destination with the intent of balancing the number of vehicles at levels the supply can handle," (Nelson\Nygaard, 2010). A key technique to manipulating demand is demand responsive pricing and time regulation. The main principle for this technique is that parking spaces typically in higher demand should cost more and have shorter time limits, while other spaces with lower demand can cost less, have longer time limits, or provide free parking. Most methods proposed by Nelson\Nygaard to manipulate the demand of parking spaces involved the use of multi-space parking meters, in-car devices, and other technologies that will be expanded on later in this report.

2.2.6 Zoning and Incentives

The zoning and incentives category cover techniques that use pre-existing resources to alter the flow of traffic. These strategies can range from simply providing parking passes to residents, to employers offering a monetary reward to employees as an incentive to not commute to work in a car. One method is a Parking Benefit District. These districts take the revenue collected from parking ticket payments within the district and redirect the money from a town or city's general fund, to instead be put towards transportation improvements within the district. For example, the revenue collected can be used to fund projects that encourage usage of public transit or other alternative means of transportation to a personal vehicle. In some circumstances the funding can go to providing transit passes to employees, installing bike parking, and improving other transportation services. These strategies would hopefully incentivize people to not use their personal vehicle, thus resulting in less overall traffic on the streets (Nelson\Nygaard, 2010).

2.3 Innovative Solutions for Parking Management

The 2017 WPI student project, *Novel Approaches to Parking Management on Nantucket*, analyzed new technologies that had been developed since Nelson\Nygaard's study was carried out in 2010. This section looks to build on previous research, while including new parking management technologies that were developed in the past year and street reconfiguring strategies that could solve Nantucket's on-street parking problems.

2.3.1 Overhead Sensors

Overhead sensors are a smart parking technology that are usually installed on streetlight poles and sometimes on nearby commercial business walls or ceilings of parking structures. Most sensors monitor parking spaces in real time and use a management system to display the data to users. The network of sensors communicate over cellular or Wi-Fi networks so that large areas can be covered (Alvarez, Hosea, Lanotte, & Macleod, 2017; Siemens, 2018). The data gathered can also display utilization information for each individual parking space. The sensors are capable of identify areas with heavy traffic which can allow for the staff enforcing parking regulations to be reduced in less crowded areas, and pricing can be adjusted to effectively maximize revenue (Alvarez et al., 2017). According to Siemens, one advantage of having an overhead sensor system in place is that drivers can have access to the real-time availability status of parking spaces. With access to the availability status of parking spaces, drivers have been observed to spend 43 percent less time looking for a parking space, and 30 percent less miles are traveled before parking (Siemens, 2018). In addition to these improvements, there was an observed 8 percent decrease in traffic volume in areas where the on-street parking was being observed by sensors (Siemens, 2018).

The Cleverciti sensors can cover over 20-30 parking spots with a range of 400 meters and up to 320 degrees as long as there are no obstructions, which can be seen in Figure 7 below

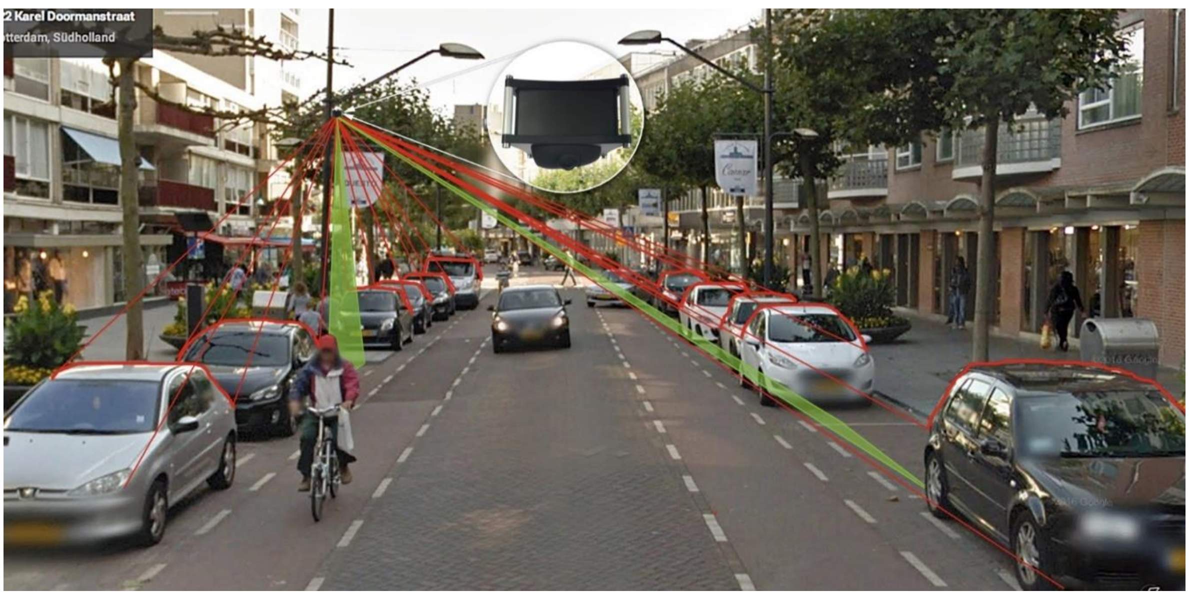

Figure 7: Cleverciti Overhead Sensor Demonstration
https://www.cleverciti.com/technology/sensors/

(Alvarez et al., 2017; Cleverciti Systems, 2018). Figure 7 also shows that the sensors can detect the exact GPS location of any available spots (i.e. the green areas in Figure 7). That information can be sent to users through an app, with the size and location of that parking spot. Cleverciti's parking app can be used to guide users to the closest parking space by GPS navigation which can reduce the time that a space is open and not collecting revenue (Alvarez et al., 2017). In addition, the sensors also measure the duration a car was parked, and can alert the authorities if a vehicle has been parked over the time limit designated for its parking space (Alvarez et al., 2017; Cleverciti Systems, 2018). Cleverciti's app can also display the cost of parking and provides the option to pay through the app rather than having to deal with a kiosk or meter. Displays can also be mounted at streets on poles in select locations so that drivers can be alerted of current parking availability in that area without needing the app (Alvarez et al., 2017). Cleverciti also mention that their sensors can heat themselves during cold weather and cool during hot weather (Cleverciti Systems, 2018). To stay complaint with privacy rights, video recordings do not leave Cleverciti sensors and are not stored as they are just needed to check the status of parking spaces. The sensors are also easily relocatable to any other location because of an easy installation process (Cleverciti Systems, 2018).

Similar to Cleverciti sensors, Siemen overhead sensors can detect vacant parking spots and guide users to the spot using their parking app with GPS navigation (Siemens, 2018). Additionally, Siemen's app is linked to public transportation alternatives so they can be recommended to the user if no parking spots are available (Siemens, 2018). Siemen also mention that their sensors can detect any parking violations that may cause a safety risk (e.g. parked on sidewalk or slightly in the driving/biking lane) so authorities can be informed. The sensors can detect the speed of vehicles, traffic conditions on the roads, and the flow of pedestrians (Siemens, 2018). The sensors can also handle any weather conditions and are not impaired by light (Siemens, 2018). Like the Cleverciti sensors, Siemens complies with privacy rights by having no image capturing (Siemens, 2018).

2.3.2 RFID–Enabled Parking Stickers

RFID parking stickers are passively powered meaning they receive power from the scanner. Typically, RFID stickers are first scanned by a parking enforcer with a handheld device, then the scanner relays information such as owner and parking privileges to the officer. The officer can then issue an accurate parking citation if needed (Alvarez et al., 2017). In combination with the sticker and reader, a database server is needed where all the user information can be stored. This process can be seen in Figure 8 (Alvarez et al., 2017).

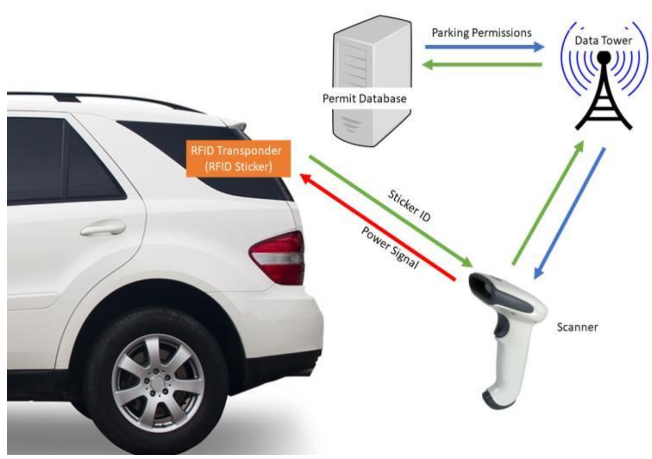

Figure 8: RFID Sticker General Usage Breakdown

The RFID stickers reduce administrative work since personal information can be updated through the database, meaning the RFID stickers do not have to be reissued when a driver's information is changed (Alvarez et al., 2017). Another benefit of the RFID sticker is unlike regular flat-rate parking stickers that do not provide any real time parking information, RFID can collect real time parking data. (Alvarez et al., 2017).

2.3.3 Kiosks

As an alternative to having many single or double space meters lining a street, a kiosk acts as a multiple parking space meter. The use of kiosks can be beneficial as a less intrusive way to manage on-street parking. For example, installing 20 parking meters for 40 spaces would be a noticeable change to the entire street, but a single kiosk can be placed on the street corner or somewhere along the sidewalk to do the job of the 20 parking meters. In 2017, kiosks were installed at the Nantucket airport, and offer up to an initial 3 hours of parking for free, and then the user must pay at a kiosk for any time they will park over the initial 3 hours (Alvarez et al., 2017). A user can input a phone number when they pay, so they can be alerted when their time limit is close to ending to add more time if needed (Alvarez et al., 2017). However, if someone does not have a smartphone they still can pay through the kiosk. While the kiosk system is autonomous at the Nantucket airport, the parking management system also includes enforcing staff, who will regularly take photos as evidence that a car is parked in violation of the local parking restrictions and can be issued tickets when necessary (Alvarez et al., 2017).

