Air Pollution in Chapel Hill
Capstone Research and Policy Proposals

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Focus

This report is focused on a variety of policy and project proposals for the Town of Chapel Hill with the specific goal of reducing air pollution from vehicle traffic in the downtown area. In the figure below our study area is outlined along with an indication of high and low traffic areas. It is clear that there is a lot of vehicle traffic around Franklin and Rosemary, but why look into air quality? Cars, buses, and trucks that run on gas or diesel produce harmful emissions that can greatly affect human health. This study focuses on the reduction of PM$_{2.5}$ or fine particulate matter less than 2.5 micrometers in diameter. Adverse health effects can be seen at any concentration of this pollutant such as respiratory disease, lung cancer, cerebrovascular disease, and the worsening of asthma. Young people (under 18) and the elderly are considered to be sensitive populations to PM$_{2.5}$, and make up over 25% of Chapel Hill’s population. Also EPA data show that for over 55% of days in 2015, PM$_{2.5}$ was the main pollutant in the Durham-Chapel Hill area.

Three strategies for improving downtown air quality are proposed: improving traffic flow, reducing the sources of pollution, and absorbing existing pollution. All of the proposals contained in these three strategies also have a variety of added benefits that can be seen in Figure 1 on page 7.

Improving Traffic Flow

As the speed of vehicles increases (from 0 MPH up to about 55 MPH), PM$_{2.5}$ and other pollutant concentrations from vehicular emissions decrease exponentially. This is due to the vehicle spending less time in the area and efficiency gains in engine operation. Based on results from a numerical model called C-LINE, an increase in average speed from 5 MPH to 10 MPH resulted in a 31% drop in PM$_{2.5}$ emissions at locations in downtown Chapel Hill. With every 5 MPH increase after that, PM$_{2.5}$ drops 14%. Therefore the following proposals focus on increasing the average speed of cars downtown through improved traffic flow. This section contains proposals for Roundabouts, Mini-Roundabouts, One Way Streets, Smart Traffic Lights and Smart Parking.
Reducing Sources of Pollution

The EPA states that the most preferred way of environmental protection is source reduction. C-LINE results showed that for every 10 gas cars taken off the road, there is a 1% decrease in PM$_{2.5}$ concentrations. This section contains several proposals that will reduce Franklin Street AADT and improve the individual practices of those in vehicles to reduce emissions. These proposals focus on Electric Bus Technology, Electric Vehicle Campaigns, Bike Share Programs, Carpooling Incentives, and Eco-Driving/Anti-Idling Campaigns.

Absorbing Existing Pollution

It has been found that one of the possible solutions for reducing PM$_{2.5}$ concentrations in urban landscapes is increased vegetation cover (Chen, et al. 1). This report explores different means through which the Town of Chapel Hill could increase its downtown canopy cover and used the software developed using U.S. Forest Service data, iTree, to calculate their air quality and other benefits. A list of seven recommended tree species for the Town to plant in future Street Greening projects downtown is presented, along with a discussion of the development of Pocket Parks and the installation of Living Walls.

Conclusion

The report recommends a combination of proposals using all three different strategies in order to achieve a comprehensive approach to air quality improvement in downtown Chapel Hill. Sources for funding that correspond to each section can be found in the Project Finance section on page 44.
### Figure 1: Summary of Benefits for Each Proposal

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Introduction

What is the focus of this project?
Chapel Hill is a special town for the fact that it shapes, and is shaped by, a stream of young, diverse minds alongside permanent residents and community members. The effects from these interactions are widespread and beneficial. Franklin Street, the preeminent and picturesque heart of Chapel Hill, has the capacity to provide these benefits to every individual. The array of possible improvements to the area presented in the Downtown 2020 Work Plan, Downtown Imagined Plan, and Streetscape MasterPlan documents the Town's efforts to improve the health, safety, and vibrancy of the downtown area. This report attempts to work within the framework of these plans in order to ensure that air quality improvements are considered, reinforcing a space where everyone can be healthy and safe.

The EPA found in their 2014 National Emissions Inventory that 21.4% of PM$_{2.5}$ in Orange County, North Carolina comes from the mobile sector (“Air Emission”). In Chapel Hill, PM$_{2.5}$ was the primary pollutant of concern over 55% of the time in 2015 (“Air Quality”). Any level of exposure to PM$_{2.5}$ can be dangerous, with serious human health impacts arising at higher levels. For this reason, this study focused on reducing PM$_{2.5}$ in the areas surrounding Franklin Street and Rosemary Street. Many of the proposals have several, additional benefits outside of reducing air pollution and improving human health including helping the town reach its goal of reducing carbon emissions. They will also make the downtown a safer, more pedestrian-friendly and attractive destination by promoting community-building and improving general well-being. While the main objective is to make the air cleaner and safer for the residents of Chapel Hill, making Franklin Street a beautiful and lively space and promoting economic vitality to the businesses that make it so unique are also considered. All of these benefits have been grouped into the following categories: health and air quality; safety; cost savings; aesthetics; stormwater management; and economic vitality, and each proposal description mentions any appropriate benefit category(ies).

Through a combination of literature and case study reviews and original research, this report describes three basic strategies to reduce air pollution in downtown Chapel Hill: improving the flow of traffic, reducing the sources of pollution, and absorbing the existing and potential future pollution. A comprehensive and diverse portfolio of proposals for mitigating air pollution is offered under each of these strategies.
Health Impacts

Why does air pollution matter for Chapel Hill?
Air pollution is no longer an environmental concern confined to metropolitan areas such as Los Angeles and Beijing. The problems associated with poor air quality now affect small cities and suburban areas which rely on automobiles for transportation— including Chapel Hill. In the United States alone, approximately one half of all citizens live in areas that fail to meet federal air quality regulations (“Vehicles, Air Pollution, and Human Health”). In order to mitigate and solve these harmful impacts, it is important to recognize and fully understand the different pollutants which most adversely affect human health.

There are several types of emitted pollutants that are hazardous to human health:

- **Carbon monoxide (CO)** is produced through vehicle exhaust, and is fatal to humans in high enough quantities (“Carbon Monoxide (CO)”).
- **Nitrogen dioxide (NO2)** is released into the atmosphere primarily by the burning of fossil fuels, and is a major component in the formation of ozone (“Nitrogen Dioxide (NO2)”).
- **Ozone (O3)** is a pollutant formed when sunlight reacts with nitrogen oxides and volatile organic compounds. It is not emitted directly from any human source, but forms due to chemical reactions between emitted pollutants already in the atmosphere. High concentrations of ozone can cause respiratory irritation and chest pain, particularly for people with asthma (“Ground-level Ozone (O3)”).
- **Sulfur dioxide (SO2)** is released into the atmosphere through industrial processes and motor vehicle emissions, also exacerbating respiratory distress (“Sulfur Dioxide (SO2)”).

However, one of the most dangerous pollutants has been found to be particulate matter, or PM. PM is composed of a combination of small particles that often cannot be seen with the human eye, and are released through a variety of processes (“Particles”). This includes things like dust, dirt, soot, sand, and smoke, many of which have a high propensity for reacting with other pollutants. There are two classes of PM based on the size of the particle released. PM_{10} is considered “coarse” and refers to particles that are 2.5-10 micrometers in diameter. PM_{2.5} is considered “fine” and refers to particles that are less than 2.5 micrometers in diameter. For reference, the diameter of a human hair is 70 micrometers—hundreds of times larger than the smallest PM.
Transportation is a primary source of PM$_{2.5}$ (see Figure 2), and in Chapel Hill, PM$_{2.5}$ is the primary pollutant on 55% of days where air pollution was recorded (Zheng, “Air Quality Index Report Chapel Hill”). According to the 2010 US Census, 17.4% of Chapel Hill’s population is 18 and younger, and 9.2% of Chapel Hill’s population is over the age of 65. Thus, a total of 26.6% of Chapel Hill, over a quarter of the population, is in a sensitive group (US Census Bureau). Figure 3 on the next page visualizes this population. This represents a significant minority of the population that is unusually susceptible to worsening air pollution, particularly for PM. Thus, it is very important that all air pollution concerns be addressed quickly, in order to make the town, and Franklin Street, a more livable, family friendly environment.

Due to the relevance of PM$_{2.5}$ in Chapel Hill, as well as its severe health effects, it is the main pollutant that is discussed in each of our policy proposals. Most proposals that reduce PM$_{2.5}$ also aid in reducing other dangerous air pollutants as well. This is important to recognize, because it presents the breadth of impact from which any proposals can mitigate not just one source, but many sources of air pollution, and, in the process, make downtown Chapel Hill a cleaner and more healthy destination for everyone.
**Figure 2**

**SOURCES OF PM$_{2.5}$**

(ZHENG)

- Diesel/Gasoline Exhaust and Paved Road Exhaust: 33%
- Other Sources: 67%

**Figure 3**

**Population of Chapel Hill [%]**

(US Census Bureau)

- Under 5 years
- 10 to 14 years
- 20 to 24 years
- 30 to 34 years
- 40 to 44 years
- 50 to 54 years
- 60 to 64 years
- 70 to 74 years
- 80 to 84 years

Population of Chapel Hill (%)

Under 5 years: 0
10 to 14 years: 5
20 to 24 years: 10
30 to 34 years: 15
40 to 44 years: 20
50 to 54 years: 25
Improving Traffic Flow

How can cars move more efficiently on Franklin St.?
The health of both the people of Chapel Hill and the surrounding environment are vitally important to the success of the Town. There are several ways in which air quality, and therefore health, can be improved. One of the major sources of pollution comes from the cars and buses traveling through the downtown area. With traffic and increased idling times due to parking issues, the flow of traffic is of particular concern. This section focuses on the how to reduce levels of PM$_{2.5}$ with improvements to the traffic flow. The policies suggested include roundabouts, implementation of one-way streets, smart traffic lights, and smart parking systems. The specific effects on emissions were analyzed and calculated by using the web-based modeling tool C-LINE, developed by the UNC Institute for the Environment with funding from the US EPA, to model concentrations of air pollution from roadways in downtown Chapel Hill.
Roundabouts

Traditional Roundabouts

A modern roundabout is a circular intersection where drivers travel counterclockwise around a center island, traditionally.

