Enhancing the Response Time of the Nantucket Fire Department

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science
by

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12/15/2016
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Introduction

> "People pay a lot of money to live here on the island, they deserve to have the best quality of emergency services possible" (Rhude, 2016)

The island of Nantucket has one active fire station servicing over 10,000 year-round residents. Fire Chief Paul Rhude is new to the island of Nantucket, having only spent one year here. However, he has made strides toward hiring more staff, creating policy change concerning public safety, and enforcing national standards on a department which had previously tended toward outdated standards. One important policy change that Chief Rhude implemented was that sirens and lights no longer need to be employed when responding to automatic alarms, hoping to reduce car accidents caused by people trying to get out of the way of emergency vehicles.

Fire organizations work hard to keep communities safe every day. Fire stations not only provide fire suppression services, they also handle medical calls and other emergencies. Response time is one key metric which measures the effectiveness of a fire department. The response time of a fire department is defined as the length of time from when a call is dispatched to when fire personnel and equipment arrive at the scene. The national standard for fire response time is five minutes. It was found that the Nantucket Fire Department (NFD) is only meeting the 5-minute national standard 39% of the time. In 2014, a WPI IQP team investigated the causes of Nantucket's extended response time. According to their research, one of the causes is that direct paths to a scene from the fire station are often unavailable due to traffic, congestion, and limited staffing at the station (Brecher et al., 2014). Limited staffing can make it nearly impossible to respond to emergencies, because there are often concurrent calls with only enough staff to respond to one call at a time. Additionally, the 2014 team noted that traffic is a more significant problem in the summer, when there is a significant swell in population due to tourists.

> "The national standard for response time is 5 minutes for 90% of calls with an additional 1 minute for gathering equipment" (NFPA 1710, 2015).

The purpose of this project was to assist the Nantucket Fire Department in reducing its call response time by exploring staffing and housing issues, station locations, and their dispatch information system. Currently, the NFD is understaffed, overworked, and hence out of compliance with the national response time standard (Table ES.1). In Nantucket, each firefighter handles nearly double the calls per person than the commonwealth average.

	National Standard	Commonwealth Average	Current NFD	Proposed Changes
90% of calls	5 mins	--	12 mins	< 9 mins
Annual Calls/Person	--	123	258	< 200

Table ES.1: Comparison of NFD to Standards

Our team offered the NFD four recommendations that each address a specific problem. In combination, these recommendations provide mutual aid, increased staffing, and better response decision making, which all culminates in a lowered response time. The goal for these recommendations is to reduce response time and improve overall emergency performance, leading to a safer, more secure community. The four recommendations are as follow:

1. **Refine the dispatch information system:** In order to perform useful analysis on call data, it first must be cleaned of anything that is not time sensitive or an emergency call. By refining the system used to record calls, no data cleaning would be necessary. If this process is streamlined, automatically cleaning calls when they are placed, then analysis can be performed immediately, and no resources would be wasted on manually cleaning the data.

2. **Implement a dynamic deployment system:** Adding a dynamic deployment vehicle in the downtown area would help decrease response time in the downtown area. Additionally, it could tailor responses more towards the medical aspect of calls. Calls from downtown scenes constitute 60% of calls, and 45% of those calls are medical. By adding dynamic deployment vehicles downtown, the quality and speed of those calls would increase.

3. **Pursue the Siasconset station renovation:** The renovation of the Siasconset station not only helps improve response times in the Siasconset area, but also helps to lower the insurance ratings of the 2,328 buildings outside of the service radius of the proposed new fire station at 4 Fairground Road. Insurance rates are based off of a buildings' proximity to a fire station, which is explained further in the recommendations section. By utilizing the station in Siasconset, vehicles would not have to drive through the congested downtown area before they respond to emergencies on the eastern end of the island.

Develop the response time simulation into a program: Our team developed a response time simulation, taking into consideration many factors of an emergency call. This program considers that all of our previous recommendations have been implemented. It uses dynamic deployment and the Siasconset station as two additional stations. Not only will the program tell the operator which station to deploy personnel from, but it will also determine the fastest route to a scene.

Methodology

The purpose of this project was to assist the Nantucket Fire Chief in reducing and improving the response time and the quality of performance of the Nantucket Fire Department by exploring all avenues for improving response efficiency such as providing housing for hiring additional fire personnel, enhancing firefighter training, adding or staffing additional fire station locations, and exploring other options for non-full time fire personnel.

Objectives and Methods:

1. **Dispatch Call Information Data Analysis and Quality Control:** Accessed and prepared the NFD's call data to analyze key trends in emergency response performance.
2. **Assess current response time and readiness of the Nantucket Fire Department**.
3. **Identify and interview different stakeholders to gain insight on opinions of the response time and potential ways to reduce the response time for the Nantucket Fire Department**: Interviewed key personnel for specific insights in their perspective fields.
4. **Study and assess potential solutions to reduce the NFD response time**: Researched other similar islands to figure out how they operate their various stations.
5. **Perform cost analysis on combinations of options to improve response time**: Insurance quotes were received from various companies and we calculated how much money can be saved by implementing our recommendations.
6. **Provide detailed recommendations to the Fire Chief of the Nantucket Fire Department**: Created recommendations based on our research and results.

Response Time and Staffing Standards

Response time is defined as the length of time from when a call is dispatched to when the fire department staff is on the scene. Fire department standards are set by an annual colloquium of fire chiefs and fire prevention analysts that are then summarized in multiple texts, including the National Fire Protection Agency's (NFPA) guidelines (NFRIS, 2010). These standards were the basis of this project analysis. For response time, the relevant NFPA standards are numbers 1710 and 1720, which are not legally binding, but are tracked by the state and other review bodies. These standards call for:

- 5-minute response time for 90% of calls
- 4-person minimum on 90% of calls for fires
- 3-person minimum for Basic Life Support (BLS): BLS is a level of medical care which is used for victims of life-threatening illnesses or injuries until they can be given full

medical care at a hospital. It can be provided by trained medical personnel, including emergency medical technicians, paramedics, and by qualified bystanders (NFPA, 2015).

- 4-person minimum for Advanced Life Support (ALS): ALS, also known as the Paramedic level of medical emergency services, is a set of life-saving protocols and skills that extend Basic Life Support to further support blood circulation and provide an open airway and adequate ventilation (NFPA, 2015):
    - The department must deploy sufficient resources to arrive within an 8-minute response time to 90 percent of all ALS incidents.
    - Minimum of two members trained at ALS level and two trained at the BLS level for all ALS calls.
    - ALS personnel need to complete over 3000 hours of rigorous life support training.

Dispatch Information System Data Analysis and Quality Control

Fire departments alert emergency personnel to respond to calls and record the detailed statistics of each call using a dispatch information system. The system used by the NFD is based out of the joint-dispatch at the police station, and is a program licensed to the department. The program currently in use on Nantucket is in active development, and updates are frequent. It is unknown if there are cloud-storage capabilities, but this topic was discussed as potentially advantageous because data would not be deleted in the case of a power outage.

Over the years, fire stations have evolved, broadening the types of calls handled. Fire departments now respond to much more than just fires. National organizations, such as the Federal Emergency Management Agency, have created a comprehensive code system to keep track of fire departments' responsibilities (NFRIS, 2010). All calls are designated a code from 100 to 900 depending on the broad nature of the call (Table ES.2). Calls are then further broken up into more specific subcategories.

SERIES	HEADING
100	Fire
200	Overpressure Rupture, Explosion, Overheat (No Fire)
300	Rescue and Emergency Medical Service (EMS) Incidents
400	Hazardous Condition (No Fire)
500	Service Call
600	Good Intent Call
700	False Alarm and False Call
800	Severe Weather and Natural Disaster
900	Special Incident Type

Table ES.2: Dispatch Incident Codes

At end of 2013, the NFD dispatch moved from the fire station to a joint-dispatch at the police station. Additionally, in 2014, the measurement of response time was redefined as the time from dispatch to arrival on scene. The previous definition of response time was between the time of alarm to arrival on scene to match the national standards. Figure ES.1 shows the difference between response times when using the two different metrics.

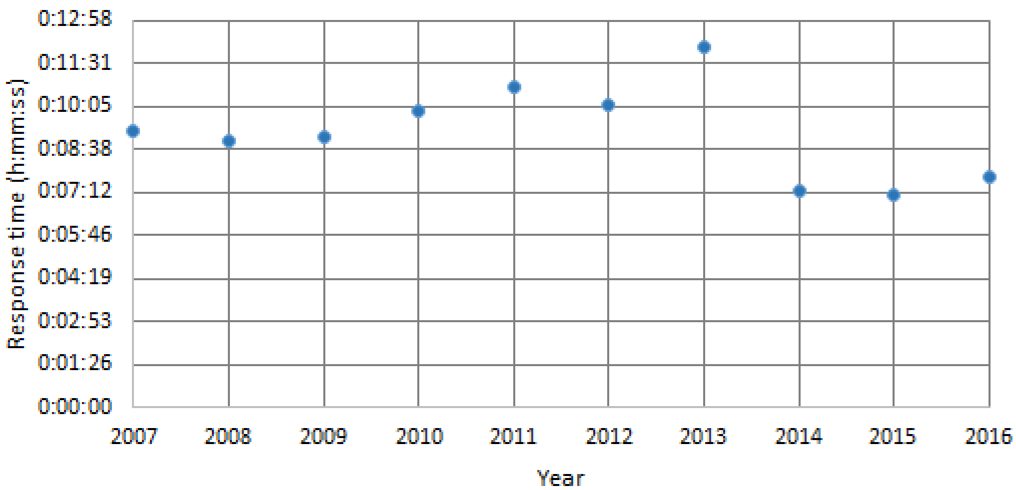

Figure ES.1: Average Response Time 2007 to 2015

Data Preparation and Cleaning

After understanding how incident codes operate, the call logs were cleaned, meaning that the call data was refined to only include certain calls. The system for recording call times is not automated, meaning that the data is prone to human error. Whether operators start calls too early, or end calls too late, there are errors and outliers in the data which may affect analysis of the response time. The following information outlines the steps in deleting unnecessary data:

1. **Delete any bad data points:** Due to either human or system error, the dispatch system was filled with incorrect data points, such as 0-minute call responses, and 30-minute call responses, as well as some two-hour call responses. According to various fire personnel, many calls above 30 minutes or calls recorded as 0 minutes are inaccurate. While some calls do last above 30 minutes, the frequency of those calls is very rare. These data points skew not only average response time, but also the standard deviation. Thus, we determined that they should be deleted to maintain accuracy.

2. **Delete data that is not time sensitive or considered an emergency to respond to**: Certain call types are not time sensitive cases or emergencies. For example, 900 type

calls are citizens' complaints, and a 462 call is an aircraft standby. Neither of these call types are affected by the speed of response. For our analysis, they were removed from the data pool.

Data Preparation Outcome: By correcting the data and deleting roughly 500 calls, the quality of the data improved. As previously mentioned, by taking out inaccurate data points and non-time sensitive calls, the standard deviation of the data decreased (Table ES. 3). When the standard deviation decreases, the data values get closer together, which suggests that the data is more accurate and reliable.

		Response Time		
	Total Calls	Average	Median	Deviation
Original	3122	7:06	6:09	5:56
Clean	2734	7:12	6:21	4:06

Table ES.3: Summary of Cleaned Data for 2015

Findings

In this section, an analysis of emergency response was developed, first by sharing basic insights into the volume and types of calls, then by describing what was found in terms of staffing, facilities, dynamic deployments, and response time simulation script.

Call Volume and Type Findings:

1. Response time is currently defined in the NFPA standards as the time from dispatch to arrival on scene of an emergency.
2. The annual total of emergency calls to the NFD is increasing.
3. Medical and false alarms make up about 80% of the calls.

The first factor impeding emergency response is simply that the number of calls has increased by 32% from 2007 to 2015 (Figure ES. 2).

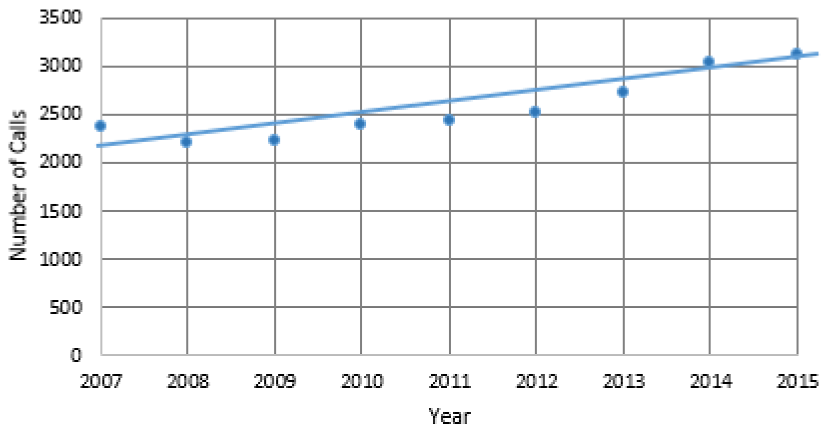

Figure ES.2: History of Call Volume with Trendline from 2007 to 2015

Next, we examined the trend over time in each incident type (Figure ES. 3), which shows that the number of medical calls and false alarm calls have risen steadily since 2007, reaching 45% and 37% of calls respectively. This upward trend in calls is largely responsible for the overall rise in calls since 2007 and indicates these two incident types have increased by about 400 calls within nine years. Other incident types make up a smaller percentage of all emergency calls, which makes them have a smaller impact on total response time.

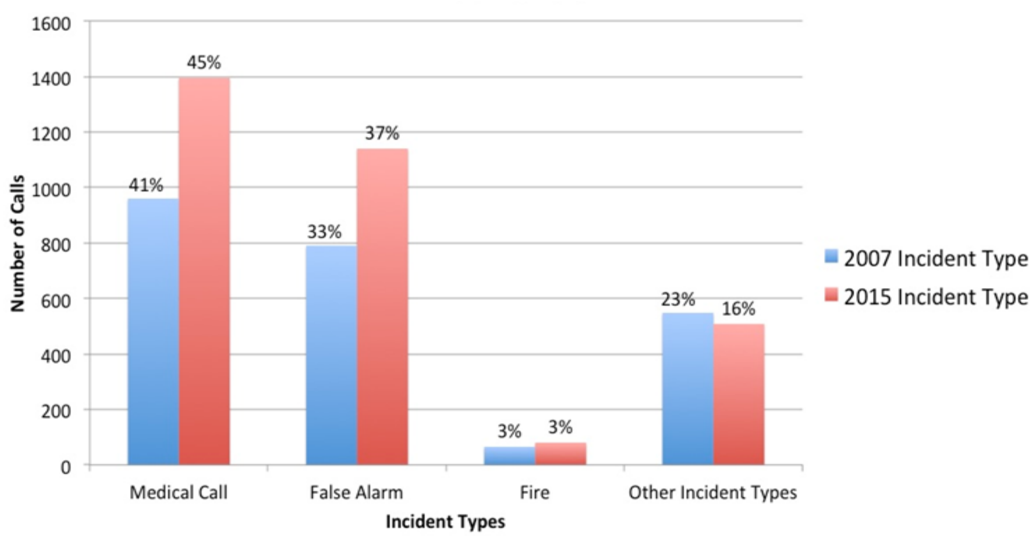

Figure ES.3: Incident Types in 2007 versus 2015

The data collected is from calls all over the island (Figure ES. 4). The densest call area is downtown, including 60% of the emergency calls. The second densest area is Siasconset. If there is an emergency call in the Siasconset area, it typically takes over ten minutes to respond due to the location of the centralized station. There are 60 calls per month in the Siasconset area in the summer and 30 calls per month in the winter. The current staffing situation in Nantucket is inadequate, which makes getting to the outer parts of the island difficult, especially when concurrent calls occur and there are not enough personnel on duty.

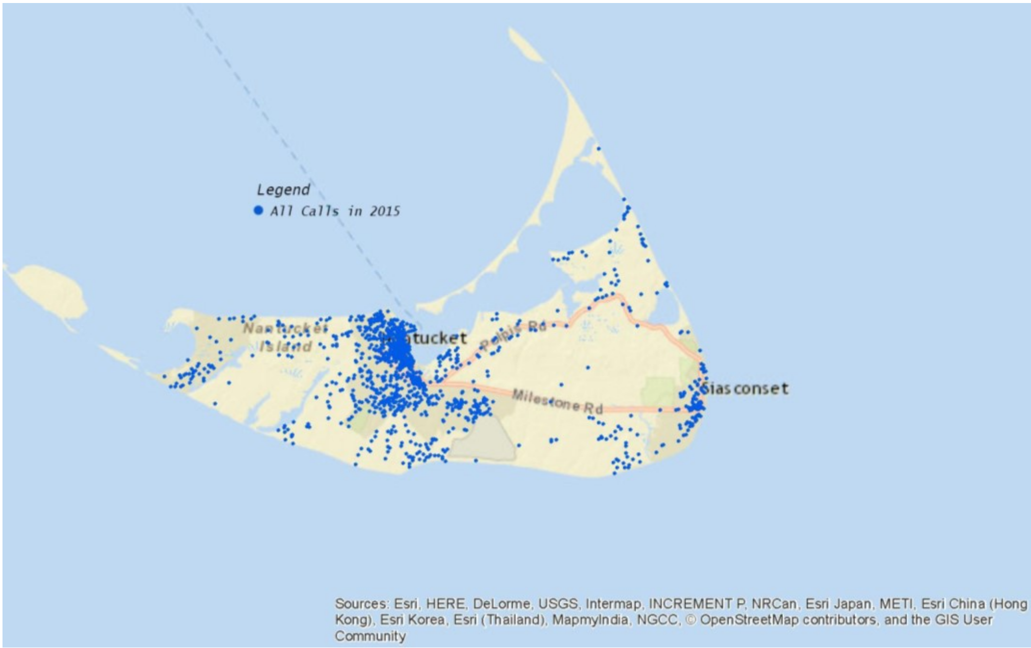

Figure ES.4: Location of all calls in 2015

NFD Staffing: 2016 & Beyond:

The single most important cause of the NFD being out of compliance with national emergency response standards is inadequate staffing. Not only is the department short on staff, but they also respond to nearly double the calls per person compared to the rest of the commonwealth (Table ES. 4). This is partially due to their total lack of staffing, but also because of their small personnel shifts (Table ES. 5).

	Commonwealth Average	Current NFD	Proposed Changes
Annual Calls/Person	123	258	<200

Table ES.4: Average Calls per Person

As previously mentioned, the standard response for fire is four people, and the response for medical is three people. In the winter, the NFD cannot respond to a fire call because they only have three people on duty at a time (Table ES. 5). This problem does not touch upon concurrent calls. The department barely has enough people to respond to one call, let alone respond to many calls at once. The following list outlines our team's findings concerning staffing in the NFD:

1. **Understaffing is due largely to lack of housing:** Housing on the island is both expensive and hard to find. The average firefighter on Nantucket makes around $64,045 a year (Salary Genius, 2015). Even with this amount of money, finding housing is still a challenge due to various reasons.[1]

2. **The NFD is currently working to increase their staff:** Four paramedics and four firefighters are proposed to be hired by the NFD in 2017. Some fire departments are reducing the number of career firefighters and adding volunteers, because the cost of two volunteers is about the same as one career firefighter (Beutner, 2012). Other communities and fire departments recruit college students to be volunteer firefighters (Beutner, 2012). The NFD has been actively exploring such creative, less expensive staffing options.

3. **The Town is negotiating the creation of an ALS level job under the NFD union contract:** The NFD's current union/town contract expires in 2017. With their previous contract expiring, this leaves the opportunity to add in new ALS jobs in their contract.

4. **On-call personnel are now alerted and asked to report to the station when the on-duty emergency personnel are out of the building:** Before this policy was enacted, the fire department only contacted on-call personnel when a concurrent call was logged. This new policy alerts on-call staff as soon as the on-duty personnel leave the station. The policy seems to contribute to the change in the response time trends for concurrent calls because it cuts out the time required for the on-call staff to get to the station before they deploy.

[1] There is another IQP team working on affordable housing. To find out more in depth information on the Nantucket Housing Crisis, visit http://wp.wpi.edu/nantucket/projects/projects-2016/town-managers-office/

		2016	Proposed
Amount of Personnel	Full-Time Personnel	24	32
	Call Personnel	17	17
	Total Personnel	41	49
	Seasonal Personnel	0	16
Shift Size	On Duty Summer	4	9
	On Duty Winter	3	5

Table ES.5: Current vs Proposed Personnel Analysis

Facilities and Resources

The NFD has all of their resources (Table ES. 6) located together in the downtown area. They used to have their facilities spread out across the island, but now they deploy out of a central station where all of the most essential equipment is stored. The following list outlines our team's findings concerning facilities and resources.

1. **The NFD is operating out of one centralized location:** The fire station currently deploys out of a central station in the downtown area (Figure ES. 5) and will be moving to the new station at 4 Fairgrounds, combined with the police station, once plans are approved.

	Amount
Engines	5
Tankers	2
Ladder Trucks	1
Ambulances	4
Specialty Units	3
Boats	0
Helicopters	0

Table ES.6: Current NFD Resources

2. **The NFD has two inactive satellite stations:** The NFD used to have three active stations, but now they only have one (Figure ES. 5). The satellite stations on either end of the island are different sizes and serve different purposes. The Madaket station is a shed that acts as a garage bay for an old fire truck. The Siasconset station is larger, housing two garage bays, a basement, and land with room for additions on the back and sides of the building. Additionally, there is a NFD owned vehicle on Tuckernuck for any emergencies that occur in that area. However, due to the lack of department personnel,

the keys are simply left in the truck for use by the residents of Tuckernuck during an emergency.

3. **Siasconset Station Reopening:** The Siasconset station is large and in a convenient location to help decrease response time. Since there is space for potential additions, we recommend that the new station include 24/7 bunk rooms for on-duty members. Not only is there space for on-duty members, but this renovation would also include a bunk room for off-duty and seasonal members. There are a few challenges to renovating this historic station, but the renovation plans and benefits will be discussed in more detail in our recommendations section.

⇨ 5 feet of setback is needed on the sides and rear of the property to comply with Nantucket zoning laws ⇨ Only 50% of the land can be built on

Table 7: Current NFD Resources

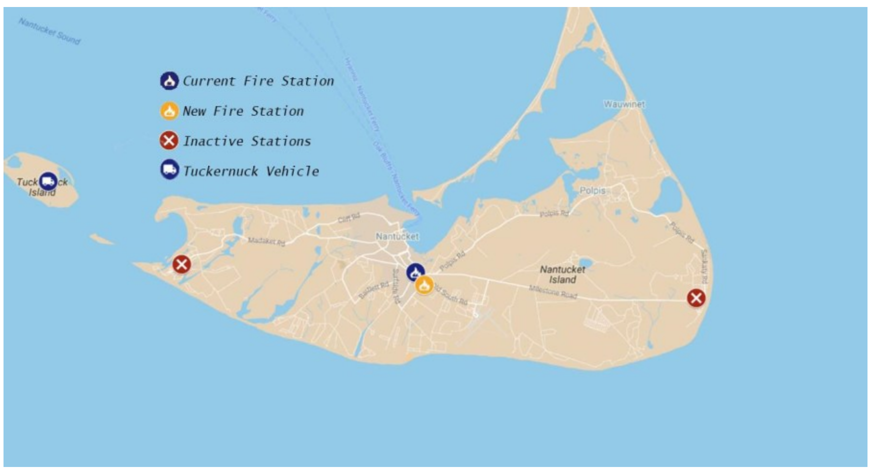

Figure ES.5: Geographic Locations of Fire Stations on Nantucket

Dynamic Deployment:

Dynamic deployment references a new idea for emergency response units to pre-allocate specialized vehicles in many locations to act as a basic station on wheels. This practice is becoming common in Europe, especially in cities with small streets (Ambulansforum, 2015). Vehicles range from Utility Task Vehicle (UTV) style to larger Sport Utility Vehicles (SUV) (Figure ES.6). The following findings relate to the need for dynamic deployment on Nantucket:

1. **The downtown area is dense with calls:** Most calls are in the downtown area (60% in 2015) with 45% of those calls being medical (1,395 medical calls). All of these calls are the NFD's responsibility because there is no private ambulance service on Nantucket.

2. **The downtown area is a problem area:** The downtown area has a lot of congestion, especially during the summer, which makes it difficult for an emergency response vehicle to mobilize.

3. **Change in medical treatment policies:** The standard for medical response in Massachusetts has changed to treat people on scene instead of moving them to a hospital (NFD 2016). These vehicles are designed to bring equipment to a scene, instead of people to equipment.

Figure ES.6: Two Potential Designs for Dynamic Deployment Vehicles (Left: UTV & Right: SUV)

Response Time Simulation:

Using the locations of the new fire station, the Siasconset station, and the standby location for the proposed dynamic deployment vehicle, we created a Google maps API[2] based simulation script to estimate response times. Our findings about the response time simulation are as follows:

1. **Simulation tools are useful for predicting results:** Simulation tools can generate insight into spatial aspects of response time, and if used properly can predict how much time can be saved if the operator implements certain recommendations.

2. **The response time simulation results are promising (Figure ES.7):** Implementing the recommendation to renovate the Siasconset station and employ the dynamic deployment vehicle caused 90% of calls to have a response time of less than 8 minutes.
    a. With implementing two recommendations, the 90% point of all calls decreases by 4 minutes.
    b. Adding concurrent calls and traffic conditions will make the estimation more precise for time analysis, but will require a dedicated team to complete.

[2] An API is a set of methods and tools that can be used for building software applications.

3. **Plenty of room to develop the simulation into a program:** There is potential for this simulation to be developed into a system for reducing response time by implementing more functions. With more functions added, the program could be able to[3]:
    a. Provide the best route for emergency vehicles
    b. Advise the most accessible station for each specific emergency call

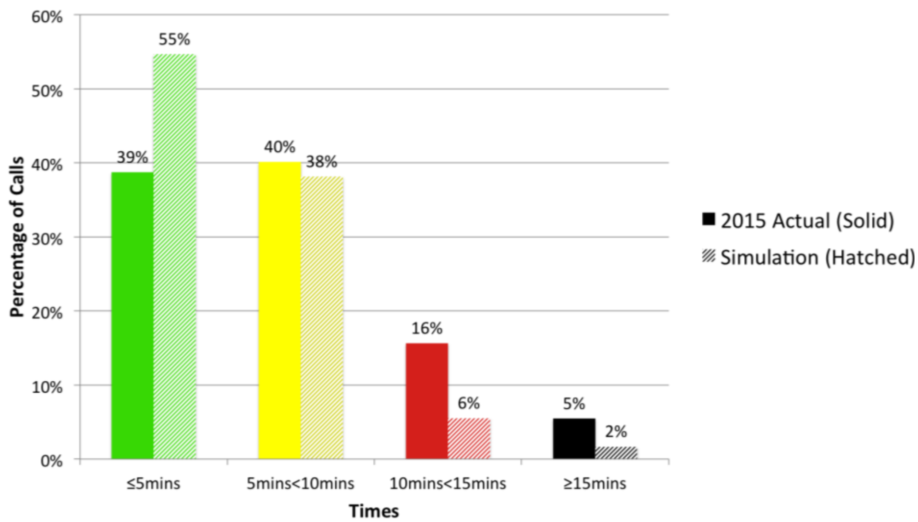

Figure ES.7: Response Improvement 2015 Actual versus 2017 Simulation (2,723 Calls Total)

Recommendations

The Nantucket Fire Department currently has a response time above the national standard due to under-staffing, facility centralization, and heavy seasonal traffic. These problems have multiple components that all connect to lead to an increased response time. Understaffing is the largest issue faced by the NFD (NFD Staffing Finding). The easiest way to remedy this would be to hire new people. However, there is nowhere to house new staff since the housing prices are so high on Nantucket.[4] Normally, staff would be located at other fire stations, but since the island does not have fully staffed satellite stations, this does not offer a solution. Solving just one of these challenges would be both expensive and difficult, so finding a solution that incorporates each would be the most effective way to improve the time and quality of emergency responses. The following writing outlines our team's recommendations to the NFD, with explanation of how each could improve NFD emergency response performance.

[3] More details are provided in recommendation 4.
[4] Another 2016 IQP team worked on affordable housing. To find out more in depth information on the Nantucket Housing Crisis, visit http://wp.wpi.edu/nantucket/projects/projects-2016/town-managers-office/

Recommendation 1: Refine the dispatch information system to improve data quality and availability for analysis. The fire station records every call, even if the call does not have any bearing on response time. To analyze response time, it is necessary to clean the data of irrelevant points. A potential future project would be to help the NFD find a way to automatically clean calls. If the fire department were to have two sets of data, cleaned and uncleaned, they could send the full data to the state as required, but still have cleaned data for statistical analysis. Developing the data information system would require programming and design skills consistent with that of WPI students, and could likely be completed within the seven week period of an IQP. In this potential project, the team would need to complete the following tasks in order to complete the system:

- Compile a standard for clean data
- Split data into two sets, clean and unclean
- Develop a program that automatically cleans the data
- Share information with the fire department

Recommendation 2: Purchase and implement a dynamic deployment vehicle and deploy it as the Nantucket Fire Department's first-responder downtown. A dynamic deployment vehicle would need to include all necessary ALS gear and be small and stable enough to handle Nantucket's narrow cobblestone streets. The downtown area is prone to having many medical calls, especially during the summer (See Dynamic Deployment Finding). This is partially because of the cobblestone and rough sidewalks functioning as challenging walking surfaces for many visitors. One potential location for this vehicle for standby is in front of the sheriff's station because not only is it downtown, but it is also close to the Madaket side of the island. Having a vehicle that can access both the downtown area as well as parts of Madaket would be extremely valuable for decreasing response time. Multiple companies were contacted for comparable vehicles. Their estimates revealed that the cost of a dynamic deployment vehicle is extremely varied, ranging anywhere from $20,000-$300,000 based on vehicle type and the amount of customization required. One potential, less expensive solution is to provide one of the companies with a vehicle, such as an SUV, to be fitted with pre-fabricated equipment racks. Further analysis could be addressed by a future student project, and should be addressed as quickly as possible, as the simulation project shows a large potential improvement for response time and quality. To complete this recommendation, the fire department and future project teams should:

- Determine necessary specifications to implement in the dynamic deployment vehicle
- Contact multiple dynamic deployment vehicle customization companies for cost estimates including:
    - Odyssey Specialty Vehicles (http://www.odysseysv.com)
    - FastLane Emergency Vehicles (http://flev.com)
    - PL Custom Emergency Vehicles (http://www.plcustom.com)

- Designate funding within the budget for the vehicle or vehicles chosen
- Train fire department personnel to ALS levels to fully utilize the vehicle with 2-3 persons.

Recommendation 3: Renovate and reopen the Siasconset fire station as a fully staffed station. This station is currently used as a garage to house older engines, and does not have any space for housing, offices, or bunk rooms. There are about 30 calls per month in the winter and about 60 calls per month in the summer in this area (NFD, 2016). An additional incentive for reopening the Siasconset fire station is that if the Siasconset station was renovated and expanded, the insurance rates in the Siasconset area would decrease substantially, as would the response times. We recommend that the data be shown to the town to support this statement, along with the simulation (Figure ES. 10). The potential savings in response time and potential to save lives could have a significant impact on Nantucket residents. In order to implement this change, the NFD would need town support and funding. To enact this recommendation as soon as reasonably possible, the town and fire department should:

- Run a feasibility study
- Establish funding
- Build the addition
- Increase staffing

The recommended renovation is displayed in Figures ES.8 and ES.9.

Figure ES.8: Top view of addition

This total addition of 3,486 square feet over two floors would allow housing for seasonal employees as well as providing capabilities for 24/7 staffing. There are two bunk rooms for seasonal employees, which would provide housing for four additional summer staff. The town owns the building, so they would not need to buy new property. This design would preserve the historic character of the building.

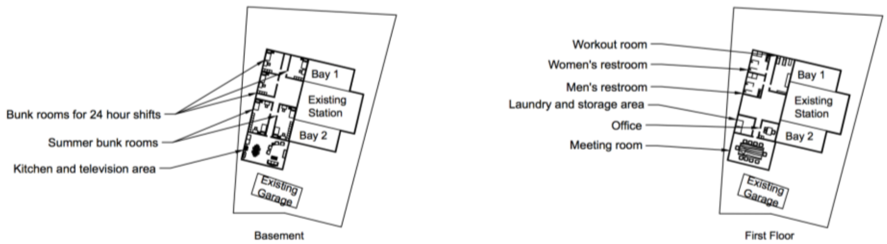

Figure ES.9: Floor plan of addition with labeled rooms

Our team found, through contacting multiple local insurance companies, that insurance rates are based on where a building is in comparison to a fire station. The least expensive insurance rates are on buildings located within a 5-mile radius of a staffed fire station. This radius has a dramatic effect on a building's ISO[5] rating, causing a large effect on annual insurance premiums. The current rating in the Siasconset area is an ISO 9 rating, while within the 5-mile radius of the centralized station there is an ISO 4 rating. If the Siasconset station were to be reopened and fully functional, 2,328 buildings would now qualify for lower ISO ratings (Figure ES. 10). Additionally, the reopening would result in savings for all properties that experience an ISO rating decrease.