Parkeon produces an on-street parking kiosk called the Strada Evolution pictured in Figure 9. According to the manufacturer the kiosk has a long battery life which runs on solar energy provided by a panel embedded into the top of the device. To increase the security of the kiosk, the cash and maintenance compartments are separate, and the cashbox is double-walled and armor-plated. The kiosk is also able to remotely detect a physical attack. There is wide graphical display and customizable keyboard to provide easy access to the payment system for the user.

Figure 9: Parkeon's Strada Evolution Kiosk for Managing On-Street Parking Fee Payments
https://www.parkeon.com/our-solutions/product-catalogue/strada-evolution-2/

2.3.4 License Plate Recognition System

License plate recognition systems on the current market can operate in a multitude of different ways. Some are handheld devices that a parking enforcer operates, while others are mounted on vehicles. The systems operate similarly to RFID stickers except instead of identifying the vehicle by a sticker on the car, the sensor reads the license plate. These sensors, like RFID stickers, also require a database server to display the data to an operator and communicate with other sensors on the same network. Genetec's License Plate Recognition System, AutoVu, is a vehicle-mounted camera that helps patrolling officers easily identify parked vehicles on the street (Alvarez et al., 2017). The system can scan the license plate of parked vehicles whether they are parallel to the curb, at a 45 degree, or 90-degree angle during both night and day. The system alerts the officer, after scanning, if the vehicle is lacking an appropriate permit or if the vehicle has been parked over the time limit for that space. The system has the capability of issuing tickets digitally so the officer does not have to leave the vehicle, which can streamline the parking enforcement system (Alvarez et al., 2017). A wheel imaging feature of the camera acts as "virtual tire chalk," which tracks vehicles that did not move since last being scanned. The system uses the data from the previous drive-by for calculations and then notifies the officer if a vehicle is parked in violation (Alvarez et al., 2017). By improving the efficiency of parking regulation enforcement with license plate reading technology, the effectiveness of regulations used to manage parking will also improve.

Figure 10: Genetec's Vehicle-Mounted License Plate Recognition Camera
https://www.varinsights.com/doc/genetec-autovu-sharp-sharpx-license-plate-recognition-cameras-0001

2.3.5 Curbside/On-Street Sensors

Curbside and in-street sensors are the least visible technologies available for collecting parking utilization data. Typically, the sensors are designed to either be installed into the road or attached on-top which keeps them out of sight and not in the way of road maintenance. The detection methods for vehicles can depend on infrared, ultrasonic, magnetic induction, or the weight of the car for detection. Most curbside or in-street sensors are wireless; therefore, they are designed to have a long-lasting battery. The sensors can operate either on Wi-Fi or cellular frequencies making integration with apps or database servers easy and efficient.

Two sensors that we investigated are both single car sensors produced by Nwave. The main difference between each model is one of the sensors is installed into the road (Figure 11) while the other sensor is installed on-top of the road. These sensors can integrate with software applications produced by Nwave, which enable users to request directions to available parking spaces and pay for parking (Nwave, 2018). These sensors operate similarly to a sensor provided by Smart Parking which uses infrared light

Figure 11: SmartParking In-Ground Sensor

for vehicular detection. (Smart Parking, 2018) Park Here is a company that developed a multi-vehicle detection sensor that uses the weight of the car to both power the sensor and detect the vehicle. This sensor however is more visible than the others given its design and may not be able to be installed on the cobblestone streets in downtown Nantucket (Park Here, 2013). A potential alternative to in-street sensors which may have difficulties being installed on the cobblestone roads, is a curb-mounted sensor produced by CivicSmart (Figure 12). The sensor detects vehicles using radio waves to avoid interference that other detection methods have difficulties with such as weather conditions, passing or adjacent vehicles, or electromagnetic interference.

Figure 12: CivicSmart Curbside Sensor

2.3.6 On-Street Parking Fee Zones

A useful strategy that involves on-street parking fees and removing on-street parking has been employed by many cities in Europe to, "optimize the use of curb space, influencing turnover and minimizing the number of vehicles slowing traffic by searching for parking" (Kodransky & Hermann 2011). In this strategy, prices for parking spaces are determined by analyzing characteristics such as average vacancy or distance to the desired destination. These characteristics can directly affect the demand for any on-street parking space. Cars that are parked for a significant amount of time prevent new customers from parking near businesses close by to the spot which can have an impact on a businesses' revenue. Using a tiered pricing system for on-street parking zones and removing on-street parking allows the town/city to influence a driver's behavior when searching for parking. However, the effects of a zonal parking fee system can vary based on whether the driver is categorized as a commuter, a short-term driver, or a resident. Five effects that altering the number of spaces and increasing pricing have on drivers are:

- Having to find an alternative parking location
- Starting the trip at another time
- Changing their mode of transport
- Changing their destination
- Avoiding making the trip at all

Amsterdam, the capital of the Netherlands, has a long history dating back to its beginnings in the late 12th century. The city has lived through many different eras and grown significantly over time and as a result the layout of the historical city center was not designed to sustain high traffic congestion. The city has implemented a stratified pay zone system which ranges the zones from

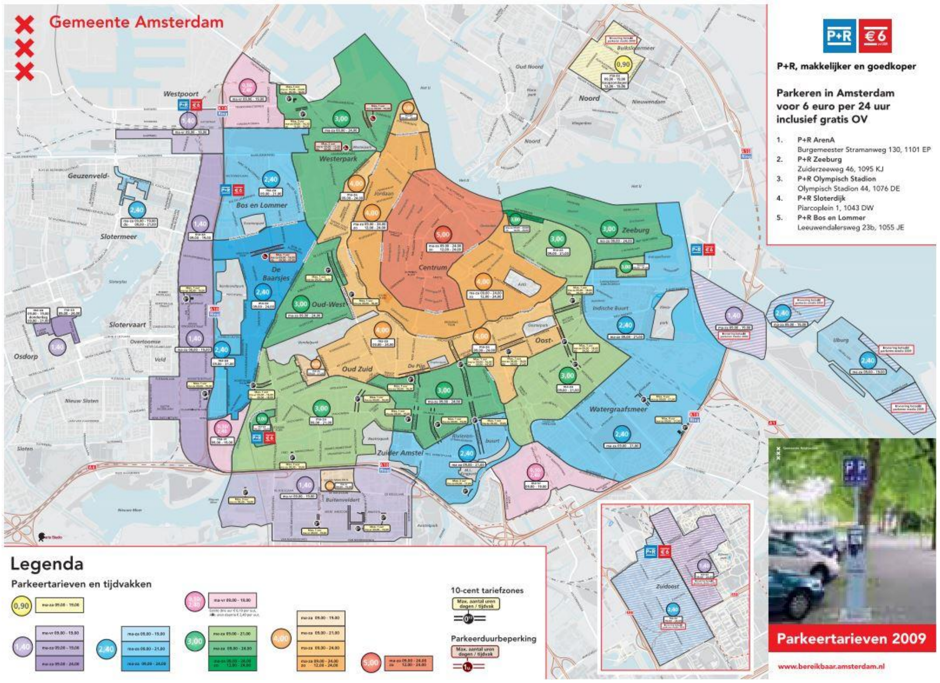

Figure 13: Map of Different Pay Zones in Amsterdam (Kodransky & Hermann, 2011)

€0.90 ($1.04) per hour up to €5.00 ($5.76) per hour with blue zones dedicated to short term free parking (Figure 13). At €5.00 per hour, the on-street parking in the historical city center is some of the most expensive street parking in the world (Kodransky & Hermann, 2011). The city incentivizes people to keep their cars out of the historical center by making it cheaper to park as you move farther from the city's center.

As an outcome from implementing the pay zone system, the city has seen a 20% decrease in car traffic in the inner city and a 20% reduction in the portion of traffic caused by vehicles searching for a parking space (Kodransky & Hermann, 2011). The revenue gained from parking fees, violation fines, and permit purchases all go in to a general parking fund managed by the city.

2.3.7 Removal of On-Street Parking and Repurposing of Streets

Another solution to relieving traffic congestion is to remove on-street parking from select streets and repurpose the area with bike lanes, pedestrian walkways, and other beneficial uses of the extra space. While this strategy will slightly decrease the overall parking supply, one of the main benefits observed in cities throughout Europe was an increased income for shops located in high pedestrian traffic zones. For example a café would gain more space for tables in front of the shop if on-street parking were removed from narrow streets and the sidewalk was extended out

(Kodransky & Hermann, 2011). By controlling the supply of parking spaces, cities can encourage other forms of transportation.

The city of Copenhagen has constraints on its on-street parking system due to its historic and unorganized layout of the city center. The city has been steadily decreasing the parking supply over the last few decades and repurposing the curbside area with biking lanes, bulb-outs, and daylighting improvements. Daylighting is the process of making streets safer for pedestrians to cross. Copenhagen has accomplished this by prohibiting on-street parking within 10 meters from a street corner and using bulb-outs to make the crossing distance shorter for pedestrians which is shown in Figure 14.