Mini-Roundabouts

Mini roundabouts have a traversable middle island so that buses and large trucks can both drive straight across and make wide turns. Using a mini roundabout instead would still allow for both large trucks and emergency vehicles to move through the intersection while still benefiting from the increased flow in traffic. This type of roundabout can often be developed to fit within the existing right of way, therefore there would be no need for reconstruction of sidewalks, walkways, etc. within the area. The overall estimated cost for an installation consisting entirely of pavement markings and signage is $50,000, which is significantly less than both traffic signal intersections and full-sized roundabout intersections (“Intersection Safety Roundabouts”).

Figure 4 Before and After Roundabout (“Intersection Cost”)

Figure 5 Statistics for Benefits of Roundabouts (Doctor)
Why are roundabouts better than intersections?

Business-Friendly

Increased Revenues • In many cases, it was found that businesses along a corridor near a roundabout experienced increased business and sales. One case study in Golden, Colorado observed a 60% increase in sales tax revenue along a business corridor next to a newly installed roundabout intersection (Doctor). This could have major beneficial outcomes for the several businesses around the intersection of Franklin and North Columbia.

Safety

Crash Reduction • Rather than an intersection where cars have the potential of crashing into one another perpendicularly, the flow of traffic within the circular nature of roundabouts removes the potential of high angled collisions. For North Carolina, crashes of all types were reduced by almost half in the areas in which roundabouts replaced an existing traffic light intersection (“Your Guide”).

Better Speeds • Speeds through intersections with roundabouts are slower and more even when compared to those that incorporate traffic lights (Doctor). This allows for more reaction time and “beating” the light—speeding up quickly to catch a changing light.

Helps Sensitive Populations • The older the driver is, the more likely they are to experience a serious crash at an intersection. 35 to 40 percent of pedestrian deaths of people aged 65+ occur at intersections (Doctor), and older drivers are two times as likely to be killed while driving through an intersection than younger drivers (Doctor). Removing the intersection altogether would increase the safety for this vulnerable population.

Lower Cost

Longer Life • According to several case studies, the service life of a roundabout compared to that of a traffic light is not only longer but cheaper as well.

Crash Reduction • The reduction of both minor and fatal crashes had huge cost-benefits that can be directly linked to the implementation of a roundabout. A study from the Maryland State Highway Association indicated that for every dollar spent, taking into account the 20-year service life of a roundabout, there was a return of approximately $13 through crash reduction (“Intersection Safety”).

Less Traffic • The decrease in vehicle stoppage from a roundabout can be monetarily calculated. As stated by the 2012 Texas Transportation Institute’s Urban Mobility report, the cost per vehicle-hour delay is $16.79 (“Intersection Cost Comparison”). With the increased efficiency provided by roundabouts, this can reap huge savings.

No Hardware • The elimination of hardware, maintenance, and electrical costs associated with traffic signals can save between $5,000 and $10,000 per year (“Roundabout Benefits”). The cost of retiming traffic signals at an intersection has a default value of $5,000 per year and annual signal maintenance costs around $3,750 per year (“Intersection Cost Comparison”). These costs would be completely eliminated with the use of a roundabout.

Project Value • Overall, the net present value of a roundabout after 30 years is estimated at $2.34 million while that of a traffic signal is calculated to be $2.94 million (“Intersection Cost Comparison”). This translates to a savings of $600,000 in favor of roundabouts over the course of their estimated lifetime.

Emissions Reduction

Less Toxins – Because of reduced traffic, an average decrease of 29 percent was found for carbon monoxide, 21 percent for nitrogen oxides, and a 28 percent decrease for overall fuel consumption (Varhelyi). Based on an annual average daily traffic (AADT) of 23,500 vehicles, these reductions translate to 23.5 kilograms of carbon monoxide, 1.9 kilograms of nitrogen oxides and 144.6 kilograms of fuel reduced and saved per year (Varhelyi).

Signals Pollute • Intersections may actually generate more emissions when compared to roundabouts. Mustafa et al. (1990) found that intersections with a traffic signal generate about 50% more emissions than a roundabout. This is especially exacerbated during heavy traffic, which causes more emissions of hydrocarbons, nearly doubling that of roundabouts (Mustafa).

Positive Public Opinion

Changing Perceptions • The benefits of implementing roundabouts are recognized and appreciated by the communities where they exist. In many cases, public opinion changed dramatically before and after the roundabouts were built. In an LSU study, 31% of those surveyed were in favor of constructing a roundabout, while 41% were opposed. However, after the roundabouts were put in place, 63% were in favor and only 15% of the public were opposed (Doctor). This shows that the public benefits were not just theoretical, but rather recognizable and widespread.

Pedestrian-Friendly

Improved Walkways • Since roundabouts can process traffic quicker, fewer lanes are needed leading up to the intersection. This could allow the pedestrian area on Franklin Street to widen dramatically. A wider pedestrian walkway provides businesses and pedestrians with more space for economic activity, such as increased dining areas and advertising and marketing spaces.
Roundabouts

In Chapel Hill...

To apply the benefits of roundabouts to Chapel Hill itself, two scenarios of implementation were chosen. The location for both of these options are shown on Figure 6 on the next page. Once the scenarios were chosen, then the health impacts of each roundabout were modeled.

Option 1

For this design, a roundabout would replace the intersection of Franklin Street and Columbia Street. This particular intersection moves a high volume of traffic every day, and would benefit the most from having a roundabout in place instead of a traditional traffic light setup.

The specific effects on emissions were analyzed and calculated by using the web-based modeling tool C-LINE. More information about C-LINE and the methodology used can be found in the Appendix on page 49. The first roundabout scenario measured reductions in PM$_{2.5}$ at three different markers close to the Franklin St. and Columbia St. intersection. The PM$_{2.5}$ concentrations were modeled at three different markers along Franklin Street that experience varying levels of emissions.

- The first marker was the University Baptist Church, right at the intersection of Franklin Street and North Columbia Street. After running the simulations, the percent reductions were calculated for both summer and winter. There was a 29% reduction seen for the winter months and a 10% reduction for the summer at this location. This large reduction is mainly due to the higher speeds expected to result with the use of a full-sized roundabout at the Franklin St. and Columbia St. intersection.

- The second marker used was the area around TRU Deli, at the corner of Henderson Street and East Rosemary Street. There was a 0.20% reduction calculated for the winter period and a surprising 35% jump in emissions during the summer, likely due to differences in meteorological conditions.

- The third and final marker was placed at the bus stop near the Franklin Street intersection on North Columbia. After adjusting speeds, a 0.27% reduction was seen for the winter period and a 19% decrease during the summer months. The trend here was the reduction in PM$_{2.5}$ emissions due to the increased speeds.

Replacing a traffic light intersection with a roundabout increases the overall efficiency of both the intersection itself and the vehicles utilizing the space. This translates to both money saved for the individual and an improvement in the air quality of the surrounding area due to decreases in potentially harmful emissions.
Option 2

As an alternative to one roundabout, four mini-roundabouts can help mitigate traffic at the proposed locations on Figure 6. These mini-roundabouts would likely require less construction costs than a full roundabout would.

C-LINE was also used to estimate air quality changes from the proposed mini roundabouts. The same three markers used in the first simulation were also used for this model.

- For the first church marker, the adjusted speeds resulted in a 30% decrease of PM$_{2.5}$ concentrations in the winter and a 11% decrease in the summer.
- Once again, the numbers for the marker at the intersection of Rosemary and Henderson were slightly different than the rest, showing a decrease of 15% during the winter and a 14% increase during the summer.
- The final bus stop marker showed very high rates of decreased pollution with the higher speeds. A 30% decrease was modelled for the winter months and a 16% decrease was modelled for the summer.

Again, these numbers support the fact that increased speeds will decrease the amount of pollution at most locations.

Figure 6  Proposition for Roundabouts
One-Way Streets

Although it may not seem like it, one way streets reap much greater benefits for towns that two-way streets. Yes they can be occasionally confusing for cars, but they improve air emissions, pedestrian lives, etc. Based on the benefits of one-way streets in comparison with two-way, the Town of Chapel Hill should embrace this city planning technique.

One way streets are another tool that city planners and people of the community can support in order to alleviate issues of air quality and air pollution. For the purpose of this section, the focus is on turning Franklin Street and Rosemary Street into two, one-way streets in order to aid in the mitigation of traffic congestion and idling times. This will be put into context throughout the sections to follow, as the benefits and logistics of using one way streets are explained.

Safety

The utilization of one way streets in areas that experience both heavy vehicle traffic as well as pedestrians can result in an increase in safety for both drivers and walkers. The main reasoning behind the decline in both pedestrian and vehicle accidents hinges upon the fact that one only has to look one way for oncoming traffic when one-way streets are used (“Should Cities Convert”). This simple fact makes it much safer for people who are crossing the street, especially if they are jaywalking.

• There are several case studies that illustrate these findings. For example, the town of Englewood Cliffs in New Jersey experienced a 38% decrease in vehicle accidents when the city converted some of its two-way streets into one ways (“No Two Ways About It”).

• In a recent review of a two-way to one-way conversion in Raleigh, a 50% drop in pedestrian accidents was found (“Should Cities Convert”). This same study refers to one way streets as “the most effective urban counter measure to pedestrian accidents” (Research Triangle Institute for the USDOT).

Efficiency

In addition to increased safety, one-way streets can provide drivers with improved efficiency during their trip.