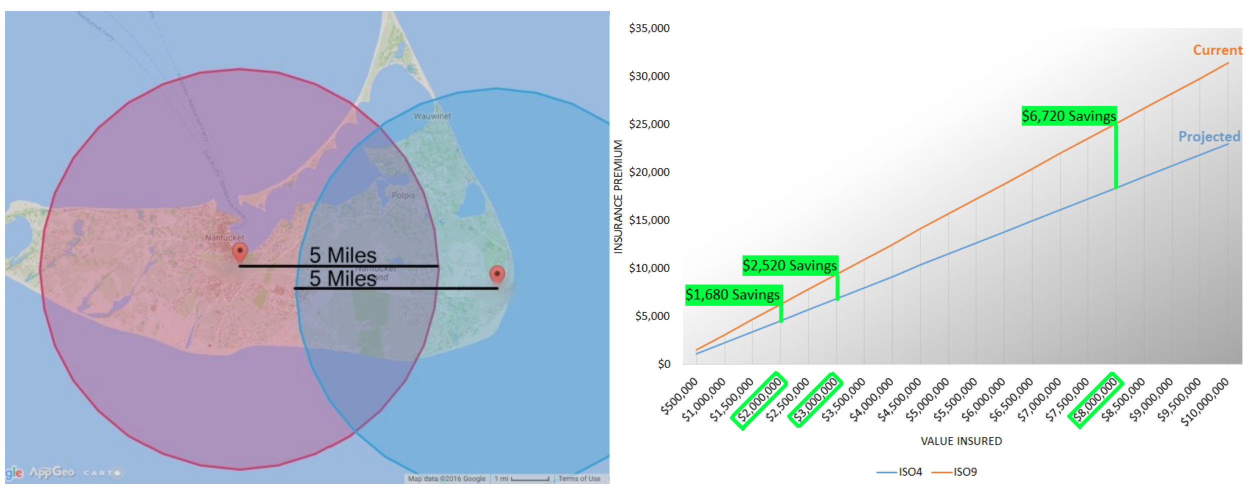

Figure ES.10: 5-mile insurance circles and savings based on ratings

The renovation costs of the Siasconset station were roughly estimated to cost $1,743,000 based on construction costs of $500 per square foot (Table ES.7). The upkeep and staffing is estimated to be $1,200,000 per year (Rhude, 2016). The total estimated annual insurance savings of $4,444,789 is based off the ISO rating changes, the number of buildings affected, and the

[5] ISO is the International Organization for Standardization. They develop and publish International Standards for a variety of fields from fire protection insurance to medical devices.

median value of the houses affected. It is important to note that the savings do not go directly to the town, they go to the property owners affected. The town could potentially explore the designation of fire protection districts into the town, which would allow for specialized taxes that could go directly to the fire department.

Siasconset Renovation		
	Renovation	Future Years
Cost	$1,743,000	$1,200,000
Annual Savings	--	$4,444,789

Table ES.8: Estimated Annual Costs and Insurance Savings of Siasconset Reopening

Recommendation 4: Use and further develop the simulation software. To estimate future response times, a basic simulation script was developed that implements Google Maps API. The simulation script can be optimized to conduct cost analysis precisely based on the NFD call data by predicting how much response time will be reduced when the solution has been proposed. For the NFD to determine the most cost effective solution, they first should:

- Decide new station locations
- Hire more staff
- Implement dynamic deployment

This script could be further developed to reduce response time through optimizing routes and choosing the best stations to deploy from. Therefore, it would be advantageous to have this program further developed after the previous two recommendations are implemented. To develop the simulation further, the following steps should be taken:

1. The script should be able to determine which station is the most accessible location for a specific emergency call. Based on the existing simulation script, this step is easily developed and could be done first in two months. In the case that this step is undertaken by a WPI IQP, the group should include all time influential factors such as concurrent calls, extreme weather, and extreme traffic as variables, and add them to the script. Once those variables are added, the team should create a user-friendly interface to let people in the fire department access the program easily.

2. After a user interface is made, the system can be further optimized. The program can be improved to find the best route to the emergency site. In the summer, there is a lot of congestion in the downtown area, which makes it difficult for emergency vehicles to reach their destinations. Through machine learning and algorithm optimization, this system can give advice as to what the fastest route for emergency vehicles is, and eventually it should be able to show detours to avoid congested areas. Finding the fastest route when there is traffic will be difficult to implement. The group that develops this

simulation should devise the algorithms by themselves instead of implementing Google API, which takes time. The time it takes to develop the system will be based on the technical ability of the group in charge of designing this system.

We recommend that this potential project be considered by the Nantucket Project Center in conjunction with WPI Fire Protection Engineering or WPI Computer Science majors and the NFD. This project could be organized as an Interactive Qualifying Project (IQP) or Major Qualifying Project (MQP). To determine the most appropriate methods to work on this project, the following necessary knowledge should be taken into consideration. The team must fully understand the following topics:

- Traffic circumstances in Nantucket
- Call codes used by the fire department
- How to code the necessary recommendations for the simulation
- How to share this simulation with the fire department and educate them on its use

Table ES.8 summarizes the initial costs of Siasconset renovations and the dynamic deployment vehicle.

	Capital
Siasconset Reopening	$1,743,000
Dynamic Deployment Vehicle	$300,000
Total	$2,043,000

Table ES.9: Cost of Proposed Fire Department Additions

The GIS maps below estimate how much the response time would be reduced after all three recommendations, including the new fire station, the Siasconset fire station, and the dynamic deployment standby location, have been implemented (Figure ES.11). Compared to the 2015 data, the downtown area in the simulation data is covered by green dots, which designates less than 5 minutes of response time. In the Siasconset area in 2015, the map is dominated by larger than 10 minute response times. After simulation implementation, the response times improve considerably.

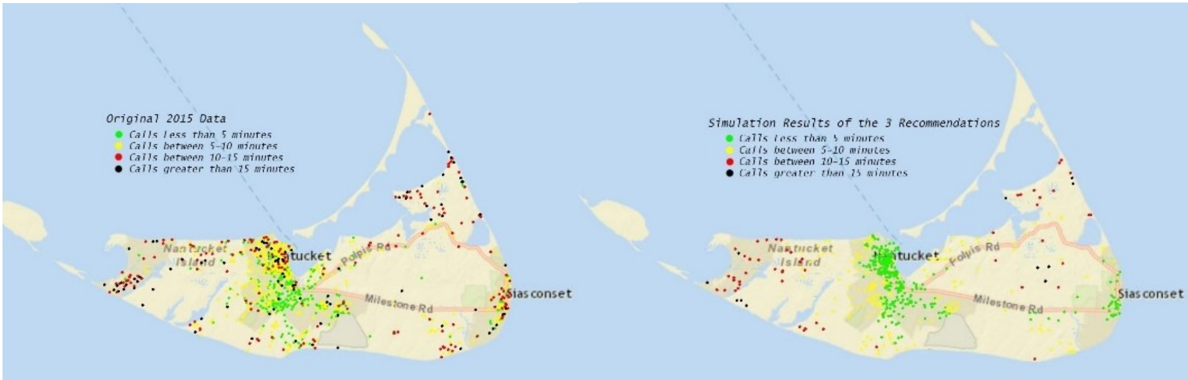

Figure ES.11: 2015 Call Data Compared to Simulation Results of Recommendation Locations

Conclusion

This project has been a great learning experience for the whole team. Not only have we gained individual skills such as coding, GIS mapping, and Excel graphing, but we have also learned how to cooperate and coordinate with other people in a team. We have learned how to work together on an in-depth project, conduct interviews, and write a report. On top of working with other students, we also learned how to conduct ourselves in a professional setting. The fire department has been an integral part of our project, and working with them has showed us not only how a fire department runs, but what it means to truly devote yourself to bettering the community for others. The fire station runs on mutual respect, discipline, and order, all things that will help us later in our personal and professional lives. Nothing would get done without the firefighters respecting each other and the engines and ambulances wouldn't work without proper maintenance done every day.

CONTINUATION OF THE REPORT IS ADDITIONAL RESEARCH CONDUCTED AND IS TO BE TREATED AS AN INFORMATIONAL APPENDIX.

2 Background

The Nantucket Fire Department is struggling to meet the standards for response time. This chapter is intended to provide detailed information on the problems faced by the department as well as a comparison to other fire departments. To fully understand the problem, the team will also assess the limitations to implementing the solutions.

2.1 Fire Departments and Response Time

Fire departments are multiple disciplinary emergency response teams. Some types of emergency calls responded to include fires, medical calls, hazardous conditions (no fire), good intent calls, and false alarms/calls.

2.1.1 Response Time

The quantitative metrics used to determine if a fire department is operating effectively is incident response time. Incident response time is defined as the length of time from when a call is dispatched to when the fire department staff is on the scene. This is different from the common conception that the clock for response time starts when the 911 call begins. There is a delay, usually around 1-2 minutes during the call when the dispatcher alerts the staff to equip gear and prepare a vehicle to be dispatched and leave the station. Although response time is not the only measurement of the effectiveness of a fire department, our analysis primarily focused on it as it is the value that gives the most insight.

2.1.2 Emergency Medical Services (EMS)

In addition to fire related calls, in the past few decades, fire departments expanded their responses to include emergency medical response. As of 2011, EMS calls made up 44% of all reported calls within Massachusetts (Coan, 2011). In comparison, the next largest category, false alarms and false calls, only made up 16% of the calls. The distribution of various categories of recorded fire department calls (Coan, 2011) can be seen in Figure 1 below.

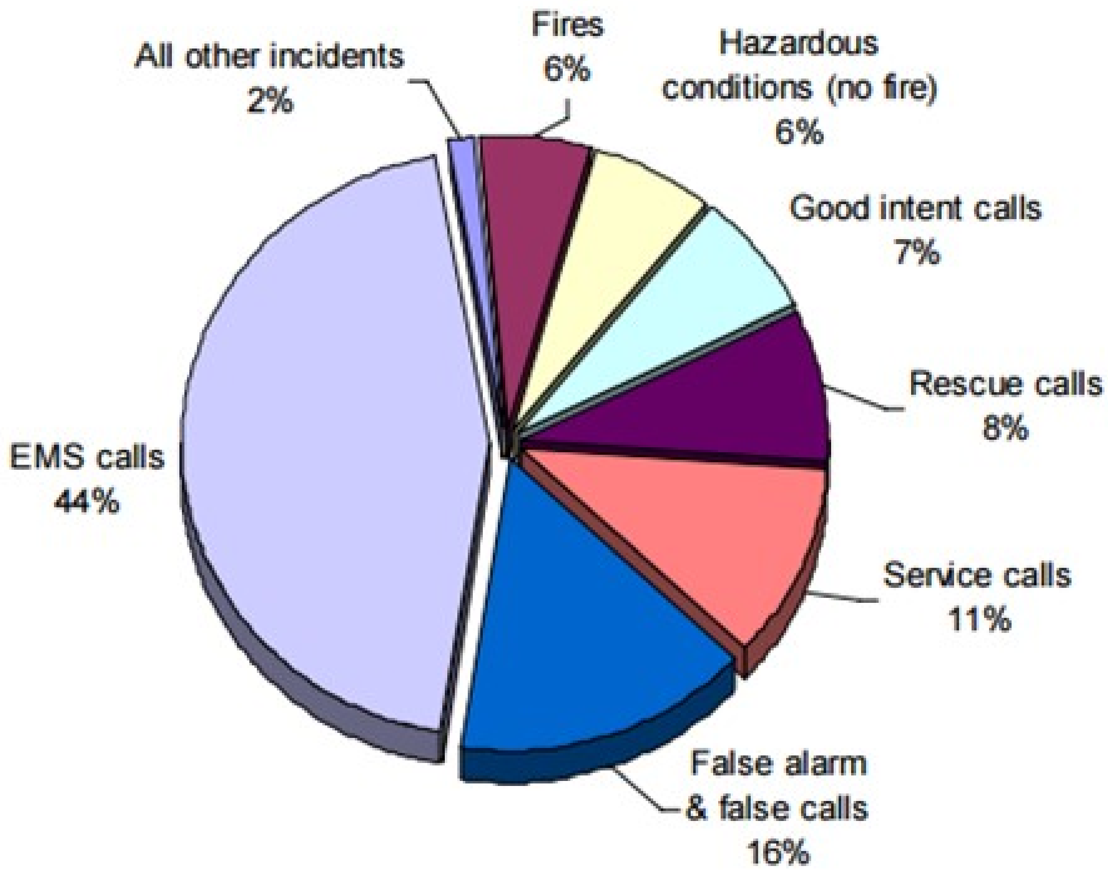

Figure 12: Fire Department Calls by Incident Type

Within the EMS category shown in Figure 1 above, there are multiple types of response including: transport, first aid/check for injuries, basic life support (BLS), and advanced life support (ALS). The percentages of the various types of medical response calls recorded between 2001 and 2009 (Coan, 2011) are shown below in Figure 2.

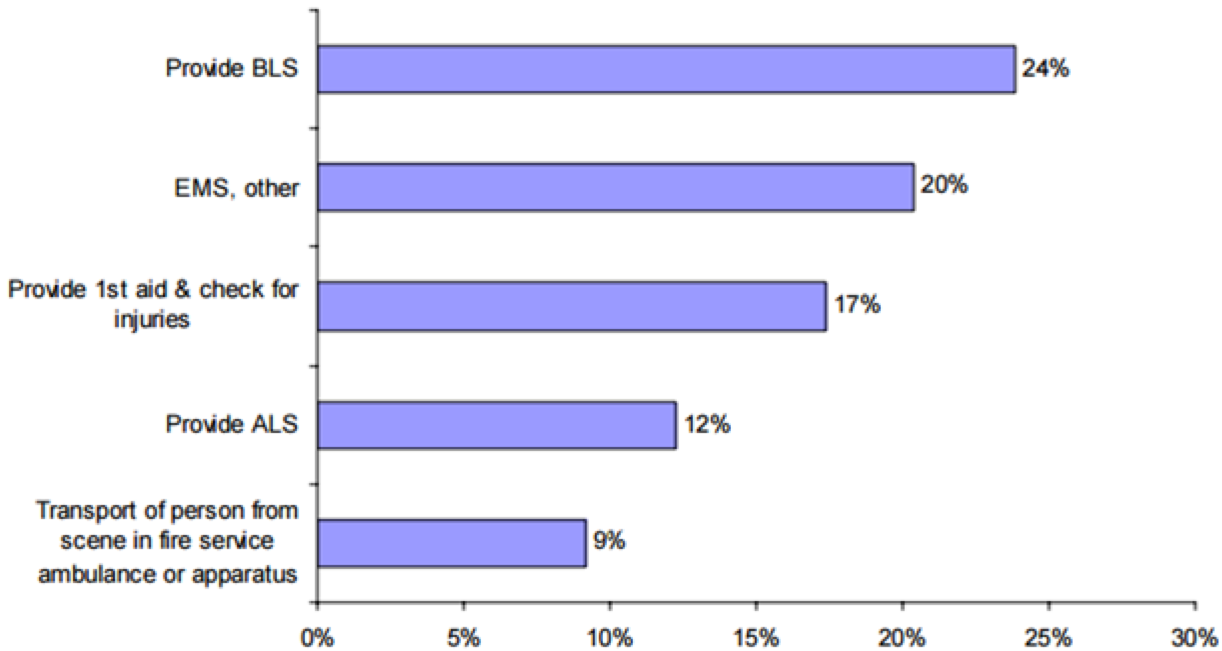

Figure 13: Leading Actions Taken During EMS Calls 2001-2009

2.1.3 Standards

Standards are not laws; however, they are recommendations set forth by a group of experienced leaders and analysts. Fire department standards are set by an annual colloquium of fire chiefs and fire prevention analysts that are then summarized in multiple texts including the National Fire Protection Agency's own NFPA guidelines. For this project, relating to response time, the relevant NFPA standards are 1710 and 1720.

NFPA 1710

The NFPA 1710 document encompasses general guidelines for fire departments. In this document, there is no distinction between unionized, nonunionized, and volunteer departments. Two important standards are those with quantitative values that departments can easily compare their averages with. Those standards are as follows:

- 5-minute response time for 90% of calls with an additional 1 minute for gathering equipment
- 4-person minimum on 90% of calls for fires

In addition, the document also explains the meaning of response time, defined as "the time interval that begins when a unit is in route to the emergency incident and ends when the unit arrives at the scene." In the 2010 edition of NFPA 1710, the following was added: "The travel times for units responding on the first alarm were clarified to indicate the first unit must arrive within 4 minutes' travel time and all units must arrive within 8 minutes' travel time." Travel time is the responsibility of the fire/ems department, but often dependent on factors not in their control, such as distance to the scene and dense traffic conditions.

Specific Response Times for the 3 Emergency Medical Response Levels

In addition to fire department standards, NFPA 1710 also sets quantitative standards for medical emergency response times. The standards are summarized in the list below from least to most severe.

- First Responder with AED
  - All personnel must be at this level at a minimum and crews must be able to arrive within a 4-minute (240 second) response time to 90% of all medical emergency incidents.
- BLS - Basic Life Support
  - Additional training and licensing required (approximately 300hrs)
  - Crews must be able to arrive within a 4-minute (240 second) response time to 90% of all medical emergency incidents.
- ALS - Advanced Life Support (EMT-Paramedic)
  - Completed rigorous training on further life support (approximately 3000hrs)
  - The department must also deploy sufficient resources to arrive within an 8-minute (480 second) response time to 90 percent of all emergency medical incidents.
  - Minimum of 2 members trained at ALS level and 2 at the BLS for all ALS calls.

NFPA 1720

The NFPA 1720 standard addresses the differences between various types of emergency response departments. Described within are the regulations for unionized, non-unionized, and volunteer fire departments. Since this project is focused on assisting a unionized department, only the union fire department standards will be used as reference material. The NFPA 1720 document states that personnel responding to fires and other emergencies shall be organized into company units or response teams and shall have appropriate apparatus and equipment. In our analysis of the department, the team will compare the available resources on Nantucket to what is recommended by this document. Additionally, upon assembling the necessary resources, on call firefighters “shall have the capability to safely initiate an initial attack within 2 minutes’ 90 percent of the time” (NFPA 1720, 2015). This data will be used as a goal for the on-call aspect of the NFD.

2.2 Current Nantucket Fire Department Situation

The Nantucket Fire Department is currently struggling with meeting the national standard for response time. This is not attributed to just one thing though, there are many parts of the puzzle that are missing.

2.2.1 Nantucket Fire Department Resources

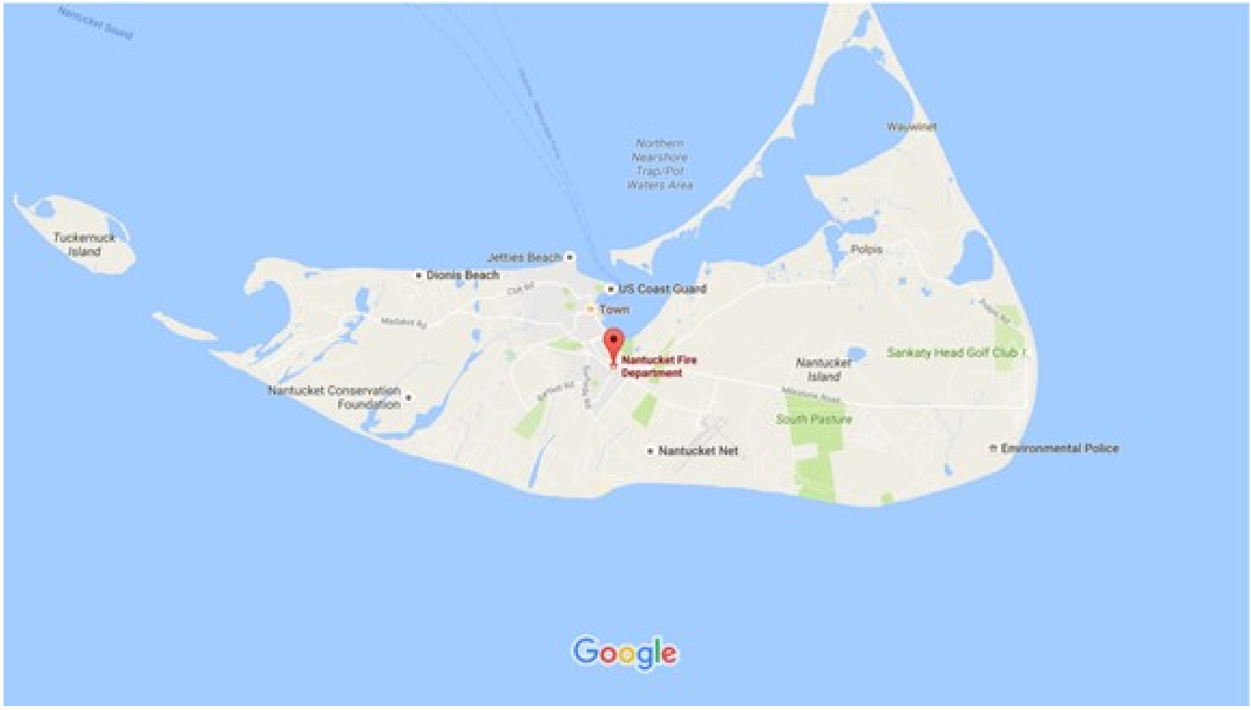

Figure 14: Nantucket Fire Department Location

Nantucket has one central station which is located at 131 Pleasant Street (Figure 3). Along with the central station, the NFD has three satellite stations which are essentially garages:

- Siasconset Station located on the east part of the island, 10 West Sankaty Rd
- Madaket Station located on the west part of the island, 293 Madaket Rd
- Tuckernuck Station (shed) on Tuckernuck Island

Among all four fire stations, only the central station is staffed, the other three remain unstaffed as storage locations for vehicles. The Nantucket Fire Department has forty members including, sixteen career firefighters with EMT skills, and nine on call firefighters, six of which have EMT skills. The fire department keeps three personnel shifts in the winter and four personnel shifts in the summer.

In addition to the staffing challenges, the team must address the available resources. The current vehicle resources are shown in Figure 4. There is no private ambulance service on Nantucket, so all ambulance transports are performed by the fire department. Additionally, for all MedFlight[6] landings, a fire engine was previously required to be on standby at the hospital; however, since the hospital is currently renovating the landing pad, the fire department now must only transport the patient between the hospital and airport. The airport is a gated in area, so when the MedFlight lands and takes off the fire department does not need to have an engine there. In the future, the hospital will have a gated area for MedFlight, so the fire department will have a substantial less amount of calls related to MedFlight.

[6] MedFlight: an emergency response airlifting company that provides transport to hospitals. Nantucket uses Boston MedFlight: http://www.bostonmedflight.org/

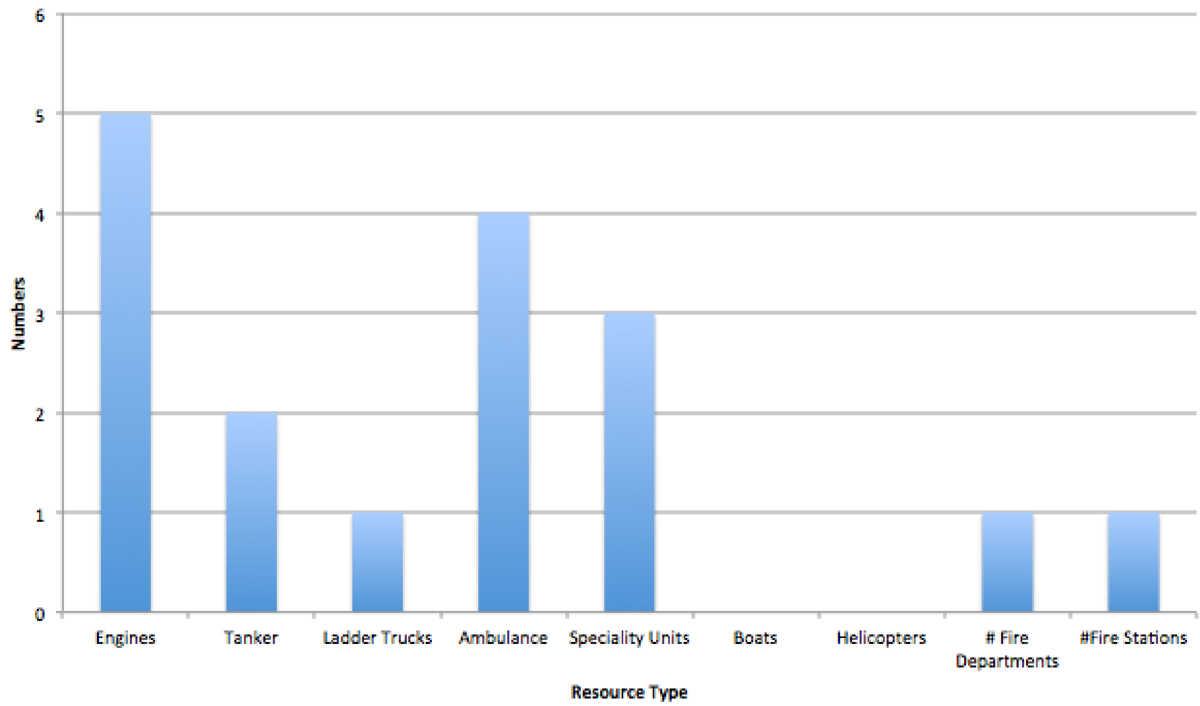

Figure 15: Vehicle Resources of Nantucket Fire Department

New Fire Station

The Nantucket Fire Department proposed to build a new fire station in a location that could provide more reliable operations and support, and was meant to divide the work with the Central Station. This new project was proposed around 2008 with the goal of shortening the response time of the fire department by enabling the NFD management to spread out their personnel more effectively. Based on the report that was written two years ago, Peter Morrison, one of our sponsors, suggested the location of the new fire station as 4 Fairgrounds Road shown in Figure 5 and Figure 6. The new fire station project got approved $15 million in funding for construction and an extra $2 million in funding for the facility at the 2015 Annual Town Meeting (The Inquirer and Mirror, Nov. 2015). The architect's latest reevaluation from early 2016 increased the estimated cost to $20 million and the Nantucket finance committee denied the proposal, requesting more cost-effective building methods (Worth, 2016).

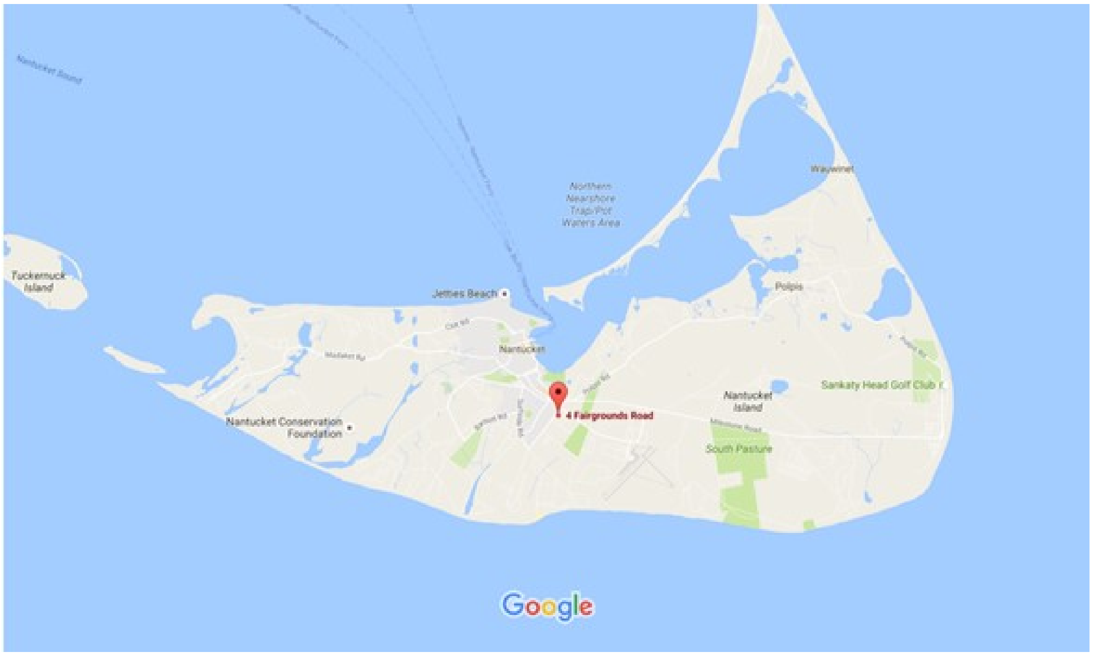

Figure 16: Potential Location of New Fire Station

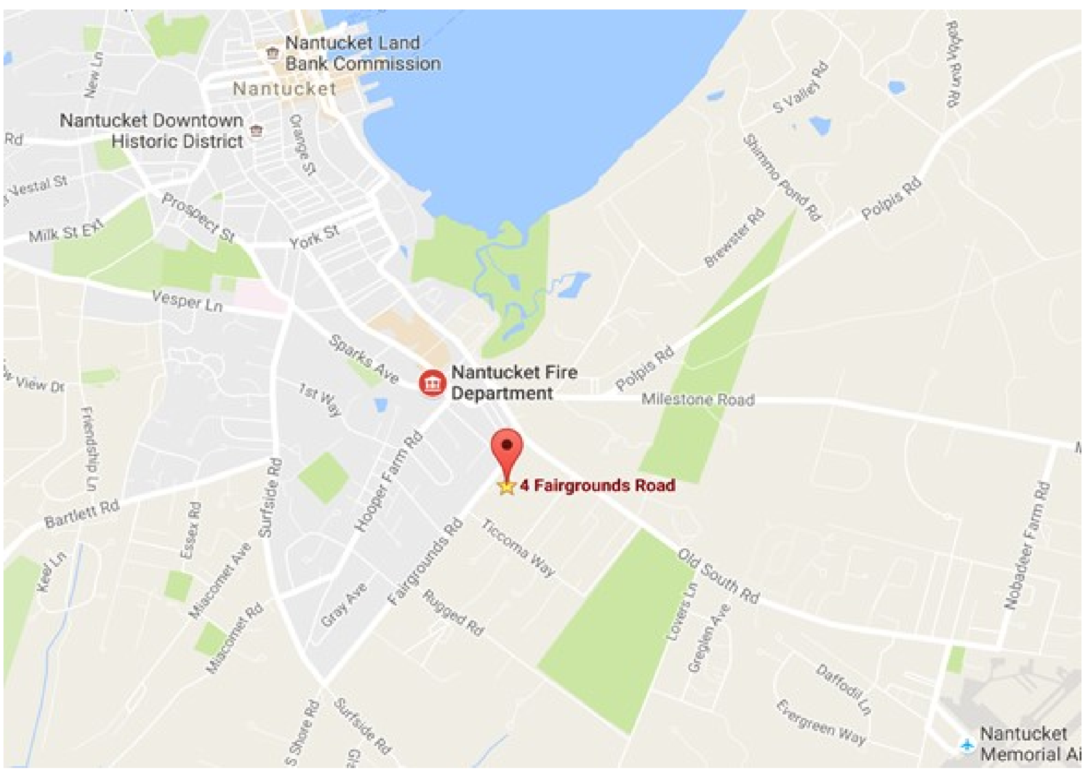

Figure 17: Distance between Nantucket Fire Department and Potential Location of New Fire Station

2.2.2 Reasons for Long Response Time

The 2014 IQP (Brecher, Sauer, Smith, & Wolf, 2014) reported that the two major problems causing the long response times are traffic and concurrent calls. Most of the calls are within 2-4 miles, but the response time of these calls are usually longer than the national standard. Of the calls that fall within 2 miles, 45% have a 10-minute response time. The center of town is heavily congested, which causes the fire trucks that leave from the central station to have to take less efficient paths. This then lengthens the travel duration to the location of the emergency.

From the Annual Town Report for 2014 (Town of Nantucket, 2014), the NFD department responded to 2,869 Emergency Calls with an additional 2,114 Service and Inspection calls. According to the report, the possibility that the fire department will encounter concurrent calls is rising every year (Table 1). The fire chief also noted that the number of people and houses will continue to increase in the following years and that this could cause an exponential growth in the number of concurrent calls if the department does not address the staffing and the other needs of the department.

Year	No. of calls annually	Daily average (1/365 of annual)	Growth in demand (1979 = 100)
1979	570	1.6 calls	100
1990	1,322	3.6 calls	232
2000	2,444	6.7 calls	429
2013	3,773	10.3 calls	662

Table 10: Annual Calls for Emergency and Non-Emergency Service: 1979 - 2013

2.3 Related Departments

To gain a better understanding of the Nantucket Fire Department's issues, the team compared the NFD to other island fire departments as well as fire departments in Massachusetts. Block Island and Martha's Vineyard, while varying in size, are like Nantucket since they are islands with seasonal populations.

Nantucket is approximately 45 square miles with a population density of 226.2 people per square mile (US Census Bureau, 2010). Comparatively, Worcester, MA has 528.6 people per square mile with 1,510.7 square miles. This means that for Nantucket, there are roughly five people per mile, where in Worcester there are .35 people per mile, making Nantucket a densely-populated area (US Census Bureau, 2010). In addition to the density being a setback, the fire department is not as thoroughly staffed as the other islands. If you look at Block Island, they have 19 staff and only 9.7 square miles of land. In comparison, Nantucket has 40 staff with almost five times the land. Theoretically Nantucket should have five times the number of staff while in reality it only has double. The table below (Table 2) shows how each island has a different ratio of square miles to fire department personnel. Nantucket's ratio is almost equal whereas Block Island has almost double the personnel compared to their mileage.

	Nantucket	Block Island	Martha's Vineyard
Square Miles	35	28	164
Fire Department Personnel	40	38	198

Table 11: Miles Versus Personnel

The suggested radius of coverage for each fire station is around 1.5 miles. On Block Island, with a size of 9.7 square miles, two fire stations cover the island. With a square mileage five times the size of Block Island, Nantucket would ideally have five times as many fire stations as Block Island. However, Nantucket has three fire stations, only one of which is regularly staffed. While Martha's Vineyard suffers from a similar lack of fire stations, it makes up for this shortcoming with more engines and manpower. Each station on Martha's Vineyard is fully staffed and equipped with equipment to account for the increased radius of the station. At the Oak Bluffs Fire Station alone, there are 80 on call firefighters, and the station has four engines, one ladder truck, three ambulances, one helicopter, and four miscellaneous fire department vehicles. On the entirety of Nantucket, there are only three fire engines and three ambulances, and 15 of the island's 40 firefighters are volunteers. The table below (Table 3) depicts, just how under equipped the NFD is.