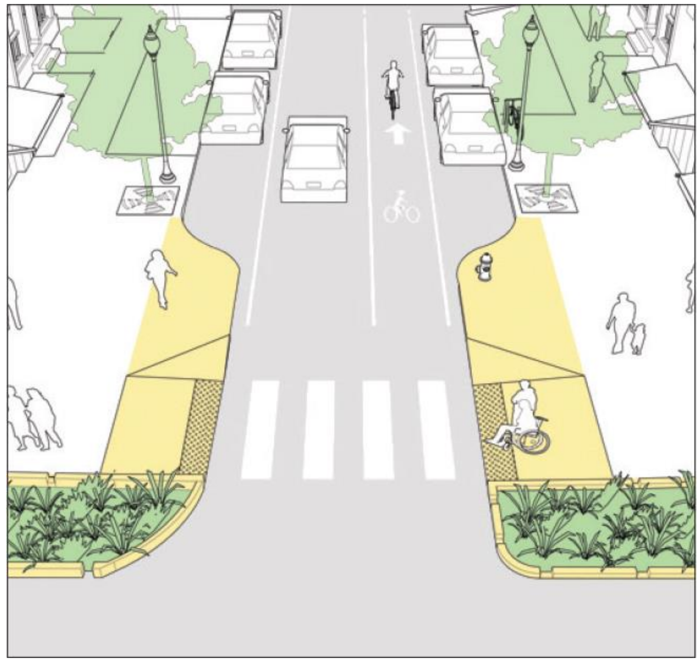

Figure 14: Bulb-out Concept for Daylighting a Street Crossing (Kondransky & Hermann, 2011)

Another example of a successful parking management technique can be seen in the city of Macao located in southeast China. Macao was given the status of a UNESCO World Heritage Center in July 2005 (Pinheiro, 2017). Due to the age of the city, the streets are narrow and were not designed with modern vehicles in consideration. There are similar characteristics between Macao and Nantucket such as the narrow roads, a steep population influx, and their historical status. The city of Macao is known for being one of the world's biggest gaming centers, so it has to deal with a similar tourism issue to Nantucket, where from 2000 to 2015 the number of visitors to Macao increased from 9.1 to 30.7 million yearly. This visitor count increase also led to the number of vehicles in the city to rise from 113,000 to 249,040 (Pinheiro, 2017). While this change in population and vehicles is not seasonal, the city planners in Macao have made attempts to solve the parking and traffic problems that come with a significant population increase.

A tactic that the planners employed was to convert certain on-street parking spots on designated streets and squares into pedestrian areas and walkways. One effect achieved by these restrictions was the city's carrying capacity for walking or stationary people increased (Pinheiro, 2017). Decreasing the supply of on-street parking can indirectly help improve the traffic flow by making it easier for people to travel in the city on foot. These restrictions will serve as discouragement for visitors to drive a car into the city due to the decrease in parking supply and the improvements made for pedestrian access. However, this process had to be attempted multiple times by the city due to strong pushback from stakeholders such as local business owners who thought that the high traffic levels were necessary for their businesses' success. Once the changes had been implemented, the business owners were surprised to see that value of the businesses in the areas affected by the repurposing went up as well as the number of visitors and customers increasing (Pinheiro, 2017). This effect was also realized after a study conducted in Rotterdam, Netherlands showed that retailers on one of the busiest shopping streets highly overestimated the percentage of their customers who arrived by car (Kodransky & Hermann, 2011).

3.0 Methodology

The first goal of the project was to improve traffic flow in the downtown area of Nantucket. We planned on accomplishing this goal by evaluating whether prohibiting on-street parking or repurposing selected streets, would benefit the overall Nantucket central district parking situation and improve traffic flow. The second goal of this project was to improve parking management in the downtown area. To accomplish this goal, we planned to provide the town an analysis of available parking management systems and assess the systems' applicability on the island.

To achieve these goals, we proposed four specific objectives:

1. Determine current on-street parking conditions
    - Research current on-street parking restrictions
    - Document the current parking conditions using pictures and video
    - Characterize traffic levels on select streets in downtown Nantucket
    - Determine approximate parking supply on selected streets
2. Propose on-street parking changes to improve traffic flow of vehicles, pedestrian's access, and promote alternative modes of transportation
    - Evaluate whether removing or in some other way changing parking spaces would benefit the flow of traffic in the historical district of Nantucket
    - Examine case studies from other cities/towns that have implemented street redesigns and list the pros and cons
    - Construct GIS parking utilization map to support proposed solutions
    - Photoshop street photos to visualize proposed repurposing of select streets
    - Consult transportation planners, engineers, and other subject matter experts (SME's) to review proposed changes
3. Evaluate new parking management systems
    - Review past study recommendations for parking management systems
    - Research parking management technologies that have not been previously suggested
    - Interview companies that provide parking management systems to determine their products specifications and capabilities
    - Create a decision matrix for the feasible parking management technologies from both new/past research
4. Analyze stakeholder opinions regarding parking management solutions
    - Interview Liaison and stakeholders
    - Evaluate data from the WPI 2017 student project parking solution surveys and town provided survey responses
    - Develop a better understanding of the stakeholders' perspectives on repurposing select roads

The project's mission and objectives are highlighted in flow chart form in Figure 15 below to display the order that we carried out the objectives to accomplish our main two goals:

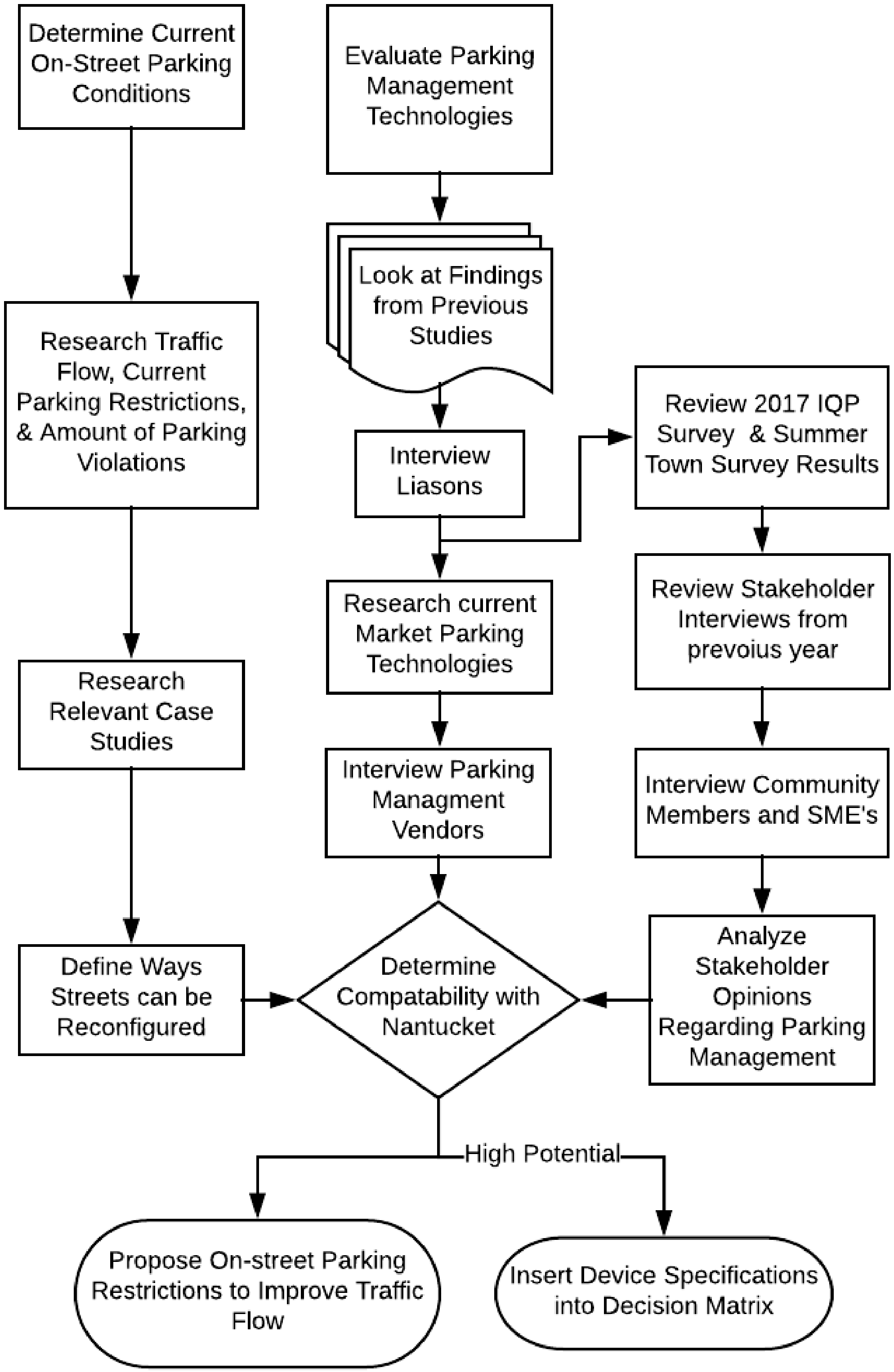

Figure 15: Project Objectives Flow Chart

Below, each of the objectives highlighted above will be explained in more detail.

3.1 Determining Current On-Street Parking Conditions

This objective was focused on determining the current street conditions such as street width, infrastructure, parking regulations, and the utilization of on-street parking spaces. This information was necessary to determine which conditions, if any, had changed since previous studies were conducted. To understand current on street parking conditions, our research primarily focused on town documents and previous studies. We used data collected by the NPO to characterize traffic levels and determine the types of parking violations and the rates they occur throughout downtown. We also took pictures of selected streets and recorded the total parking supply for each street. The four steps listed below were followed to complete this objective.

Step 1: Provide an overview of the study area
Step 2: Identify the problem areas
Step 3: Identify why the problems are occurring
Step 4: Identify when the problems arises

To complete Step 1, we used the town's GIS software, ArcGIS by Esri, to identify and delineate the study area in downtown Nantucket. We also used the GIS software to highlight the individual streets we performed parking inventories on. Step 2 was carried out by printing maps of the selected streets and using them to collect parking inventory data by hand at 9AM, 12PM, 3PM, and 5PM on multiple days. Once gathered, we transferred the data into GIS software from our paper maps. The parking data was then extracted from the GIS software into an excel sheet for further analysis.