• One-ways have proven to permit higher average speeds without raising the speed limit of the road (“One Way Street Systems”). This is because less stop and go traffic allows cars to go the desired speed limit for a longer period of time, instead of having to wait in long lines of traffic while someone tries to make a turn. Converting two-way streets to one-way led to a 19% increase in traffic, averaging 37% faster speeds (“No Two Ways About It”). The speed limit on the one-way streets was not any greater than the two-way streets, but rather the drivers experiences 60% fewer stops.

• Higher average speed from one-ways means fewer emissions, which then translates to improved air quality within the area (“One Way Street Systems”). There are several case studies in which this link to one-way streets and lowered emissions has been found. Planners in Austin, Texas found that converting one-way streets to two-way streets increased the traffic delay by 23% and air pollution in the downtown area by 10-13% (“Should Cities Convert”).

Cost

The conversion of one-way streets to two-way has not been found to be significantly more than keeping as is.

• Electric and maintenance cost of traffic light signals are generally calculated to be around $8,000 per signal per year. Switching to one-way streets would eliminate signals at intersections, therefore saving money (“Traffic Signals”).

• The cost of converting a one-way intersection to a two-way is estimated at $150,000, so it is assumed that converting it to a one-way would cost no more than this, and would likely cost significantly less (“Intersection Cost Comparison”).
In Chapel Hill...

A vision of Chapel Hill with one-way streets is proposed in Figure 7, where Rosemary St. is set up as westbound and Franklin St. as eastbound. This setup can remediate traffic congestion and decrease air pollution; some of the lanes can even be used as bike lanes or widened pedestrian walkways.

However, one way streets can seem confusing to new visitors to Chapel Hill. The networks of one-ways in larger cities are often unintelligible and difficult to navigate. In contrast, Chapel Hill will not be a network, but rather a single couplet. Navigating would not become any more confusing. If a car were to miss a turn, there are a number of roads that can be taken to redirect onto the original route.

Figure 7 One-Way Proposition
Smart Traffic Lights

Another technology that should be considered are smart traffic lights. These are designed to be incredibly efficient and sensitive to traffic trends, in order to create a faster flow of traffic for everyone on the roads. One version of this technology uses a network of sensors and cameras to monitor traffic in real time. In addition to this, these systems then have a computer that optimizes the traffic signals at each intersection based on data gathered from the sensors (Keith). An alternative technology utilizes the vehicles on the street as well to collect data. This is done by equipping the vehicles with “IntelliDrive” hardware that gathers data from the car, such as the location and speed, and sends it to the network of traffic lights (“Next Generation Traffic Signals”). This data is then used to create optimal timing of the traffic lights to ensure faster travel for those on the roads. The major obstacle to this type of technology is the actual implementation, as it would be difficult to install proper technology into every vehicle to really make it worthwhile. Another obstacle this particular system faces is the bias towards vehicles, without being able to take into account bicycles and pedestrians.

Benefits of Smart Traffic Lights

Traffic Reduction
Smart traffic lights encourage an improvement in the flow of traffic, and the overall efficiency of the cars is increased since drivers get to their destinations faster. There are several studies that showcase these findings. Pittsburgh installed nine smart traffic lights in 2012 that showed significant improvement in idling times and emissions (Okonkwo and Gong). The signals used employed a software known as SURTRAC (Scalable Urban Traffic Control). This study claims that travel times reduced by 26% due to the added sensitivity of the traffic signals, idling time was reduced by 41%, and overall vehicle emissions were reduced by 21% (Okonkwo and Gong). Additionally, the study showed that vehicles made 30% fewer stops along their route with the applied technology in place. the Community Development Block Grant Program.

Cost-Effectiveness
As opposed to the roundabouts or one-way street solutions, the smart traffic lights can be installed one at a time instead of having to do a large, all encompassing project that costs the town large amounts of money. Signals can instead be installed one at a time, and efficiency of the system gradually improves as more of the lights are integrated into the overall system (Barry). This gradually improves the efficiency of the light system while still maintaining a budget that the town could afford. Being able to slowly implement this new technology saves money through reduced delay. Generally speaking, providing intersections with smart traffic light technologies costs around $20,000 per intersection (Ononkwo and Gong). While this is a relatively sizable amount of money to put down, costs of the technology decreases as more intersection are fitted with the software. There is potential for government grants that could at least partially fund the process of replacing current lights with smart traffic light technologies.
In Chapel Hill...

To implement more smart traffic lights in Chapel Hill (as shown by Figure 8), it is suggested to add this technology in phases. This allows for much easier financing on the part of the town. If there isn’t money to retrofit several intersections at one time, it can instead be done as little as one or two at a time (see Figure 9 for recommendation).

**Figure 8** Diagram of Smart Traffic Light (Damra)

**Figure 9** Proposed Phases of Smart Traffic Light Implementation
Smart Parking

Smart parking is a tool used by cities to increase overall efficiency of traffic, which helps decongest the streets and improve the air quality in the area. This can be very useful for Franklin street; it is often blocked by cars searching for parking spots and parallel parking. While there are several parking garages and lots near the downtown area, many people do not know which lot has empty spaces. According to a national study, drivers spend 20 minutes looking for a parking spot on average in urban environments (Galligan and Jensen-Lamka). Additionally, around 30% of urban traffic is caused by drivers searching for parking and around 60% of drivers admit to abandoning their search for parking altogether at least once in their driving career (Shoup 2005 and 2011, Galligan and Jensen-Lamka). These delays and wasted time, not to mention fuel, can cost a city like San Francisco an average of $600 million per year (Frost and Sullivan, qtd. in “INRIX On-Street Parking”). This translates to enormous amounts of greenhouse gases and particulate matter being emitted into the air by cars that are idling or searching for a spot to park.

This is where smart parking comes in, and there are several different ways in which this can be done. Parking guidance systems with real time or predictive information can be used by individuals to quickly assess a parking situation and find the best possible location for them. There are two main types of smart parking technology. Parking garages (and parking meters on the street) can be outfitted with sensor technology that can detect the number of vehicles entering and leaving the garage, which can be used to determine how occupied the lot is (“Parking Garage Data Guide”). Additionally, on-street parking spaces can have sensor technology installed into the pavement which detects the car in the space. This technology is also linked to the internet and can also provide users information about how many parking spaces are being filled on a given street (“The Specifics”). However, sensing devices installed directly into pavement is extraordinarily expensive, so this proposal will focus primarily on outfitting parking garages and street meters with sensor technology based on car entry and exit or ticketing.

Benefits

Smart parking makes finding and paying for parking faster and easier. Demand-responsive pricing information online, via text, and through smartphone apps helps drivers find a space. Longer time limits and new meters that accept credit/debit cards and coins make parking more convenient and result in fewer parking tickets. On top of this, decreasing the number of drivers circling and double-parking will help keep roads clear so Chapel Hill public transit and emergency vehicles can get through streets faster and more reliably. Drivers looking for parking are frequently distracted and fail to see bicyclists and pedestrians. Less double-parking and circling means fewer accidents and safer roads. With parking faster to find and pay for, it’s easier to enjoy the commercial areas. Less congested, safer and more pleasant neighborhoods mean better business. Plus, with less smog and greenhouse gas, air pollution could be reduced significantly, resulting in improved health for the people in the surrounding areas. In short, smart parking would make Chapel Hill more accessible while improving safety and the local environment.
Technology and Data Behind Smart Parking

Sensor data can be shown at the entrance of a parking garage or be linked to a website or app that people can access before and during their trip. This helps drivers get to parking areas more quickly, therefore getting them off the road and relieving a portion of the congestion (Fabusuyi et al. 2013). Sensor data can serve a variety of purposes, including helping drivers find nearby spaces through in-car guidance apps, guiding law enforcement officers to parking violations, and aiding policy decision-making. This particular method is used in San Francisco. Cars roll over a “loop counter” (which is essentially a metal detector) which engages a ticket machine. Hourly parkers press a button for a ticket upon entry, or insert a ticket upon exit, and monthly parkers scan their card. The counter registers the car as being in the lot, and registers it leaving upon exit. This data is linked to the internet, which can be displayed in an app for users to see. Pricing and routes to the lot are also given in-app, allowing people to get to parking places faster (“Parking Garage Data Guide”).

In Chapel Hill...

The Town of Chapel Hill could potentially benefit from Smart Parking technology by decreasing the amount of time drivers spend looking for a spot. Equipping parking decks as well as town parking meters with sensing equipment would assist with this overall decrease in idling times. Utilizing a roll over “loop counter” is a particularly promising solution that the town could implement. This “loop counter” is essentially a metal detector that engages a ticket machine in order to count the number of cars entering the parking deck. This information could then be linked to a website or phone application (see Figure 10) to show users where there is parking available. The detector would also be able to detect the car leaving upon exit, assisting with the flow of traffic in and out of the parking decks. Additionally, the parking meters in the downtown area could be linked with a website or application, as previously mentioned, that would show where open parking spots were available. This could be done with sensing technology or just by retrofitting the ticket machines to relay information to a network. This results in the reduction of traffic levels which, in turn, leads to emissions reductions. This decrease in number of cars on the road searching for parking could assist the town in its goal to higher air quality in the downtown area.

Figure 10 Phone Application for Parking (“Apps”)
Reducing Sources of Pollution

How can the car population decrease?
There are a variety of methods that can reduce air pollution in a region by cutting vehicle emissions, and reducing the number of vehicles on the road is the most obvious way of doing this. Modeling work done through C-Line has found that for most roads, removing 100 gas cars from the road per day reduces PM$_{2.5}$ concentration by 1%. All streets in Chapel Hill would see a significant improvement in local air quality merely by reducing the number of vehicles on the road. Thus large reductions in emissions can be obtained by relatively minor steps. Commuters and visitors can be incentivized to ride electric buses, drive electric vehicles, take a bike to work, or carpool. Alternatively, they can be taught how to drive their current vehicles in a more efficient manner in order to conserve fuel and reduce emissions, a practice known as eco-driving.