	Nantucket	Block Island	Martha's Vineyard
Engines	5	2	9
Tankers	2	unknown	unknown
Ladder Trucks	1	1	2
Ambulances	4	2	4
Specialty Units	3	1	5
Boats	0	0	2
Helicopters	0	0	1
# Fire Departments	1	1	3
# Fire Stations	1	2	5

Table 12: Island Fire Department Resources

Currently the Nantucket Fire Department does not have enough staffed stations to be considered up to standard. As previously stated in the NFPA 1710 document, to be considered standard, each fire department should have a station that can reach any part of Nantucket in about five minutes. When you also take into account that many of Nantucket's roads are narrow and unpaved, it becomes even more important to have at least equal to, or even more than the suggested number of fire stations. To compare the distances between stations, the team used the OLIVER GIS system to locate where the fire departments of both Worcester and Nantucket are (Figure 7). The radius drawn is about a mile and a half.

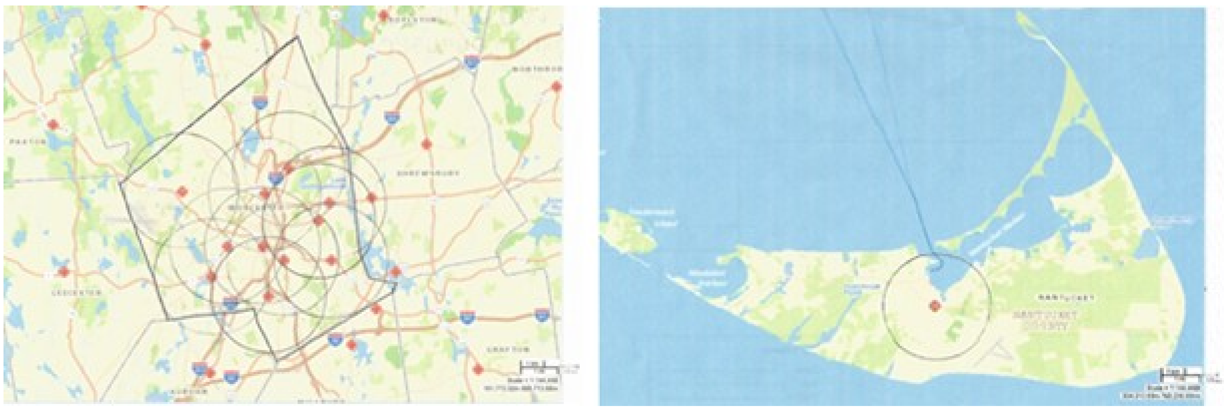

Figure 18: GIS Fire Station Comparison Worcester v. Nantucket

As shown, Worcester has many stations where their radii overlap, whereas Nantucket has no overlap. Along with ensuring at least one fire station will make it to a site on time, having multiple stations can increase the number of firefighters responding to a scene and allow for more accessibility specialty equipment such as ladder trucks. It also lets them respond to concurrent calls because one station can fill in for an on call station so that there are no gaps in coverage. This overlap makes Worcester's response time faster. Adding more stations could lower Nantucket's response time and take some of the pressure off the current firefighters.

In Brentwood, California there was a fire that took the fire department twelve minutes to respond to. This resulted in 600 residents being left without power (Beutner, 2012). This number could have been much lower if their response time wasn't so high. What many people might not realize is that insurance companies classify each town by how fast their response times are. The scale, ISO[7], goes from 1-10, 1 being the best and 10 being the worst. In a 2004 study, it was found that Nantucket's ISO was at a 3-4 in downtown (Deadly Delays: The Decline of Fire Response, 2005). Due to being more than 5 miles from a staffed fire station and not having a fire hydrant within 1000 feet, the outskirts of the island on both the Madaket and Siasconset side receive a rating of 9-10 as shown in Figure 8.

[7] Insurance Service Office - This is a, for profit, organization that provides statistical information on risk.

Figure 19: Five Miles Radius around The Central Station

2.4 Island Housing

One solution to our complex problem of lowering the NFD response time would be to hire new firefighters and paramedic personnel for the on season. To do so, the NFD would either need to have they can find housing themselves. In the special case of the NFD, neither option is likely viable at the present time.

There are two ways to try and fix our housing problem: first, the firefighters who are coming to work on the island could pay for their own lodging, or the NFD could have a place to put them while they stay on the island. Unfortunately, Nantucket is a very expensive place to live because it is such a popular island for tourism. For example, to stay in a one-bedroom studio cottage is 175 dollars a night. To stay in a two-bedroom studio cottage goes up to 620 dollars a night and a three-bedroom cottage is 1,020 dollars a night. If these rates stay constant throughout the summer season that would come out to be 5,250 – 30,600 dollars a month just to have a place to live, this wouldn't cover any other expenses. To put this into perspective, the average firefighter in Nantucket makes 64,045 dollars a year, which means that trying to have incoming firefighters pay for their own lodging doesn't make any sense (Salary Genius, 2015).

The next option would be for the NFD to provide housing that could be used specifically for incoming firefighters and paramedic personnel. Just as before, however, prices of houses and land lots are expensive. The average house on Nantucket costs an average of 2.5 million dollars, which does not provide a cost-effective solution for our housing needs. Fortunately, according to the previous IQP team, there are several places that would be ideal to build fire department personnel housing on. The first location would be an old police station (Figure 9) in the downtown area which is close to the town center and would be easy to repurpose since it is already a government run property. The second spot would be an empty lot that the town owns (Figure 10) which gives nice access to both Madaket and the main town. The third spot is actually already a “satellite” station (Figure 11) which houses the NFD’s smallest fire engine already. This station is basically just a garage, so it would be nice if the NFD could repurpose this space as a barracks or at the very least a place to put both the firetruck and some additional personnel.

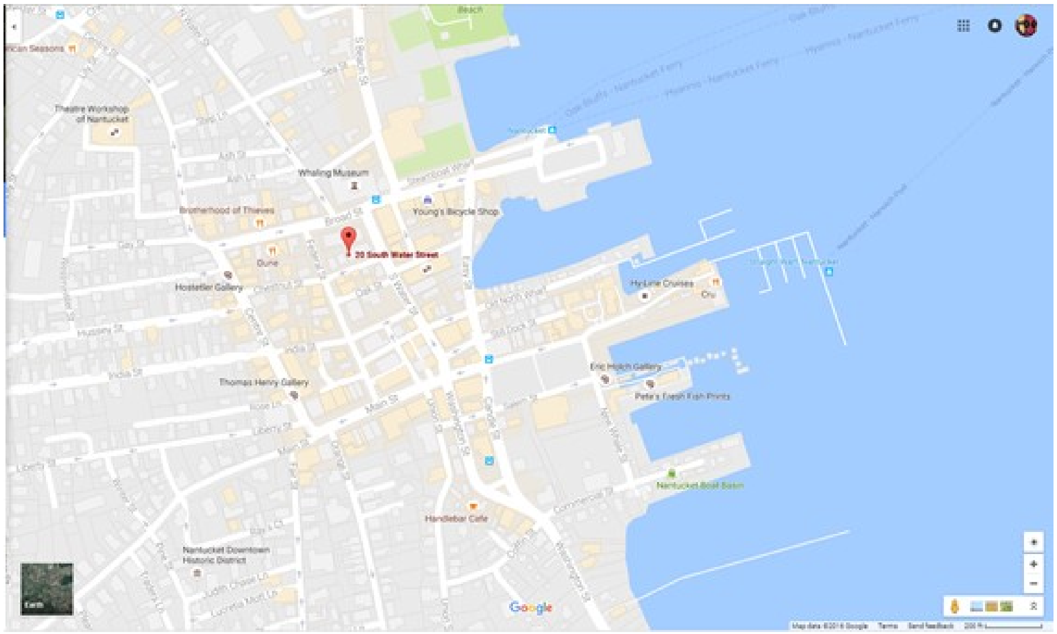

Figure 20: First Fire Station Recommendation

Figure 21: Second Fire Station Recommendation

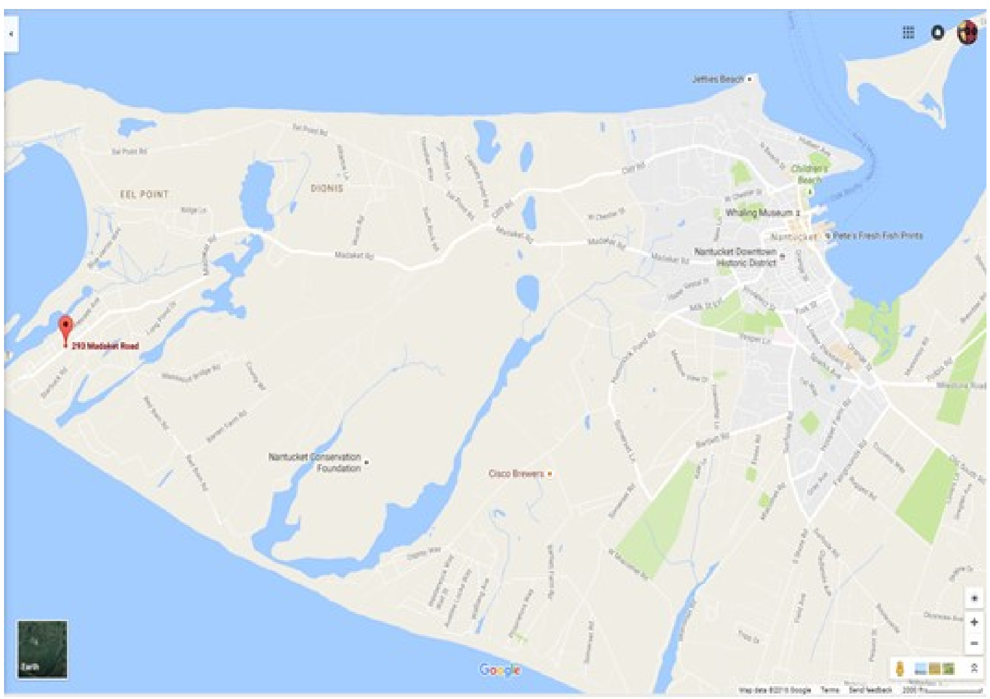

Figure 22: Third Fire Station Recommendation

Part of the reason why housing is so expensive on the island is because of all the conservation land and other restrictions that the island imposes on building. Close to 50% of the island is owned by private conservation companies. This is good for the environment and wildlife that live there, but is unfortunate for people since it drives the price of the useable land up. On top of what is already conservation land, the government just passed tax incentives for conservation restrictions that makes donating land or money to any conservation companies more beneficial to the person. These benefits include raising the deduction that can be taken off taxes, extending the amount of time you can use said deduction and farmers can deduct 100% of their income (Nantucket Land Council, 2016).

2.5 Reducing Response Time

To find out how to help the Nantucket Fire Department's response time, the team considered what other places are doing to improve their response time. We started with the general subject, broke it down into individual ideas, and then summed it all up.

1. How other fire stations deal with low staffing
2. Using satellite/forward stations to reduce response time
3. Partnering with other agencies
4. Seasonal housing options
5. Summary

2.5.1 How other fire stations deal with low staffing

One of the major issues that the Nantucket Fire Department is facing is understaffing. "Fire companies usually consist of two to five firefighters, led by a company officer (usually a lieutenant or captain)" (Cortez, 2001). Based on tests conducted by Fire Technology in 2001, it was shown that the more hands available in a fire station, the faster essential fire department tasks can be completed, and the easier it is to complete more complex tasks like constructing a ladder or unwinding a fire hose. Conversely, understaffing can cause reduced effectiveness, which could lead to property loss among other problems. If the fire department does not have enough people on call, their response time will be slower and the effects of the emergency will be worse. This is because understaffing can result in situations where fire personnel at an active scene may not have the backup needed to be safe in all situations, thus, resulting in a potentially dangerous situation for responding fire personnel.

The National Fire Protection Agency describes the ideal crew size as follows; "In the initial stages of an incident where only one crew is operating… a minimum of four individuals shall be required, consisting of two individuals working as a crew in the hazardous area and two individuals present outside this hazardous area" (NFPA, 2007). The following graph (Figure 12) shows how the number of firefighters relates to effectiveness during a test. This test required teams to carry a 24' extension ladder 75', raise it to the third floor, advance 1.5" line up ladder, force entry, remove victim, and flow water. In this scenario, effectiveness is based on the time it takes the firefighters to complete this test. Although it may seem that this could be a one-person job, the more hands they had the faster they went, and the faster the firefighters go, the more lives and objects they can save. Currently the Nantucket Fire Department has three person shifts, and looking at the graph, it would be more efficient if they had four to six on a crew. In short, this means that in order to be effective with more than one call at a time, the department would need to quadruple the number of personnel per shift.

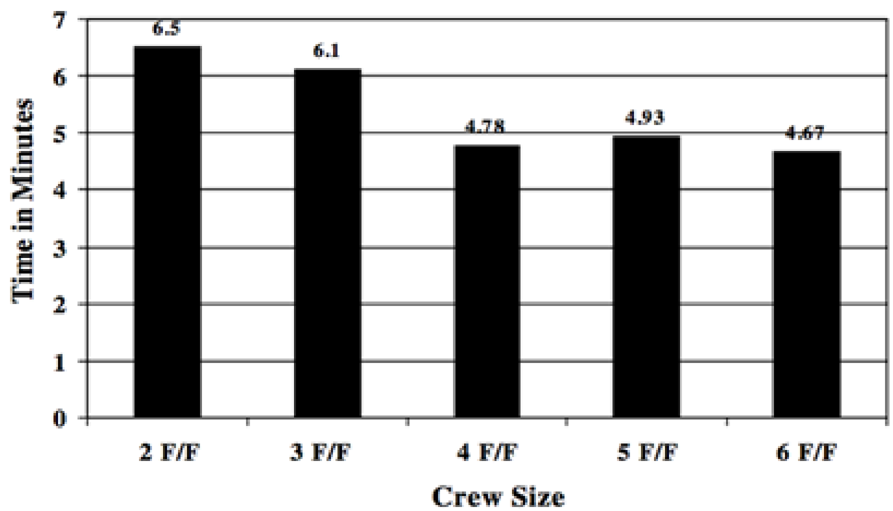

Figure 23: Test Averages for All Iterations per Crew Size

Some fire departments are reducing the number of career firefighters and adding volunteers, because the cost of two volunteers is about the same for one career firefighter (Beutner, 2012). In some communities and fire departments many volunteer firefighters are college students (Beutner, 2012). This could be an issue for Nantucket because if the NFD were to rely on college students, once students go back to school, there are no more volunteers. Such a solution would not necessarily be an option for the NFD since most of the population in Nantucket is either retired or has a job that does not allow for them to go through the training necessary to become a firefighter, and few college students could afford to spend the summer on Nantucket.

Another option would be to provide living for the firefighters. The Auburn Fire Department in Alabama provides living quarters in the fire stations (Beutner, 2012). Unfortunately, the Nantucket stations do not have enough space to house any workers. Thus, to provide housing, Nantucket would either must find land to build fire personnel housing on, rent rooms for fire personnel, or expand the stations so there would be enough room for living.

Many fire departments rely on neighboring towns for extra staff, but Nantucket is unique in the way that they are an island with no connection to the mainland or any neighboring settlements to call on. In North Carolina, only the large cities used to be able to afford full-time firefighters, and that left the more rural areas with the same issue that Nantucket struggles with. Now North Carolina can support the whole state by having cities work together (Cortez, 2015).

2.5.2 Using Satellite/Forward Stations to Reduce Response Time

Satellite/Forward Station Use

Throughout the United States, fire departments are working to solve the problem of growing response times by spreading out the distribution of on-duty firefighters between multiple stations to cover a larger area. In more populated areas, these stations are almost always fully staffed and able to operate independently from the central station. In more rural areas, these forward stations tend to be staffed only part-time and receive their dispatched calls from the central station. These substations are necessary to keep the response times of the department within the standard of 5 minutes for 90% of all calls. It is recommended by the NFPA 1710 that staffed stations are spaced approximately 1-2 miles apart in urban regions and up to 5 miles apart in rural areas (Toregas, Swain, ReVelle, & Bergman, 1971).

Nantucket's Situation

Unlike the national models, in Nantucket, the only station that is staffed is the central station. The satellite stations that are on Nantucket are used as storage locations for the reserve vehicles and equipment and are not staffed. There is hope of renovating the Siasconset satellite station to allow for 24/7 staffing, with a $100,000 budget proposed for examination in early 2017. However, there is concern that once the building is renovated, Nantucket will be unable to staff the forward station, as they are already understaffed at the central station (Rhude, 2016).

2.5.3 Partnering with other Agencies

Staffing Challenges and Benefits of Partnering with Other Agencies

Rapid urban expansion and the ensuing use of resources challenges land and resource managers, urban planners, governing entities, and emergency service agencies. According to fire Chief Rhude, the number of personnel per shift has decreased from 5 year-round to 3 in the winter and to 4 in summer, making the staffing problem the main issue for the fire department. Understaffing is a problem for many reasons, with the most significant being the lack of capability to handle with concurrent calls. Since it is not practical for the NFD to build multiple new fire stations in a couple of years, one of the solutions is partnering with other agencies on the island. There are many potential agencies that can partner with NFD. This solution takes less time than building new satellite stations and can efficiently help with staffing issues.

Potential Partner Agencies

There are a couple of agencies on the island that the Nantucket Fire Department already collaborate with. The Nantucket Land Bank has a program of conducting prescribed burn programs on conserved lands, with some of the NFD staff taking part as a training exercise. Multiple members of the Nantucket Public Works (NPW), located at 188 Madaket Rd, are currently undergoing firefighter training including the supervisor of NPW. The other cross-trained firefighters are those who work at the airport on the crash crews.

Seasonal Workforce

In using a seasonal workforce, the Nantucket Fire Department is trying to model the Amherst Fire Department Student Force, which is independent to the Amherst Fire Department. For the AFD, the Student Force is one of the three forces that make up the Amherst Fire Department. They have their own company and engines, as well as 36 personnel. The Student Force can be trusted because they receive the same training as the career firefighters. Students get about 70 hours of intense training in the heat of August and they continue to train weekly (Lederman, 2015). The Nantucket Fire Department is trying to hire a student workforce to deal with summer time inflation. If the NFD could find student firefighters from Universities, then the number of staff on island will drastically increase during the summer, which could improve response times.

2.5.4 Seasonal Housing Options

When summer starts, the population increases, as does the workforce that provides all the services that makes towns run so smoothly. Nantucket is no different in terms of demand for its labor, however, it doesn't currently have the infrastructure to support all of the people who come and work over the summer.

Nantucket's policy for municipal workers is typically that housing is not provided. If a municipal worker is considering summer work there, then they need to hope that the employer offers housing or has rental arrangements. If that is not the case, then the employee must try and find on island housing either by using the classified section in Nantucket's local newspaper "The Inquirer and Mirror" or by posting flyers with accommodation requirements around the main town. Such a process is tedious and difficult and for many part time workers, the time commitment of securing living arrangements is a reason for them to not apply for the job. For seasonal firefighters who already must work 2-3 other jobs to afford the housing, the commitment to finding housing is difficult on Nantucket,

One solution to this problem would be to provide housing for any seasonal and full time staff. The Charles M. Russell National Wildlife Refuge in Montana does this with their seasonal firefighters. CMR needs more help in the dry season fighting bushfires so when they put out ads for seasonal fire personnel they also provide their housing. CMR has 3 different bunkhouses that are offered as residences to their on-call firefighters. It is government housing, which means that rooms are shared with other seasonal firefighters and they need to bring their own sheets and other bedding materials. This makes the cost of living much more reasonable since it is a communal living area. Such a simple and effective strategy won't work well on Nantucket because they don't have the land or the resources to try and put up several bunkhouses. This also doesn't help anyone who has a family as bunkhouses are communal living and don't support a family life very well.

Another way to try and supply housing for incoming staff is by providing them housing, but subtracting their rent from their salary on a regular basis. Glacier National Park in Montana uses this business model, subtracting rent on a bi-weekly basis with the cost generally from 60-160$ depending upon where the housing is located. This might be a viable strategy for Nantucket, but it depends on if they could secure a spot to build housing on and how much money they would charge.

Other parks across the US will either offer housing for a short period of time and have you camp outside for the rest of the time, or flat out don't offer any housing. A forestry fire technician job in Port Angeles, Washington offers no help or housing whatsoever. In the job description, it just says "no government housing" and it assumes that you will be able to find your own housing. In that case, Port Angeles is a big town, so finding housing isn't a problem, but it is good to see that Nantucket isn't the only one who makes their seasonal workforce find their own housing.

2.5.5 Summary

In summary, the team will be assessing the viability of 4 options: increasing staff, designating satellite stations, partnering with other agencies, and increasing the availability of housing. No singular option will suffice, so we will be assessing these options together. How we will be assessing the options will be addressed in the following methodology chapter.

3 Methodology

Mission Statement: The purpose of this project was to assist the Fire Chief in reducing and improving the response time and the quality of performance of the Nantucket Fire Department by exploring all avenues for improving response efficiency such as providing housing for hiring additional fire personnel, enhancing firefighter training, adding or staffing additional fire station locations, and exploring other option for non-full time fire personnel.

Objectives:

- Assess current response time and readiness of the Nantucket Fire Department.
- Identify and interview different stakeholders to gain insight on opinions on the response time and potential ways to reduce the response time for the Nantucket Fire Department.
- Study and assess potential solutions to reduce the NFD response time.
- Perform cost analysis on combinations of options to improve response time.
- Provide detailed recommendations to the Fire Chief of the Nantucket Fire Department.

To address these objectives the team followed the methodology outlined in Figure 13. As shown in this figure we, took the four options that we were given for reducing response time and went through each of the objectives. Below, we will describe in more detail how the team will describe the specific methods used for each objective and outlined in this figure.

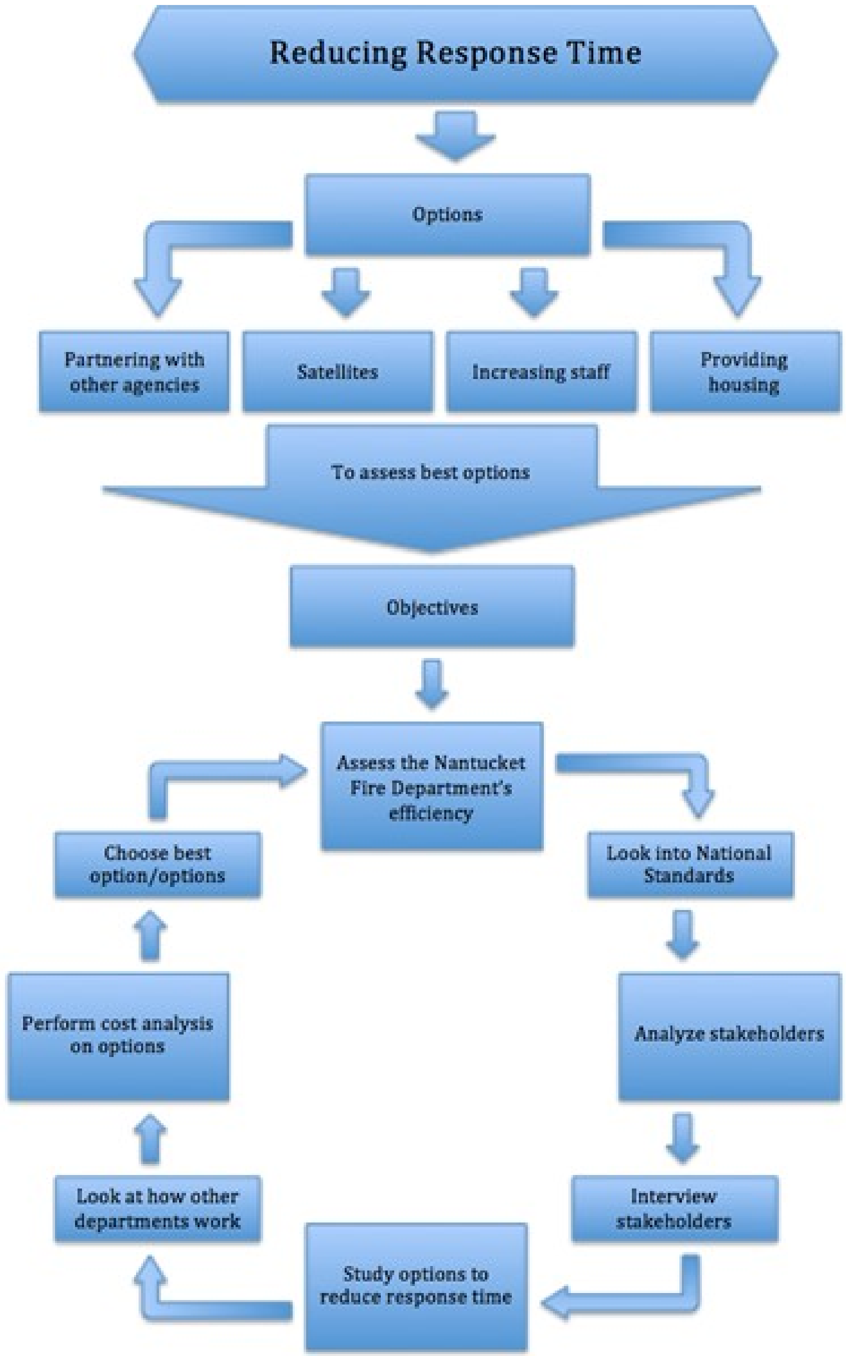

Figure 24: Methodology Flowchart

3.1 Assess Efficiency of the Nantucket Fire Department

This project builds off the analysis from a WPI student report similar to this one completed in 2014 (Brecher, Sauer, Smith, & Wolf, 2014). To begin our project, the team assessed the current efficiency of the Nantucket Fire Department by breaking up response times as a function of location, multiple calls, and staffing levels, over the past few years. To further our comparison study, we compared the national standards to the data provided to us by the Fire Department, as illustrated in Table 4 in the results section. The national standards were then incorporated in a cost benefit analysis of various solutions to response time and staffing issues. In this section, we discuss:

1. GIS Mapping
    i. Prepare the call data
    ii. GIS Mapping system
2. Categorical analysis
3. Historical analysis

3.1.1 GIS Mapping

Prepare the Call Data

To analyze the response times of the NFD for the past few years, the team obtained the database of all calls and response times for approximately 24,000 emergency calls between January, 2007 through to June, 2016. Using this data set, the team started our analysis in Microsoft Excel, using formulas to calculate the response time and the total time for each emergency call by comparing the time of dispatch, arrival, and completion. We also concatenated the street locations into a single text string to be in a format that could be geocoded easily.

GIS Mapping System

Once the team had the emergency data response times linked to street addresses, a batch Google API based online geocoder[8] was used to take the street locations and return the latitude and longitude. To visualize the calls and how the response time varied with location, we used GISMap to take the data and show it in a more visual manner. GISMap inputs excel files of geocoded location data and plots the data by year, response time and emergency type onto a map in reference to a coordinate plane. To get a full representation of the data, we broke it down in a couple of different ways: by year, by time, and by the type of call. The plots were then labeled and used to examine the current state of response time for the Nantucket Fire Department and the trends over time. For example, in Figure 14, all of the calls were displayed by response time to the emergency. Additional maps like Figure 14 can be found in chapter 4: Results as well as in Appendix B.

[8] batch Google API based online geocoder used was: http://www.findlatitudeandlongitude.com/batch-geocode/

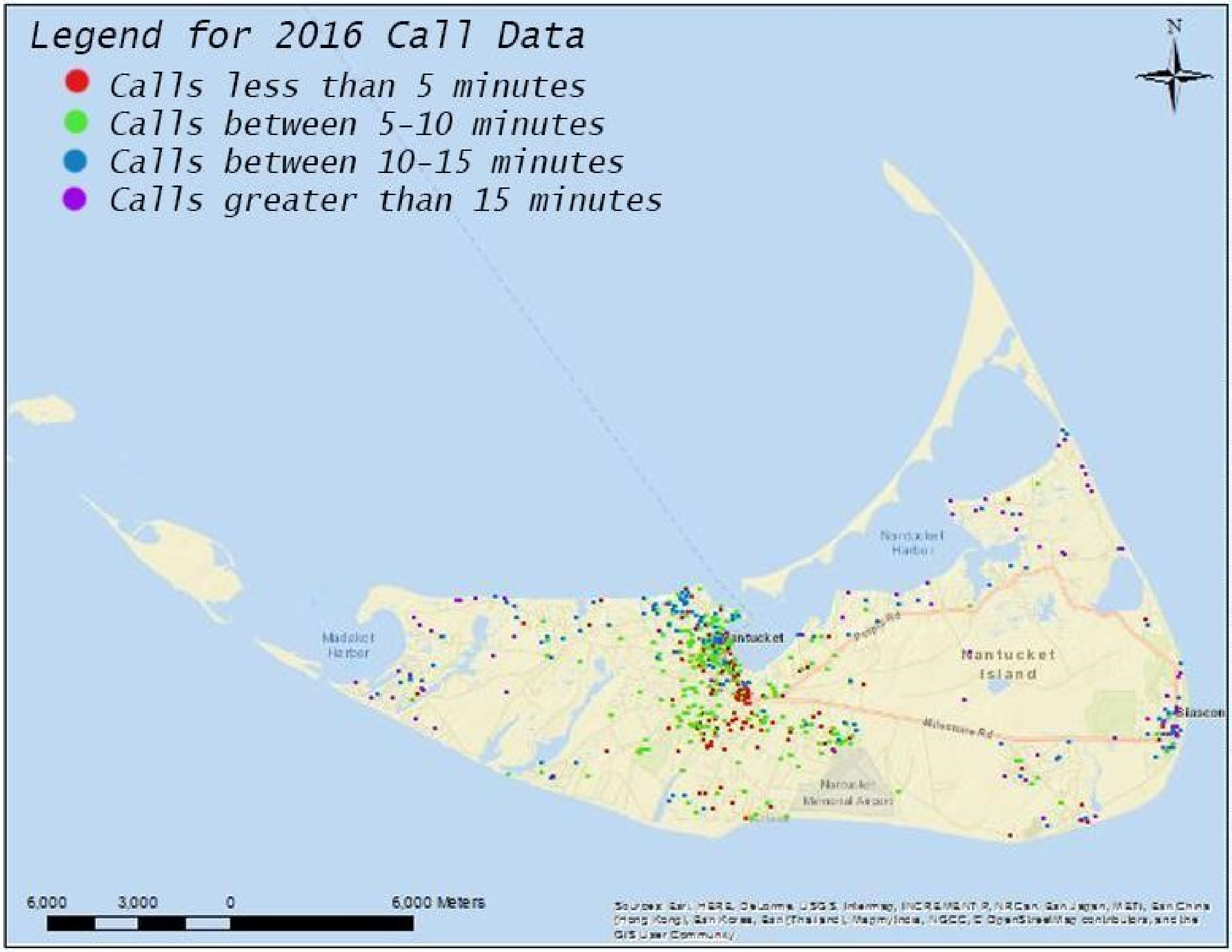

Figure 25: The distribution of different call times for 2016

3.1.2 Categorical Analysis and Typology

Once the team had the data plotted and separated for response time, location, and type, we then analyzed the data for trends in the different types of calls. To examine if there were trends for each incident type, we counted the occurrence of the incident types per each year, then compiled the results in charts to see trends in each one. Besides the analysis for each incident types through 2007-2015, a pie chart was made to show percentage distribution of nine different incident types. These charts were compiled in the Results chapter.

3.1.3 Historical Analysis

The team analyzed the gathered data by comparing what was found to the data from previous years. By analyzing the trends in the data over time, the team was able to notice irregularities such as the one shown in Figure 18 in the Results chapter where there was a significant drop in the average response time between 2013 and 2014. Other irregularities that we looked for included locations with numerous recurring calls.

In addition to average response time, we also calculated the average total call times for historical analysis. This was used to estimate the time that a crew would be out of the station once the call was deployed. The third statistic that was analyzed was the number and call type. We used the number of calls per year as the basis for many of the percentage calculations. In addition, the team compared the historical data to the historical records of quantity of fire and EMS personnel as well as the quantity of vehicles and equipment. A full analysis of the results obtained by these methods is provided in the Results section of this document.

3.2 Identify and Interview the Different Stakeholders

The team organized the stakeholders into three preliminary groups: Nantucket Fire Department, Nantucket town residents and property owners, and Nantucket town officials. Each group of stakeholders has different outlooks on the fire department and their response time.

3.2.1 Nantucket Fire Department

The first group of stakeholders was the group that was the most impacted by this project, the Nantucket Fire Department. Personnel interviewed included the fire chief, Paul Rhude, the supervisors upstairs, the deputy, and on duty fire and EMS personnel. The fire department personnel was affected the most on a personal level and the team was looking to them for information and opinions on whether partnering with other agencies, increasing staffing, adding more housing, or adding more stations would work best for Nantucket. What we hoped to learn was:

- Department staff perspective on response time limitations
- Department staff opinions on improving the response time
- Affordable housing ideas
- Willingness for satellite deployment

3.2.2 Town Residents and Property owners

The second group focused on the town residents and the Nantucket property owners. First, the team addressed the property owner’s interest in reducing the response time. This group was recorded as either property owners or renters. The team also recorded whether they were employed full time, part time, unemployed, or retired. Business owners were interviewed as property owners, but their ownership of a business was noted as a consideration. What we hoped to learn was:

- Residents’ opinions about the fire station and response time
- Residents’ knowledge of ISO ratings influence on property insurance costs
- Potential for housing firefighters in private residences

3.2.3 Town Officials

The final group of stakeholders that interviewed was the town officials. The town officials create the laws, regulations, and budget, therefore the team hoped to record their perspective and any information they had to offer. In addition to the town officials, the team interviewed the chief of police, as they may have experienced similar response time issues. Officials interviewed include the town manager, the chief of police, and members of the board of selectmen. What we hoped to learn was:

- Town officials' opinions on the fire station and the response time
- Town officials' opinions on the budget for the fire department
- Affordable housing ideas

3.3 Study and assess potential options to reduce the response time of Nantucket Fire Department

The four potential solution topics derived by the sponsor and the team to reduce response time were providing increasing firefighter and EMS personnel staffing, housing to department members, developing staffed satellite fire and emergency response stations, and partnering with other agencies to enhance mutual aid. For each potential solution, the barriers and ways to overcome these barriers were addressed. In our study, we attempted to find the best combination of ideas.