3.2 Proposing On-Street Parking Changes

After compiling data about current conditions for on-street parking, we planned to analyze whether changing the parking design on specific streets would benefit the flow of traffic. We also evaluated if other types of changes would be more beneficial than just removing parking, such as making streets one-way, adding parking time limits, or changing the sidewalk configurations.

To evaluate restructuring options under the current parking regulations, we researched relevant case studies regarding street redesign and parking management to determine the impact on vehicle and pedestrian traffic, safety, and other factors. With the knowledge gained from the case studies, we continued our step by step process from the first objective (see above) onto Steps 5 and 6 which are listed below:

Step 5: Determine multiple solutions to the problem

Step 6: Visualize the solutions via Photoshop of street views with before and after images

To complete steps 5 and 6, we took the images of problem areas such as narrow sections or places where the sidewalk was obstructed by parked cars, and photoshopped various changes that could be made to the street to improve traffic flow and/or on-street parking. Providing a visual when proposing changes to be made to the street allowed us to show how widening the road or sidewalk, removing the sidewalk, adding a bike lane, etc. would look if implemented. We then consulted with transportation planners, engineers, and other SME's experienced with parking management to get their professional input on our proposed solutions. Based on the feedback, we proposed multiple options for specific changes on selected streets to improve traffic flow during the peak season.

3.3 Evaluate New Parking Management Systems

The purpose of this objective was to explore innovative parking management systems that could be applied to Nantucket's downtown historic district. Nantucket wanted an efficient and accurate way to gather parking utilization data. To determine which technologies could work on Nantucket, we examined a variety of options. We began by looking at previously conducted parking management studies carried out in Nantucket's downtown. Our plan also entailed constructing an interview outline and contacting parking management technology companies we were interested in talking to about their parking management products. After receiving responses to our initial interview request, we conducted interviews with representatives from the companies to better understand their technology's specifications, and if there are any cities or communities currently implementing their product. After receiving and evaluating vendor information, we discussed with our liaisons to learn their perspectives on the technologies presented to us. Finally, we analyzed the technologies through the use of a decision matrix to compare and contrast the different systems along with assessing the feasibility of the systems being implemented on Nantucket.

The first step towards achieving this objective was reviewing what previous studies and projects achieved and proposed. In the case of our project, there are three specific Nantucket studies that we investigated:

1. Downtown Parking Study Nantucket, Massachusetts: Tetra Tech Rizzo, 2010, 3rd draft
2. Parking Management Plan: Potential Parking Management Strategies: Nelson\Nygaard, 2010
3. Novel Approaches to Parking Management on Nantucket: Shannon Alvarez, Richard Hosea, Nicholas Lanotte, and Angela MacLeod, 2017

Each of these studies proposed various management systems and technologies to address the parking conditions on the island. We adopted the system evaluation strategy used in the Nelson\Nygaard study by creating a decision matrix to compare the proposed solutions and systems to each other. In particular, we used the WPI student project (#3 above) to understand recent technological developments on the market and stakeholders' opinions of these systems.

To further evaluate the current conditions and the progression of proposed parking management solutions on the island, we conducted an interview with our liaisons Mike Burns and Peter Morrison, to understand why solutions from previous studies had not been implemented. After we determined what the previously proposed technologies were, we began our own research on parking management technology. For each parking management system, we investigated how the entire system operates, how the hardware is installed, and what its capabilities are. We also made preliminary assessments on how compatible the system would be with the historic climate of Nantucket. Additionally, case studies that described solutions to parking and traffic problems using new strategies and new technologies were compiled and analyzed to cross-reference with our work (Kodransky & Hermann, 2011). By analyzing these studies, we saw real-world examples of how effective some parking management techniques are and could determine whether they benefitted the city's parking availability, reduced traffic congestion, or improved accessibility of the streets to other modes of transportation.

3.4 Analyzing Stakeholders Opinions

To better understand the different opinions regarding parking management and proposed solutions, we analyzed survey results from the WPI 2017 project, *Novel Approaches to Parking Management on Nantucket*, and the survey the town's Planning Office conducted. The surveys helped us evaluate opinions regarding paid parking and transportation from different stake-holding groups. The willingness to pay for parking, how much the respondents are willing to pay, and what kind of transportation people use were among the topics addressed by the surveys. A section for additional comments allowing people to explain their answers was included on the surveys as well.

Along with the surveys, there were interview notes from the WPI 2017 project team with other stakeholders, such as the police chief. These interview notes provided a more technical insight on the topics since the interviewees are experienced in parking management. In addition to the previous information, we developed outlines to interview various community members and parking management technology vendors. We interviewed the Deputy Chief of Police and Chief of Police to understand the technological limitations on the island, such as bandwidth and unstable connections with servers. The interview helped us organize what we planned to discuss with parking management companies. Finally, we interviewed selected representative community members to help determine the pros and cons of each alternative solution we proposed.

4.0 Results

In this chapter the findings made, and deliverables created during this project will be discussed. The deliverables are to serve as tools to guide future teams and stakeholders in gathering and comparing data, to aid in making an informed decision regarding parking management technologies and street reconfigurations. The section will cover the following:

1. Manual Parking Inventory Process Improvements and Findings: The manual inventory system is the process of collecting information on parked vehicles in the downtown area. This helps identify when and where problem areas occur. The original process was tedious thus improvements were made.
2. Options available to reconfigure streets to improve traffic flow and accessibility to pedestrians, bikers, and the mobility impaired.
3. Findings made throughout the project that are critical factors for consideration when trying to implement any parking management technology on the island of Nantucket. Additionally, a decision matrix template that will be left with the town to aid in future comparisons between parking management technology systems and their feasibility with Nantucket.

4.1 Improved Parking Inventory Process

The inventory process is a system in place to help identify when and where parking related problems occur in a specified area. It's a combination of fieldwork data collection and data processing. The original method for performing this was found to be too tedious and long, thus improvements were made to help the town repeat this process in a more organized and efficient way. Throughout the process, findings regarding parking related problems in the downtown area such as narrow streets, sidewalk parking, and damaged sidewalks were discovered. While the system was improved there were limited resources available, therefore there are recommendations to further improve this process.

4.1.1 Street Inventory Data Collection Process

The most effective way to record the classification of vehicle, its location, and at what time, was to simply make marks on a printed map from the GIS software with identifying layers such as the parcel lines. Although parking spaces were not delineated, vehicles would typically park in a consistent pattern as though spaces were delineated. From this discovery, we found that

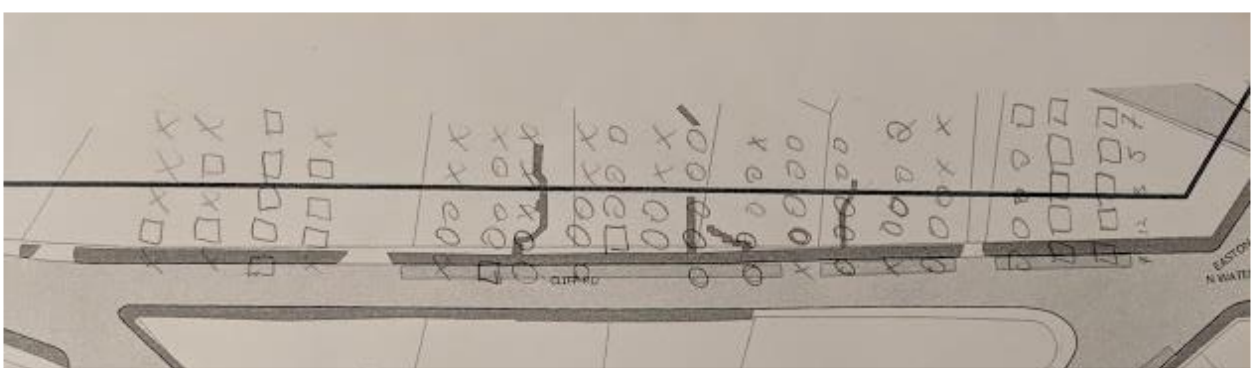

Figure 16: Parking Inventory Paper Map Sample

it was easier to record the data from all the time sessions onto one map. This was done by marking whether spaces were occupied, using appropriate symbol to denote vehicle classification as shown in Figure 16 above.
Below is a list of findings regarding problems that were identified during the fieldwork process.

- Narrow roads
- Sidewalk parking (Figure 17)
- Limited pedestrian access (Figure 17)
- Damage to sidewalks from vehicles driving on them (Figure 17)
- Bumper to Bumper parking limits vehicle departures
- Vehicles using an excessive amount of space

Figure 17: Sidewalk Parked Vehicle Obstructing Pedestrian Access & Damaged Sidewalk

After collecting parking data, it would be inputted via Google Forms into separate spreadsheets for each day. This allows multiple people to simultaneously enter data as opposed to only one person. This improvement allows the data entry to be completed over 5 times faster, according to the data we collected.