Any of these suggestions, or more ideally, a combination of them, can be used to reduce pollutant emissions in Chapel Hill as well as traffic and gridlock. Fewer cars on the road would also increase the amount of available parking and make Chapel Hill more accessible to visitors and tourists who can better enjoy all the city and Franklin Street have to offer.
Bike Share

Bike share programs are defined by a dense network of bike stations where users can swipe a share-card or chip to access a bike. They can then return the bike to another bike station within this network once they are done using it. The network is typically composed of stations that are 300 meters apart from each other (Gauthier et al.). The density of the bike stations is crucial—in Montreal, people were 3.2 times more likely to use the program if docking stations were within 500 meters of their location (Kille 2015). This makes it an ideal and simple way to reduce motor vehicle use in downtown Chapel Hill.

In the past, the Town of Chapel Hill experimented with a similar bike-share system with limited success, largely due to an inability to require and enforce the return of bikes to their proper docking stations. However, newer and more advanced systems discourage theft and misuse through multiple methods such as active registration, small deposits, and wireless tracking systems. A bike station would also have a fully automated locking system to keep the bikes from being stolen (Gauthier et al.). Real time monitoring of the bike station and occupancy rates can help users stay aware of when bikes are available and where, and also helps ensure that bikes are not missing. Because of these implementations, the bike share system can be safe and effective. It is an easy way to encourage public transportation and improve health while still being quick, simple, and straightforward for the busy residents of Chapel Hill.

**Benefits of Bike Share** (Kisner)

- 50% reduction in risk of heart disease from 3 hours per week
- 43% of bike share rides took place of car trips
- $7 produced in local spending for every bike share trip

**Figure 11**

- Increased physical activity **improves human health** and allows for 75 deaths to be avoided for every one death that occurs due to crashes with vehicles or exposure to car exhaust, according to a study based on the Barcelona bike share system in 2011 (Kille 2015).
- There is a **massive reduction in emissions**—the same program in Barcelona was found to reduce nine million kilograms of CO2 per year (Kille 2011).
- **Traffic congestion decreases**, which is critical for Chapel Hill—a city which faces a lot of traffic gridlock every afternoon on Franklin Street.
- The need for new hardware and software in order to effectively run and maintain a bike share is believed to have the potential to bring about development of new products and services, **spurring the local economy** encouraging local technological growth (Hamilton et al.).
- Programs already implemented are seeing an increase in users—indicating that these programs will **continue to grow** and reap benefits both for the environment, human health, and the town’s community in the years after it is implemented.
Cities love bikes!

Many cities around the country have launched similar programs with great success.

Minneapolis
With 700 bikes and 65 stations, the program runs from April to November. 89% of riders reported using Nice Ride for transportation, not just recreation. In fact, 4.3% of workers bike to and from work now. Minnesota’s bike share program was developed through a combination of funding from public and private sources.

Denver
43% of bike rides took the place of car trips, reducing 313,000 lbs of CO2 per year. Members can even use the B-Cycle website to track things such as their ride history, calories burned, and carbon emissions reduced (Kisner).

In Chapel Hill...

Mission Alignment with the town
A bike share program in Chapel Hill aligns well with the Town’s bike plan and 2020 plan by supporting an entrepreneurial atmosphere, as well as creating “bikeable connections” with downtown and the surrounding areas, connecting the town with varying spaces and encouraging people to travel, work, and shop in different areas that may be too far away to walk to. In the Town’s bike plan, a variety of recommendations were included to help direct the process of creating a bike share. These include making a coordinator for the plan, conducting bicycle counts to determine current conditions, increasing coordination between town departments and supporting local advocacy groups, among other things (“The Chapel Hill Bike Plan”).

The Triangle as a Bicycling Hub
Other areas in the Triangle and beyond have similar programs. For instance, the UNC campus, Raleigh, and Charlotte all have other bike programs that can be used as a model and, in the case of the UNC campus, can even be tied into the nascent Chapel Hill bike program. And for Triangle cities, there are many ways to get a bike program off the ground. Raleigh received a 1.6 million dollar federal grant to fund its program, leaving less than $500,000 necessary in public funding to start the program and cover initial operating costs (Specht).

A Continuous Bicycle System
Carrboro is also exploring a bike share program. As of 2015, Carrboro was developing a parking management plan that included a recommendation for a bike share program. If UNC’s campus and Carrboro both have a bike share, the Town of Chapel Hill can include its own program to create a unified network. This could increase the total number of users and reduce the traffic in Chapel Hill even more than an isolated program.
Chapel Hill Transit is the second largest transportation system in North Carolina and covers over 160 square miles (Facts and Figures). The Town of Chapel Hill has identified a reduction in emissions by 20 pounds per day when individuals chose to travel by transit over individual car trips (Facts and Figures). With 98 fixed route vehicles annually covering over 2.5 million miles, this provides an excellent opportunity for reducing the town’s reliance on fossil fuels for transportation services (Facts and Figures). Electric power buses complement this goal by providing an identical method of transportation without the corresponding air pollution. These buses run on electricity, which eliminates the need for fuel burning to power the vehicle and thus the amount of pollution emitted. The system utilizes features such as electric motors, electric energy storage devices, electric controllers, and inverters to allow the bus to function purely or primarily on electrical power (Eudy and Gifford). In general, electrification has been found to reduce harmful ground level ozone, the primary ingredient of smog, by lowering emissions of compounds that react together to create ozone—nitrogen oxides (NOx) and volatile organic compounds (VOCs) (Tonachel).

Electric Bus Technology

Purely electric propulsion buses requires a relatively large electrochemical battery, which is used as the sole power source (Callaghan and Lynch). An electric traction motor (or several) provides power for propulsion and all accessory systems. Proterra, a startup in San Francisco, is working on new innovations for electric buses. Their model can go a full day with no charging. This saves $50,000 a year in diesel costs, and even more money is saved in maintenance costs. The bus can even charge in less than 30 minutes, fitting well into the rapid bus schedules of many major cities. However, the 35 foot Proterra model costs approximately $650,000 and the 40 foot Proterra model costs approximately $750,000 (“The Proterra Catalyst 40-Foot Transit Vehicle”). Although this is very expensive, they can be government subsidized, drastically improving the affordability of the vehicle (Eudy and Gifford). Electric buses can also be centrally located and charged, allowing for easier maintenance and scheduling, and have a greater tolerance for added weight. They also have less rigorous pull-out and start-up requirements. However, some issues exist with purely electrical vehicles. Storing the electricity effectively remains a challenge, and electrical errors could cause major problems for the vehicle (Eudy and Gifford).

Hybrid buses have a fuel-burning prime power source, which is typically an internal combustion engine (ICE), and couple it with an electrochemical or electrostatic energy storage device (Callaghan and Lynch). The two systems work together to provide energy for propulsion through an electric traction drive system. Power for all vehicle accessory systems can thus be provided for using either electrical power or mechanical power from the ICE, or it can be provided for using a mix of the two. Hybrid-electric propulsion technology is developing quickly. It allows for direct energy replacement capability in transit, as the energy storage system and ICE are designed in a way so that the batteries are never depleted, meaning the only cap on the range of the vehicle is the amount of fuel (Callaghan and Lynch). And although they are not purely electric, there are big mileage increases—hybrid buses have been found to have 20% better mileage than diesel buses (Thoms et al.). Additionally, they have 15-17% better fuel economy (Feldman et al.). However, there are very high maintenance costs to maintain such a complicated system, and one study found that hybrid buses actually increased NOx emissions, suggesting that not all pollutants will be reduced by redesigning the bus fleet (Barnitt). Hybrid buses are less expensive than purely electric buses. Costs can range anywhere from around $385,000 up to $450,000 (Barnitt; Eudy and Gifford).

Fuel cell buses convert chemical energy from a fuel source into electrical energy. The electrical energy produced by the fuel cell is used for propulsion and accessory systems via one or several electric traction motors. This can be used on its own as a power source, or can be used as the primary power source in a hybrid-electric system (Callaghan and Lynch). Many fuel cell vehicles use this configuration. Fuel cells have a lot of potential, but are still in an early stage of development (Callaghan and Lynch). In other cities around the country, hybrid and electric buses have begun to take off as an alternative mode of transit. In Durham, the “Bull City Connector” is a hybrid-electric bus service that charges no fares to its passengers. It runs from downtown Durham to Duke University, and allows movement of people between Durham’s major city centers while ensuring that such movement does not harm the environment (“Bull City Connector”). Charlottesville, Virginia, is going a step further by planning to have all its diesel buses replaced by hybrids by 2020 (Thoms et al.). The first two hybrids—which went into use in 2011—consume 7,000 less gallons of fuel per year, which saves the city $21,000 (“CAT Introduces Hybrid Buses to Charlottesville”).
**Electric buses for schools**

Electric buses can even be used in school districts. In the San Joaquin Valley in California, the Kings Canyon Unified School District has become one of the earliest adopters of multiple all-electric school buses, with the use of these buses beginning in 2014 (Tweed). Due to predictable routes for school buses, the battery’s limited range is less of an issue, and a schedule for charging can be developed so that the bus does not run out of power (Tweed). Although many states already have anti-idling laws that apply to school buses to reduce air pollution around children, exceptions are often made. For instance, in order for the bus to run heat or air conditioning, the bus must be powered on, so idling is permitted in these cases.

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**In Chapel Hill...**

**Create a Pilot Program**

In Chapel Hill, there is a large opportunity for integrating electric buses into the fleet. Though the fleet already has 14 hybrid buses out of 99 total, it has great room for growth and expansion towards its goal of providing safe and reliable transportation to the town (“Chapel Hill Transit Facts and Figures”). The fleet covers 160 square miles, with over 2.5 million miles per year and 7 million rides, speaking to the fact that adding even a few more all-electric or hybrid buses could have a big impact on the area’s long-term air quality.

Because of the long-term cost effectiveness of the Proterra buses mentioned before, adopting one of these vehicles as a pilot test is a step the Town of Chapel Hill can take to a fuel-free fleet.