3.3.1 Increased Staff

The team discussed the staffing budget with the chief to get a better idea. We also looked into the national standards and what other relatable fire stations have for staff. We determined that the procedures and goals that the Chief set forth in his presentation in 2015 was sufficient to get to the national and state standards in the next few years (Rhude, 2015).

3.3.2 Housing

Because the fire department is examining an increase in personnel in next few years, NFD hopes to provide housing for new firefighters and paramedic personnel. In order to identify the potential for housing new fire department personnel, we visited several locations:

- Sheriff's Office
- Madaket Station
- Siasconset Station

The team explored the inside of these locations two times by ourselves as well as with the group working on "The Municipal Housing Crisis" to assess how much space the locations have for repurposing and renovating. The team took many pictures and measurements of the inside and outside at these locations for reference. In order to determine if these locations were suitable for housing, we had joint-meetings with the municipal housing group to assess and analyze the notes that were taken from the joint exploratory assessment expedition. The contents below are what were discussed during the meeting.

- Crucial people that need to be interviewed
- Valuable information between teams
- Renovation potential for the locations

3.3.3 Satellite Stations and Dynamic Deployment

To assess the viability of adding satellite stations the team looked into expanding the Siasconset station. This seemed like the most realistic and important place to expand. With expanding this station, the department could put some 24/7 living in the station, which would reduce the response time to the eastern side of the island.

The chief also suggested the team do something to improve the downtown response time. To do this we looked into smaller dynamic deployment vehicles to put in the downtown area. The team then discussed the findings with the Chief, who helped decide which vehicle would work the best for Nantucket.

3.3.3 Partnering with Other Agencies

The team discussed how to improve response time by partnering with other agencies with Chief Rhude. Companies worked with include the Nantucket Land Bank, the airport crash team, and the Nantucket Public Works. Our team toured facilities and discussed the operations with the employees.

3.3.4 Simulation

To assess the potential options above, the team developed a simulation script using Python[9]. We implemented Google Map API to estimate the future travel time of fire trucks and ambulances from a potential fire station, like the Siasconset Fire Station, to all emergency sites. The script has six parameters:

- Origin latitude
- Origin longitude
- Destination latitude
- Destination longitude
- Season: summer or winter
- Time of the day: morning, noon or evening

To make the script run for multitask, we created an Excel spreadsheet with all the emergency locations from the call data. Duplicate locations were deleted and then a command line was created by using various formulas.

Below is an example of the command line that is generated by Excel:

```
python simulation_winter.py 41.2847963 -70.0990968 41.272057 -70.094224 -s -m &&
python simulation_winter.py 41.2847963 -70.0990968 41.279843 -70.094412 -s -e
```

[9] A programming language

(-s stands for summer, -e stands for evening and -m stands for morning)

After generating all the command lines, the team copied all the command lines to Terminal[10] to run the simulation script. The script will generate a Text file which will include the latitude and longitude of each destination with the travel times. To show the simulation time clearly, we converted the Text file to Excel and broke it down by time. Lastly, all the destination locations were into GIS to generate a map.

3.4 Perform cost analysis on various solutions to improve response time

The cost is a large part of why NFD has such a difficult time improving their response time. In order to determine the best combination of options for Nantucket, the team looked into the long and short term costs of different ideas to improve the department. In addition to the monetary cost, it was important to note the cost of inaction. For the fire component, the difference of only a couple of minutes could be the difference between a small house fire and a house completely ablaze. For medical emergencies, a few minutes of delay could mean permanent damage or even death.

3.5 Provide detailed recommendations

The final objective of this project was to provide recommendations to Chief Rhude on how to lower their response time. From the cost analysis of potential solutions, the team created recommendations to direct the fire department towards meeting the national standards in the quickest and cheapest way. These recommendations were intended to be implemented within five to fifteen years and should help the fire department transition into a new phase of medical care and fire protection.

4 Data Analysis and Quality Control

This section is comprised of components of both methods and results. The order we discuss the material is:

1. Incident type organization
2. Data cleanup

4.1 Incident Type Organization

Over the years, fire stations have evolved, taking on more and more emergency call types. Fire departments handle much more than just fires, and to keep track of their responsibilities, National

[10] An application in Mac which can run command line

organizations have created a complex code system (Appendix C). Any call that is accepted is designated 100 through 900 depending on the nature of the call which can be seen below in Table 4.

100	Fire
200	Explosion, Overheat (No Fire)
300	EMS
400	Hazardous Condition(No Fire)
500	Service Call
600	Good Intent Call
700	False Alarm/False Call
800	Severe Weather/Natural Disaster
900	Special Incident Type

Table 13: The different codes broken down by 100s.

After the codes are designated (in the hundreds), they are then broken up further into more specific subcategories which can be seen below in Table 5. For example, a 700 type call, which is false alarms or false calls, is then further broken down into 730-740 (system detector malfunction), which is then further broken down in specific system types like a fire alarm or a carbon monoxide alarm.

System or detector malfunction. Includes improper performance of fire alarm system that is not a result of a proper system response to environmental stimuli such as smoke or high heat conditions.

731	Sprinkler activated due to the failure or malfunction of the sprinkler system. Includes any failure of sprinkler equipment that leads to sprinkler activation with no fire present. Excludes unintentional operation caused by damage to the sprinkler system (740 series).
732	Extinguishing system activation due to malfunction.
733	Smoke detector activation due to malfunction.
734	Heat detector activation due to malfunction.
735	Alarm system activation due to malfunction.
736	Carbon monoxide detector activation due to malfunction.
730	System or detector malfunction, other.

Table 14: The different codes in the 700s category.

When the team first arrived on Nantucket, the first priority was to get a better understanding of how these codes work. There are many different call types, and getting the small details mixed up is easy. For example, the difference between System Malfunction calls (730-740) and Unintentional System Operation calls (740-750) is small. The first deals with alarms going off randomly without any stimulus and the second deals with alarms being tripped accidentally by the wrong stimulus. To avoid getting codes like this mixed up, the team compiled a comprehensive list of the codes in Excel, containing not only the textbook definition, but a description of what that type of alarm actually means. This table was a big help in keeping the codes straight in our heads and will remain to assist the NFD and future analysts, and can be found in Appendix H.

4.2 Data Cleanup

After understanding how the incident codes operate, we needed to go through and clean the call logs. Since the system for recording the times of the calls isn't automated, this means that it is operated by humans, and humans make mistakes. Whether it be ending the call late, or starting the call too early, there are always errors and outliers in the data which then throws off the average and median values of the response time.

There are a few call types that are inherently flawed, so the team counted them as outliers. To start off with, 900 and 911 calls are designated as special type incidents and citizens' complaints respectively. These data were removed from response time analysis since the NFD isn't responding to an emergency, and it isn't time sensitive. The second type deleted from the call logs was any 611 type calls which are calls cancelled in route. We felt that since the call wasn't complete, it shouldn't be counted. The last call type deleted was type 462 which is aircraft standby. According to the Chief, aircraft standby is when the NFD has to send a truck to watch over an aircraft landing just in case something goes wrong. In his opinion, it isn't worth it to count this call type since they are often times very lengthy and it is just a truck sitting and watching an aircraft land (Rhude 2016).

Besides deleting these specific call types, we also removed any call that was above a half an hour since they were skewing the data. We talked to the Chief and some other on call firefighters and they all agreed that for the most part, any call over 30 mins is most likely a mistake. There are always exceptions to the rule, but we decided to get rid of those calls, including them would skew the results more than deleting them. Any calls recorded with a response time of 0 were also removed as they are very unlikely to have been correctly recorded by dispatch (Rhude, 2016).

By deleting the "bad" call data, the number of calls decreased by roughly 500 (Figure 15). It is important to note that the data and statistics used are based off of this decreased total number of calls. Even though the total number of calls decreased, the quality of the data is improved.

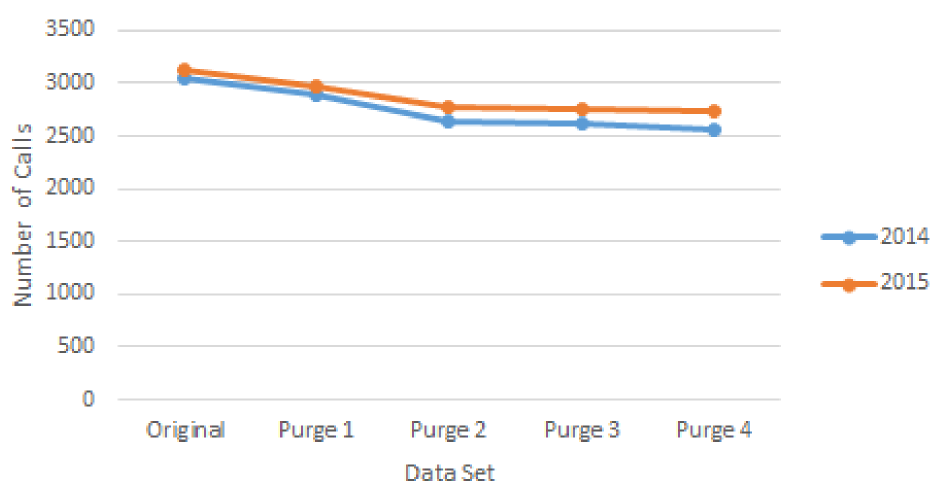

Figure 26: Decrease in calls during cleaning process

To display how the quality of the response time data improved, in Figure 16, the standard deviation of the response time is depicted. From this figure, it can be seen that the standard deviation value decreases and stabilizes for both the 2014 and 2015 data as the data cleaning increases. A lower standard deviation means that the data is more accurate about the median, so our data cleanup had a positive effect.

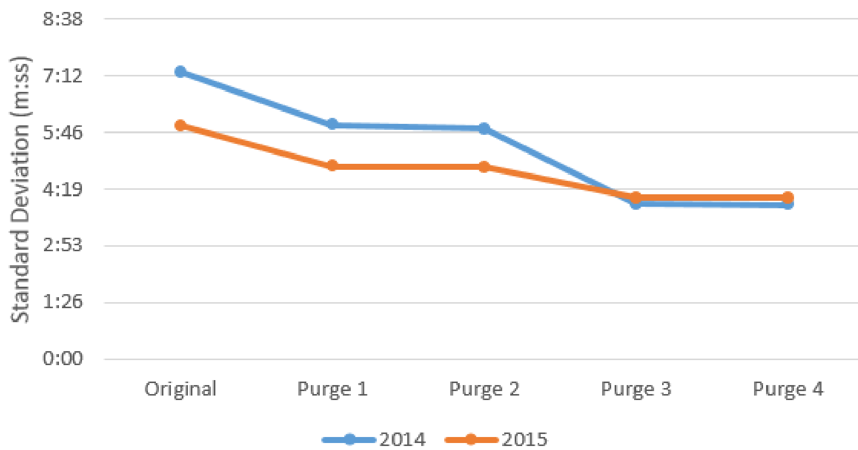

Figure 27: 2014/2015 Standard Deviation of Response Time through Data Cleaning Process.

To summarize the cleaned data, we created a chart comparing the cleaned data for 2014 and 2015 (Table 6). These statistics give our best estimate for the true condition of the data. From the chart, we can see that the department is not meeting the national standard of 90% of all calls per year responded in less than 5 minutes. The department is currently responding to 86% of all calls within 10 minutes.

		Response Time				Calls by Response Time			
Year	Total Calls	Average	Median	Deviation		<5	5-10	10-15	>15
2014	2563	7:08	6:20	3:56	Quantity	1175	1021	286	81
					Percent	45.8%	39.8%	11.2%	3.2%
2015	2734	7:12	6:21	4:06	Quantity	1229	1121	274	110
					Percent	45.0%	41.0%	10.0%	4.0%

Table 15: Summary of Cleaned Data for 2014 and 2015

5 Results

The team uncovered important data and information about the state of the department and how to proceed in the future. In this section, the results of the following are presented:

1. Response time analysis
    i. Categorical analysis
    ii. Historical response time analysis
    iii. Change in policies
    iv. Staffing analysis
    v. Resource analysis
2. Dynamic deployment investigation

3. Siasconset renovation investigation
    i. Proposals for Siasconset renovation
4. Insurance investigation
5. Simulation
    i. Results of simulation
6. Cost analysis

5.1 Response Time Analysis

In this section, we describe the results we got in each of the following analyses:

1. Response time analysis
    i. Categorical analysis
    ii. Historical response time analysis
    iii. Change in policies
    iv. Staffing analysis
    v. Resource analysis

The volume of calls has risen markedly since 2012 (Figure 17). The team chose not to include the number of calls for 2016 in this graph due to having only from January 1, 2016 through June 30, 2016. Extrapolating from the number of calls recorded between Jan. 1 & June 30, 2016, the implied number of calls for the entire year 2016 would be 2,690, however due to the data not following the trend, the team will exclude it from the estimate.

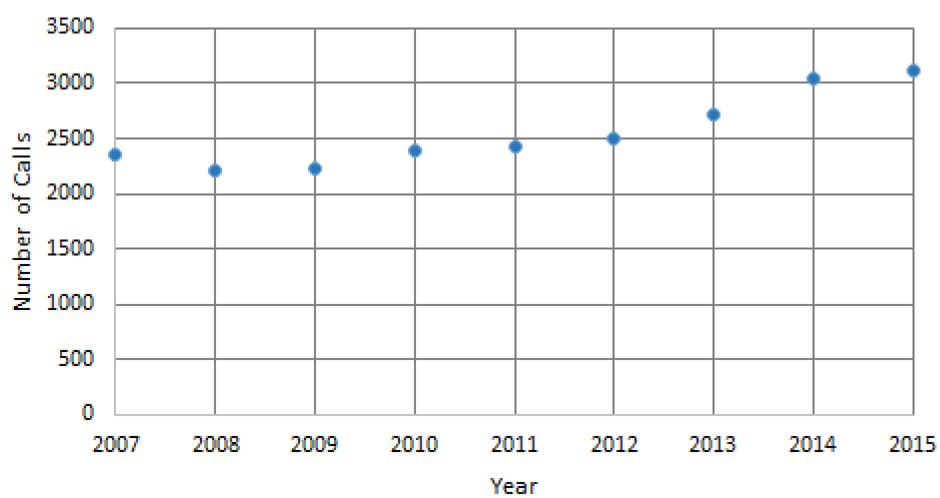

Figure 28: History of Call Volume

5.1.1 Results of Categorical Analysis

Series	Heading
100	Fire
200	Overpressure Rupture, Explosion, Overheat (No Ensuing Fire)
300	Rescue and Emergency Medical Service (EMS) Incidents
400	Hazardous Condition (No Fire)
500	Service Call
600	Good Intent Call
700	False Alarm and False Call
800	Severe Weather and Natural Disaster
900	Special Incident Type

Table 16: Incident Types

In the Table 7, we listed the general series for incident types. For more specific incident types, like fires including fires due to gas vapor explosions (with extremely rapid combustion) (111) or Rescue and Emergency Medical Service Incident (321), in Appendix C, the team created a table that includes all incident types with definitions and how many personnel and vehicles are required for that specific incident type. All the incident types in Appendix C are emergencies, except for the citizens' complaints (900). In figure 18 below, we can see the call volumes of each incident type. In 2015, there was a total of 3123 calls. The figure 18 shows that sum of the medical calls and false alarms calls are 2,535, which takes over 80% calls of the whole year.

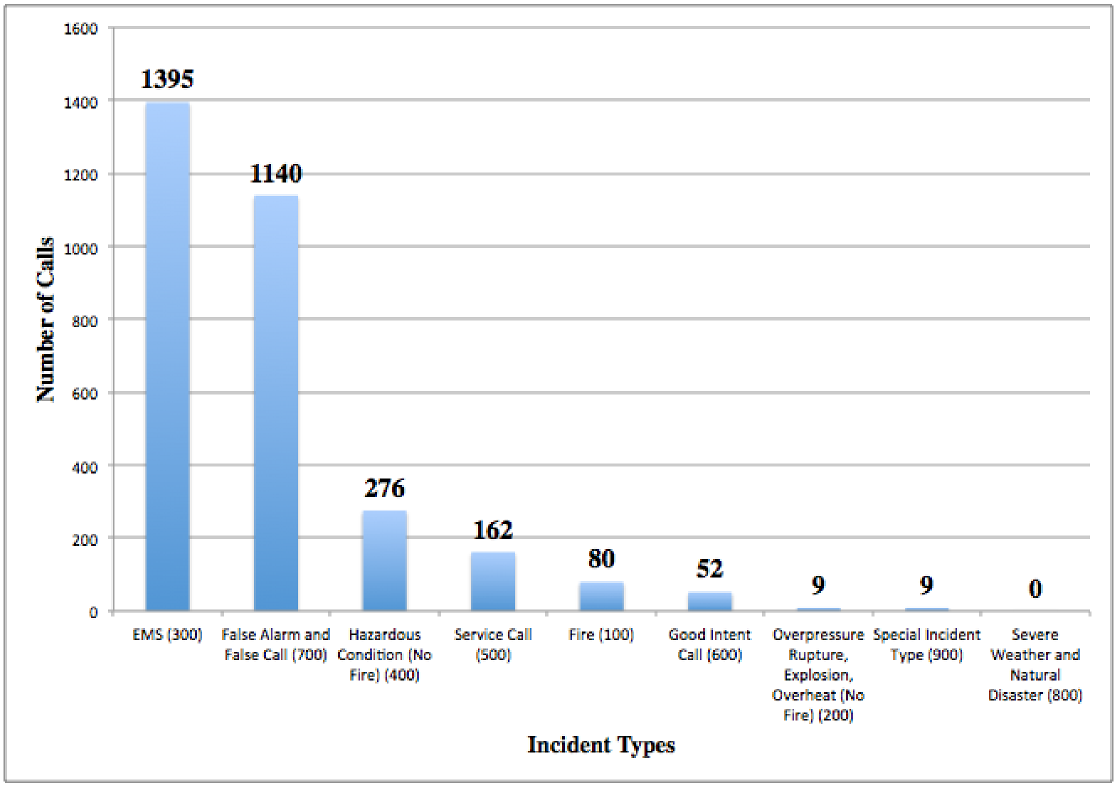

Figure 29: Incident Types 2015

The chart below (Figure 19) shows a comparison of all call types between 2007 and 2015. This shows that not only is there an increase in total calls, but there is also an increase in EMS calls and false alarm calls.

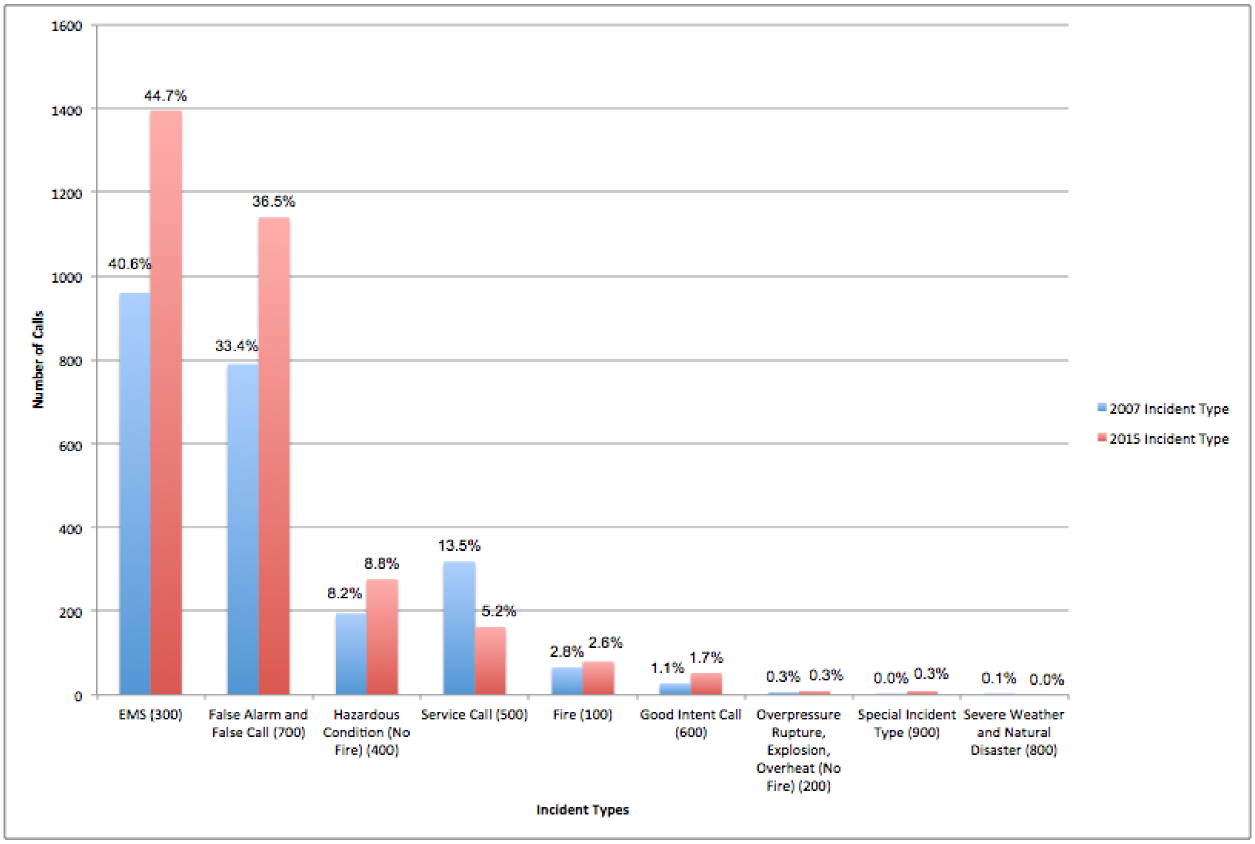

Figure 30: Incident Types in 2007 versus 2015

Next, we examined the trend over time in each incident type, shown in the figures below. Figures # show that the number of medical calls (300) and false alarm calls (700) have risen steadily since 2007. This upward trend in 300- and 700-type calls is largely responsible for the overall rise in all emergency calls since 2007. Figure 20 indicates these two incident types have increased about 400 calls within nine years. Incident types other than these two incident types are a small part of all emergency calls, which has less relevant to the response. As far as calls being prioritized to improve overall response times, these two incident types should have precedence over the other types of calls because they are responsible for taking up the most amount of time.

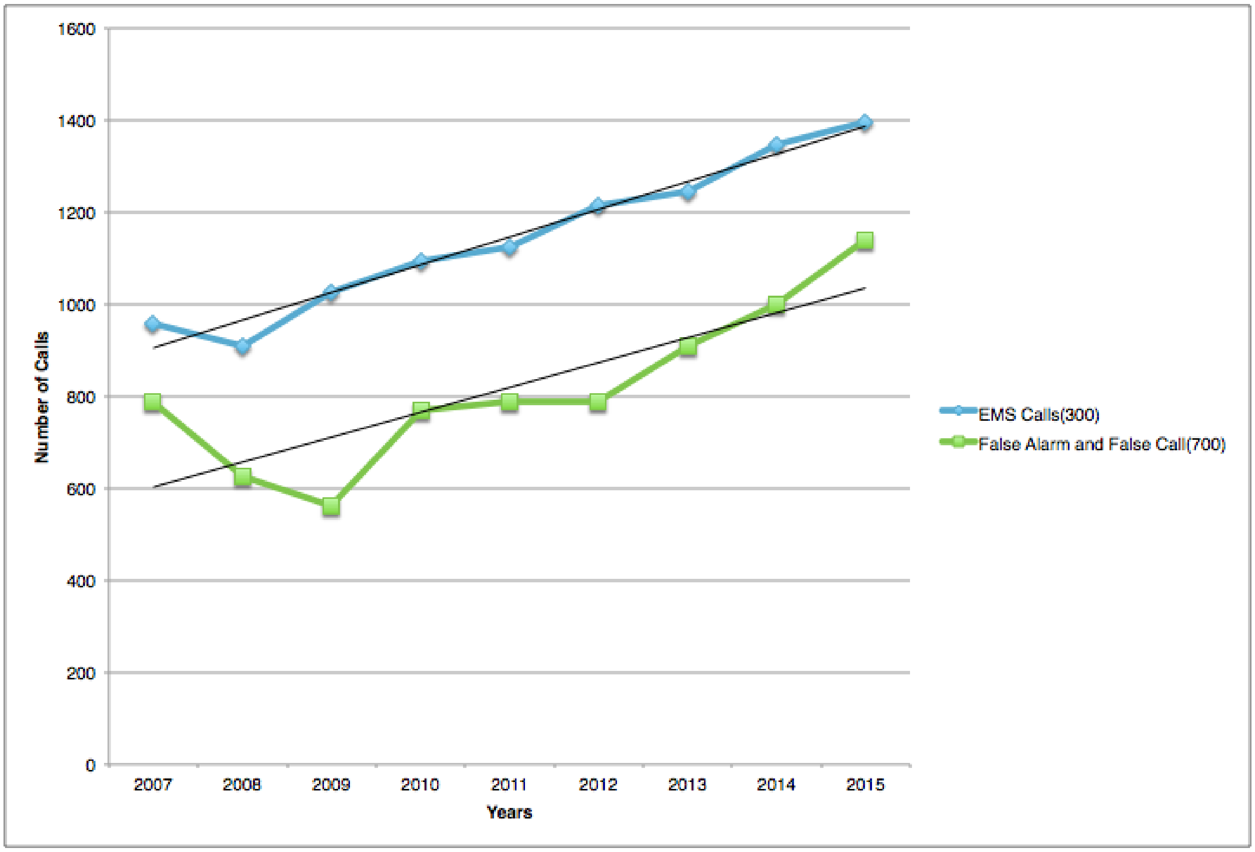

Figure 31: Trends Analysis for EMS Calls and False Calls 2007 - 2015

5.1.2 Historical Response Time Analysis

The dispatch was relocated from the Fire Station to the central dispatch facility at the new police station near the end of 2013 (Figure 21). According to one of the call supervisors, who has worked at the station since before the change was implemented; the response time is now recorded as initiating at dispatch time instead of initiating at the alarm/call time. This procedural change eliminates the elapsed seconds of time between alarm/call and dispatch, so the response time should be better.

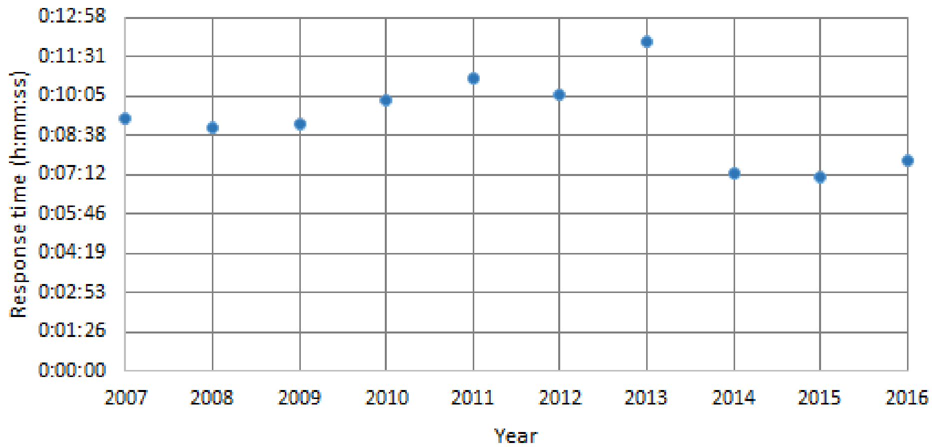

Figure 32: History of Average Response Time

Figure 22 shows that the average total response time of the raw data stays fairly consistent from 2007-2011, increases in 2012, and then stays much lower from 2014-2016. To avoid the data discontinuities, for the time sensitive analysis we focused on 2014-present while including all years in the categorical analysis. These irregularities with the fire chief, it is his belief that the various policy changes enacted on January 1, 2016 are responsible for the increased numbers. The policy change that has had the biggest impact is the way automatic alarms are responded too. If the call is an automatic alarm, the truck will go with traffic instead of using lights or a siren. This is because most of the time, automatic alarms are false alarms and the Fire Department doesn't want to put others in danger by using lights and sirens when it isn't an emergency.

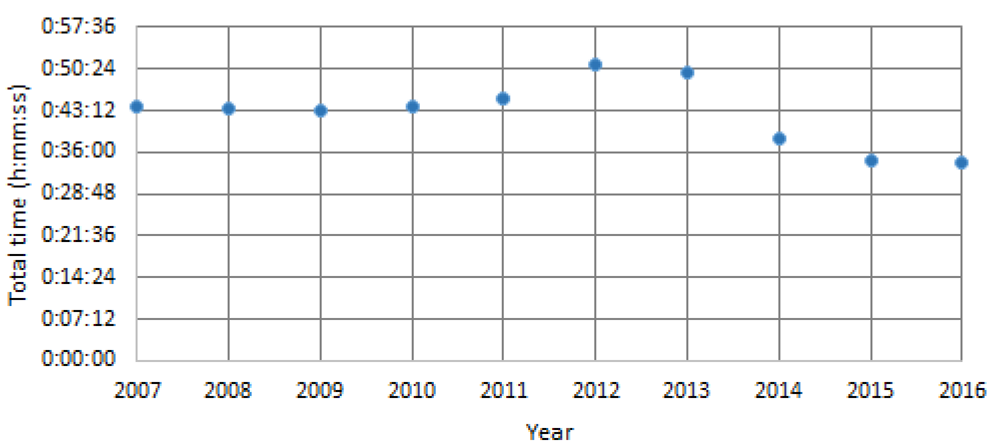

Figure 33: History of Average Total Time

To examine the current 2016 data, we compared the first half of the year, January 1st through the June 30th, to the same time span in 2015 in Table 8. This data shows a moderate increase in response time. This was hypothesized to be a result of the policy changes enacted on January 1st, 2016. These policy changes will be listed in section 5.1.3.

First Half of Year		
	2015	2016
Average Response Time	7:22	7:42
Average Total Time	34:04	34:14
Num Incidents	1423	1226

Table 17: Comparing Statistics for the first half of 2015 to 2016

To examine our hypothesis, we compared the response times per each category. The distribution of call types was consistent with the analysis summarized previously in the 5.1.1 with EMS and false alarm and false calls making up the majority of the emergency calls. As such, these two categories have the largest influence on response time. From the comparison, it can be seen that the two categories offset each other (Figure 23). From this, we conclude that the incomplete data for the year must be the culprit for the large increase in response time.

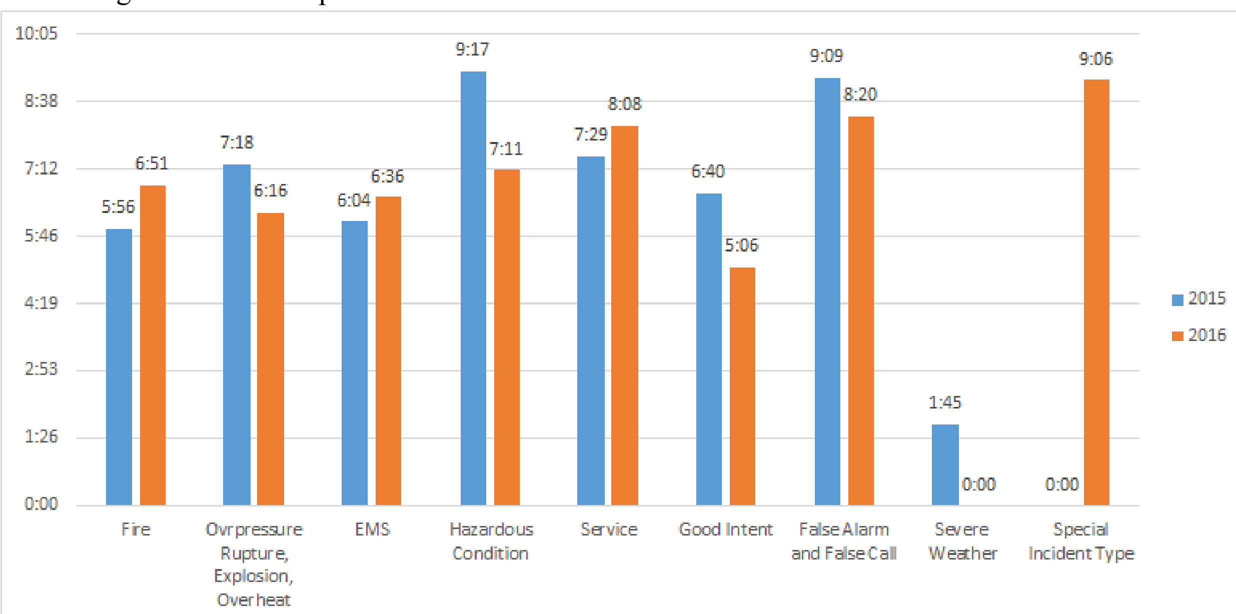

Figure 34: Comparing Response Times of first half of 2015 vs 2016

5.1.3 Change in Policies

At the beginning of 2016, new policies for the fire department were enacted to increase the safety while traveling. The largest change is that automatic alarms are not responded to with lights and sirens. This is an experiment with the department due to almost all calls being reclassified as false alarms upon arrival. The goal of this procedural change is to avoid unnecessary accidents and injuries for civilians while in transit to the scene of the call.