4.1.2 Converting Data to GIS

Once all the data is inputted, it is converted to an Excel file. The reason for doing this was to ensure that the data was in a compatible format for ArcGIS and our dynamic table (see section 4.1.3 for an overview of the dynamic table). Through Excel, the data was sorted alphabetically based on the associated road names, and the headings for the data columns were changed into field names that are compatible with ArcGIS. It is best to save the data as an Excel worksheet instead of a .csv to prevent data loss. After importing the data into ArcGIS, the

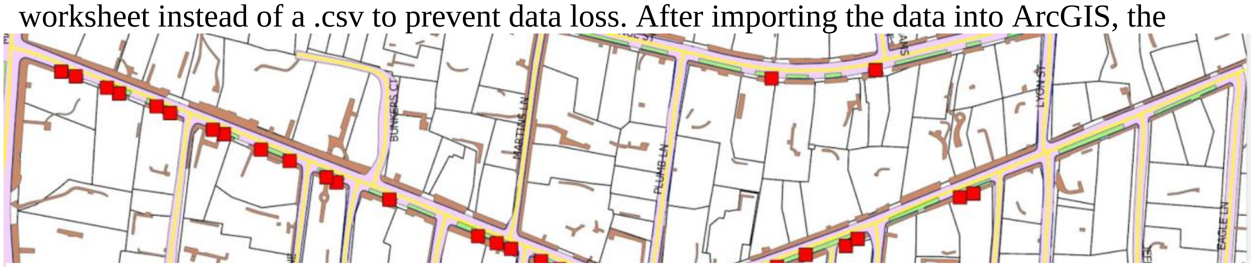

Figure 18: Filtered ArcGIS Data Layer of Fair St

generated layer was formatted to visually express the data. An example of what this looks like is shown above in Figure 18.

4.1.3 Street Inventory Spreadsheet

With the data separated by the date of the inventory in the ArcGIS software, the data can be exported back into Excel spreadsheets for further analysis. A table was created with the capability to read through a sheet of data from a specific day of inventory, and automatically evaluate totals of each vehicle classification. The table then separates the information further by street name, and by what time period during the day the data was gathered. Figure 19 shows the 9:00 AM time block of the table and is displaying data gathered on December 1st, 2018 which was the Saturday of Christmas Stroll. The "Total Vehicles Parked" column sums up all the

Time of Day	Road Name	Total Vehicles Parked	Cars	Cars on Sidewalk	Work Vehicles	Work Vehicles on Sidewalk	Total on Street Spaces	Utilization %
	CLIFF RD	11	11	4	0	0	15	73%
	FAIR ST	39	37	26	2	1	52	75%
	PINE ST	20	17	5	3	3	30	67%
	SUMMER ST	7	6	5	1	1	22	32%
	LIBERTY ST	19	19	19	0	0	35	54%
9:00 AM	GAY ST	7	7	7	0	0	11	64%
	INDIA ST	22	22	6	0	0	32	69%
	PLEASANT ST	5	5	0	0	0	23	22%
	YORK ST	5	5	5	0	0	17	29%
	UNION ST	30	29	2	1	1	49	61%
	ORANGE ST	31	30	3	1	0	53	59%
	CAMBRIDGE ST	11	9	0	2	0	17	65%
	FEDERAL ST	11	11	0	0	0	35	31%
	CENTER ST	36	30	2	6	1	65	55%
	INDIA ST (COB)	24	24	0	0	0	24	100%
	BROAD ST	27	27	0	0	0	47	57%
	MAIN ST	28	25	0	3	0	100	28%

Figure 19: Image of Dynamic Table Display Data from December 01, 2018

vehicles parked on a street for a specific time slot (Cars column + Work Vehicle column). Then the table uses that number along with the total amount of parking spaces to calculate a utilization percentage for each street. Streets that had a high utilization percentage were highlighted as seen above and would help identify problem areas.

The goal of creating this table was not just to view and analyze the data we collected, but to give the town an adaptable tool for future use. This goal was accomplished in multiple ways that involved making the fields for street names and time blocks easily editable to accommodate new inventories that the town may perform in the future. The most important feature regarding adaptability is the table's ability to read data from any sheet located within the Excel file (as long as it is formatted according to a template within the file), and update all of its fields accordingly. In Figure 20, the cell that dictates what data the table is analyzing is highlighted in yellow, with

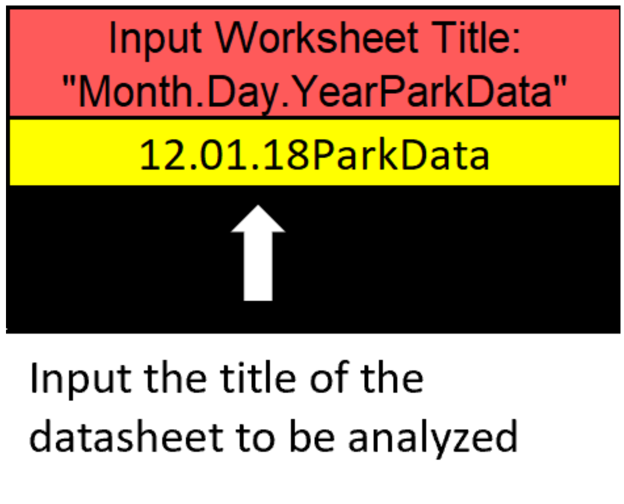

Figure 20: Highlighted Cell that Determines which Sheet to take Data From

accompanying text to explain to the user how to correctly use it. Two other integral features of the table allow the user to edit and add to the list of which streets are being displayed, and what time blocks the inventory were taken at. These capabilities will allow the town to continue to use this table for parking data analysis even if they choose to take an inventory at different times than our team, and if they change which streets are being inventoried.

4.1.4 Improvements to the Parking Inventory Process

Initially, the data collection process alone would take approximately 5.5 hours over the course of a day for selected streets at 4 separate time intervals, and then an additional hour for inputting data directly into Excel tables. The process of inputting data to the ArcGIS software could only be done by one person at a time and would take that person approximately 12+ hours to input an entire day's data, approximately 600 vehicles. This means about 32 vehicles were processed per hour. With the improved process an inventory of over 2000 vehicles could be processed in about 11.5 hours. This means that approximately 174 vehicles were processed per hour using the improved system, which is approximately 5.5 times more efficient than the original method. The improved process would take about 4.5 hours for fieldwork inventory, 6 hours for inputting the data through Google Forms, and an additional hour to format the ArcGIS layer and export the data into the dynamic table for analysis.

4.1.5 Recommendations for Improving Parking Inventory Process

Below are some recommendations for improving the manual parking inventory process.

- Option 1) Print maps on larger paper or divide the selected streets into smaller sections and print them on separate maps.

For this option simply enlarging the images used for the paper maps would help improve the accuracy of the marks made.

- Option 2) Use smartphones with LTE and GPS capabilities to record geographic location of vehicles and have workers fill out the Google Form in the field.

For this option by using smartphones with LTE and GPS capabilities it is possible for the workers inventorying the vehicles to record the data directly in the field. Given the setup of the Google form it is recommended to use a different application to copy the GPS coordinates of the smartphone to the text entry box on the form. This will remove the need to mark the data on a paper map and therefore reduce the amount of time of converting information from a physical form to a digital one.

4.2 Proposing Street Redesigns

Select streets on Nantucket encounter a multitude of problems, which include sidewalk parking, lack of pedestrian access, sidewalk damage from being driven on over time, and narrow roads. After investigating 16 streets and the problems that occur on them, the team came up with a list of reconfiguration options that can be considered to improve traffic flow and overall accessibility of such roads. These options range from delineating spaces to prohibiting parking to more complicated options, such as altering sidewalks and street width. After assembling all the options explored and visualized, they were presented to community members and SME's. The meetings lead to many findings that needed to be considered when proposing these options, such as who uses the sidewalks and regulations to know as well as the history of the streets. After analyzing options and finding there is a list of recommendations regarding how to go about implementing these options.

4.2.1 Options for Street Reconfigurations

Using Adobe Photoshop, concept images were able to be created to visualize proposed reconfiguration options. Some of the options that were explored ranged from prohibiting parking, delineating spaces, changing sidewalk or street width, and curb modifications, each with their own positive, negative and uncertain implications. The sections below goes into more detail on the proposed options.

Delineating Spaces

Delineating parking spaces is the process of putting down lines or other indications of separate parking spots for on-street parking instead of having a general parking zone or area. Nantucket does not currently delineate their parking spaces as to allow for a more flexible parking supply so that more vehicles can be accommodated. Delineating spaces aims at solving the problem of vehicles taking up an excessive amount of space, which leads to an underutilization of the on-street parking. Delineating spaces is geared towards making the parking situation more organized at the potential cost of losing a few spaces. To implement this option, small white T shaped lines would be painted on the street to mark parking spots. Delineating spaces for cobblestone roads would not be feasible, however, for the paved streets, there is generally less worry about ruining the historic aesthetic. An example of this option can be seen in Figure 21 (original) and Figure 22 (photoshopped). This option can be investigated

Figure 21: Original Image of Parked Vehicles on India St

Figure 22: Photoshopped Image of Vehicles on India St with Delineated Parking Spaces

further if the need to delineated spaces on cobblestone roads is wanted. Such options that can be explored are putting small wooden dividers up for parking areas similar to Main Street.

Prohibiting Parking

Prohibiting parking is the process of making certain areas on streets or the whole street to have no on-street parking. This option is most useful in situations where vehicles must park on the sidewalk, blocking pedestrian access, because the street is too narrow. Additionally, this solution can be used on streets where the driving lane is too narrow from the parked cars, causing some vehicles to have to drive onto the opposite sidewalk, damaging the sidewalk in the process, or to slow down, increasing street congestion. Prohibiting parking on these narrow areas will open up the driving lane for passing traffic and open the sidewalk for pedestrian access since there will be no parked vehicles obstructing part of the street and sidewalk. The cost of having no parking zones is that a select number of parking spaces will be lost based on the street's current supply and how much of the parking area will be taken away. To implement this option, yellow lines that mark no parking zones will need to be added or lengthened on select streets with accompanying street signs telling drivers no parking in the determined areas. An example of this option can be seen in Figure 23 (original) and Figure 24 (photoshopped).