**Charlottesville as a Funding Example**

For example, Charlottesville, Virginia now has a variety of alternative fuel vehicles in operation. This includes 23 hybrid-electric vehicles, three all-electric vehicles, two compressed natural gas (CNG) school buses, and several others that utilize fuels such as ethanol/gas blends and biodiesel, adding up to a total of 49 alternative fuel vehicles (“Alternatively Fueled Vehicles”). Providing this may seem prohibitively expensive, but Charlottesville received 3.7 million dollars in federal funds to get these buses. Some of the federal funding was paid for with money budgeted from the American Recovery and Reinvestment Act (ARRA), with other funds coming from more local sources (“City Receives $3.7M for Hybrid Buses, Transit Projects”). Charlottesville shows that ample federal and local funds are available to pay for significant portions of the upfront costs of purchasing electric buses. Funding ideas for getting an electric bus are mentioned in the Funding Section on page 44.
Eco-driving is a practice that encourages people to change their driving habits in order to reduce the emissions of their car. It is composed of two major categories: things you can do to maintain your vehicle before your trip that will reduce your emissions, and things you can do during your trip that will reduce your emissions. Drivers can also save money through fuel savings. Depending on what combination of practices a person uses, fuel savings can reach upwards of 40% (Wengraf). Eco-driving averages about 10% of fuel saved, but getting up to 30 miles per gallon instead of 20 miles per gallon saves the average driver about $990 dollars per year solely in fuel costs according to the NC Department of Transportation.

One of the main components of eco driving is reducing idling. Running an engine when the vehicle is stopped needlessly wastes 5-8% of fuel in the tank (Barkebus). While stop-start systems can help reduce this problem, drivers must learn to become more aware of how they are driving so that they can save money and reduce pollution, especially in places like schools, where idling in carpool lines is a serious problem for the children who go there. Avoiding idling is an important part of eco-driving, as drivers save in fuel and maintenance costs, extend the lifetime of their vehicle, and of course, reduce emissions. Anti-idling programs use three main methods to encourage better driving habits: technology, policies, and education.

**Before Driving**

- Performing regular vehicle maintenance.
- Checking tire pressure to avoid be wasting fuel just trying to get the car to move on low-pressure tires.
- Planning the trip route to allow the driver to avoid slowdowns in high traffic areas and to avoid getting lost, also saving fuel and money.
- Reducing the amount of weight in the car to reduce the car’s strain under a lot of unnecessary weight (Wengraf).

**During Driving**

- Below 40 miles per hour, it is more fuel efficient to just open a window; after 40 miles per hour, it is more fuel efficient to use the air conditioning.
- Drive at reasonable speeds, as driving too far below or too far above energy efficient speeds means a driver will waste more fuel.
- Turn off the engine if the car is going to be stopped for more than one minute (Wengraf).
- Reduce idling by purchasing stop-start systems and learning to become more aware driving habits (Barkebus).
Encouraging eco-driving also presents an opportunity for Chapel Hill to meet the goals of its Green Fleets policy, and with much less upfront cost. Section 4b of the Green Fleets Policy emphasizes that Chapel Hill should work to operate and maintain its current fleet in a manner that is energy efficient and reduces emissions (Horton). Eco-driving and anti-idling practices can be implemented in a variety of ways:

**Policy**

There are also a variety of policies that the Town of Chapel Hill can implement to reduce idling.

- In sensitive locations such as Franklin Street, idling is a big problem, especially for delivery trucks and buses that idle in the area for extended periods throughout the day. This is also a problem in schools in Chapel Hill. Fines can be implemented to discourage the practice.

- Incentives can be implemented to help people afford the costs of anti-idling technologies. This can include things like cash incentives or tax reductions.

**Technology**

Many promising devices are now on the market that can reduce idling.

- The Governor to Reduce Idle and Pollution (GRIP): turns the engine off after a set period of time but keeps the battery on. It costs $3,000, but saves $3,500 after the first year, easily paying itself back.

- Energy Xtreme: battery pack that automatically recharges when the car is running. This lets the driver turn the engine off and avoid idling. It allows for $3,000 worth of savings per year. The Dallas Police Department saves an estimated 72.75 lbs of CO2 emissions per vehicle per day.

- Scangauge: works with most cars produced after 1996 and acts as a real time vehicle monitor, providing drivers with information on fuel consumption, trip costs, carbon dioxide emissions, and much other useful information (“Scangauge E”). It allows for 10% of savings in fuel economy and can be purchased individually for about $150.

**Education**

One of the most crucial ways to encourage eco-driving is through education (Ryan).

- This can include information flyers, or utilizing events such as Earth Day celebrations to include information as part of the celebration and activities.

- Training at motor shows can also teach people how to use vehicles in an environmentally-friendly way (Wengraf). In fact, there are many professional training associations that work to promote these goals, and they can collaborate with school-based driver education programs to teach people when the information is most likely to stick: when they learn how to drive.

There are many existing programs that the Town can use as a model, such as the EPA’s Idle Free Schools Toolkit.
Electric Vehicles

Electric vehicles are fueled primarily by electric power instead of fossil fuels. Encouraging commuters to invest in electric vehicles, or replacing town vehicle fleets with electric vehicles, has many benefits including fewer emissions and lower operational costs. There are two main types of electric vehicles: plug-in electric vehicles, or PEVs, and battery-electric vehicles, or BEVs (“Alternative Fuel Tool Kit · How To Implement: Electric Vehicles.”). PEVs have both a gas engine and an electric motor, and the battery can be recharged by plugging into the local power grid or through running the engine. A BEV only uses electricity, which is obtained from the power grid (“Alternative Fuel Tool Kit · How To Implement: Electric Vehicles.”).

PEVs have lower fuel and maintenance costs than traditional gasoline-powered cars which can offset the higher initial cost of purchasing the vehicle. Per gallon of gasoline, PEVs run at a cost equivalent to 50-70 cents, saving the user a lot of money. Because electricity rates are more stable than the price of gasoline, it is easier to budget and plan ahead. PEVs have much lower emissions than conventional vehicles, and battery-electric vehicles (BEVs) have no emissions at all. The combined effect is that encouraging Chapel Hill commuters to purchase PEVs or BEVs will not only improve the air quality in Chapel Hill, but will save consumers money on gasoline, which they can then spend at local businesses (“Alternative Fuel Tool Kit · How To Implement: Electric Vehicles.”).

Charging Infrastructure Challenges

Perhaps the biggest challenge a department must face when transitioning a fleet to EVs is the lack of charging stations, especially for departments that regularly travel on longer stretches of road. Oregon addressed this in 2009 with funding from the American Recovery and Reinvestment Act (ARRA) which allowed the Oregon Department of Transportation to install DC fast charging stations at 10 intersections along I-5 in southern Oregon. This created 200 miles of interstate that was “PEV-ready.” Level 1 and 2 charging units are also being installed all over residential and commercial spaces in Oregon, and as of September 2014, there were already 373 publicly available EV stations. In June 2013, Oregon Senate Bill 536 was passed, which allowed state agencies to install charging equipment at locations owned by the state. These developments cover a crucial step that must be taken to encourage people to buy EVs: creating a network of charging stations vast enough and dense enough so that the consumer can be sure that their vehicle will be able to get them to their destination without running out of charge. This is particularly an issue for BEVs, but all EVs need to have a dense network of charging stations for them to be a good financial decision, and Oregon’s model represents a smart, strategic way of alleviating these concerns (“Feasibility and Implications of Electric Vehicle (EV) Deployment and Infrastructure Development.”).

In fact, the city of Houston calculated that in order for every point in the Houston area to be within one mile of a charging station, the city would need 400 charging stations. For an urban area covering 1,300 square miles with 1,000 fossil fuel stations, 400 charging stations seems feasible (“Electric Vehicle Charging Long Range Plan for the Greater Houston Area.”). Public funding for installing charging stations is available in many places. In the Bay Area of California, for example, one million dollars was budgeted from the Bay Area Air Quality Management District (BAAQMD) to provide up to $20,000 per DC Fast Charger assuming it meets their program requirements. Other state organizations and bills such as SB 359, which provides funding for programs that encourage environmentally-friendly automobile purchases, and AB 1092, which requires building changes to include the installation of EV charging infrastructure, also pushes businesses and organizations to make EV usage more accessible. While California leads the way in terms of green technology, North Carolina also has programs that encourages infrastructure projects designed with EV usage in mind—such as in Charlotte.
In Chapel Hill...

Mission Alignment with the Town
The Town of Chapel Hill has already expressed interest in transitioning the town’s fleet of vehicles to a fleet that has reduced emissions and is more efficient in the Green Fleets Policy (Horton). The Town emphasizes three key goals: reducing the energy consumption of its current fleet in order to save costs, reducing dependence on foreign oil, and improving air quality across the region. These are all necessary for establishing Chapel Hill as a progressive city committed to technological advancement and environmental health. As noted in the policy, it would also save money: as of 2005, 68% of the Town’s energy bill comes from its transportation, which consists of a mixed vehicle fleet and a transit bus fleet. The policy outlines a need for Chapel Hill to purchase or lease vehicles which are as energy efficient as possible, while also ensuring that they can still perform the duties required of them (Horton). In this, transitioning to a fleet that is more heavily composed of EVs would be an obvious extension of this policy.

Power2Charlotte as a Model
There are many good examples around the country and state of electric vehicle programs that have been effective in addressing challenges posed in transitioning from fossil fuel vehicles to EVs. Charlotte has been energized to start thinking about cost-effective electric vehicle solutions. The Power2Charlotte campaign was launched by the Queen City in order to encourage energy efficiency awareness and was funded by the U.S. Department of Energy through an Energy Efficiency Conservation Block Grant, or EECBG (“Power2Charlotte”). Of the 16 projects covered by the campaign, one focused on electric vehicles, budgeting $275,000 for the city to add eight EVs to their fleet plus install 26 EV charging stations in seven places. Policy initiatives are also in place to support the EV campaign. For example, PEVs are exempt from emissions inspection requirements throughout the state of North Carolina, and are permitted to use High Occupancy Vehicle (HOV) lanes even if there is only one person in the vehicle. Green vehicle loans are offered through the Local Government Federal Credit Union to allow people to buy new and used fuel-efficient vehicles, with interest rates 0.5 percent lower than typical new or used car loan rates. These initiatives not only make it easy for people to use EVs, but help offset the initial cost of purchasing one through loans and offering additional financial perks throughout the lifetime of the vehicle (“Power2Charlotte”).