Additionally, on call members are now alerted and asked to report to the station when the on duty emergency staff is out of the building. This is to avoid the problem of backfilling during concurrent calls, where on call staff is only requested for assistance after an additional emergency call is reported. The traditional backfilling method typically results in long response times. This policy change helps the most during the calls with longer total time, and as 2016 has had a much higher total time, it appears to be a lucky coincidence.

The third policy change was to attempt to treat all medical emergencies on the scene. This allows for serious injuries to be treated and the ambulance to only be used for transporting the patient to the hospital.

5.1.4 NFD Staffing: 2016 & Beyond

The team has interviewed the Fire Chief, Paul Rhude, about staffing. He said the NFD is going to hire new firefighters and paramedic personnel in next few years, which is about four paramedic personnel next year and four more firefighters in the following year. In July of 2017, the union will be renegotiating contracts, including the creation of a paramedic level job for the NFD. He also said that the NFD is seeking 16 seasonal personnel for the summer, most of them college age firefighters and EMT personnel, because that age group already lives on island, which means the NFD would not have to worry about supplying additional housing for them. Through interviews with the chief and our assessment of the current situation, it was determined that in order to increase the staff, the housing situation must be remedied first.

5.1.5 Resources Analysis

Both the Madaket and Siasconset Stations were once fully staffed fire stations. Today, both are used as storage locations and remain unstaffed with no living quarters. The Madaket Fire House (Figure 24) is a fire station built in 1981. This station is currently a shed able to house one fire engine inside. The plot of land that it is on is quite small so it does not have much space to be extended.

Figure 35: Madaket Fire Station

The Siasconset Station (Figure 25) is two and a half times larger than the Madaket Station and has two garage bays, capable of storing two vehicles and a decent amount of fire gear. We inspected the station and there is potential to extend the station further so it makes better use of all of the property. The fire department is considering renovating the station to allow for 24/7 staffing and to be used to handle the approximately 60 nearby calls per month during the summer.

Figure 36: Siasconset Fire Station

The Sheriff's Office was the original fire station in the downtown area. Since then, it has been repurposed as the police station and fitted with cells and offices. Most of the garage bay was repurposed as an office; the upstairs offices remain unused. On the second floor, there are approximately 6-8 rooms, the largest of which houses costumes for the Dreamland Theatre across the street. The second floor of the Sheriff's Office might potentially be renovated as dormitory-style housing for fire department personnel or other municipal employees. While the town did have plans to repurpose this old office, currently the plans have been put on hold due to budget restrictions. Hopefully, given the chance, the town will find funds. The building lies in the flood zone.

We studied the final 2015 blueprints for the new fire station, to be built on 4 Fairground Rd, as an extension onto the Police Department. The new fire station will provide eight rooms, each with two beds for on-duty fire and emergency personnel. The garage bays are much larger than the current station; however most bays will be completely full at the time of move in. It will be able to house all four ambulances, six engines and two ladder trucks as well as multiple brush breakers and potentially the military surplus Humvee.

5.2 Dynamic Deployment

From our geographic analysis using GIS software, we found that the majority of calls that occur in the downtown area are located within the historic district of Nantucket. By adding dynamic deployment on the northwestern side of the downtown area, approximately 1500 calls could be responded to. Since, a large number of calls in this area are medical, 45% in 2015; the focus for a dynamic deployment system should be on the medical calls. From our interviews with Chief Rhude, it was determined that the Massachusetts government is changing the standards for medical calls (Rhude, 2016). Now instead of immediately rushing patients into an ambulance, the standard is to try and provide as much medical care as possible on the scene. To facilitate this, the potential use of a smaller vehicle with room for three medical personnel and equipment was discussed.

5.3 Siasconset Renovation

In this section, the team came up with a proposal for Siasconset as can be seen below in this order:

1. Siasconset renovation investigation
    i. Proposals for Siasconset renovation
        i. Restricted
        ii. Unrestricted
        iii. Cost

The team looked into the idea of expanding the Siasconset station. This idea would include an addition to the back and inside of the station. Currently the station has room for two fire trucks, but no space for living. None of the fire fighters currently live on that side of the island, so adding some 24 hour living quarters would substantially help not only the department, but also the citizens in Siasconset.

5.3.1 Proposals for Siasconset Renovation

In the investigation into Siasconset, it was determined that there was potential for renovation. To establish the potential, the team recorded the zoning laws and created potential floor plans in AutoCad. Currently, restrictions include:

- 5 feet of setback on the sides and rear of the property
- Only 50% can be built on

Chief Rhude believed that demolishing the entire building would not be likely to happen, because it is a historic building. In an effort to make the building more aesthetically pleasing, the Chief also suggested to make the building something other than a square. The team's top suggestion is seen below in Figures 26, 27, and 28.

Figure 37: Top view of addition

This total addition of 1,743 square feet is only for one floor. Since we are thinking of adding two floors, the total area would be 3,486 square feet. This is a large amount of space that is currently not being used, so adding this addition would be very beneficial and noninvasive.

Figure 38: Floor Plan for Potential Renovation

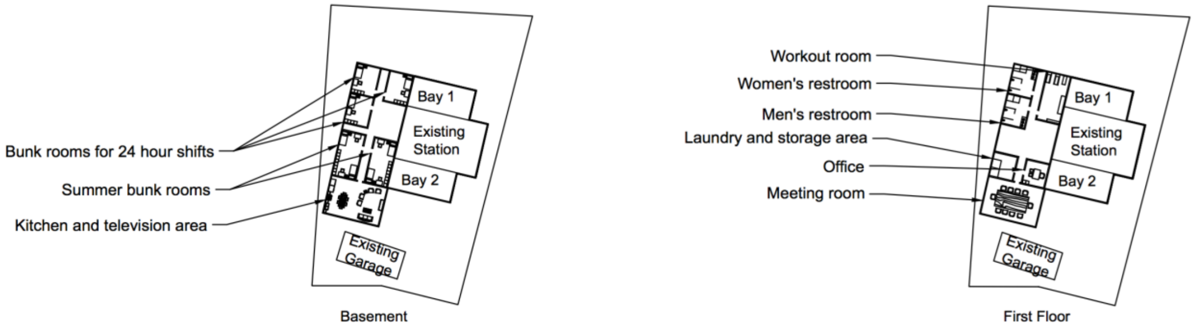

Figure 39: Floor plan of addition with labeled rooms

The team came up with other designs, but they aren't as realistic or as beneficial as the option above.

Restricted

Our potential floorplans meeting the current restrictions are illustrated in Figures 29-31.

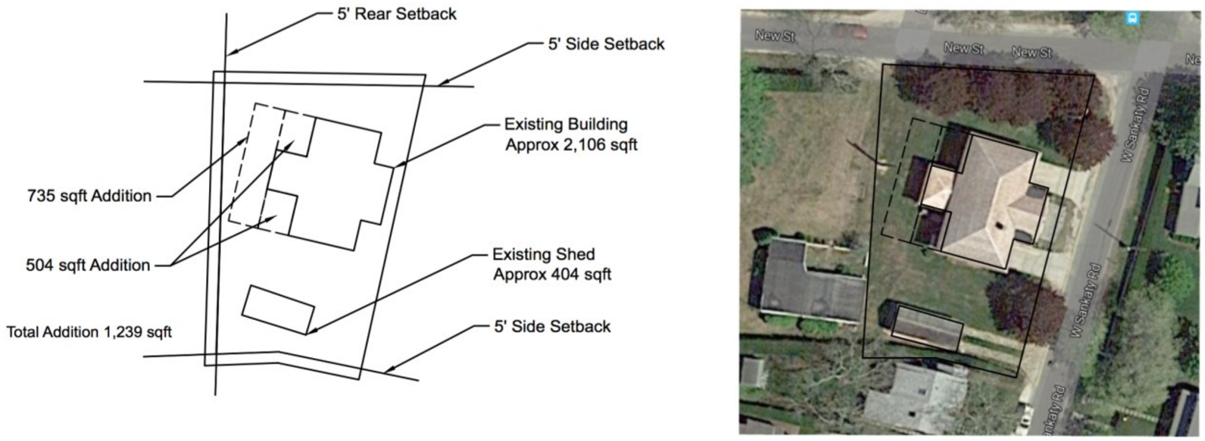

Figure 40: Top view of additions to cover 35% of the land.

Figure 41: Top view of additions to cover 50% of the land

Figure 42: Top view of a building with 50% of the land covered.

Unrestricted

Since this building would be for emergency personnel, there is a possibility that the NFD could get an exception to the zoning laws to expand to more than 50% of the land. If this is a possibility, then Figure 32 shows one idea that covers 75% of the land.

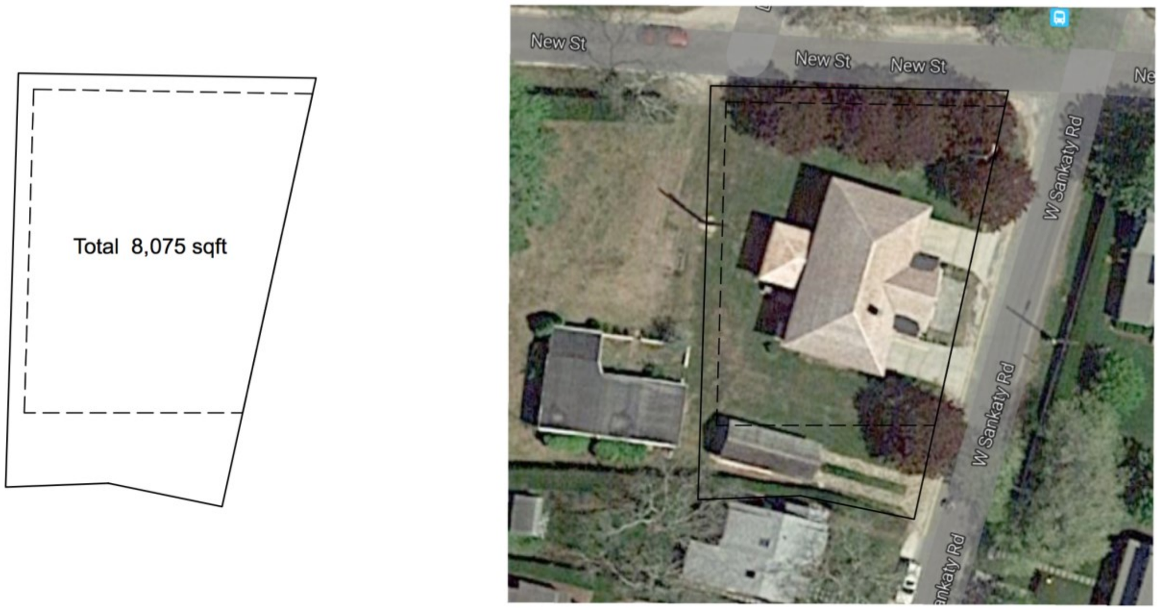

Figure 43: Top view of a building with 75% of the land covered.

To further the investigation, we estimated the renovation costs of the Siasconset station and broke it down into simpler terms. These numbers are purely hypothetical and hope to give a potential insight into the costs as shown in Table 9. As shown, with the estimated cost of $1,743,000 based off of the usual construction costs of $500 per square foot on Nantucket with the square footage from Figure #, the estimated cost per person is only $174.30 if the renovation cost is spread among the approximately 10,000 full time residents of Nantucket. If the costs were to be financed over 30 years, as many buildings are, the cost for each resident would only be $5.81 per year.

Cost of Siasconset	1 Year	over 30 years
$1,743,000	$174.30	$5.81

Table 18: Hypothetical costs of renovations separated to cost for different time spans

5.4 Potential Insurance Changes

In figure 33, everything on the inside of the 5 mile radius, is “safe” according to insurance companies, where anything on the outside is not. Insurance companies rate everything with an ISO rating, which relies on where the building is in comparison to a staffed fire station. Currently the insurance rates for Siasconset are a higher than the ones downtown.

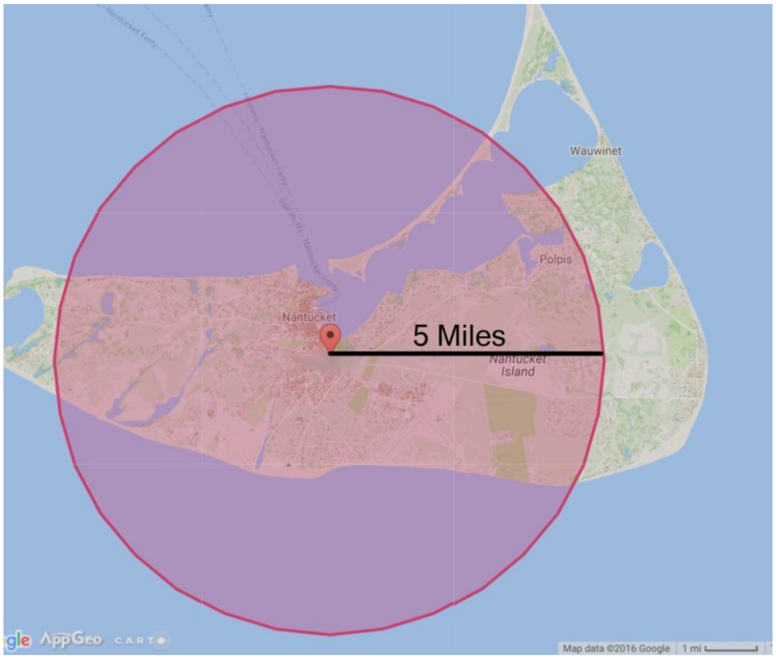

Figure 44: 5 mile radius around the current station

From an insurance company on the island, the rate of property insurance premium is 0.23% for ISO 4 and 0.314% for ISO 9. If the Siasconset station was able to be staffed with a couple of firefighter, the ISO rating would be better and the response time would also improve. Currently there are 13,929 buildings within a 5 mile radius. Figure 34 shows the amount of coverage the fire department would have if they were able to staff the Siasconset station. If the Siasconset station is added, 2,328 buildings would be affected. These 2,328 building would have their ISO rating substantially lowered.

Figure 45: 5 mile radii around the fire stations if the Siasconset station was fully staffed

In the communications with the Nantucket insurance companies, the team discovered that the ISO 4 and ISO 9 rated properties have significantly different insurance rates. Property insurance premiums for ISO 4 is approximately 0.23% of property value and premiums for ISO 9 is approximately 0.314% of the property value. To show how this affects the premiums, we summarized the values in Table 10.

	Insurance Type		Savings	
Value Insured	ISO 4	ISO 9	per year	per day
$500,000	$1,150	$1,570	$420	$1.15
$1,000,000	$2,300	$3,140	$840	$2.30
$1,500,000	$3,450	$4,710	$1,260	$3.45
$2,000,000	$4,600	$6,280	$1,680	$4.60
$2,500,000	$5,750	$7,850	$2,100	$5.75
$3,000,000	$6,900	$9,420	$2,520	$6.90
$3,500,000	$8,050	$10,990	$2,940	$8.05
$4,000,000	$9,200	$12,560	$3,360	$9.21
$4,500,000	$10,350	$14,130	$3,780	$10.36
$5,000,000	$11,500	$15,700	$4,200	$11.51
$5,500,000	$12,650	$17,270	$4,620	$12.66
$6,000,000	$13,800	$18,840	$5,040	$13.81
$6,500,000	$14,950	$20,410	$5,460	$14.96
$7,000,000	$16,100	$21,980	$5,880	$16.11
$7,500,000	$17,250	$23,550	$6,300	$17.26
$8,000,000	$18,400	$25,120	$6,720	$18.41
$8,500,000	$19,550	$26,690	$7,140	$19.56
$9,000,000	$20,700	$28,260	$7,560	$20.71
$9,500,000	$21,850	$29,830	$7,980	$21.86
$10,000,000	$23,000	$31,400	$8,400	$23.01

Table 19: Difference from ISO 4 to ISO 9 as well as the savings between them.

Another way to view this is the trend line graph, Figure 35. In addition, we showed the potential savings of going from ISO 9 to ISO 4 in the table. For an average house value of $1.5 million, the potential savings is $3.45 per day, which a little bit more than a cup of coffee.

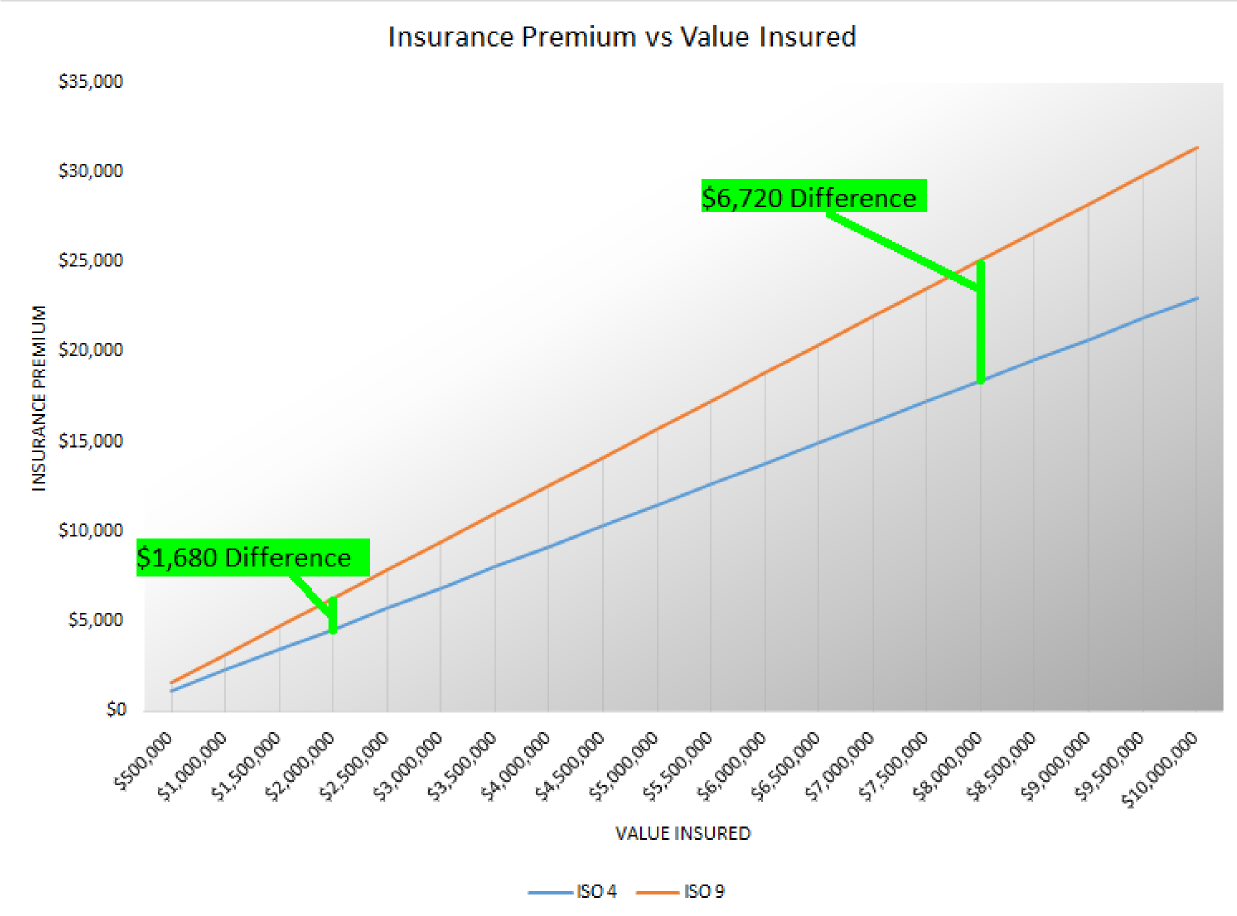

Figure 46: Trend lines for the ISO 4 and ISO 9 rates of insurance.

As shown, the potential savings of the average house being re-designated an ISO4 rating from an ISO9 rating is greater than the potential costs of renovating the Siasconset station.

5.5 Simulation

In this section, we look into the results of creating a simulation.

5.5.1 Response time simulation

The simulation script will estimate response time with assuming one of the solutions has been implemented. In the Figure 36, the team assumes all the three potential locations, new fire station, Siasconset Fire Station and Sheriff's office have been implemented. The data showing in Figure 36 generated by simulation script with the parameter as winter. From Figure 36 we can see that the response time can be lowered to around 5 mins in downtown area. For Siasconset area, compare Figure 36 and Figure 37, the green and blue dots have become red dots which is less than 5 minutes. After calculations and analysis, the team concluded that if the downtown deployment program was implemented and

Siasconset Fire Station was renovated and staffed, the average response time will be lowered to 6 mins and median response time will be lowered to 5 mins.

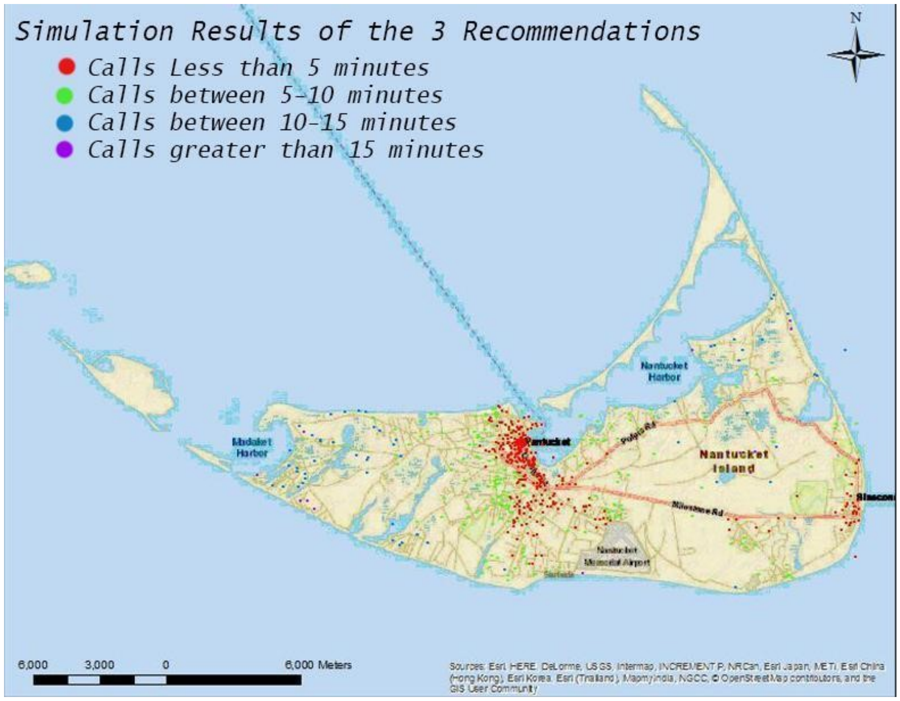

Figure 47: Simulation Results of the Three Recommendation Locations

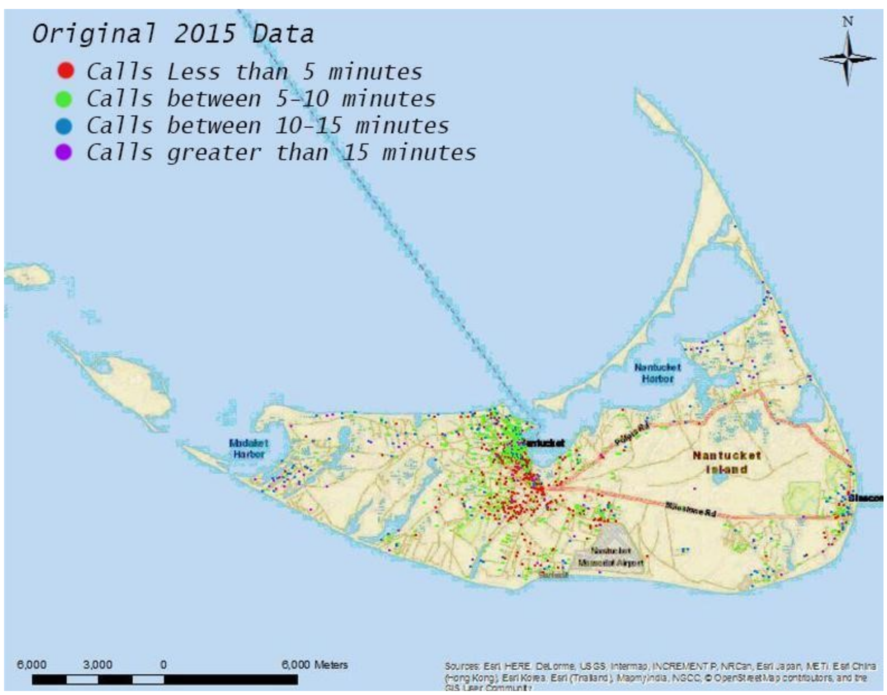

Figure 48: 2015 Call Data

This simulation system is only a basic script and has inaccuracy of the travel time of fire engines and ambulances because of these factors:

- Traffic: the fire engines could get stuck on the way to the emergency site due to the narrow roads and congested areas in the summer.
- Concurrent calls: sometimes the off duty personnel need to respond to the next call, which increases the response time.
- Weather: extreme weather could slow the speed of the fire engine or ambulance.

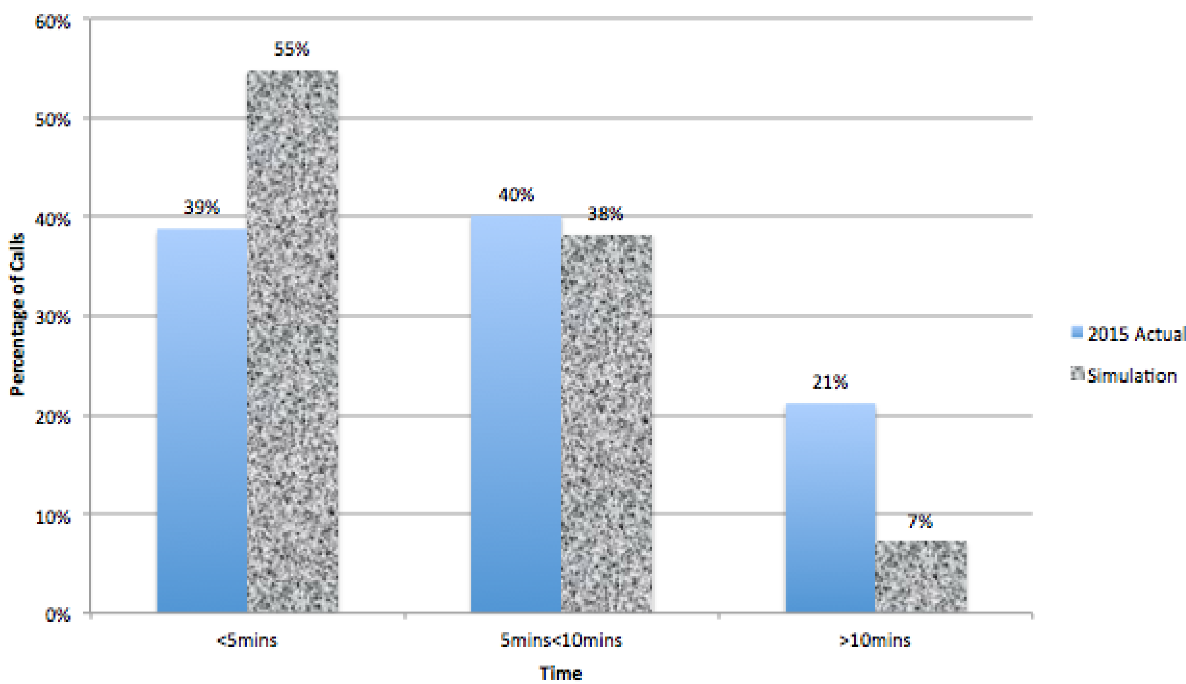

Figure 49: 2,723 Emergency Calls Divided by Time 2015 versus Simulation

From the figure 38 above, after the simulation, the response time of emergency calls improved from 39% to 55%. The response time over 10 mins, which is much longer than national standard, has been lowered by 7%. If the three locations had been implemented, the response time will get improved considerably.

6 Recommendations

The Nantucket Fire Department currently has a response time above the national standard due to under-staffing, facility centralization, and heavy seasonal traffic. These problems have multiple components that all connect to lead to an increased response time. Understaffing is the largest issue faced by the NFD (NFD Staffing Finding). The easiest way to remedy this would be to hire new people. However, there is nowhere to house new staff since the housing prices are so high on Nantucket.[11] Normally, staff would be located at other fire stations, but since the island does not have fully staffed satellite stations, this does not offer a solution. Solving just one of these challenges would be both expensive and difficult, so finding a solution that incorporates each would be the most effective way to improve the time and quality of emergency responses. The following writing outlines our team's recommendations to the NFD, with explanation of how they could improve the issue stated above.

Recommendation 1: Refine the dispatch information system to improve data quality and availability for analysis. The fire station records every call, even if the call does not have any bearing on response time. To analyze response time, it is necessary to clean the data of irrelevant points. A potential future project would be to help the NFD find a way to automatically clean calls. If the fire department were to have two sets of data, cleaned and uncleaned, they could send the full data to the state as required, but still have cleaned data for statistical analysis. Developing the data information system would require programming and design skills consistent with that of WPI students, and could likely be completed within the seven weeks period of an IQP. In this potential project, the team would need to complete the following tasks in order to complete the system:

- Compile a standard for clean data
- Split data into two sets, clean and unclean
- Develop a program that automatically cleans the data
- Share information with the fire department

Recommendation 2: Purchase and implement a dynamic deployment vehicle and deploy it as the Nantucket Fire Department's first-responder downtown. A dynamic deployment vehicle would need to include all necessary ALS gear and be small and stable enough to handle Nantucket's narrow cobblestone streets. The downtown area is prone to having many medical calls, especially during the summer (See Dynamic Deployment Finding). This is partially because of the cobblestone and rough sidewalks functioning as challenging walking surfaces for

[11] There is another IQP team working on affordable housing. To find out more in depth information on the Nantucket Housing Crisis, visit http://wp.wpi.edu/nantucket/projects/projects-2016/town-managers-office/

many visitors. One potential location for this vehicle for standby is in front of the sheriff's station because not only is it downtown, but it is also close to the Madaket side of the island. Having a vehicle that can access both the downtown area as well as parts of Madaket would be extremely valuable for decreasing response time. Multiple companies were contacted for comparable vehicles. Their estimates revealed that the cost of a dynamic deployment vehicle is extremely varied, ranging anywhere from $20,000-$300,000 based on vehicle type and the amount of customization required. One potential, less expensive solution is to provide one of the companies with a vehicle, such as an SUV, to be fitted with pre-fabricated equipment racks. This could be addressed by a future student project, and should be addressed as quickly as possible, as the simulation project shows a large potential improvement for response time and quality. To complete this recommendation, the fire department and future project teams should:

- Determine necessary specifications to implement in the dynamic deployment vehicle
- Contact multiple dynamic deployment vehicle customization companies for cost estimates including:
    - Odyssey Specialty Vehicles (http://www.odysseysv.com)
    - FastLane Emergency Vehicles (http://flev.com)
    - PL Custom Emergency Vehicles (http://www.plcustom.com)
- Designate funding within the budget for the vehicle or vehicles chosen
- Train fire department personnel to ALS levels to fully utilize the vehicle with 2-3 persons

Recommendation 3: Renovate and reopen the Siasconset fire station as a fully staffed station. This station is currently used as a garage to house older engines, and does not have any space for housing, offices, or bunk rooms. There are about 30 calls per month in the winter and about 60 calls per month in the summer in this area (NFD, 2016). An additional incentive for reopening the Siasconset fire station is the current ISO insurance ratings. If the Siasconset station was renovated and expanded, the insurance rates in the Siasconset area would decrease substantially as would the response times. We recommend that the data be shown to the town to support this statement, along with the simulation (Figure ES. 10). The potential savings in response time and potential to save lives could have a significant impact on Nantucket residents. In order to implement this change, the NFD would need town support and funding. To enact this recommendation in the next 5-10 years, the town and fire department should:

- Run a feasibility study
- Establish funding
- Build the addition
- Increase staffing

The recommended renovation is displayed in Figures ES.8 and ES.9.

Figure ES.50: Top view of addition

This total addition of 3,486 square feet over two floors would allow housing for seasonal employees as well as providing capabilities for 24/7 staffing. There are two bunk rooms for seasonal employees, which would provide housing for four additional summer staff. The town owns the building, so they would not need to buy new property. It is important to note that this design would retain the historical components of the building.

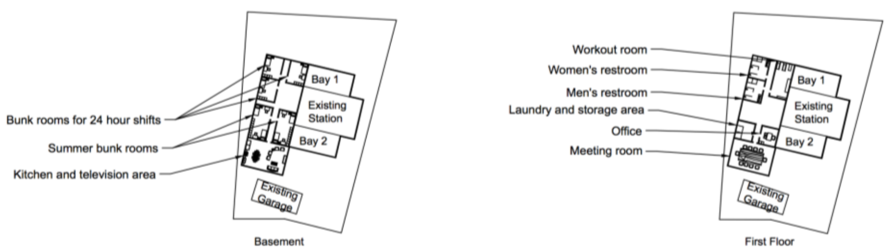

Figure ES.51: Floor plan of addition with labeled rooms

Our team found, through contacting multiple local insurance companies, that insurance rates are based on where a building is in comparison to a fire station. The least expensive insurance rates are on buildings located within a 5-mile radius of a staffed fire station. This radius has a dramatic effect on a building's ISO[12] rating, causing an immense effect on annual insurance premiums. The current rating in the Siasconset area is an ISO 9 rating, while within the 5-mile radius of the centralized station, there is an ISO 4 rating. If the Siasconset station were to be reopened and fully functional, 2,328 buildings would now qualify for lower ISO ratings (Figure ES. 10). Additionally, the reopening would result in savings for all properties that experience an ISO rating decrease.