Figure 23: Union Street

Figure 24: Union Street with Prohibited Parking

The option of prohibiting parking can be investigated further by considering time periods that parking is prohibited. For example, parking can be allowed at times of low traffic and then prohibited at peak times throughout the day. Other considerations can be allowing parking for certain people, such as letting residents park in front of their house or commercial vehicles with work in that area. Prohibiting parking also opens more width on a street for other improvements to be potentially implemented, such as a bike lane, which can be viewed in Figure 25.

Figure 25: Removing Parking Would Allow for a Bike Lane to be Integrated

Mountable Curb

Altering a normal vertical curb to a mountable curb (circled in red Figure 26-D) is the process of making a slanted plane between the road surface and the sidewalk. This option is most useful in situations where vehicles need to park on the sidewalk, but the steep vertical curb (A) makes that difficult and is rough on the vehicle's tires. Additionally, a mountable curb can benefit bikers who are traveling on narrow roads and want to move onto the sidewalk to move out of the way of traffic. Bikers will not have to stop to lift and mount their bike on to the sidewalk to evade the traffic. A mountable curb is meant to ease the transition from the street to the sidewalk and vice versa since the slanted curb creates a smooth transition from the street surface to the sidewalk plane while also keeping the sidewalk higher up. To implement this option, the old curb would be removed, and the mountable curb installed, so this option requires construction. An example of this option can be seen in Figure 27 (original) and Figure 28 (photoshopped).

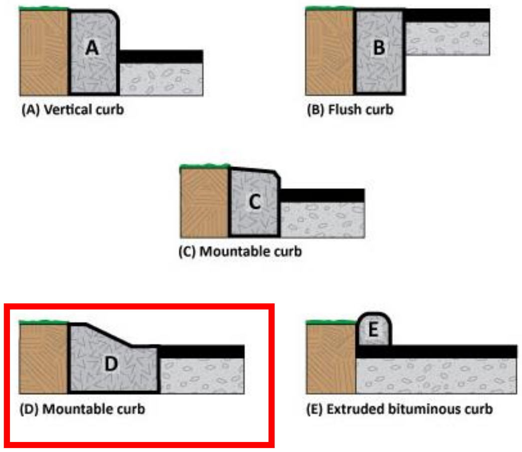

Figure 26: Mountable Curb Compared to Other Types
http://www.chescoplanning.org/MuniCorner/MultiModal/24-RoadDesign.cfm

Figure 27: Original Image of York Street

Figure 28: York Street with Mountable Curb

Flushed Curb

Flushing out the curb (circled in red, curb B, in Figure 29) is the process of making the street and curb level the same height. This option is most useful in situations similar to those mentioned above in the mountable curb section, but most applicable in a situation where vehicles have to drive up onto the sidewalk because the driving lane is too narrow. A flush curb is meant to open the whole street up for all users, making it a shared space. The safety of this option comes into question since vehicles can easily get onto the sidewalk with no vertical curb as a barrier. A slight modification to this option is to make the sidewalk slightly slanted to force drivers to stay on the road, similar to how the mountable curb would look. To implement this option, reconstruction of the road and sidewalk is required to bring them to somewhat the same height. An example of this option can be seen in Figure 30 (original) and Figure 31**Error! Reference source not found.** (photoshopped).

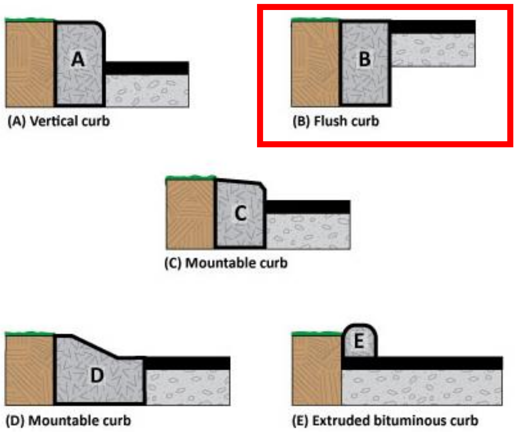

Figure 29: Flush Curb Compared to Other Types
http://www.chescoplanning.org/MuniCorner/MultiModal/24-RoadDesign.cfm

Figure 310: Gay Street with Original Curb

Figure 301: Gay Street with Flush Curb

The flush curb option can be further investigated by looking into ways to improve the safety of pedestrians walking on the sidewalk. In addition, this option can be considered for improving drainage since gutter-like troughs can be installed next to the slightly slanted sidewalk, which will direct water into the gutter that leads to the drain on the street.

<u>Open Street Design</u>

The open street concept is an option specifically tailored to the section of Cambridge St between Federal St and South Water St during the summer. An open street design is when the road is closed off from all vehicle traffic, opening it for pedestrians to walk freely down the road. The reason this option is being considered specifically for Cambridge St, is because it is a an extremely narrow road with parked vehicles that gets closed some days to vehicle traffic during the summer for a market to open up for tourist and residents to visit. The road also closes for special events, such as Christmas Stroll, to set up a food stand in the middle. To have more days to open the market, closing the street off from vehicle traffic during the summer months is being considered. The parking spaces there allow people to park there for only 30 minutes at a time, so no long-term parking options would be removed. An open street design will close down the road during the summer, allowing people to walk down it as well as for a farmer's market to open up more often. The cost is the loss of nine parking spaces, with one being a handicapped space. An example of Cambridge St on a normal day and when it was closed for a farmers' market are showed below in Figure 32 and Figure 33 respectively.

Figure 32: Cambridge Street on a Normal Day

Figure 33: Cambridge Street when Closed for Farmer's Market
https://www.nantucketchronicle.com/sustainability/2014/sustainable-nantuckets-farmers-artisans-market-saturday

Changing Sidewalk and Street Width

Changing sidewalk and street width is the process of either increasing or decreasing the sidewalk width, which will in turn decrease or increase the street width respectively. Increasing the sidewalk width can be most useful on streets where there is sidewalk parking preventing pedestrians from being able to pass by on the sidewalk. Decreasing the sidewalk width is most useful in a situation where a street has sidewalks on both sides, and one sidewalk may be too wide causing the driving lane to be too narrow. Increasing or decreasing sidewalk width is meant to help open the driving lane, increase traffic flow, and to make sure that pedestrians have access to at least one sidewalk. To implement this option requires reconstruction of the road and sidewalks. An example of decreasing one sidewalk can be viewed below with the original image being Figure 34, and the photoshopped image being Figure 35. Since there was a utility pole, the curb was pushed back in front and behind it, creating a “bulb-out” around that pole where parking would be restricted. To further improve the effectiveness of this solution, the opposite sidewalk can be made smaller, within regulations, to open the driving lane and space for parking even more.

Figure 34:India Street Original Width

Figure 35: India Street with Right Sidewalk Reduced

4.2.2 Findings Regarding Street Reconfigurations

During fieldwork on select streets as well as interviews with community members and SME's, many factors for reconfiguring the streets were discovered. The findings we collected are:

- Bulb outs in curb
    - ADA requires 3 feet of space between cars and building
- ADA requires a sidewalk to be at least 3 feet wide
- Many elderly citizens from Academy Hill Apartments at the top of Gay St walk down Gay St's sidewalks
- Because of sidewalk damage and sidewalk parking, many people walk in the middle of the streets
- Slight and small reconfigurations are the mostly likely ones to be accepted by the community
- Some residents do not have driveways, so they park on the street in front of their house
- While the laws say that renovated streets must be modernized this does not always apply in the historic district
- Sidewalks are modern not historical, installed in the 80s
- Roads were paved over and then ripped up and cobblestone was installed
    - Cobblestone under India St in the first 25 feet
- Failed renovations to town lots at Fairgrounds and Washington St
- Contractors park for free at Fairgrounds lot

These findings will help gauge what certain reconfiguration options work best for certain streets and who will be impacted by these reconfigurations.

4.2.3 Options for Street Reconfigurations

Step 1) Study the traffic flow and behavior in the downtown area: The reason for this step is to develop a better understanding of how traffic behaves in downtown given the current conditions. By observing the traffic patterns, it will be easier to identify what kind of solutions are needed for individual streets.

Step 2) Evaluate options for reconfiguring streets: Each street has different conditions and factors that contribute to traffic behavior. As a result, there is no one solution that can fix all the streets in downtown. Each option for each street will have to be analyzed to determine whether it will achieve the intended results needed to better traffic flow.

Step 3) Reconfigure certain streets and evaluate traffic flow: After reconfiguring a certain street, the impact that the redesign has on traffic will have to be observed. This is especially critical if the solution involved removing parking space from the inventory since people will still need to park their vehicles as so forth. By observing the traffic flow again after reconfiguration, one will be able to see if and how other surrounding streets have been impacted by the redesign. Roads that use to have minimal problems may now be extremely stressed and may require a redesign of their own.

4.3 Parking Management Technology Evaluation and Recommendations

Parking management systems are technological systems designed to aid in managing parking systems. Typically, these systems include an array of sensors used to detect vehicles, information gateways that transmit data from the sensors, software applications to be used by the operator. The town of Nantucket is in need of an improved method for managing parking in the downtown district. These technologies are capable of reporting and recording the real time status of parking spaces available. Due to this data can be accurately collected in an instance allowing for a more in-depth analysis of parking situations. In addition, these systems are versatile and usually allow for third party applications to be integrated. This allows the operator of these systems to incorporate a use case specific application, given the circumstances of the regulations in place. This section evaluates the criteria related to system feasibilities with Nantucket as well as recommendations for moving forward with system implementation. After analyzing options and finding there is a list of recommendations regarding how to go about implementing these options.