Opportunities in Chapel Hill
The Town of Chapel Hill can implement similar programs revolving around marketing campaigns to change the culture of electric vehicle decisions in Chapel Hill. This can be in the form of advertisements on the shells of Chapel Hill Transit Buses, commercials during UNC football games on charging locations around the town, and so much more. By creating a community that prioritizes vehicles that do not consume fuel, the Town of Chapel Hill can better demonstrate the need to fund more charging infrastructure.
Carpooling

EXISTING CARPOOLING PROGRAMS

The people of Chapel Hill currently have a variety of programs that allow them access to information about how to set up a carpool or vanpool, which is the most important step in establishing a carpool program. These programs include ShareTheRideNC, which is a carpool matching service sponsored by the North Carolina Department of Transportation and GoTriangle. This service helps drivers find people to make carpools with. Carpoolers can register for the Emergency Ride Home Program, which allows drivers to use a vehicle to go home in the case of an emergency, which lets participants carpool while still being flexible (“Carpool”). Chapel Hill also has a thriving vanpool program, with several van routes available between different cities in the Triangle and Triad. Commuters sign up for a vanpool, pay a yearly fee, and can ride the van to work instead of paying large amounts of money for gas and car maintenance by driving every day. The fee is approximately $624, though it varies by the number of riders and the miles traveled by the van. Currently, there are seven vanpools available, and they are leased by GoTriangle or the Piedmont Authority for Regional Transportation, or PART (“Vanpool”). Although carpools and vanpools are accessible in Chapel Hill, there are no programs that encourage people to make the leap to carpooling. Creating an incentives program in Chapel Hill would encourage people to start carpooling and stay carpooling, reducing air pollution and traffic.

INCENTIVIZING CARPOOLING

An incentives program provides some incentive (usually monetary) to carpoolers to encourage commuters to share rides. Even once the incentive ends, many people tend to continue carpooling (Ben-Akiva and Atherton). There are several types of incentives that can be used. Payments encourage people to begin carpooling by giving small, limited payments to those who do. These can be private and based with the employer, or public and sponsored by a local government. This proposal will focus on government-based incentives, however incentivizing businesses to start programs of their own is also possible. Preferential parking is another type of incentive which lets carpoolers have designated, preferred parking spaces (Ben-Akiva and Atherton). In Chapel Hill, where one of the biggest complaints about transportation is lack of parking, this could be particularly effective.

Government-based payment incentives work by sending money to registered carpoolers—usually 1-3 dollars a day. Usually, the program is capped at some amount of money or some length of time. Cheating is discouraged through methods such as registering carpoolers and requiring them to provide the contact information of their employer, who can then be randomly called to ensure that the driver is still carpooling. There have been successful programs in many cities, such as Atlanta, Washington D.C., Redmond, WA, and Los Angeles (Brown). According to surveys done by the University of Vermont, cash incentives have a high likelihood of encouraging people to carpooling (Watts). In Washington D.C., this program has had much success. A test program was started in the fall of 2009, and it allowed commuters along three congested corridors to get $2/day for carpooling. The program was paid for with federal Congestion Mitigation and Air Quality Improvement funds that were budgeted for 2009 but never used. The total projected cost in 2009 was determined to be $192,000, with $95,000 budgeted directly for the payments for approximately 700 carpoolers and the rest going to administration and advertising (Brown). The program discouraged cheating by making random calls, and also required carpool members to vouch for one another’s travel reports to ensure honesty. Since 2009, the original corridor restrictions of this project have been lifted, and the program has been expanded to appeal to a wider variety of commuters. Nicholas Ramfoss, the program director of the transportation operations programs in D.C., described a follow-up survey in fiscal year 2011 that found that 93% of the original demonstration project participants continued carpooling after the incentives were completed (Ramfoss). Of new participants, 98% said they planned to carpool after the incentives stopped coming. Based on the success of the original program, a vanpool incentives program was created in 2012. In 2014, another survey was conducted of all program participants that had completed the program and found that there was a 55% retention rate among carpoolers and vanpoolers. The eligible vanpools receive a $200 per month incentive, and the carpool program allows new carpoolers to get $130 over a 90 day time frame (Ramfoss). The success of the D.C. program over more than five years is a testament to the effectiveness and versatility of carpool incentive plans.

A similar program was launched in Atlanta, which offers $3/day for up to three months for commuters to switch to alternatives. This includes carpooling, biking, public transit, or working from home (Brown). From 2002-2009, 29,000 commuters participated in the program, which reduced 32.8 million vehicle miles of travel (VMT) according to the Clean Air Campaign. 9-12 months after the cash flow stopped, 64% of participants were still using these alternatives at least once a week, according to a survey from the Center for Transportation and the Environment. The success of carpooling programs is not just limited to D.C.— it can take off in many cities and really last. Cheating was discouraged in Atlanta by requiring commuters to provide employer contact information when they register, as well as signatures from their supervisors. As of 2009, only 25 cheaters were caught, suggesting that it is unlikely that a significant amount of people will try to manipulate the program (Brown).
Preferential parking is another method that can be used to encourage drivers. Here, the city (or employers) would give preferential parking spaces to carpoolers. One can also combine this policy with area-wide parking disincentives for single-occupancy vehicles, which has an even greater increase in shared rides but also sees a spike in public transit use, as well (Ben-Akiva and Atherton). According to the transportation survey done by the University of Vermont referenced earlier, respondents said that parking measures, such as preferred spots or reduced parking fees would also be likely to encourage them to start carpooling (Watts). This is especially relevant in Chapel Hill, where a lack of parking is a constant complaint. Giving carpoolers preferred spots would not only reduce traffic and air pollution, but the increase in the number of carpoolers would mean that less vehicles would be on the road and thus less vehicles would be taking up parking spaces. This would free up more spaces for even more visitors to Chapel Hill, alleviating parking stress.

There are many financial, economic, and of course, environmental benefits to incentivizing carpooling. Pollutant reductions were calculated based on data from the Washington D.C. program, EPA guides, and data from the Fayetteville Area Metropolitan Planning Association (Rogers et al.: “Sample Calculation of Emission Reductions and Fuel Savings from a Carpool Program”; and “Vehicle Occupancy Rate”). Using the assumption of an incentive of $2/day, the new vehicle occupancy rate (the average number of passengers per vehicle) of Chapel Hill was determined based on the Washington D.C. pilot program estimates. The reduction in the number of vehicles on the road was then determined by comparing the old vehicle occupancy rate with the new vehicle occupancy rate. The original number of vehicles on the road was determined based on the C-LINE model, which included information about the average annual daily traffic (AADT) on each road. Using this data, the reduction in vehicles was calculated. For a $2 daily incentive, the calculations predict the number of vehicles on the road will decrease by 4.3%.

C-LINE Modeling
Using data from the C-LINE model, PM$_{2.5}$ reductions based on changes in AADT were calculated. Each 5% decrease in the number of gas car trips is associated with a decrease in the concentration of PM$_{2.5}$ of 0.053 micrograms per cubic meter (ug/m$^3$), assuming the AADT is 10,000 vehicles. Roads with higher AADTs, such as Franklin Street, see even greater reductions in PM$_{2.5}$ (about 0.003 ug/m$^3$ for every additional 500 trips). Most of downtown Franklin Street sees PM$_{2.5}$ concentrations from transportation-related sources ranging from 1-10 ug/m$^3$. Thus, a decrease in PM$_{2.5}$ due to carpooling would be significant and would have a large impact on the environment of Franklin Street.

Even More Benefits
Beyond reducing pollution and making Franklin Street a more hospitable place, more carpooling means that more people can access Franklin Street without having to confront traffic and low parking. This encourages business growth, as more patrons are visiting. A reduction in air pollution will also make Franklin Street a more welcoming environment, encouraging visitors and tourists to come. An increase in carpooling would also put money in commuters’ pockets by allowing them to save money on gas and vehicle maintenance, and this is money they can easily spend at local businesses to grow the economy of Chapel Hill.
Absorbing Existing Pollution

How can existing air pollution be remediated?
The incorporation of policies to improve the flow of traffic and reduce vehicular sources will have a large impact on the environment and atmosphere in downtown Chapel Hill, however they will not remove all pollution-emitting vehicles from the roads. Therefore, this report outlines a set of proposals to absorb the existing pollution from vehicle traffic. It has been found that one of the possible solutions for reducing PM$_{2.5}$ concentrations in urban landscapes is increased vegetation cover (Chen, et al. 1). This section discusses the installation of some pocket parks in the downtown area, street greening, and living walls. The U.S. Forest Service has found that over a 50-year lifetime, one tree can generate $31,250 worth of oxygen and provide $62,000 worth of air pollution control along with many other benefits, including stormwater retention, carbon sequestration, improvement of a street’s image, and increased human health (Sherer, 19). It is not uncommon to see several inches of water inundating parts of Franklin street during a severe storm. Surveys have also shown a preference for more shade while walking down the sidewalk on a hot summer’s day, and many feel connected to a beautiful tree that breaks up some of the urban monotony. For all these reasons and the many benefits trees and other types of vegetation produce through the reduction of PM$_{2.5}$ and ozone, three approaches to greening Chapel Hill are proposed.
The Street Greening proposal aims to provide the Town with suggestions for specific species of trees for planting in the future that will improve air quality. iTree is software that uses U.S. Forest Service data with several useful tools for the urban planner looking to green their city. The iTree species tool allows the user to rank different processes and benefits on a scale of 1 to 10 that they want in an urban tree. The software also takes into account the area’s climate. Research for this project produced a top 10% list of species from iTree by ranking air quality as the highest priority. This list was cross-checked with recommended street tree species from the State of North Carolina Division of Forest Resources to come up with seven species that the Town of Chapel Hill can plant in the future in order to insure improved air quality and more resilience in tree populations. These species include: Freeman Maple (Acer X freemanii), Horsechestnut (Aesculus hippocastanum), Sugarberry (Celtis laevigata), Turkish Hazelnut (Corylus colurna), Ginkgo (Ginkgo biloba), Littleleaf Linden (Tilia cordata), and Silver Linden (Tilia tomentosa). iTree modeling also prioritized air temperature reduction, carbon storage, and stream flow reduction as functions of the trees. Therefore, these species will not only be effective in improving air quality, they will be effective in retention of storm water, carbon storage, and cooling downtown Chapel Hill.