[12] ISO is the International Organization for Standardization. They develop and publish International Standards for a variety of fields from fire protection insurance to medical devices.

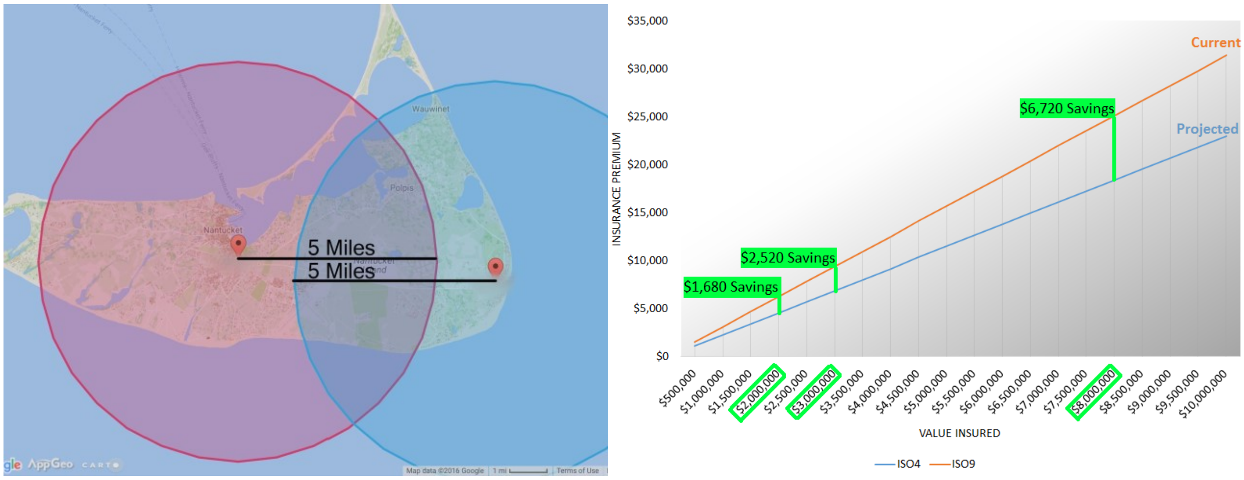

Figure ES.52: 5-mile insurance circles and savings based on ratings

The renovation costs of the Siasconset station were roughly estimated to cost $1,743,000 based on construction costs of $500 per square foot (Table ES.7). The upkeep and staffing is estimated to be $1,200,000 per year (Rhude, 2016). The estimated annual insurance savings is based off the ISO rating changes, the number of buildings affected, and the median value of the houses affected. It is important to note that the savings do not go directly to the town, they go to the property owners affected. The town could potentially explore the designation of fire protection districts into the town. This would allow for specialized taxes that could go directly to the fire department.

Siasconset Renovation		
	Renovation	Future Years
Cost	$1,743,000	$1,200,000
Annual Savings	--	$4,444,789

Table ES.20: Estimated Annual Costs and Insurance Savings of Siasconset Reopening

Recommendation 4: Use and further develop the simulation software. To estimate future response times, a basic simulation script was developed that implements Google Maps API. The simulation script can be optimized to conduct cost analysis precisely based on the NFD call data by predicting how much response time will be reduced when the solution has been proposed. For the NFD to determine the most cost effective solution, they first should:

- Decide new station locations
- Hire more staff
- Implement dynamic deployment

This script could be further developed to reduce response time through optimizing routes and choosing the best stations to deploy from. Therefore, it would be advantageous to have this program further developed after the previous two recommendations are implemented. To develop the simulation further, the following steps should be taken:

3. The script should be able to determine which station is the most accessible location for a specific emergency call. Based on the existing simulation script, this step is easily developed and could be done first in two months. In the case that this task becomes a WPI IQP, the group should include all time influential factors such as concurrent calls, extreme weather, and extreme traffic as variables, and add them to the script. Once those variables are added, the team should create a user-friendly interface to let people in the fire department access the program easily.

4. After a user interface is made, the system can be further optimized. The program can be improved to find the best route to the emergency site. In the summer, there is a lot of congestion in the downtown area, which makes it difficult for emergency vehicles to reach their destinations. Through machine learning and algorithm optimization, this system can give advice as to what the fastest route for emergency vehicles is, and eventually it should be able to show detours to avoid congested areas. Finding the fastest route when there is traffic will be difficult to implement. The group that develops this simulation should devise the algorithms by themselves instead of implementing Google API, which takes time. The time it takes to develop the system will be based on the technical ability of the group in charge of designing this system.

We recommend that this potential project be considered by the Nantucket Project Center in conjunction with the WPI Fire Protection Engineers or WPI Computer Science majors and the NFD. This project could be organized as an IQP or MQP. To determine the most appropriate methods to work on this project, the following necessary knowledge should be taken into consideration. The team must fully understand the following topics:

- Traffic circumstances in Nantucket
- Call codes used by the fire department
- How to code the necessary recommendations for the simulation
- Share this simulation with the fire department and educate them on its use

Table ES.8 summarizes the initial costs of Siasconset renovations and the dynamic deployment vehicle.

	Capital
Siasconset Reopening	$1,743,000
Dynamic Deployment Vehicle	$300,000
Total	$2,043,000

Table ES.21: Cost of Siasconset Station Reopening

The GIS maps below estimate how much the response time would be reduced after all three recommendations, including the new fire station, the Siasconset fire station, and the dynamic deployment standby location, have been implemented (Figure ES.11). Compared to the 2015 data, the downtown area in the simulation data is covered by green dots, which designates less than 5 minutes of response time. In the Siasconset area in 2015, the map is dominated by larger than 10 minute response times. After simulation implementation, the response times improve considerably.

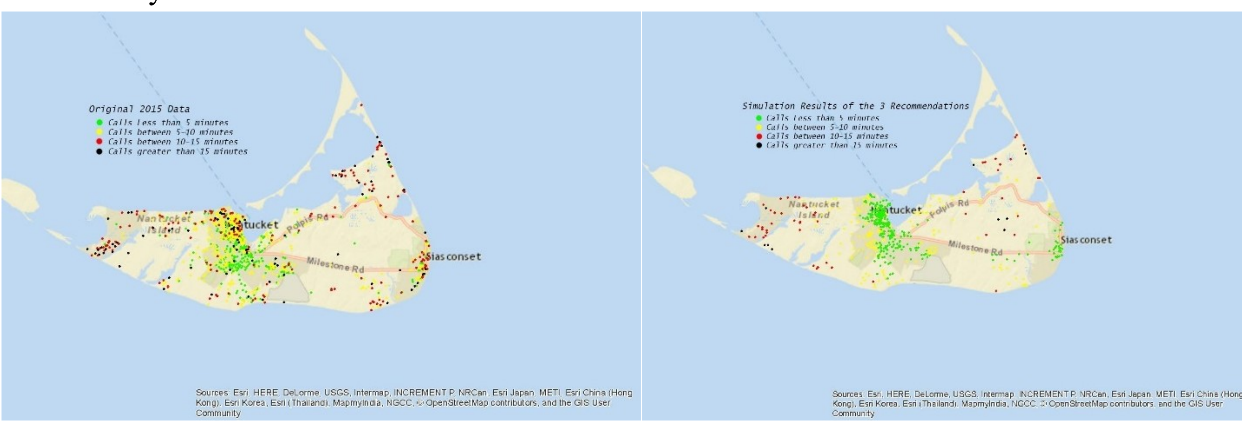

Figure ES.53: 2015 Call Data (left) Compared to Simulation Results of Recommendation Locations (right)

7 Conclusions and Acknowledgements

This project has been a great learning experience for the whole team. Not only have we gained individual skills such as coding, GIS mapping, and Excel graphing, but we have also learned how to cooperate and coordinate with other people in a team. We have learned how to work together on an in-depth project, conduct interviews, and write a report. On top of working with other students, we also learned how to conduct ourselves in a professional setting. The fire department has been an integral part of our project and working with them has showed us not only how a fire department runs, but what it means to truly devote yourself to bettering the community for others. The fire station runs off mutual respect, discipline and order, all things that will help us later in life. Nothing would get done without the fire fighters respecting each other and the engines and ambulances wouldn't work without proper maintenance done every day.

The team would like to give a huge thank you to both of our advisors. Scott Jiusto showed us how important it is to clean data before using it. He took the time to learn every little detail about our project and gave us feedback in a timely manner. Not only was Scott Jiusto an informative and capable advisor, but he always took the time to try and make meetings fun and less stressful. Fred Looft was a huge part in finding information about the insurance data. He also came up with many interesting and helpful ideas. Fred Looft also took the time out of his busy schedule to take several of us to the hospital when we were in need. They both made sure the team was prospering and on track to success. These two advisors truly cared about how the project turned out and spend a huge portion of time editing our work. We appreciated that they came up with many good points and really made the team think about the effects we would have on Nantucket.

Peter Morrison was also a huge help with our project. We would like to thank him for his expertise in data analysis and taking the time to come to our weekly meetings. He also did our team a huge favor and reviewed our data sections and helped us compile useful data. He is a very kind and interesting man. Mr. Morrison also always came up with very interesting and helpful ideas that helped us branch out our project. We truly appreciated all his help and advice.

The team loved working the with Nantucket Fire Department. We would like to thank the fire department staff for talking with us and being so kind. Their expertise in their profession provided invaluable insight that helped make a complicated task a little bit easier. We truly appreciated how welcoming and helpful they were. We enjoyed the talks, truck rides, and dogs.

We would like to thank Chief Paul Rhude for not only being so helpful with our project, but also for taking the time out of his busy schedule to show us the island. The trips were not only fun, but very helpful as they gave us insight into the various issues on the island. He was willing to drive us to the station in bad weather so we could continue to work on our project. Paul Rhude is truly one of the kindest men we have ever met. We were extremely lucky that we had him as a sponsor and we wish him luck in his pursuit of excellence at the fire station and all his other endeavors.

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Appendices

Appendix A:

This appendix includes important background information found within the previous project's report[13]. They are the examples that the team designed our own GIS analysis upon.

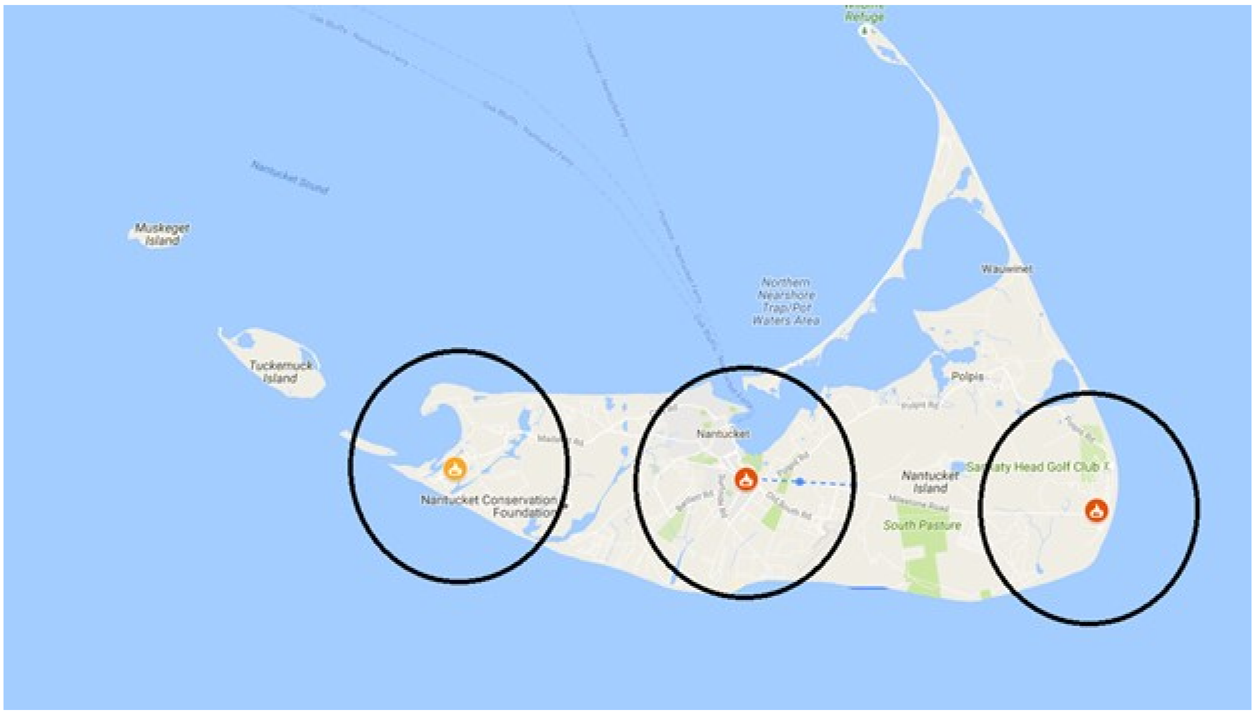

Figure A.1: Spatial distribution of central station and 2 satellite stations with industry standard radius of 2 miles for an ideal 5 min response time

[13] Previous group's report can be accessed at: http://wp.wpi.edu/nantucket/files/2014/11/NFD-Enhancing-Emergency-Response.pdf

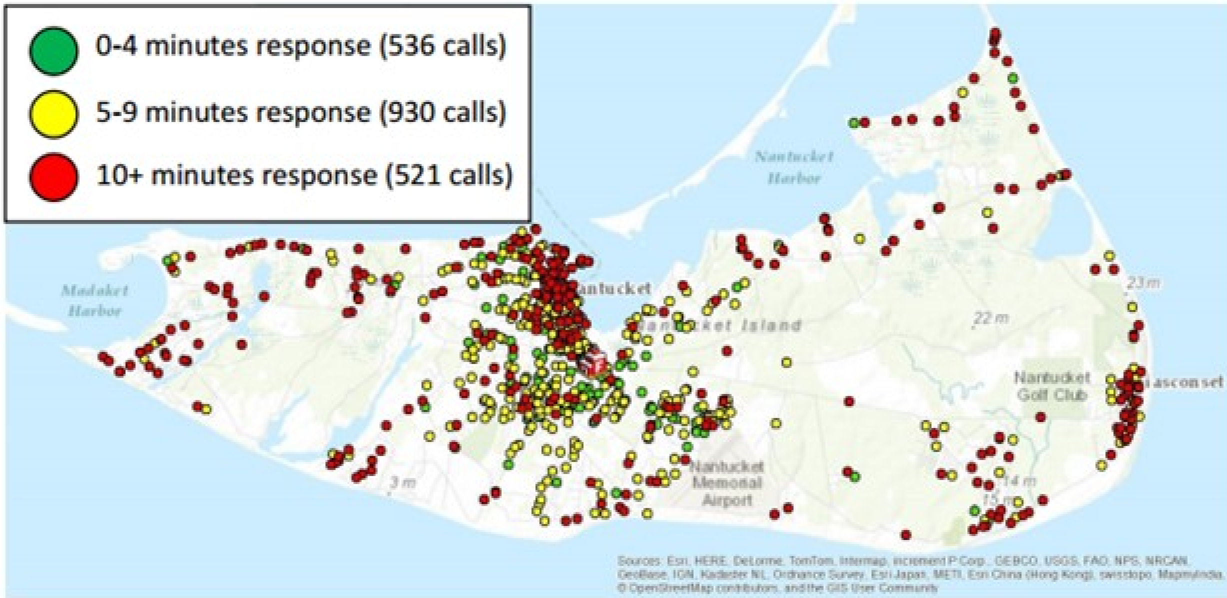

Figure A.2: Spatial Distribution of Response Times on Nantucket for 2013 Grouped by Response Time

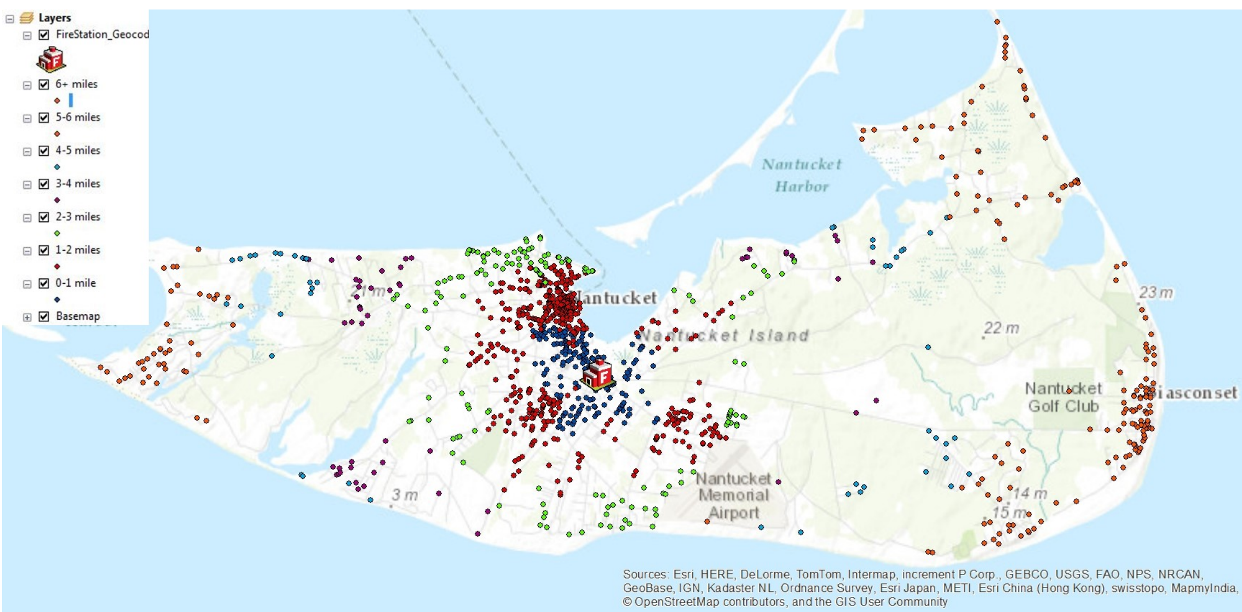

Figure A.3: Spatial Distribution of 2013 Calls Grouped by Distance from Station

Appendix B:

This appendix shows the GIS maps that the team created using the data recorded by the state of Massachusetts for Nantucket. Figures B.1-B.10 break the data down into call types. For more information on what the call type numbers mean, see Appendix C. Figures B.11-B.14 break the information up into the different times the fire department takes to respond to a call.

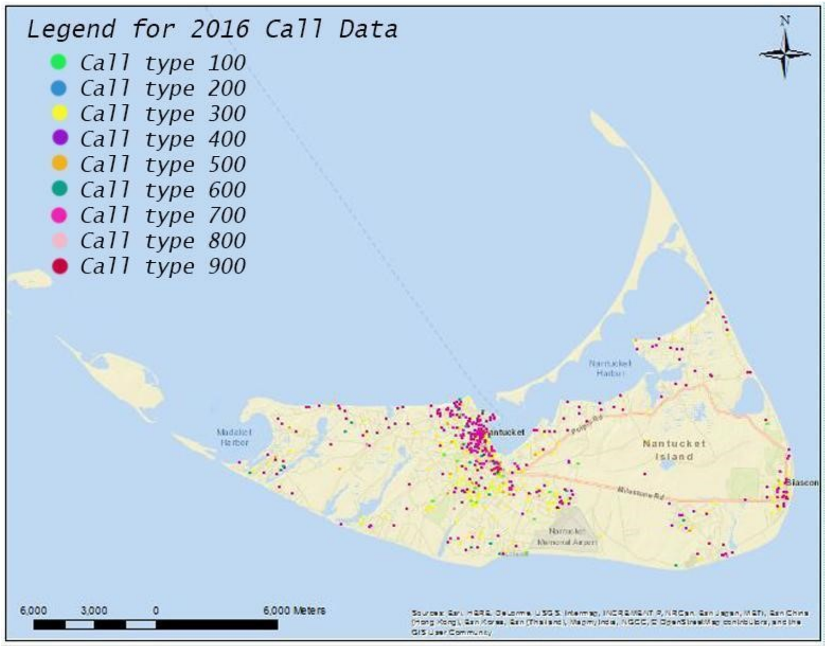

Figure B.1: The distribution of different call types for 2016

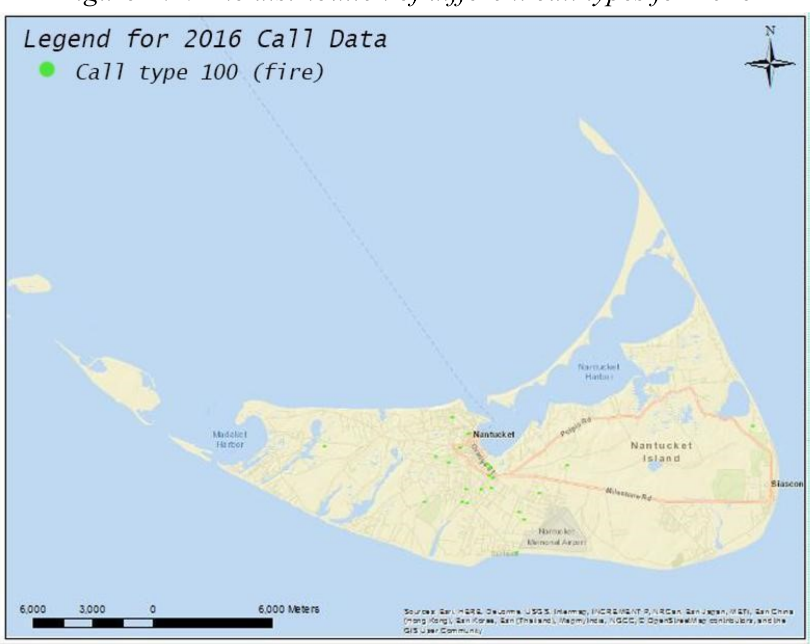

Figure B.2: 2016 Call Data of Type 100 (Fire)

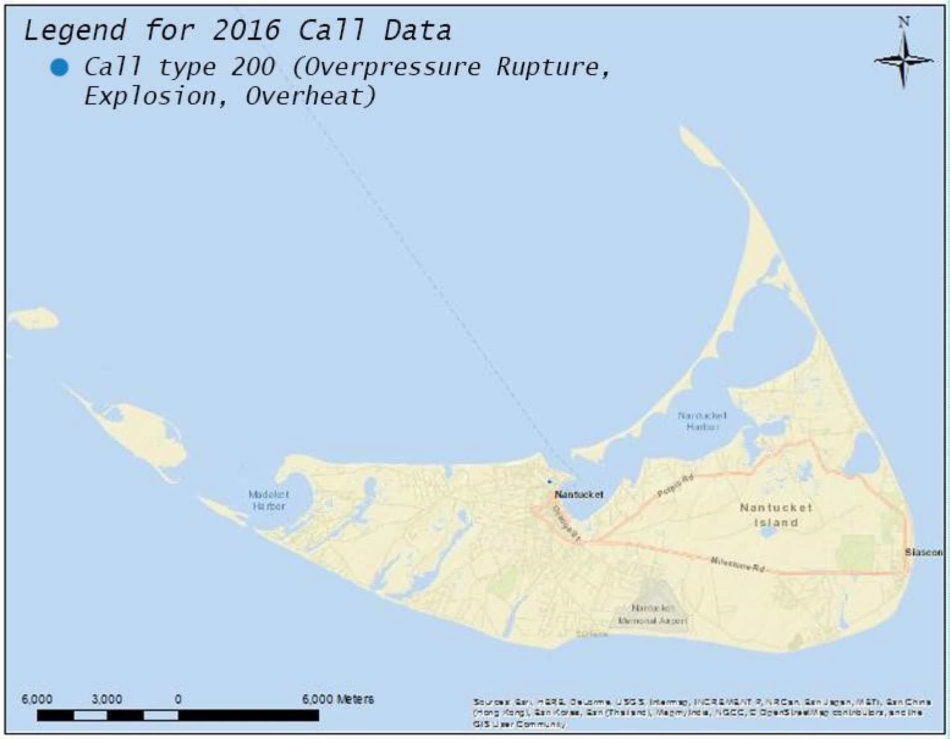

Figure B.3: 2016 Call Data of Type 200 (Overpressure Rupture, Explosion, Overheat)

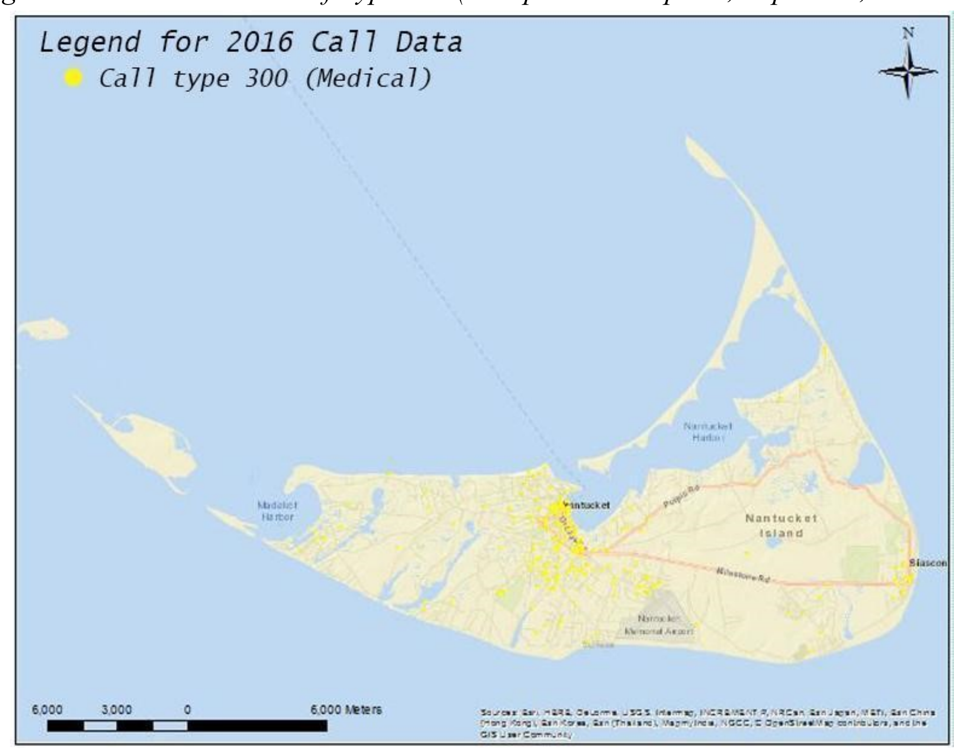

Figure B.4: 2016 Call Data of Type 300 (Medical)

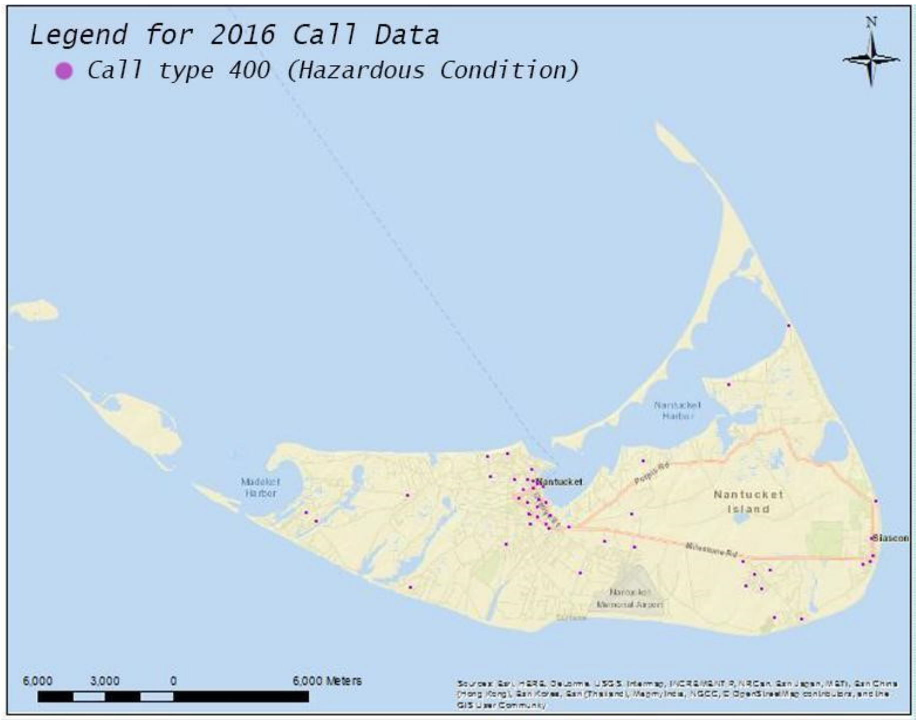

Figure B.5: 2016 Call Data of Type 400 (Hazardous Condition)

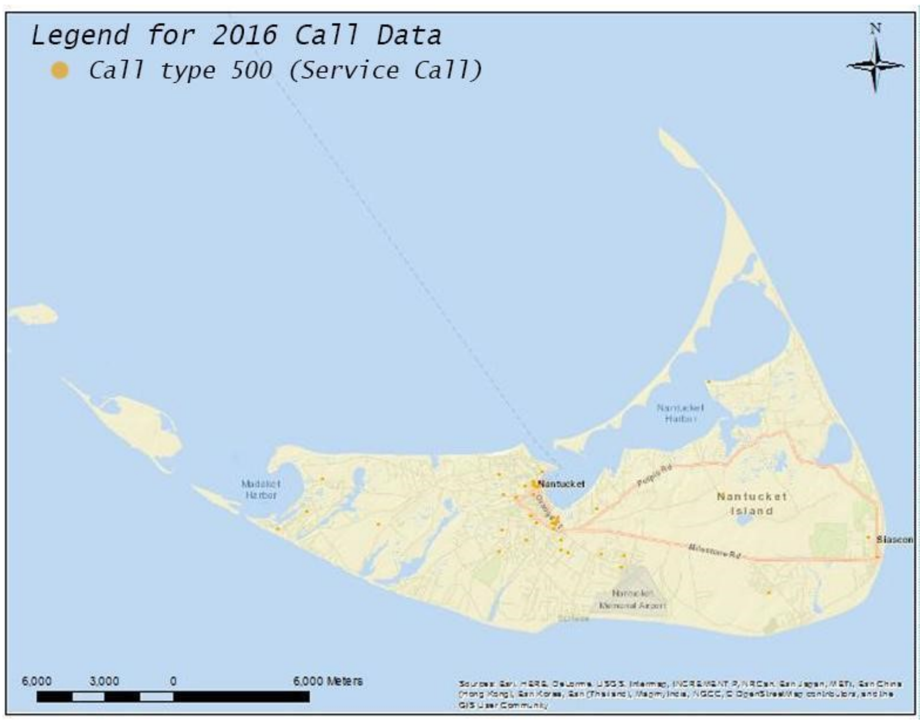

Figure B.6: 2016 Call Data of Type 500 (Service Call)

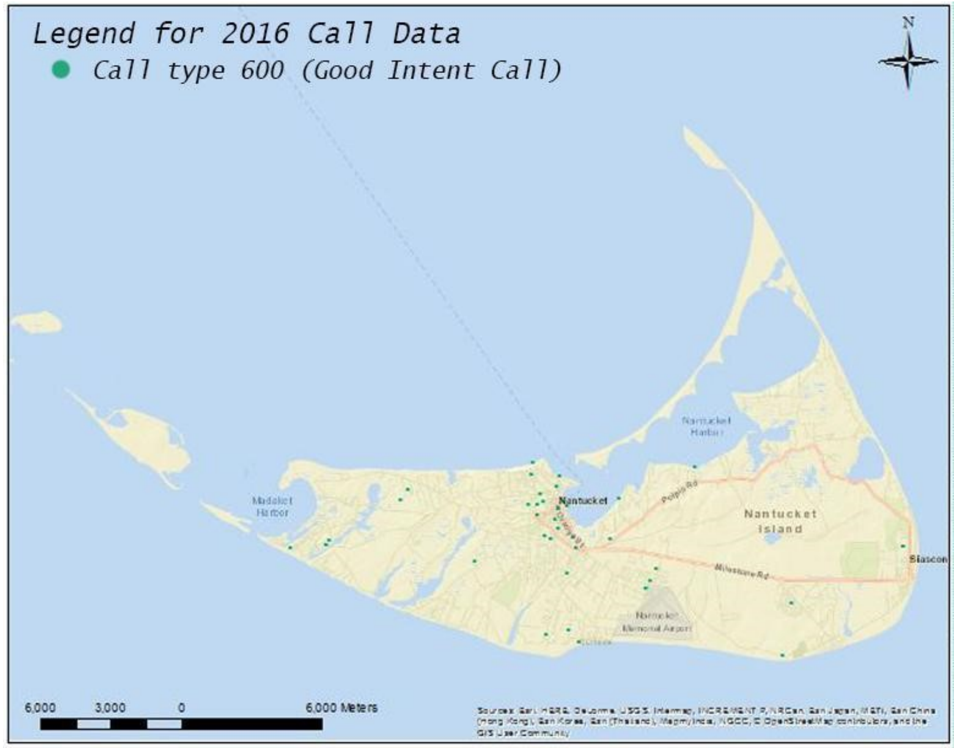

Figure B.7: 2016 Call Data of Type 600 (Good Intent Call)