4.3.1 Parking Management Technology Evaluation

An evaluation was done on a wide variety of sensor types ranging from in-ground to overhead sensors. Six parking management systems were analyzed by viewing available resources. By contacting the manufactures of the systems more information regarding the technical specifications of these systems could be obtained. As a result, two companies were interviewed, and an evaluation of their parking management systems was made (see Decision Matrix in Appendix F). Below is the list of factors from the decision matrix, the bolded subsections mean that they are deemed more critical.

System Attributes
Device Location (ground, above, curbside)
Vehicle Detection Method
Multispace Sensor?
Range of Detection & Area
Power Supply/ Battery Life
Ingress Protection Rating/ Weather Resistance
Data File Type Receivable as CSV
Compatible Network Types
Operating Temperature Range?
Gateway Required
Calibration / Configuration?
Sensor Connection Frequency
System Features
Pay for Parking App Integration
Viewable Data History
Enforcement usage
Available Parking Guidance
Real Time Updating
Open API/ Integration with other systems
Sensors Usable as Peripheral Devices
Reservation Parking
Misc. Factors
Aesthetic redesign
Delineate Spaces for Accuracy
Road Maintenance Hazard?
Privacy/ Security
Estimated Installation Period
Pricing
Cost per Sensor
Installation Fee
Maintenance Fee
Software Fee
O&M Cost

Table 1: Decision Matrix Categories

4.3.1 Parking Management Technology Recommendation

- Step 1) Focus on improving the island infrastructure to allow for more data processing especially in the downtown region.
  - Increase the bandwidth amount
  - Increase coverage

Due to conversations with Nantucket's IT manager, Linda Rhodes, IT Technician, Patrick McGloin, and Chief Technology Officer, Karen McGonigle it is necessary that the above step is taken. The current downtown network infrastructure would not be able to support any technological system implementation.

- Step 1.5) **Do this in parallel with Step 1** While improving infrastructure use interns or other employees to collect parking data either using our improved method or a more suitable one.

The purpose of this step is that as the infrastructure is being upgraded in the downtown region further data can be gathered to help identify more problemed areas. This data will be critical to identifying problem areas and aid in determining which areas need to be managed.

- Step 2) Using the decision matrix determine which technological system is best for Nantucket.

After calculating how many spaces you wish to manage and where they are located it is important to determine which parking management technology is the most feasible. The decision matrix is designed to aid in comparing different specifications of technical systems and how compatible they are with Nantucket.

- Step 3) Do a pilot program if possible, with the chosen parking management technology system.

This step serves to verify that the system is truly compatible with Nantucket. If the system shows that it does not operated as desired go back to **Step 2** and re-evaluate the options given the results of the pilot program.

- Step 4) Integrate a parking management system and use the revenue generated by the Parking Benefit Districts to maintain and improve the system.

The systems proposed are not cheap and obviously need to be maintained over time. Although there is a budget for the system, it is recommended to establish a Parking Benefit District in the areas where the system is being implemented. The revenue generated from the Parking Benefit District will focus on maintaining the system and potentially expanding the system.

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Appendices

Appendix A: Interview with Liaisons Plan

Interview Plan

Mike Burns:

- Method: Key Informant Interview
  - The information gathered comes from people who have relevant knowledge and insight.
  - They allow for new and unanticipated issues and ideas to emerge.
- The purpose of the interview is to begin our connection with our liaison Mike Burns and give us access to data that might help us in our research
- Where: Library tech suite
- When: TBD (have to hear from liaison first)
- Who?
  - Mike Burns - Transportation Planner
  - Peter Morrison - Co-President of Nantucket Civic League
- How: Planning on calling over the conference phone or skype
  - See if possible to record the interview
- Roles:
  - Note-taking - Luke
  - Intro Speaker - Michael
  - Summary Writer - Orion
  - Recording/Notes (recording if possible) - Josh

- Questions for both of them
  - What is your expectations for this project? What do you want us to focus on?
  - How long have you been working on this type of project?
    - What has been getting in the way?
    - What solutions have been suggested?
  - What are your main concerns?
    - I.e time constraints
    - Response times for fire department
  - Is there anyone you think we should contact to better our research?
  - When do you want to talk next about the project?
  - Can you explain in depth the laws that were passed last year in late November that relate to this project i.e. the Transportation and Parking Commission?
  - Current parking conditions?
  - Time restrictions?

- Questions: (For Mike only)
  - As Transportation Planner, what do you oversee on the island?
    - Day-to-day

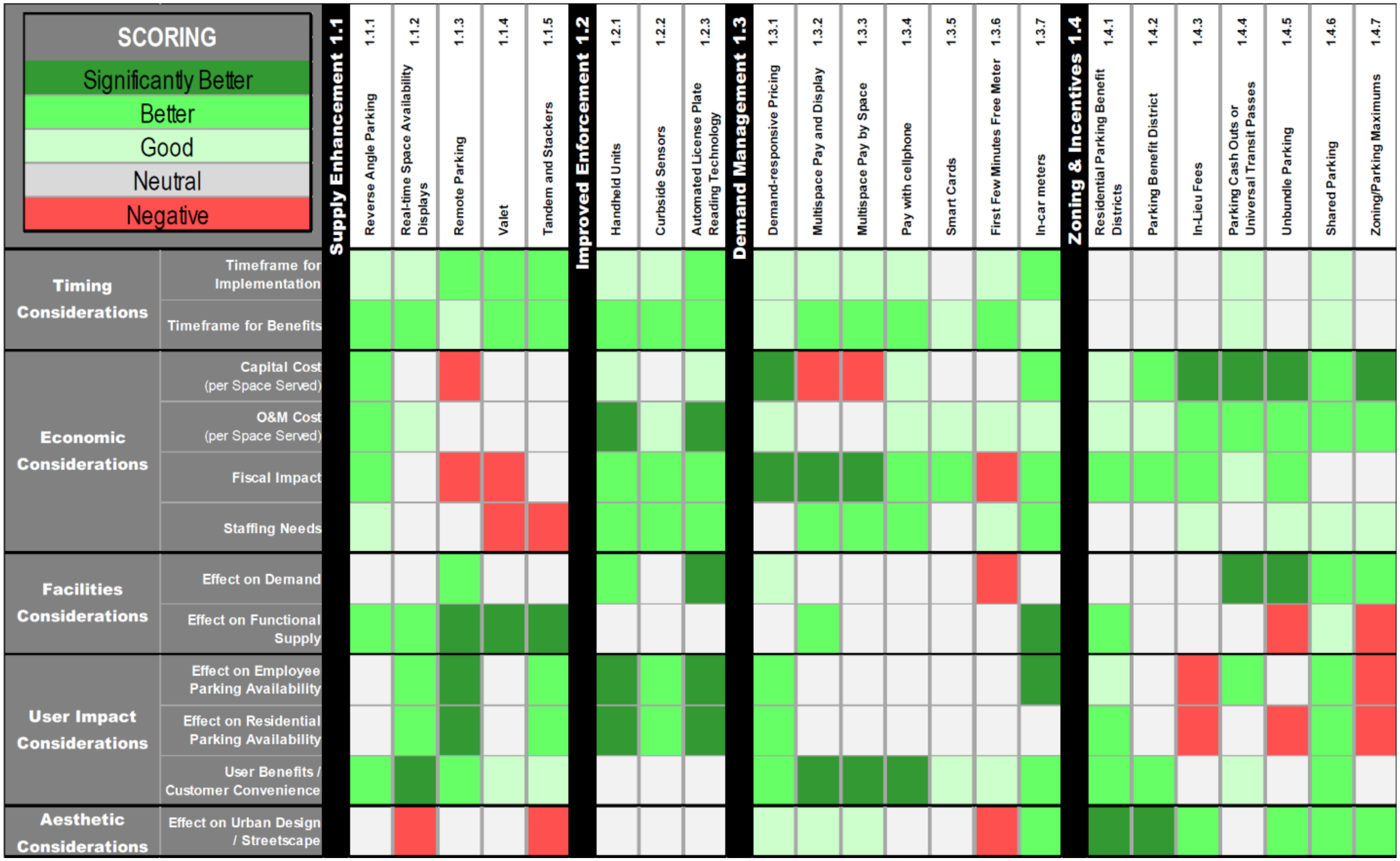
        - Things related to our project
    - What are the recent plans in place involving transportation and parking?
        - What have been the biggest forms of resistance to these plans?
    - What actions have you taken?
    - Have you considered [Insert idea]?
        - Why or why not has it been implemented?
        - what were the pros and cons?
    - What are some possible solutions that you think could work to solve the issue?
        - Personal opinion?
        - What's the towns opinion?
        - Residents/tourist opinion?
        - Business Owners?
    - Where have the complaints about parking and traffic come from?
        - Who are the stakeholders?
    - How closely was your involvement in the 2017 IQP?
    - Are there any previous studies or projects we should include in our research?
    - Are there any specific areas (streets that we should target with our research?
    - Are there future plans in place to solve the parking problem?
    - How do you monitor traffic?
    - What is the impact of the parking problem on the community?
    - What is the current public transportation system like?
        - Which methods?
        - How much does it cost?
        - What is the current load on the transit system? Can it take on more?
        - Are there plans to change the system?
        - What are some changes that have been made and what was the observed outcome?
    - Who are some people we should reach out to to gain more knowledge on the current parking and traffic situation?
    - What are possible solutions we should lean towards / avoid?
    - Transportation hub?

- Questions: (For Peter Only)
    - What is the mission statement for the NCL?
    - As Co-President of the Nantucket Civic League what are some things that you oversee?
        - What is your experience with the parking issue?
    - Uber? Turn areas to drop off areas?
    - What are you looking for as an outcome to this project?
        - What are some concerns you or the people have that we should keep in mind?
        - What are some solutions that the people want to see put in place?
        - What do the people want as an outcome to this project?
    - Are there any specific areas that we should target with our research?