In Chapel Hill...

In order to measure the real effect that planting these species could have on air quality on Franklin Street, a survey of the tree species was conducted on October 13th of this year to record each tree species, diameter at breast height (DBH), and crown condition from Crook’s Corner to the Henderson Street intersection. These data were then processed through another iTree tool, iTree Eco, which uses local hourly air pollution and meteorically data to quantify the value of trees and their environmental effects. One hundred and twenty-four trees were recorded. The current population of trees on Franklin Street annually removes 64 pounds of air pollution, sequesters 1 ton of carbon, produces 4 tons of oxygen, and retains 2,520 cubic feet of stormwater runoff. To then create a report of how the recommended species could improve the air in the downtown area, the tree population was then modified to include the seven new species. Trees that were classified in the worst condition were replaced, Google Maps was used to estimate that 21 trees could be planted along the street at the construction site of Carolina Square (see picture). With a new total of 145 trees, including the recommended species entered with a median DBH of the current trees (12in), the benefits increased substantially. The amount of air pollution removed went up to 78 pounds per year, with 2 tons of carbon sequestration, 5 tons of oxygen produced, and 3,123 cubic feet of avoided runoff. Also when looking specifically at the air pollution removal of the new population of trees, the most economic savings comes from their removal of ozone and PM_{2.5}. While the trees remove the most pounds of ozone per year, the smaller amount of PM_{2.5} removed is highly valuable due to its severe health implications, saving $74.64 per year.
Pocket Parks

Another way to increase the canopy cover in downtown Chapel Hill and capitalize on the benefits of recommended species is through the development of green spaces where they are feasible. Pocket parks are usually small lots (less than ¼ acre) in urban areas that are converted into green spaces. Often they are abandoned or vacant building lots, but they can also be created around an art piece similar to the Exhale in 140 West Plaza (“Creating Mini-Parks”, 1). Along with having the same benefits as street greening (i.e. stormwater retention, carbon sequestration, etc.) they also provide areas for people to relax, engage, learn, exercise, and more. A 2015 review of urban parks concluded that for a majority of cases, their benefits “largely overcome” their management costs, making them an economically viable option for air quality improvement (Tempesta, 1).

In Chapel Hill...

The 2020 Master Plan already includes the activation of areas on Franklin Street into public green spaces such as the IT Plaza and 140 West Plaza. Therefore, an area outside of Old Chicago was used as a case study for planting recommended species in a pocket park.

The iTree tool, iTree Design, was used to place ten Ginkgo trees around the Exhale statue, using the median DBH of 12 inches, to predict the monetary benefits of converting the area to a green space (see Figure 12). According to the USDA Natural Resources Conservation Service, Ginkgo biloba “is often planted in parks, arboreta and botanical gardens as a point of interest” (2). This species is chosen for its aesthetic appeal and tolerance to air pollution. However, any of the recommended species listed above could be planted with similar results. The Town should plant a diverse population of the recommended species in this park in order to promote health and resilience of the trees and wildlife in the downtown area. The results can be seen in Figure blank.

A polygon was drawn around the area of the building containing Crepe Traditions in order to calculate the reduction in heating/cooling costs attributed to the new trees. It is estimated that the addition of only 10 trees could annual save the town $7.71 in air quality improvements (see Figure 13). The total value of all services provided by these 10 trees would be approximately $426 per year. Given that there is more available space in this lot to plant other types of vegetation which could aid the trees in their stormwater retention, air pollution reduction, carbon sequestration, and other benefits, these dollar estimates of benefits may be conservative. Also the development of this green space wouldn’t require the acquisition of any land, as the only costs that would be incurred are the development of the land and its management. As the Town is already planning to develop this public space, and it is suggested to do it with the goal of air quality improvement in mind.

Other possible areas where recommended species could be built to help the development of air-cleansing pocket parks include IT Plaza, Porthole Alley, Carolina Square, and all others mentioned in the Downtown Imagined: Community Visions write up.
Living Walls

Green walls are classified in two categories: living walls and green facades. Green facades require the utilization of climbing plants such as vines or ivy that can be planted at the ground at the base of a structure. Living walls (example shown in Figure 14) are more complex systems of pre-vegetated panels that are fixed vertically to a structural wall or frame, consisting of a diversity of plant species (Green Roofs for Healthy Cities, 5). Three types of living wall systems include the trellis system, planter box system, and felt layer system (Feng). The facades can hold groundcovers, ferns, low shrubs, perennial flowers, and even edible plants (Sharp, et al., 8). As Chapel Hill is looking to grow the “town and gown” collaboration, they could expand the Edible Campus initiative to include aspects of Franklin Street with living walls. See the map and tables to discover the locations identified as suitable for living walls, along with estimates of size, cost of installation, and air quality benefits. Given the relatively high cost of green walls, green facades should be considered as a cheaper alternative. However, it is likely that green facades are less effective in absorbing air pollutants such as PM and ozone. Many of the open space on structural walls are located in alleyways. The downtown area is setup such that pedestrians often travel across Franklin and Rosemary street using alleyways. Living walls could be a way to make the common pedestrian alleyways more aesthetically pleasing to the Chapel Hill resident or visitor.

Benefits of Urban Greening

The three proposals aimed at reducing existing pollution all have a similar array of diverse benefits. There is significant improvement of the mental well-being of citizens who can access green spaces and aesthetic appeal. Data from the 2005 Danish Health Interview Survey was used to analyze the relationship between “distance to green space and self-perceived stress.” Not only did the survey reveal a strong positive correlation between distance from green space and poorer “health-related quality of life,” they found that Danes were aware that green spaces are essential to environments which promote health (Stigsdotter, U. K., et al., 411).

Green spaces held real importance for the residents of that particular urban area. It is highly unlikely that development of these greening initiatives will fade into the background of everyday life for the average Chapel Hill resident. They will be utilized, they will be enjoyed, and they will be appreciated. Not only for the way they improve the physical health of those breathing in less vehicle-related air pollution, but also for the way they reduce stress and increase overall well-being. The reason that Ram Reality developed 140 W Plaza to include Exhale was to increase the appeal of the surrounding businesses. Utilizing these green proposals can make certain areas on Franklin Street more appealing, creating spaces for people to relax, engage, build community, and educate. Therefore, not only do public green spaces and landscaping improve property value, they can also increase retail activity (Kozloff).

Mounting evidence from previous studies and from our own research suggest that urban greening can greatly improve the air quality of the area by absorbing the existing pollution from vehicles. However, it is important to note that they are not the only solution to this problem. As the study of urban trees in Strasbourg City, France concluded, it is essential to pair managing urban forest resources with other strategies that consider built structures and street design (Selmi, et al., 192). If the three projects from this section, street greening, implementation of Pocket Parks, and living wall installations, were used in conjunction with a combination of the plans previously proposed, serious progress can be made on the front of air quality.
In Chapel Hill...

Based on a number of analytical methods, nine possible sites for living walls, as shown in Figure XX. Given existing plans to make Porthole Alley pedestrian only, the Town should consider the installation of a green façade on the east-facing wall of the alley way, across from the Carolina Coffee Shop. As this is a University owned building, this project could strengthen the “town and gown” collaboration in order to encourage sustainability and improved safety of the residents and students. Also having the living walls in an alleyway rather than facing the street wouldn’t necessarily reduce their effectiveness at absorbing air pollutants. Living walls have a “filtered avenue” effect, in which they absorb pollutants with long atmospheric times (ozone and PM) even in non-dense urban areas (Pugh, 7697). Along with their air quality benefits, living walls can increase the energy efficiency of the buildings on which they are fixed, and reduce noise pollution by an average of 15 decibels (Green Roofs, 9-10). However, all of these benefits don’t come without a cost. It is estimated that living walls cost anywhere from $75-$125 per square foot for installation, plants, soil, and irrigation (Mathew, 14). On this particular wall, there would be two separate section both measuring 549 ft² with a total of 1,098 ft² covered by vegetation. This wall would reduce PM₁₀ annually by 114-220 grams and would absorb 876-1419 grams of total air pollutants yearly depending on the type of vegetation. The recommended types of vegetation include short grass, tall herbaceous plants, and small, deciduous trees. Installation of this wall would cost anywhere from $104,000 to $181,000. Using a University building as a pilot is a great jumping off point for discussing the high cost of this project. First of all, it is not uncommon for living walls to be utilized as advertising for large companies. Coke-a-cola, PNC, Adidas, and many other companies have taken to this innovative and exciting way to communicate to people through plants. A locally recognizable company such as PNC, Wells Fargo, or even Nike, with its strong relationship with University athletics, could contribute significantly to the cost of installing a living wall in Porthole Alley. Other funding options can be found in the Appendix. Because green façades reduce the ambient temperature around buildings through evapotranspiration and shading and buffer against wind during winter months, the University could share the data on its energy efficiency savings from before the installation to a few years after (“Green Walls Benefits”). This way local businesses and other buildings downtown could become interested in developing living walls themselves.