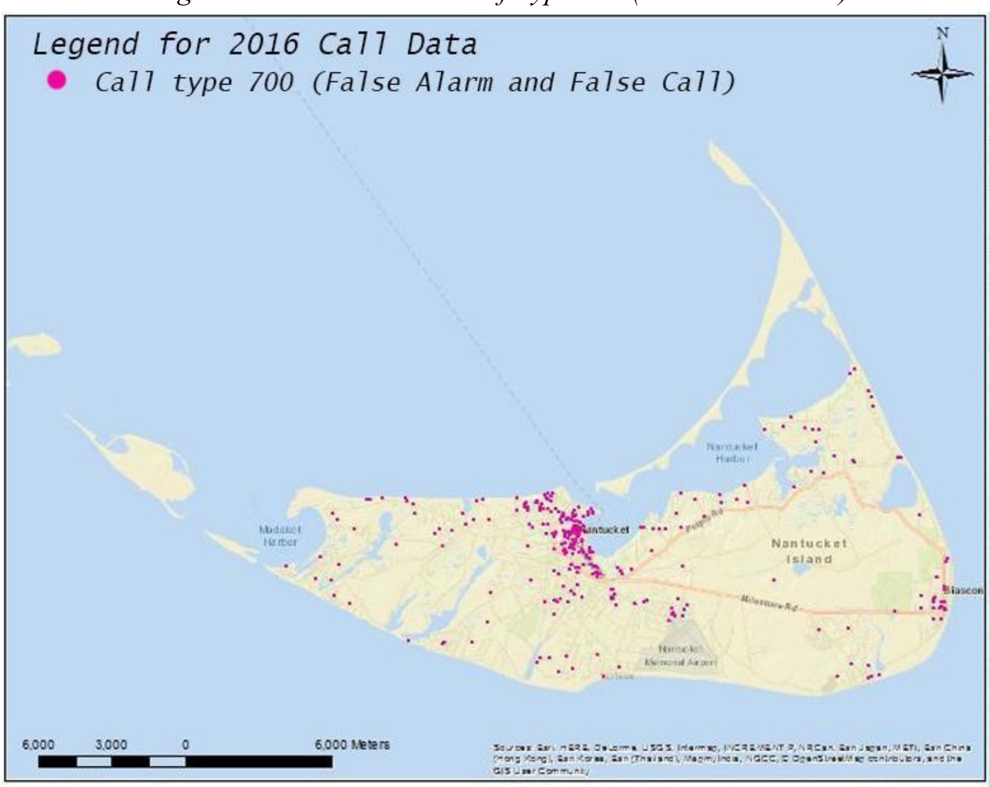

Figure B.8: 2016 Call Data of Type 700 (False Alarm and False Call)

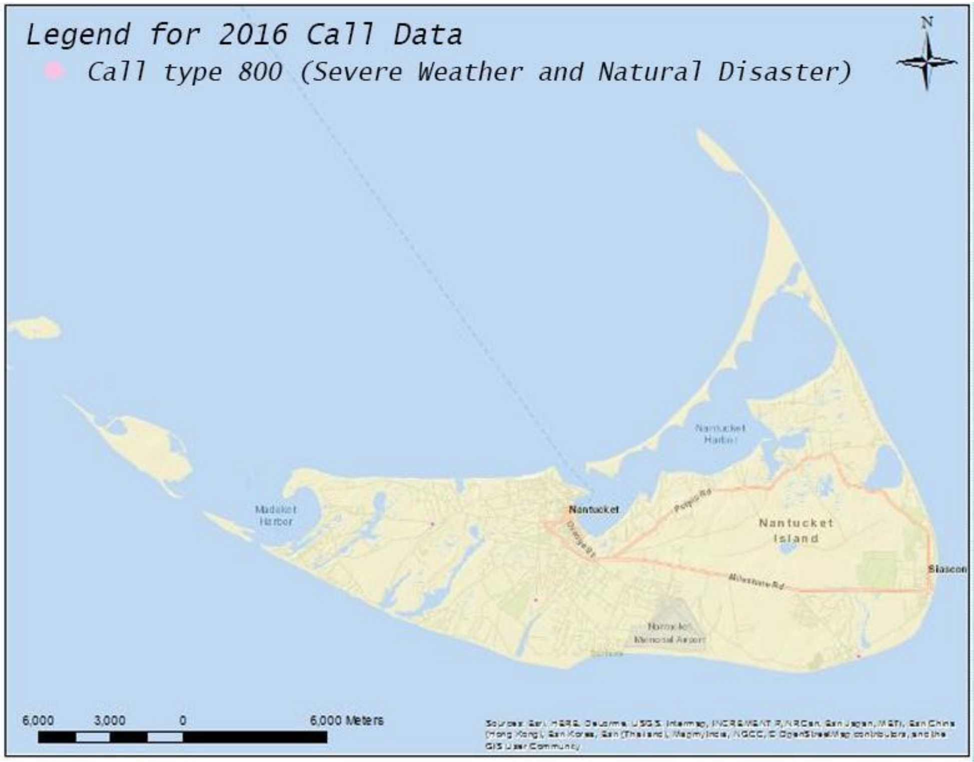

Figure B.9: 2016 Call Data of Type 800 (Severe Weather and Natural Disaster)

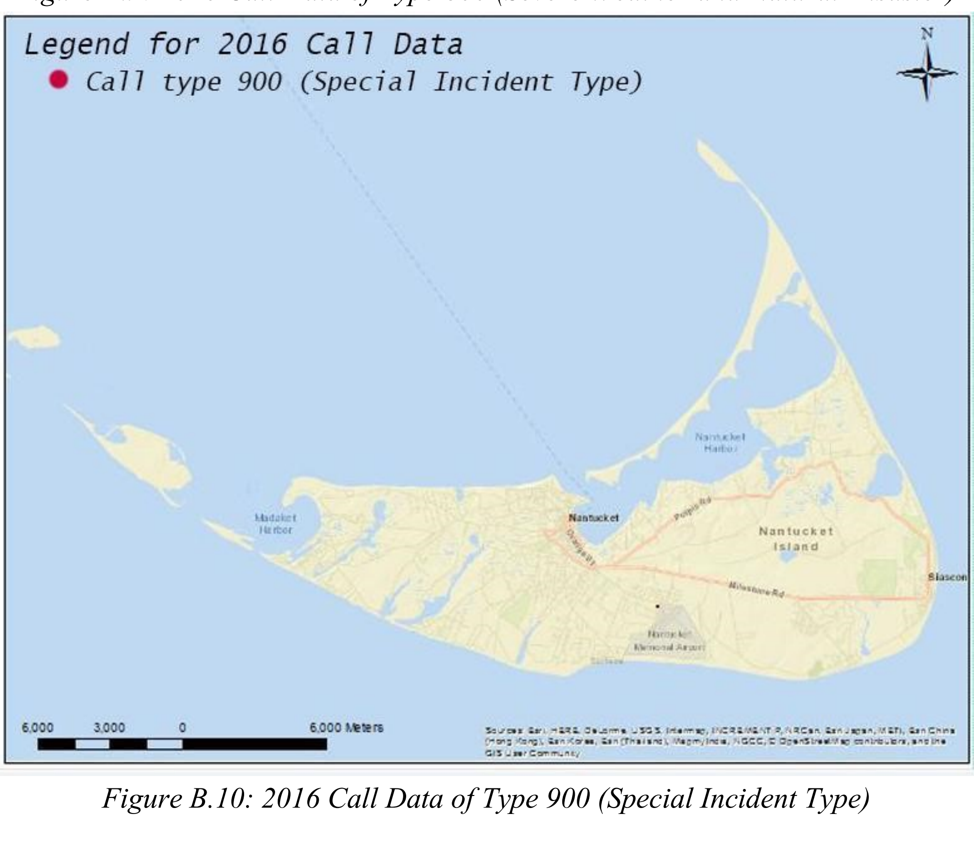

Figure B.10: 2016 Call Data of Type 900 (Special Incident Type)

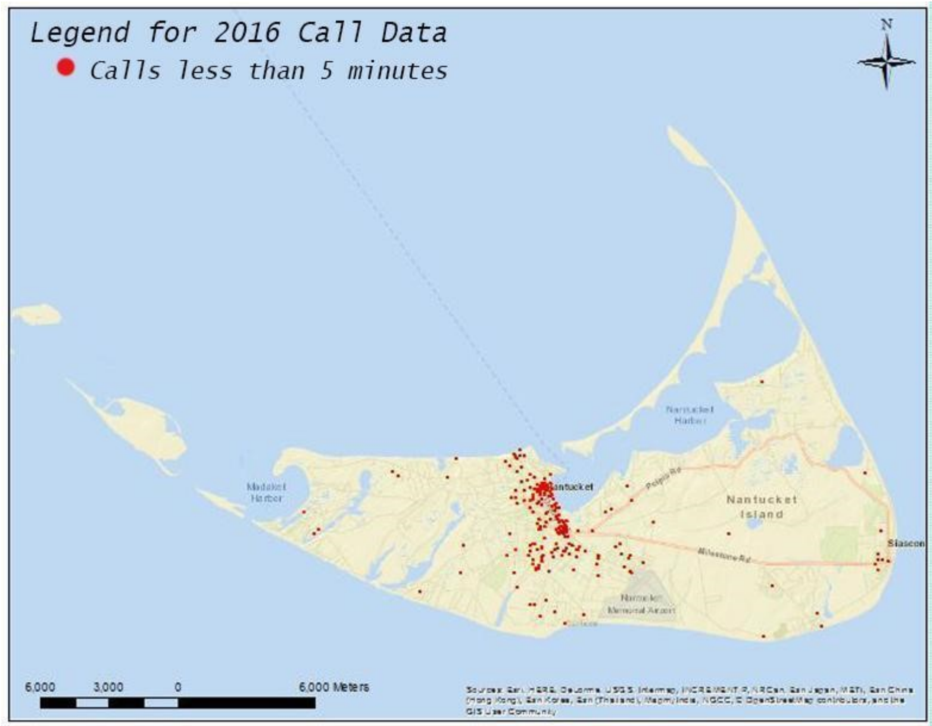

Figure B.11: 2016 Call Data of Response Time less than 5 minutes

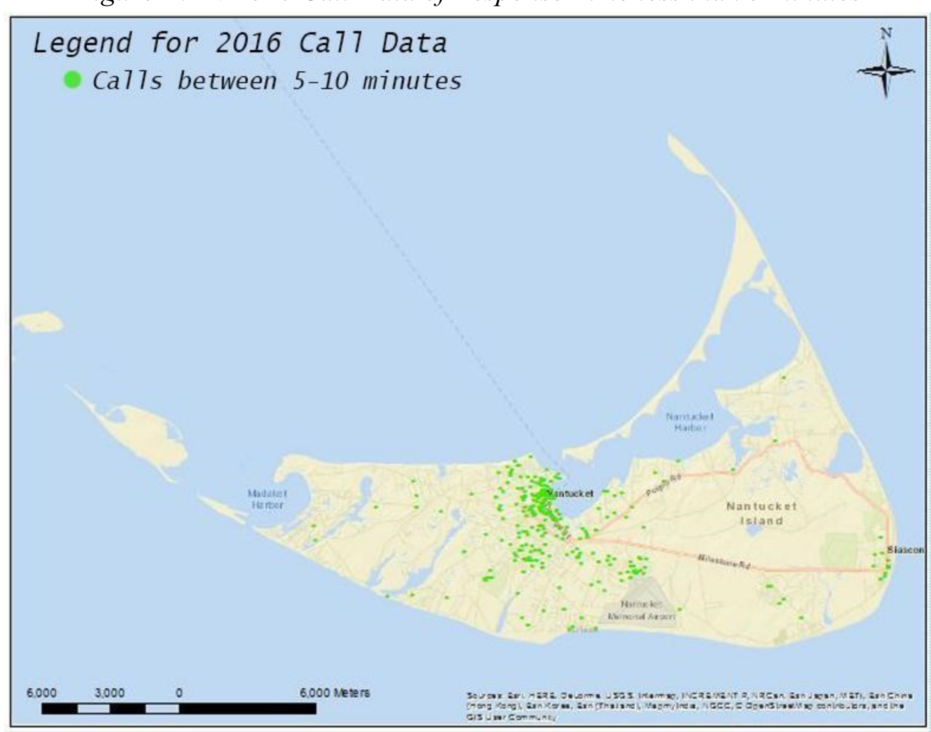

Figure B.12: 2016 Call Data of Response Time between 5-10 minutes

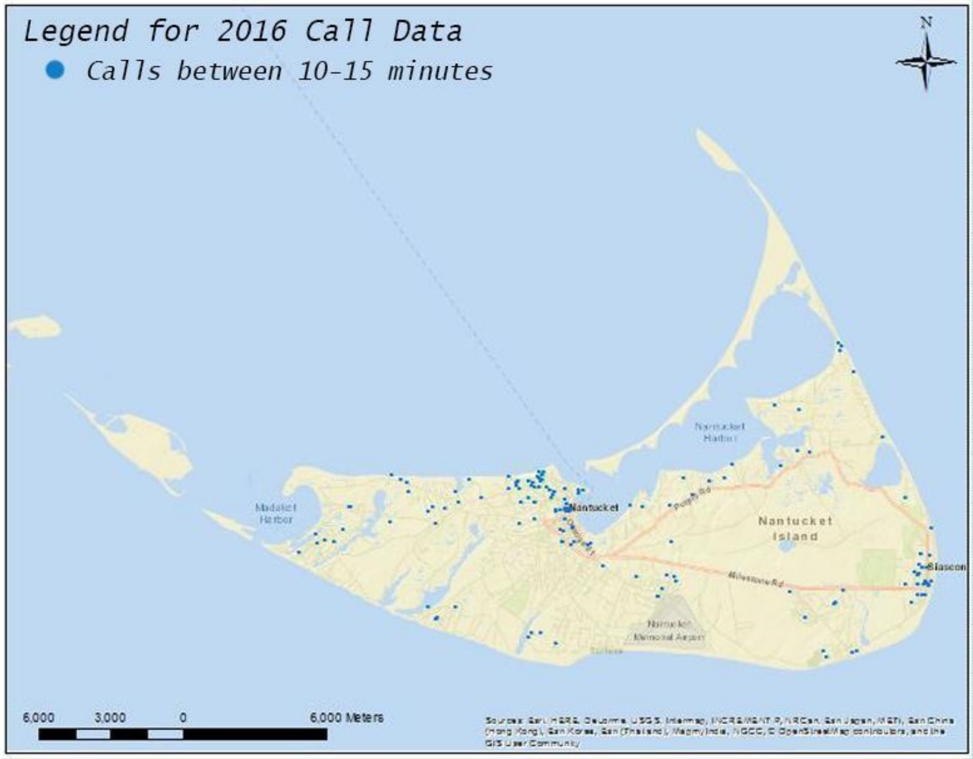

Figure B.13: 2016 Call Data of Response Time between 10-15 minutes

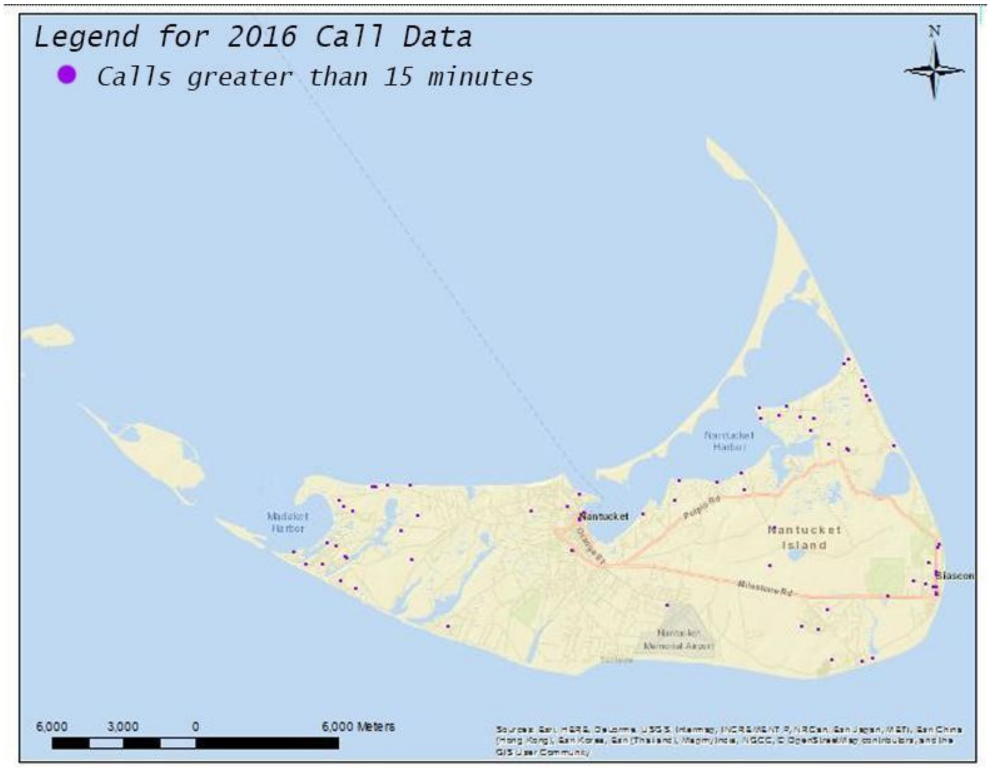

Figure B.14: 2016 Call Data of Response Time more than 15 minutes

Appendix C: Incident Types (NFIRS 5.0 COMPLETE REFERENCE GUIDE[14])

This appendix describes all the different incident numbers. For each type of call the fire department has a three-digit number that correlates with it.

☛ *Incident Type* was known as *Type of Situation Found* in NFIRS 4.1.

Definition

This is the actual situation that emergency personnel found on the scene when they arrived. These codes include the entire spectrum of fire department activities from fires to EMS to public service.

☛ The type of incident reported here is not always the same as the incident type initially dispatched.

Purpose

This critical information identifies the various types of incidents to which the fire department responds and allows the fire department to document the full range of incidents it handles.

This information can be used to analyze the frequency of different types of incidents, provide insight on fire and other incident problems, and identify training needs.

☛ This element determines which modules will subsequently be completed.

Entry

Enter the three-digit code and a written description that best describes the type of incident. This entry is generally the type of incident found when emergency personnel arrived at the scene, but if a more serious condition developed after the fire department arrival on the scene, then that incident type should be reported. The codes are organized in a series:

SERIES	HEADING
100	Fire
200	Overpressure Rupture, Explosion, Overheat (No Fire)
300	Rescue and Emergency Medical Service (EMS) Incidents
400	Hazardous Condition (No Fire)
500	Service Call
600	Good Intent Call
700	False Alarm and False Call
800	Severe Weather and Natural Disaster
900	Special Incident Type

[14] Massachusetts Fire Incident Reporting System Version 5, Quick Reference Guide: here.

Fire. Includes fires out on arrival and gas vapor explosions (with extremely rapid combustion).

Structure fire

111	Building fire. Excludes confined fires (113–118).
112	Fire in structure, other than in a building. Included are fires on or in piers, quays, or pilings: tunnels or underground connecting structures; bridges, trestles, or overhead elevated structures; transformers, power or utility vaults or equipment; fences; and tents.
113	Cooking fire involving the contents of a cooking vessel without fire extension beyond the vessel.
114	Chimney or flue fire originating in and confined to a chimney or flue. Excludes fires that extend beyond the chimney (111 or 112).
115	Incinerator overload or malfunction, but flames cause no damage outside the incinerator.
116	Fuel burner/boiler, delayed ignition or malfunction, where flames cause no damage outside the fire box.
117	Commercial compactor fire, confined to contents of compactor. Excluded are home trash compactors.
118	Trash or rubbish fire in a structure, with no flame damage to structure or its contents.

Fire in mobile property used as a fixed structure. *Includes mobile homes, motor homes, camping trailers.*

121	Fire in mobile home used as a fixed residence. Includes mobile homes when not in transit and used as a structure for residential purposes; and manufactured homes built on a permanent chassis.
122	Fire in a motor home, camper, or recreational vehicle when used as a structure. Includes motor homes when not in transit and used as a structure for residential purposes.
123	Fire in a portable building, when used at a fixed location. Includes portable buildings used for commerce, industry, or education and trailers used for commercial purposes.
120	Fire in mobile property used as a fixed structure, other.

Mobile property (vehicle) fire. *Excludes mobile properties used as a structure (120 series). If a vehicle fire occurs on a bridge and does not damage the bridge, it should be classified as a vehicle fire.*

131	Passenger vehicle fire. Includes any motorized passenger vehicle, other than a motor home (136) (e.g., pickup trucks, sport utility vehicles, buses).
132	Road freight or transport vehicle fire. Includes commercial freight hauling vehicles and contractor vans or trucks. Examples are moving trucks, plumber vans, and delivery trucks.
133	Rail vehicle fire. Includes all rail cars, including intermodal containers and passenger cars that are mounted on a rail car.
134	Water vehicle fire. Includes boats, barges, hovercraft, and all other vehicles designed for navigation on water.
135	Aircraft fire. Includes fires originating in or on an aircraft, regardless of use.
136	Self-propelled motor home or recreational vehicle. Includes only self-propelled motor homes or recreational vehicles when being used in a transport mode. Excludes those used for normal residential use (122).
137	Camper or recreational vehicle (RV) fire, not self-propelled. Includes trailers. Excludes RVs on blocks or used regularly as a fixed building (122) and the vehicle towing the camper or RV or the campers mounted on pick ups (131).

138 Off-road vehicle or heavy equipment fire. Includes dirt bikes, specialty off-road vehicles, earth-moving equipment (bulldozers), and farm equipment.

130 Mobile property (vehicle) fire, other.

Natural vegetation fire. *Excludes crops or plants under cultivation (see 170 series).*

141 Forest, woods, or wildland fire. Includes fires involving vegetative fuels, other than prescribed fire (632), that occur in an area in which development is essentially nonexistent, except for roads, railroads, power lines, and the like. Also includes forests managed for lumber production and fires involving elevated fuels such as tree branches and crowns. Excludes areas in cultivation for agricultural purposes such as tree farms or crops (17x series).

142 Brush or brush-and-grass mixture fire. Includes ground fuels lying on or immediately above the ground such as duff, roots, dead leaves, fine dead wood, and downed logs.

143 Grass fire. Includes fire confined to area characterized by grass ground cover, with little or no involvement of other ground fuels; otherwise, see 142.

140 Natural vegetation fire, other.

Outside rubbish fire. *Includes all rubbish fires outside a structure or vehicle.*

151 Outside rubbish, trash, or waste fire not included in 152–155. Excludes outside rubbish fires in a container or receptacle (154).

152 Garbage dump or sanitary landfill fire.

153 Construction or demolition landfill fire.

154 Dumpster or other outside trash receptacle fire. Includes waste material from manufacturing or other production processes. Excludes materials that are not rubbish or have salvage value (161 or 162).

155 Outside stationary compactor or compacted trash fire. Includes fires where the only material burning is rubbish. Excludes fires where the compactor is damaged (162).

150 Outside rubbish fire, other.

Special outside fire. *Includes outside fires with definable value. Excludes crops and orchards (170 series).*

161 Outside storage fire on residential or commercial/industrial property, not rubbish. Includes recyclable materials at dropoff points.

162 Outside equipment fire. Includes outside trash compactors, outside HVAC units, and irrigation pumps. Excludes special structures (110 series) and mobile construction equipment (130 series).

163 Outside gas or vapor combustion explosion without sustained fire.

164 Outside mailbox fire. Includes dropoff boxes for delivery services.

160 Special outside fire, other.

Cultivated vegetation, crop fire

171 Cultivated grain or crop fire. Includes fires involving corn, wheat, soybeans, rice, and other plants before harvest.

172 Cultivated orchard or vineyard fire.

173 Cultivated trees or nursery stock fire. Includes fires involving Christmas tree farms and plants under cultivation for transport off-site for ornamental use.

170 Cultivated vegetation, crop fire, other.

Fire, other

100	Fire, other.

Overpressure Rupture, Explosion, Overheat (No Fire). Excludes steam mistaken for smoke.

Overpressure rupture from steam (no ensuing fire)

211	Overpressure rupture of steam pipe or pipeline.
212	Overpressure rupture of steam boiler.
213	Overpressure rupture of pressure or process vessel from steam.
210	Overpressure rupture from steam, other.

Overpressure rupture from air or gas (no ensuing fire). Excludes steam or water vapor.

221	Overpressure rupture of air or gas pipe or pipeline.
222	Overpressure rupture of boiler from air or gas. Excludes steam-related overpressure ruptures.

223 Overpressure rupture of pressure or process vessel from air or gas, not steam.
220 Overpressure rupture from air or gas, other.

Overpressure rupture from chemical reaction (no ensuing fire)

231 Overpressure rupture of pressure or process vessel from a chemical reaction.

Explosion (no fire)

241 Munitions or bomb explosion (no fire). Includes explosions involving military ordnance, dynamite, nitroglycerin, plastic explosives, propellants, and similar agents with a UN classification 1.1 or 1.3. Includes primary and secondary high explosives.
242 Blasting agent explosion (no fire). Includes ammonium nitrate and fuel oil (ANFO) mixtures and explosives with a UN Classification 1.5 (also known as blasting agents).
243 Fireworks explosion (no fire). Includes all classes of fireworks.
244 Dust explosion (no fire).
240 Explosion (no fire), other.

Excessive heat, scorch burns with no ignition

251 Excessive heat, overheat scorch burns with no ignition. Excludes lightning strikes with no ensuing fire (814).

Overpressure rupture, explosion, overheat, other

200 Overpressure rupture, explosion, overheat, other.

Rescue and Emergency Medical Service Incident

Medical assist

311 Medical assist. Includes incidents where medical assistance is provided to another group/agency that has primary EMS responsibility. (Example, providing assistance to another agency-assisting EMS with moving a heavy patient.)

Emergency medical service incident

321 EMS call. Includes calls when the patient refuses treatment. Excludes vehicle accident with injury (322) and pedestrian struck (323).
322 Motor vehicle accident with injuries. Includes collision with other vehicle, fixed objects, or loss of control resulting in leaving the roadway.
323 Motor vehicle/pedestrian accident (MV Ped). Includes any motor vehicle accident involving a pedestrian injury.
324 Motor vehicle accident with no injuries.
320 Emergency medical service incident, other.

Lock-In

331 Lock-in. Includes opening locked vehicles and gaining entry to locked areas for access by caretakers or rescuers, such as a child locked in a bathroom. Excludes lock-outs (511).

Search for lost person

341 Search for person on land. Includes lost hikers and children, even where there is an incidental search of local bodies of water, such as a creek or river.

342 Search for person in water. Includes shoreline searches incidental to a reported drowning call.

343 Search for person underground. Includes caves, mines, tunnels, and the like.

340 Search for lost person, other.

Extrication, rescue

351 Extrication of victim(s) from building or structure, such as a building collapse. Excludes high-angle rescue (356).

352 Extrication of victim(s) from vehicle. Includes rescues from vehicles hanging off a bridge or cliff.

353 Removal of victim(s) from stalled elevator.

354 Trench/Below-grade rescue.

355 Confined space rescue. Includes rescues from the interiors of tanks, including areas with potential for hazardous atmospheres such as silos, wells, and tunnels.

356 High-angle rescue. Includes rope rescue and rescues off of structures.

357 Extrication of victim(s) from machinery. Includes extrication from farm or industrial equipment.

350	Extrication, rescue, other.

Water and ice-related rescue

361	Swimming/Recreational water areas rescue. Includes pools and ponds. Excludes ice rescue (362).
362	Ice rescue. Includes only cases where victim is stranded on ice or has fallen through ice.
363	Swift-water rescue. Includes flash flood conditions.
364	Surf rescue.
365	Watercraft rescue. Excludes rescues near the shore and in swimming/recreational areas (361). Includes people falling overboard at a significant distance from land.
360	Water and ice-related rescue, other.

Electrical rescue

371	Electrocution or potential electrocution. Excludes people trapped by power lines (372).
372	Trapped by power lines. Includes people trapped by downed or dangling power lines or other energized electrical equipment.
370	Electrical rescue, other.

Rescue or EMS standby

381	Rescue or EMS standby for hazardous conditions. Excludes aircraft standby (462).

Rescue, emergency medical service (EMS) incident, other

300	Rescue and EMS incident, other.

Hazardous Condition (No Fire)

Combustible/Flammable spills and leaks

411	Gasoline or other flammable liquid spill (flash point below 100 degrees F at standard temperature and pressure (Class I)).
412	Gas leak (natural gas or LPG). Excludes gas odors with no source found (671).
413	Oil or other combustible liquid spill (flash point at or above 100 degrees F at standard temperature and pressure (Class II or III)).
410	Combustible and flammable gas or liquid spills or leaks, other.

Chemical release, reaction, or toxic condition

421	Chemical hazard (no spill or leak). Includes the potential for spills or leaks.
422	Chemical spill or leak. Includes unstable, reactive, explosive material.
423	Refrigeration leak. Includes ammonia.
424	Carbon monoxide incident. Excludes incidents with nothing found (736 or 746).
420	Toxic chemical condition, other.

Radioactive condition

431	Radiation leak, radioactive material. Includes release of radiation due to breaching of container or other accidental release.
430	Radioactive condition, other.

Electrical wiring/Equipment problem

441 Heat from short circuit (wiring), defective or worn insulation.
442 Overheated motor or wiring.
443 Breakdown of light ballast.
444 Power line down. Excludes people trapped by downed power lines (372).
445 Arcing, shorted electrical equipment.
440 Electrical wiring/equipment problem, other.

Biological hazard

451 Biological hazard, confirmed or suspected.

Accident, potential accident

461 Building or structure weakened or collapsed. Excludes incidents where people are trapped (351).
462 Aircraft standby. Includes routine standby for takeoff and landing as well as emergency alerts at airports.
463 Vehicle accident, general cleanup. Includes incidents where FD is dispatched after the accident to clear away debris. Excludes extrication from vehicle (352) and flammable liquid spills (411 or 413).
460 Accident, potential accident, other.

Explosive, bomb removal

471 Explosive, bomb removal. Includes disarming, rendering safe, and disposing of bombs or suspected devices. Excludes bomb scare (721).

Attempted burning, illegal action

481 Attempt to burn. Includes situations in which incendiary devices fail to function.
482 Threat to burn. Includes verbal threats and persons threatening to set themselves on fire. Excludes an attempted burning (481).
480 Attempted burning, illegal action, other.

Hazardous condition, other

400 Hazardous condition (no fire), other.

Service Call

Person in distress

511 Lock-out. Includes efforts to remove keys from locked vehicles. Excludes lock-ins (331).
512 Ring or jewelry removal, without transport to hospital. Excludes persons injured (321).
510 Person in distress, other.

Water problem

521 Water (not people) evacuation. Includes the removal of water from basements. Excludes water rescues (360 series).
522 Water or steam leak. Includes open hydrant. Excludes overpressure ruptures (211).
520 Water problem, other.

Smoke, odor problem

531 Smoke or odor removal. Excludes the removal of any hazardous materials.

Animal problem or rescue

541 Animal problem. Includes persons trapped by an animal or an animal on the loose.
542 Animal rescue.
540 Animal problem or rescue, other.

Public service assistance

551 Assist police or other governmental agency. Includes forcible entry and the provision of lighting.
552 Police matter. Includes incidents where FD is called to a scene that should be handled by the police.
553 Public service. Excludes service to governmental agencies (551 or 552).
554 Assist invalid. Includes incidents where the invalid calls the FD for routine help, such as assisting a person in returning to bed or chair, with no transport or medical treatment given.
555 Defective elevator, no occupants.
550 Public service assistance, other.

Unauthorized burning

561 Unauthorized burning. Includes fires that are under control and not endangering property.

Cover assignment, standby at fire station, move-up

571 Cover assignment, assist other fire agency such as standby at a fire station or move-up.

Service call, other

500 Service call, other.

Good Intent Call

Dispatched and canceled en route

611 Dispatched and canceled en route. Incident cleared or canceled prior to arrival of the responding unit. If a unit arrives on the scene, fill out the applicable code.

Wrong location, no emergency found

621 Wrong location. Excludes malicious false alarms (710 series).
622 No incident found on arrival at dispatch address.

Controlled burning

631 Authorized controlled burning. Includes fires that are agricultural in nature and managed by the property owner. Excludes unauthorized controlled burning (561) and prescribed fires (632).
632 Prescribed fire. Includes fires ignited by management actions to meet specific objectives and have a written, approved prescribed fire plan prior to ignition. Excludes authorized controlled burning (631).

Vicinity alarm

641 Vicinity alarm (incident in other location). For use only when an erroneous report is received for a legitimate incident. Includes separate locations reported for an actual fire and multiple boxes pulled for one fire.

Steam, other gas mistaken for smoke

651 Smoke scare, odor of smoke, not steam (652). Excludes gas scares or odors of gas (671).
652 Steam, vapor, fog, or dust thought to be smoke.
653 Smoke from barbecue or tar kettle (no hostile fire).
650 Steam, other gas mistaken for smoke, other.

EMS call where party has been transported

661 EMS call where injured party has been transported by a non-fire service agency or left the scene prior to arrival.

HazMat release investigation w/no HazMat found

671 Hazardous material release investigation with no hazardous condition found. Includes odor of gas with no leak/gas found.
672 Biological hazard investigation with no hazardous condition found.

Good intent call, other

600 Good intent call, other.

False Alarm and False Call

Malicious, mischievous false alarm

711 Municipal alarm system, malicious false alarm. Includes alarms transmitted on street fire alarm boxes.
712 Direct tie to fire department, malicious false alarm. Includes malicious alarms transmitted via fire alarm system directly tied to the fire department, not via dialed telephone.
713 Telephone, malicious false alarm. Includes false alarms transmitted via the public telephone network using the local emergency reporting number of the fire department or another emergency service agency.
714 Central station, malicious false alarm. Includes malicious false alarms via a central-station-monitored fire alarm system.
715 Local alarm system, malicious false alarm. Includes malicious false alarms reported via telephone or other means as a result of activation of a local fire alarm system.
710 Malicious, mischievous false alarm, other.