- What are some possible solutions that you think could work to solve the issue?
    - Personal opinion?
    - What's the towns opinion?
    - Residents/tourist opinion?
    - Business Owners?
- What is the impact of the parking problem on the community?
- Who are some people we should reach out to to gain more knowledge on the current parking and traffic situation?
    - Or just to find other opinions or where we should go with our project for solutions
- What are possible solutions we should lean towards / avoid?
- How often do cases similar to the Mill Hill Park and Nantucket Boy Scouts arise?
    - What are some other examples if there are any?

Appendix B: Nelson\Nygaard Decision Matrix

Strategy Evaluation Summary Matrix



Appendix C: Interview Summary for Community Members

Topic 1: Key aspects to consider

What do you believe are some key factors that we should consider while working on this project?

- What are some factors to consider for Residential roads like [insert names of 2 illustrations]?
- What are some factors to consider for Main roads like [insert names of 2 illustrations]?
- What are some factors to consider for the sidewalks?

Topic 2: Opinions on proposed solution

What potential solutions are there for the parking management problems?

- Do you know of any that have any been tried before?
  - What happened? What went wrong or right? Is it being implemented now?
- What are your views on changing things as they are now--e.g., bulbing out the sidewalk or widening particular streets, etc.)
- What are your views on removing the sidewalks on one side of a street or on both sides, so as to ease the flow of vehicle traffic?
- What are your views on removing just parking from streets? (EX. Cambridge Street, etc.)
- Are there specific streets/roads that you recommend we pay close attention to? If so which ones, and why?
  - What are the specific problems occurring at these streets?
- Overall, what do you see as the main issues with these solutions?
- What one overall solution would you favor?

Appendix D: Interview Summary for Technology Vendors

Topic 1: Types of Sensors offered

What kind of parking management sensors do you/ your company supply?

- Where are these technologies now in use?
- How do the sensors detect vehicles?
- Are there limits to the working conditions for these sensors?
- What is their recommended schedule of maintenance and/or replacement?
- What are their minimal and optimal network requirements?
- How many parking spaces can one sensor cover?

Topic 2: Nantucket's situation

- Roads
    - One-way roads, uneven cobblestone roads in downtown, unsafe/inappropriate sidewalk parking, narrow drive lanes hazardous for pedestrians and vehicles,
- Infrastructure
    - No street signals; minimal street lights; brick sidewalks; historic trees intruding on edges of streets.
- Community
    - Influx of tourist during summer months (17,200 population increases to roughly 45,000)
    - Biking community and mentality as main form of transportation during the summer
- Weather challenges
    - Typical Massachusetts/New England weather that can range anywhere from 0-100 degrees Fahrenheit over the course of the year with the risk of high winds during Winter and Fall storms

Topic 3: Your Technologies' Feasibility

How could your technologies meet Nantucket's needs?

- Can your sensor be adapted to Nantucket?
- What is the cost for the sensor?
- Is it possible to implement the sensors with other sensors or peripheral devices?

Appendix E: Email to Technology Vendors

To Whom It May Concern,

We are a group of Worcester Polytechnic Institute students collaborating with the Nantucket, MA Planning Office to improve parking management in Nantucket's downtown historic district. The Town is exploring currently available technologies for doing so. We are working directly with Michael Burns, the Town's Transportation Planner. Feel free to contact him at MBurns@nantucket-ma.gov.

As engineering students, we would like to learn more about the types of parking management technologies your company supplies and their technical specifications. We would like to interview you sometime after the week of Thanksgiving (between Monday, 11/26 to Friday, 11/30), preferably after reviewing any technical documents we could access online beforehand or receive via mail. An overview along with technical details will enable us to formulate recommendations on parking management technologies suitable for the Town's consideration.

Kindly email our group at gr-ack18npo@wpi.edu and feel free to contact Michael Burns or us if you have further questions. Any materials you wish to overnight to us should be addressed to: Michael Burns, 2 Fairgrounds Rd, Nantucket, MA 02554 and alert us at our above group email address as to its expected arrival.

We look forward to hearing back from you.

Sincerely,

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Appendix F: Decision Matrix

	SmartParking SmartSensor 3rd Generation	SmartParking SmartSpot Gateway	SmartRep (Software System)	CivicSmart Subterranean Sensor	CivicSmart AutoIssue (Handheld Device)	CivicSmart Curbside Sensor	CivicSmart Gateway	Parking Enterprise Management System (PEMS) (Software)
Product Description	These 3 Products (sensor, gateway, and software) are distributed by SmartParking and integrate together to form a complete system. As such we evaluated them all together to best reflect the			The following sensors, handheld device, software, and gateway are distributed by CivicSmart. They are all apart of the same system and we thought best to evaluate them as a system together. To form a complete system a sensor, a gateway and the software system are required. However, for the system only one sensor is required, either the curbside or subterranean. Both can be used in conjunction with each other. The handheld sensor is an additional device specific to enforcement management and is included in the system analysis but is not required for the sytem.				
System Attributes								
Device Location (ground, above, curbside)	Ground	Above		Ground	Handheld	Curbside	Above	
Vehicle Detection Method	Infrared and Magnetic Field			Radar		Radar (2 side by side for better accuracy)		
Multispace Sensor?	No			No		No		
Range of Detection & Area	A few feet above sensor & straight above	TBD		A few feet above sensor	Manual Input/ LPR	approx 15degrees above road	2 per 400ft	
Power Supply/ Battery Life	Battery/ 10 years	Solar Panel/ Self Sustaining		Battery/ 10 years	Depend on Device Model	Solar Panel (battery backup)/Self Sustaining	Solar Panel/ Direct Line	
Ingress Protection Rating/ Weather Resistance	IP68	IP67		IP 65/ ASTM B117, ISO 9227 Salt Spray/ASTM D1735 Humidity Testing	Depends on Models but up tp IP 68	IP 67/ ASTM B117, ISO 9227 Salt Spray/ASTM D1735 Humidity Testing	IP 54/ ASTM B117, ISO 9227 Salt Spray/ASTM D1735 Humidity Testing	
Data File Type Recievable as CSV			Yes		Map based GIS Reporting			Yes
Compatable Network Types		433/868/915MHz LPD ISM Band, 802.15.4/Zigbee, WiFi, 3G, 4G and LoRaWAN.					Penta-band GPRS/UMTS/HSDPA radio operating in the 850/900/1800/1900/2100 MHz bands. Cellular Networks with a Sim Card	
Operating Temperature Range?	-30°C to 80°C			-20°C to 80°C		-20°C to 80°C		
Gateway Required	Yes			Yes		Yes		
Calibration / Configuration?	TBD			Yes		TBD		
Sensor Connection Frequency	ISM 902-928MHz			Platform with low power 2.4 GHz ISM band operation, 16 selectable channels in the 2405 MHz to 2480 MHz range		Platform with LoRa 2.4 GHz ISM band operation, 16 selectable channels in the 2405 MHz to 2480 MHz range	Platform with LoRa 2.4 GHz ISM band operation	
System Features								
Pay for Parking App Integration			Yes					Yes
Viewable Data History			Yes					Yes
Enforcement usage			Possible		Yes			Yes
Available Parking Guidance	Yes		Yes	Compatible		Compatible		Yes
Real Time Updating	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Open API/ Integration with other systems	No		Partially	Yes	Yes	Yes	Yes	Yes
Sensors Usable as Peripheral Devices	No	No		Yes	Yes	Yes	Yes	
Reservation Parking	Compatible	Compatible		Compatible		Compatible		

	SmartParking SmartSensor 3rd Generation	SmartParking SmartSpot Gateway	SmartRep (Software System)	CivicSmart Subterranean Sensor	CivicSmart AutoIssue (Handheld Device)	CivicSmart Curbside Sensor	CivicSmart Gateway	Parking Enterprise Management System (PEMS) (Software)
Product Description	These 3 Products (sensor, gateway, and software) are distributed by SmartParking and integrate together to form a complete system. As such we evaluated them all together to best reflect the			The following sensors, handheld device, software, and gateway are distributed by CivicSmart. They are all apart of the same system and we thought best to evaluate them as a system together. To form a complete system a sensor, a gateway and the software system are required. However, for the system only one sensor is required, either the curbside or subterranean. Both can be used in conjunction with each other. The handheld sensor is an additional device specific to enforcement management and is included in the system analysis but is not required for the sytem.				
Reservation Parking	Compatible	Compatible		Compatible		Compatible		
Misc Factors								
Aesthetic redesign	No	Yes		No	No	Minimal	Yes	
Delineate Spaces for Accuracy	Yes			Yes	No	Yes		
Road Maintence Hazard?	No	No		No		Potential	No	
Privacy/ Security	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Estimated Installation Period	1 week per 100 sensors (est 5 weeks total)			8 to 12 weeks	8 to 12 weeks	8 to 12 weeks	8 to 12 weeks	
Pricing								
Cost per Sensor	$150-%180 per sensor	~$1000 per gateway		250-265 for install available through MAPC	Upfront cost based on one piece or two piece. $3500 one piece.	250-265 for install available through MAPC	$500 each	
Installation Fee	Varies on installer	Varies on installer		Varies on installer	None/But Training	Varies on installer	Varies on installer	
Maintaince Fee	TBD	TBD		TBD	TBD	TBD	TBD	
Software Fee	TBD	TBD		$3 a month per sensor	Software licence fee upfront $15,000 to $20,000. Monthly fee for data usage $125 to $175 per device per month all varies on integration	$3 a month per sensor	$6 a month for services	
O&M Cost	TBD	TBD	TBD	TBD	TBD	TBD	TBD	

Color Code

- Significantly Better
- Better
- Good
- Neutral
- Negative
- Not Beneficial
- Unknown or Unapplicable