Bomb scare

721 Bomb scare (no bomb).

System or detector malfunction. *Includes improper performance of fire alarm system that is not a result of a proper system response to environmental stimuli such as smoke or high heat conditions.*

731 Sprinkler activated due to the failure or malfunction of the sprinkler system. Includes any failure of sprinkler equipment that leads to sprinkler activation with no fire present. Excludes unintentional operation caused by damage to the sprinkler system (740 series).
732 Extinguishing system activation due to malfunction.
733 Smoke detector activation due to malfunction.
734 Heat detector activation due to malfunction.
735 Alarm system activation due to malfunction.
736 Carbon monoxide detector activation due to malfunction.
730 System or detector malfunction, other.

Unintentional system or detector operation (no fire). *Includes tripping an interior device accidentally.*

741 Sprinkler activation (no fire), unintentional. Includes testing the sprinkler system without fire department notification.
742 Extinguishing system activation. Includes testing the extinguishing system without fire department notification.
743 Smoke detector activation (no fire), unintentional. Includes proper system responses to environmental stimuli such as non-hostile smoke.
744 Detector activation (no fire), unintentional. A result of a proper system response to environmental stimuli such as high heat conditions.
745 Alarm system activation (no fire), unintentional.
746 Carbon monoxide detector activation (no carbon monoxide detected). Excludes carbon monoxide detector malfunction.
740 Unintentional transmission of alarm, other.

Biohazard scare

751 Biological hazard, malicious false report.

False alarm and false call, other

700 False alarm or false call, other.

Severe Weather and Natural Disaster

811 Earthquake assessment, no rescue or other service rendered.
812 Flood assessment. Excludes water rescue (360 series).
813 Wind storm. Includes tornado, hurricane, or cyclone assessment. No other service rendered.
814 Lightning strike (no fire). Includes investigation.
815 Severe weather or natural disaster standby.
800 Severe weather or natural disaster, other.

Special Incident Type

Citizen complaint

911 Citizen's complaint. Includes reports of code or ordinance violation.

Special type of incident, other

900 Special type of incident, other.

Appendix D: Interview Questions

This is how the team started each interview:
Hello, we are students from Worcester Polytechnic Institute (WPI). We are working with the Nantucket Fire Department on two issues that impact response time, namely understaffing and lack of resources. What we would like to do is ask you a series of questions related to the overall response time of the NFD, so that we can get a better understanding on how to help improve the Nantucket community. For this project, we will be writing a report and some of your answers might be included, if that is okay with you. If there are any questions you would rather not answer, feel free to say "pass" and we will move on. You are also free to leave at any point of the interview, if you feel the need. We will be asking you a series of questions relating to the Nantucket Fire Department. Before we start, do you have any questions?
Okay, for a little bit of background:

- The current average emergency response time of the NFD is 7 and a half minutes with 90% of the calls responded to within 15 minutes.
- The national standard is to respond within 5 minutes for 90% of calls.

Nantucket Fire Department

1. In your experience, is there enough staff at the station to respond to the calls? Are there any instances where having more staff would have made your job get done faster?
2. Do you have an additional job other than working at the fire department? If so how many?
3. Given that the average response time is significantly longer than the national standard, can you identify some problems that you have experienced that made the response slower?
4. One potential solution the team has identified is partnering with another agency such as the police department and cross-training. What are your thoughts on this?
5. Another potential solution is involved with the possibility of creating affordable housing for fire department staff. Are you currently living on Nantucket?
    a. If no, why do you not live on Nantucket? (where do you live, and how do you get here?)
    b. If yes, what is your current housing situation (rent/lease/own, stipend from department)?

Town Residents and Property owners

1. Is the property that you are living in on the island owned by you or are you renting/leasing?
2. Are you currently employed full time, part time, unemployed, or retired?
3. Have you ever personally experienced a fire on Nantucket? If so, were you satisfied with the service?
4. Have you ever needed to call the fire department? If so, were you satisfied with their response?
5. Would you be willing to pay more in taxes, if it helps to improve the fire department's emergency response time, and potentially decrease the insurance number?

6. Limiting factors are traffic and congested streets in downtown, the long distance from the central station for Siasconset and Madaket, and understaffing when there is concurrent (more than one at a time) calls. Is there a way that you think they could reduce the response time?
7. Currently the firefighters are having a hard time finding housing and this is part of the reason why they are understaffed. Do you have any empty rooms? If so, would you be willing to rent one to a firefighter?

Town Officials

1. Have you worked with the fire department before?
2. Have you ever needed the fire department? If so, how?
3. The national standard is response within 5 minutes for 90% of calls. Do you think the response time of the Nantucket fire department is satisfactory?
4. Limiting factors are traffic and congested streets in downtown, the long distance from the central station for Siasconset and Madaket, and understaffing when there is concurrent (more than one at a time) calls. Is there a way that you think they could reduce the response time?
5. Is there any room for the budget to be increased to either increase wages for fire and medical personnel or hire further additional staff? Why or why not?
6. Housing is a huge part in why the fire department is understaffed. Do you think there is a way to fix this?
    a. Do you think any land conservation company be willing to donate land to help with housing or a new fire station?
7. Do you think the public is satisfied with the fire department? Why or why not?

Appendix E: Nantucket Zoning Laws for Three Potential Locations

Siasconset Fire House

- Area: .25 AC
- SOH zone
    - Minimum Lot Size: 5,000 ft^2
    - Frontage: 50 ft.
    - Ground Cover Ratio: 50%
    - Front Setback: 0 ft.
    - Side/Rear Setback: 5 ft.

Madaket Fire House

- Area: .14 AC
- VR zone
    - Minimum Lot Size: 20,000 ft^2

    - Frontage: 75 ft.
    - Ground Cover Ratio: 10%
    - Front Setback 20 ft.
    - Side/Rear Setback: 10 ft.

Old Fire Station (Sheriff Station)

- CDT zone
    - Minimum Lot Size: 3,750
    - Frontage: 35 ft.
    - Ground Cover Ratio: 75%
    - Front Setback: 0 ft.
    - Side/Rear Setback 0/5 ft.

Appendix F: Purging the Data

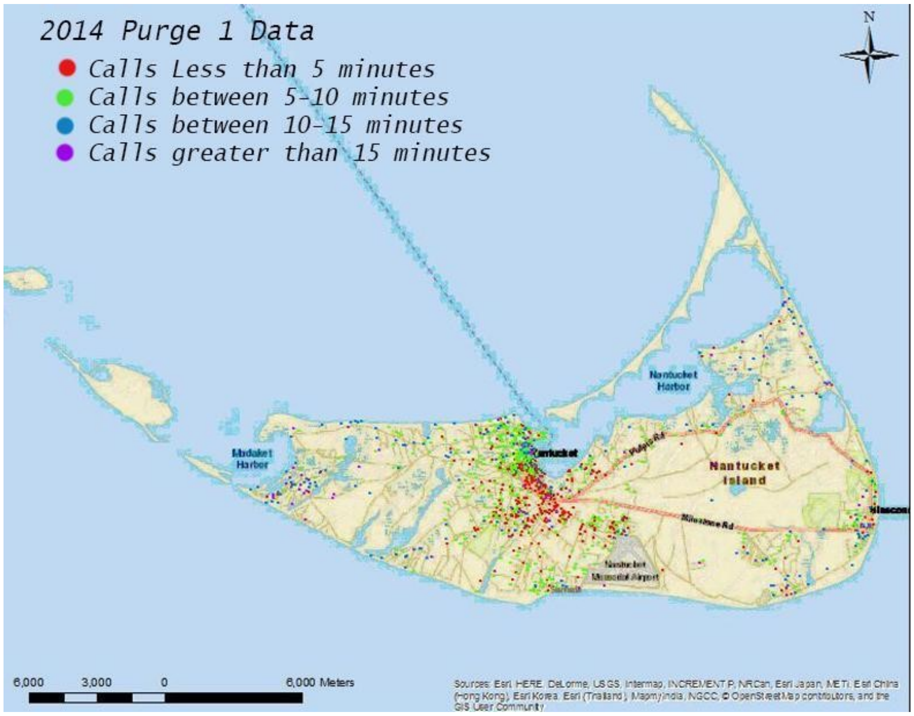

Figure F.1: 2014 Cleaned Data 1

The first round of cleaning deleted all 0's in the call data and anything above an hour response time at the airport or the hospital.

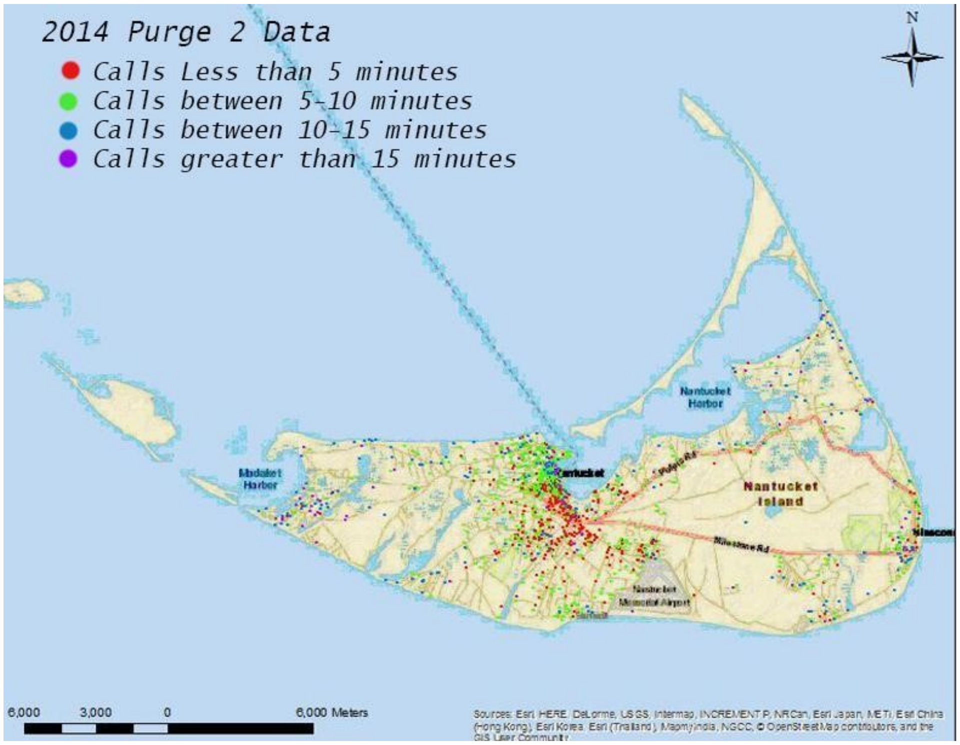

Figure F.2: 2014 Data without any 462 calls

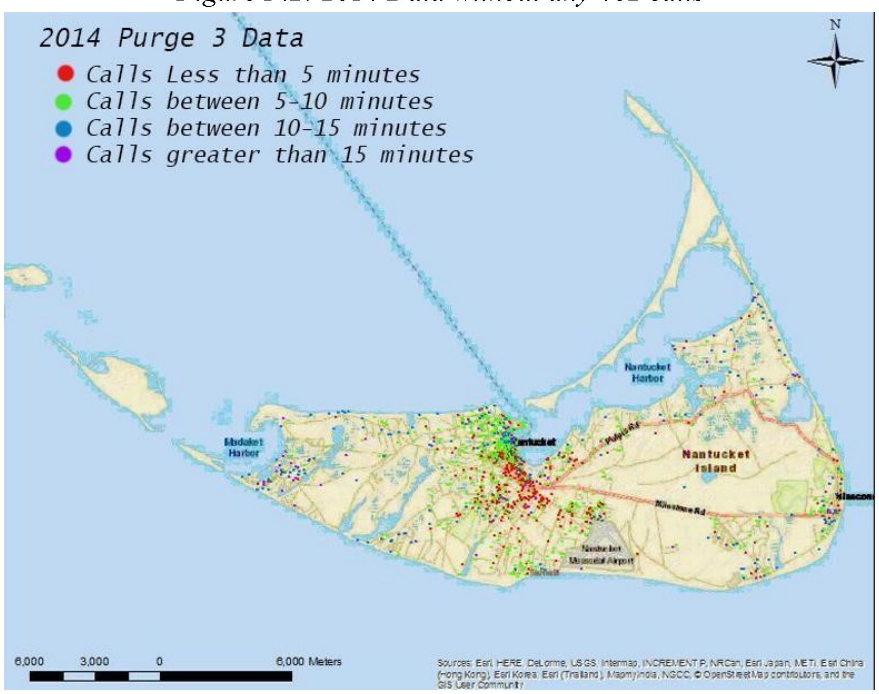

Figure F.3: 2014 Cleaned data 3

The third round of cleaning data excluded any response time above 30 mins and any response that was 1 minute that went to the hospital.

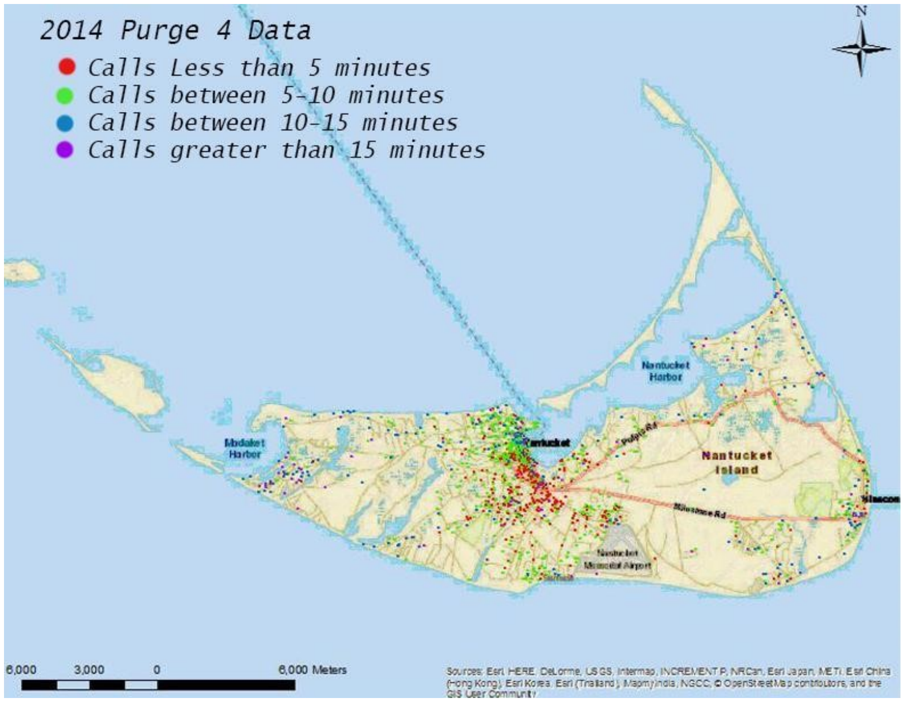

Figure F.4: 2014 Data Cleared of all 611, 900 and 911 calls

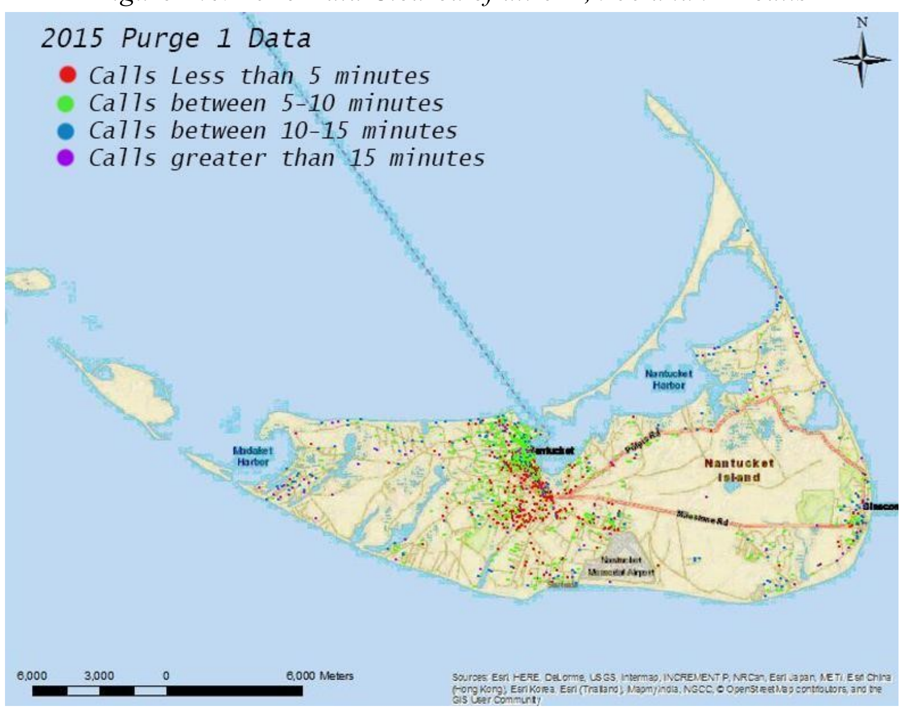

Figure F.5: 2015 Data Cleaned data 1

The first round of cleaning deleted all 0's in the call data and anything above an hour response time at the airport or the hospital.

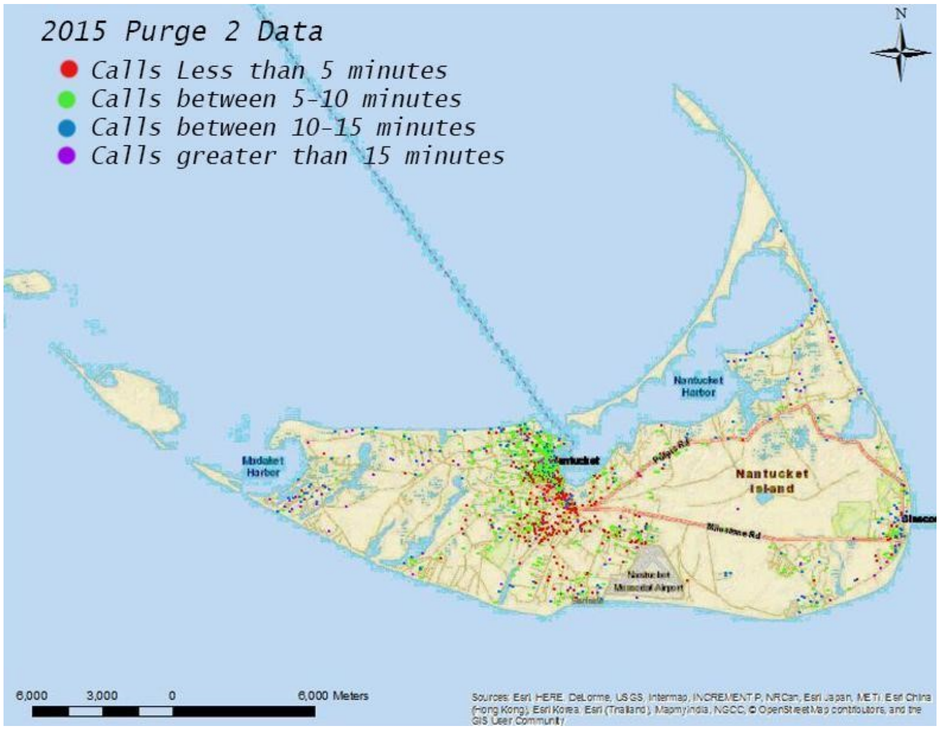

Figure F.6: 2015 Data without any 462 calls

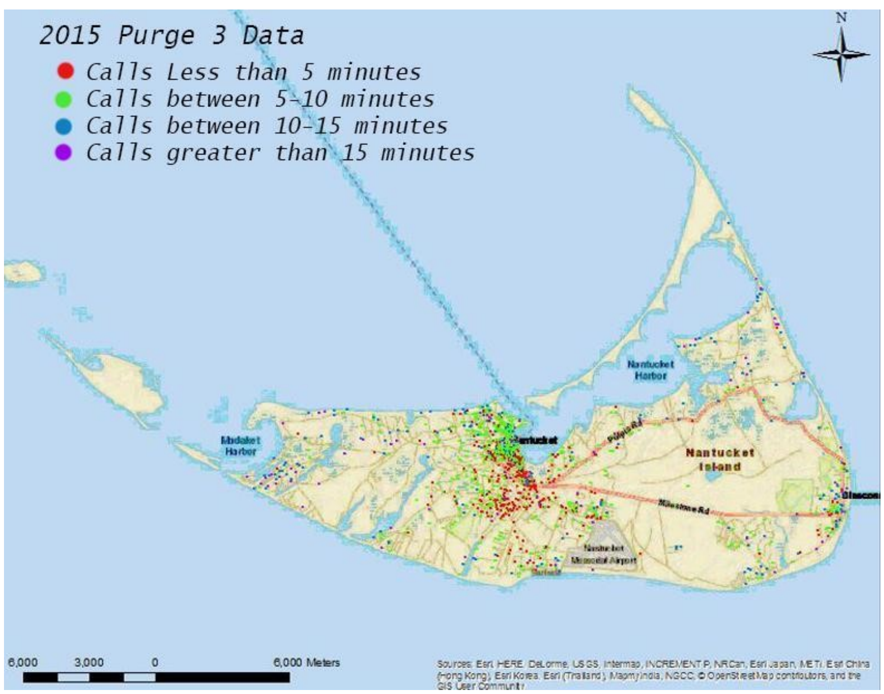

Figure F.7: 2015 Cleaned Data 3

The third round of cleaning data excluded any response time above 30 mins and any response that was 1 minute that went to the hospital.

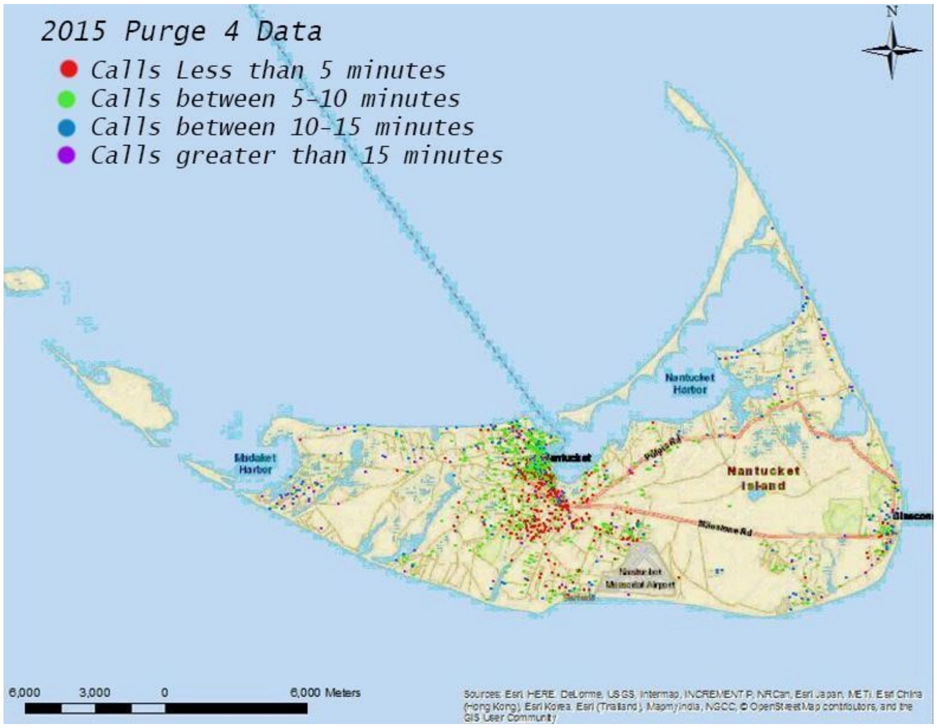

Figure F.8: 2015 Data Cleared of all 611, 900 and 911 calls

Appendix G: Simulation Data

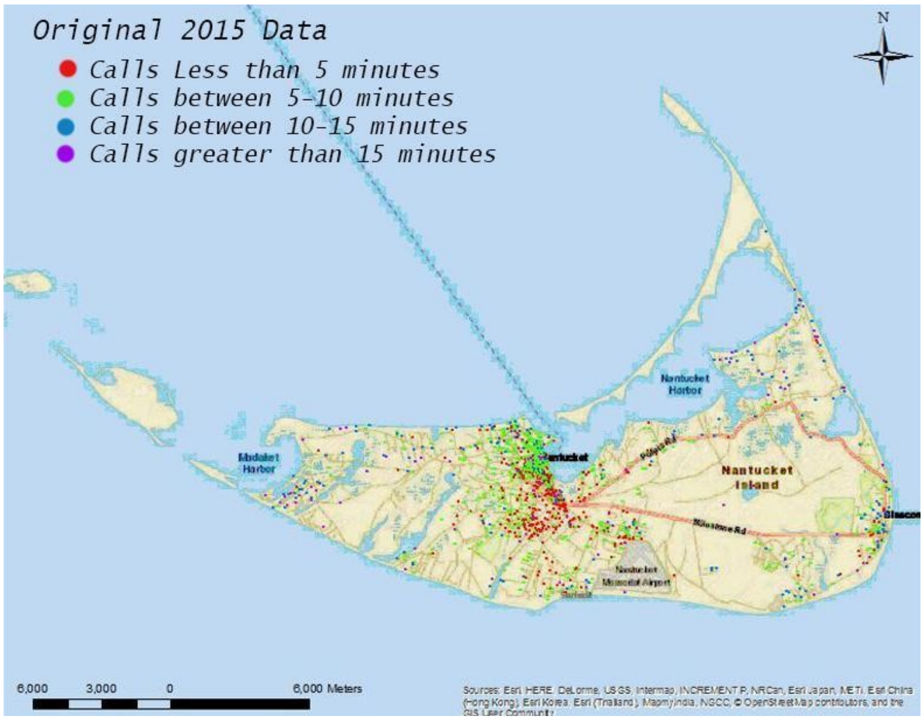

Figure G.1: 2015 Original Data

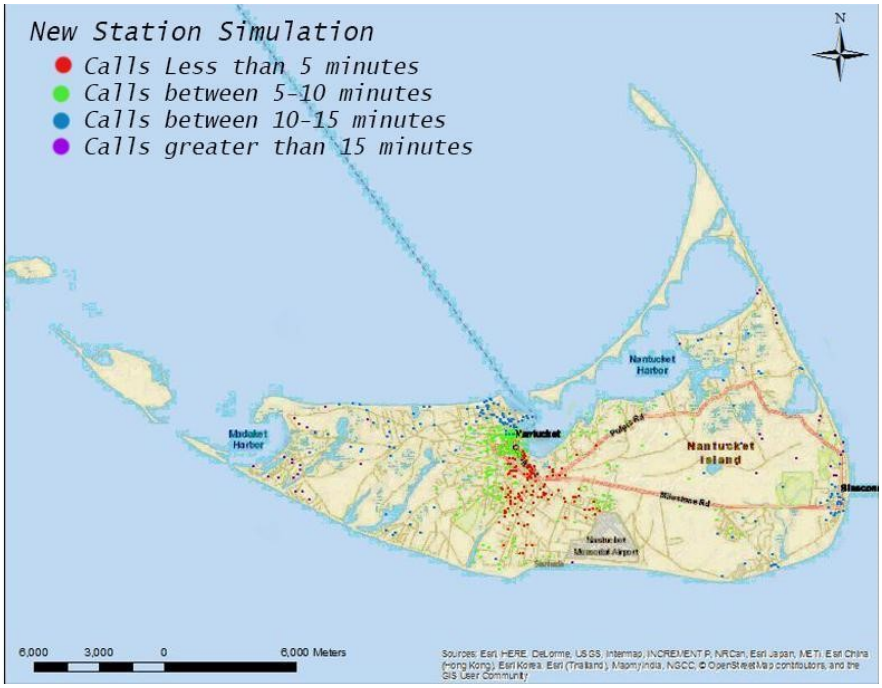

Figure G.2: 2015 Data if the New Station was used

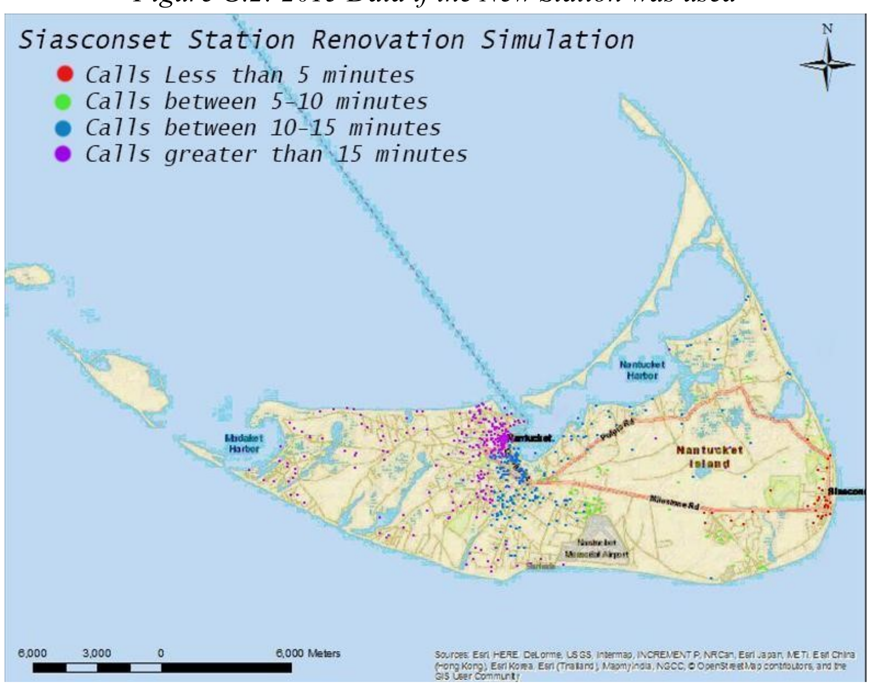

Figure G.3: 2015 Data if the Siasconset Station was renovated

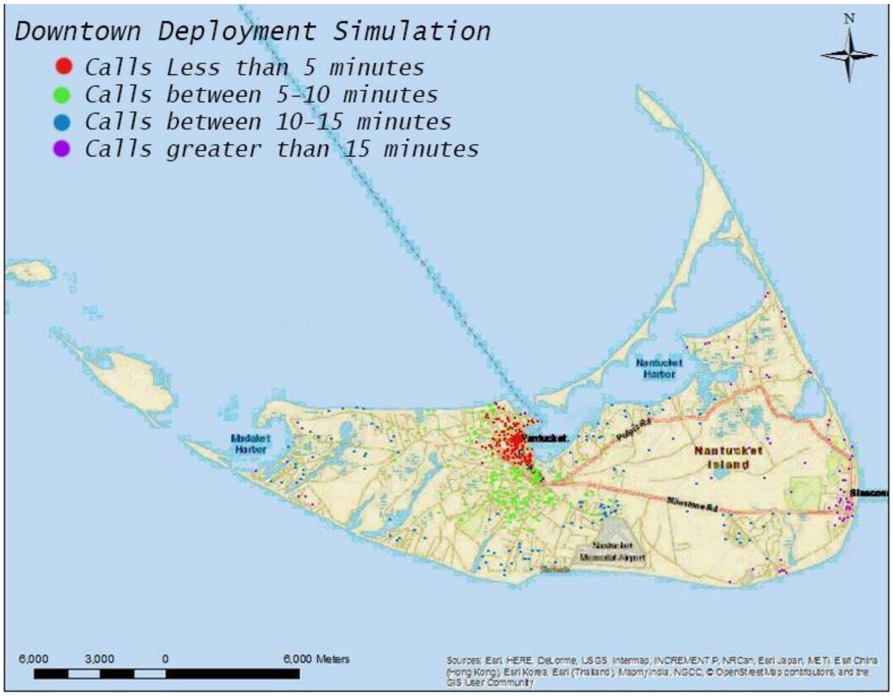

Figure G.4: 2015 Data if the Downtown dynamic deployment was added

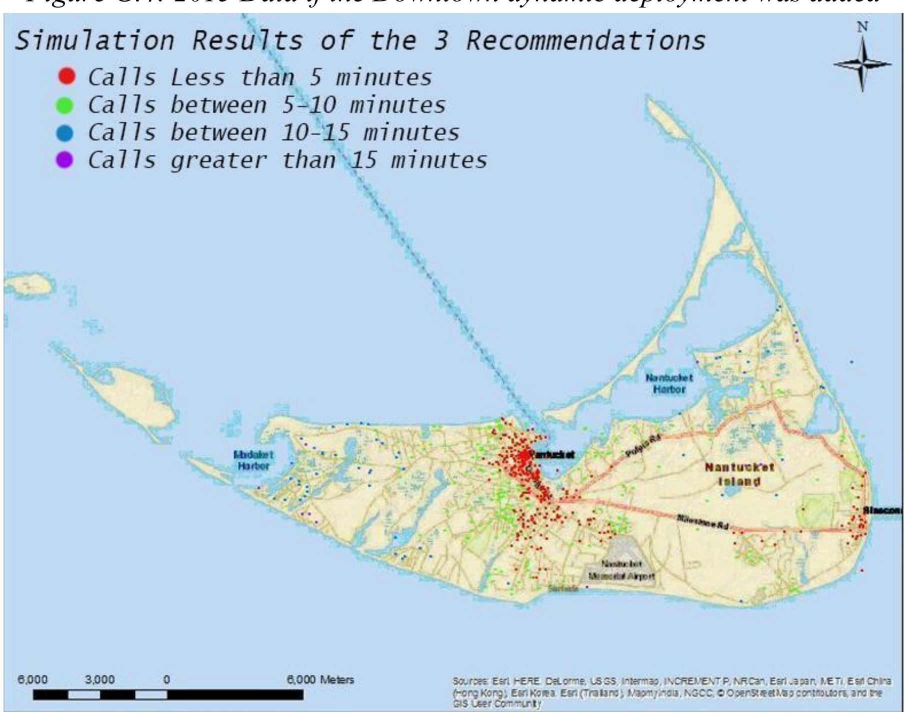

Figure G.5: 2015 Data if all recommendations were used