Figure 15 Potential Living Wall Sites
Project Finance

Where will the money come from?
Regardless of all of the aforementioned policies’ strengths and benefits, the feasibility of implementing such measure depends heavily on the existence of funding sources. The area from which funding sources are most likely available varies from case to case and section to section. This section provides evidence to the town that these policies could potentially be funded, regardless of the current budget of the town. There are several federal sources of funding that could be used for both the traffic flow improvement suggestions as well as the suggestions regarding the reduction of the sources of pollution. These are often focused on air quality and public health issues, which is one of Chapel Hill’s main concerns for the downtown area. There are also several state-wide funding programs that could provide funds for several of the flow improvement measures detailed previously. Much of the state funding comes directly from the North Carolina Department of Transportation.

The final section regarding the absorption of existing pollutants has the potential to receive funding from both private sources such as independent companies as well as from universities. These sources of funding would likely be partnerships, displaying an advertisement or piece of art in some cases. The importance of finding funding sources for the above-mentioned policy suggestions cannot be stressed enough. Many municipalities have plans in existence to implement air quality improvement measures, there is just a lack of funding. This section provides sources of funding as well as their completion dates and areas of interest.

For the simplicity and clarity of the information presented, links to the information found on the table are located in the References section on page 54 instead of directly in the table.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Amount</th>
<th>Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low and No-Emission Vehicle Program</td>
<td>The Low or No Emission Competitive program provides funding to state and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses as well as acquisition, construction, and leasing of required supporting facilities.</td>
<td>$55 million</td>
<td>May 13, 2016 (Passed)</td>
</tr>
<tr>
<td>Low and No-Emission Component Assessment Program</td>
<td>On September 29, 2016, FTA announced the opportunity for eligible institutions of higher education to apply for funding to conduct testing, evaluation, and analysis of low or no emission (LoNo) components intended for use in LoNo transit buses used to provide public transportation.</td>
<td>$3 million</td>
<td>November 28, 2016 (Passed)</td>
</tr>
<tr>
<td>Flexible Funding Programs - Congestion Mitigation and Air Quality Program</td>
<td>CMAQ provides funding to areas in nonattainment or maintenance for ozone, carbon monoxide, and/or particulate matter. States that have no nonattainment or maintenance areas still receive a minimum apportionment of CMAQ funding for either air quality projects or other elements of flexible spending. Funds may be used for any transit capital expenditures otherwise eligible for FTA funding as long as they have an air quality benefit.</td>
<td>$20 million</td>
<td>February 23, 2016 (Passed)</td>
</tr>
<tr>
<td>Public Transportation Innovation</td>
<td>Provides funding to develop innovative products and services assisting transit agencies in better meeting the needs of their customers. Eligible applicants and recipients under this program are limited to nonprofit organizations leading a consortium of entities. All consortia must include at least one provider of public transportation.</td>
<td>$2.75 million</td>
<td>Feb 21, 2017</td>
</tr>
<tr>
<td>TIGER</td>
<td>The Transportation Investment Generating Economic Recovery, or TIGER Discretionary Grant program, provides a unique opportunity for the DOT to invest in road, rail, transit and port projects that promise to achieve national objectives.</td>
<td>$500 million</td>
<td>April 29, 2016 (Passed)</td>
</tr>
<tr>
<td>Congestion Mitigation &amp; Air Quality</td>
<td>Congestion Mitigation &amp; Air Quality (CMAQ) is a Federal program that funds transportation projects and programs in air quality nonattainment and maintenance areas to help achieve and maintain national standards for air quality pollutants.</td>
<td>$200,000</td>
<td>Summer 2017</td>
</tr>
<tr>
<td>Duke Energy</td>
<td>Settlements with NC/EPA for coal ash spill and Clean Air Act Violations</td>
<td>$120 million</td>
<td>July-August 2017</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Amount</td>
<td>Deadline</td>
</tr>
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<td>-----------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Safety Research and Demonstration Program</td>
<td>The Safety Research and Demonstration (SRD) Program is part of a larger safety research effort at the U.S. Department of Transportation that provides technical and financial support for transit agencies to pursue innovative approaches to eliminate or mitigate safety hazards. The SRD program focuses on demonstration of technologies and safer designs.</td>
<td>$7 million</td>
<td>October 14, 2016</td>
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<tr>
<td>Community Development Block Grant Program, Economic Development</td>
<td>The Community Development Block Grant, Economic Development Program (CDBG ED) is administered by the North Carolina Department of Commerce; it provides grants to local governments for public infrastructure development.</td>
<td>$45 million</td>
<td>Unknown</td>
</tr>
<tr>
<td>North Carolina’s Utility Account</td>
<td>Grants are awarded to local governments for infrastructure improvements that are publicly owned and maintained. The applicant must demonstrate that the project is expected to lead to job creation in the near future.</td>
<td></td>
<td>No deadline</td>
</tr>
<tr>
<td>FASTLANE</td>
<td>The Fixing America’s Surface Transportation Act (FAST Act) established the Nationally Significant Freight and Highway Projects (NSFHP) program to provide Federal financial assistance to projects of national or regional significance and authorized the program at $4.5 billion for fiscal years (FY) 2016 through 2020, including $850 million for FY 2017 to be awarded by the Secretary of Transportation</td>
<td>$850,000</td>
<td>Dec 15, 2016</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>The Coca-Cola Company partner with governments, NGOs and other organizations to support community improvement in four main areas: water stewardship, healthy and active lifestyles, community recycling and education</td>
<td>$76 million</td>
<td>Rolling deadline</td>
</tr>
<tr>
<td>Pepsi</td>
<td>Through our Global Citizenship initiatives, PepsiCo supports programs that: encourage healthy lifestyles; improve availability of affordable nutrition; expand access to clean water; enhance sustainable agriculture capability; enable job readiness; and empower women and girls.</td>
<td>$37 million</td>
<td>No information online, must approach directly.</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Amount</td>
<td>Deadline</td>
</tr>
<tr>
<td>---------------</td>
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</tr>
<tr>
<td>Wells Fargo</td>
<td>The programs operate as a closed RFP, invitation-only process where Wells Fargo engages specific organizations whose work aligns with our giving priorities.</td>
<td>$15 million</td>
<td>Must approach directly</td>
</tr>
<tr>
<td>CVS</td>
<td>The CVS Health Foundation has made a multi-million commitment to expanding access to quality health care nationwide through partnerships with the National Association of Free &amp; Charitable Clinics (NAFC) and the National Association of Community Health Centers (NACHO).</td>
<td>$5 million</td>
<td>Invitation only</td>
</tr>
<tr>
<td>Walgreens</td>
<td>Funding given to: Access, outreach and education geared toward health, National nonprofit organizations focused on the research and treatment of a single disease, Civic and community outreach</td>
<td>$3 million</td>
<td>Rolling deadline</td>
</tr>
<tr>
<td>Home Depot</td>
<td>The Home Depot Foundation offers grants to IRS-registered 501c designated organizations and tax-exempt public service agencies in the U.S. that are using the power of volunteers to improve the physical health of their community. Grants are given in the form of The Home Depot gift cards for the purchase of tools, materials, or services.</td>
<td>$5,000</td>
<td>December 31st, 2016</td>
</tr>
</tbody>
</table>
Appendix
References

Introduction


Health Impacts


Improving Traffic Flow


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Absorbing Existing Pollution


References


Project Finance


References


Methodology: C-LINE

As a major part of analysis for the project, the web-based modeling tool C-LINE, developed by the UNC Institute for the Environment with funding from the US EPA, was used to model concentrations of air pollution from roadways in downtown Chapel Hill. C-LINE uses the Highway Performance Monitoring System (HPMS) road network by default, but allows the user to upload their own network, as well. The HPMS roads in C-LINE were deemed inaccurate in their speed and Average Annual Daily Traffic (AADT) values based on information gathered from the Town of Chapel Hill and from personal experiences with driving through downtown in heavy traffic. ESRI’s ArcGIS software was utilized to construct a grid of roads through downtown that are more representative of the Franklin Street corridor, export that information from ArcMap to Excel, and finally import it into C-LINE.

The process began by opening ArcMap, loading a basemap of streets, and zooming the layout to Franklin St. Then, using the editor tool, line features were created for each segment of road where it is believed speed would change, creating a network of roads comprised of segments with different speeds that simulate what driving through downtown is like in reality. Figure 1, a screenshot of morning traffic in Chapel Hill from Google Maps, illustrates the traffic environment. Thus, the closer a segment is to a stoplight or intersection, the slower the speed becomes, ultimately with 5 mph being the minimum speed attributed to any segment. These segments were established for Franklin St., Rosemary St., Columbia St., Church St., Henderson St., Raleigh Rd, and Martin Luther King Jr. Blvd. Once the features were created, the Calculate Geometry tool allowed the generation of latitude and longitude coordinates for the endpoints of each segment. This provides C-LINE with the spatial reference it needs to ensure accurate placement of the network on the map. The overall study area can be seen in Figure 2.

Once the roads were imported to C-LINE, their attributes (speed, AADT) were verified to be correct and the fleet mix on all road segments was adjusted based on information from the Town. Figure 3 illustrates the road editing interface of the tool. C-LINE uses a default fleet mix for each county and road type but allows the user to apply multipliers to adjust the fleet mix as needed. Using a spreadsheet and data representing C-LINE fleet mix defaults, this study calculated the appropriate multipliers for all four vehicle types (gas cars, gas trucks, diesel cars, and diesel trucks).

The first analysis was of the base case scenario for Chapel Hill, so C-LINE was run for the project’s custom road network using the adjusted fleet mix for neutral Winter and convective Summer meteorological conditions to get baseline concentrations for each season. In order to monitor changes in pollution made by various changes to the road network, three
points on the map were chosen to take PM$_{2.5}$ concentration values for each scenario run - in front of University Methodist church, the bus stop at Columbia & Rosemary, and the playground behind TRU deli.

Now that the base scenarios had been calculated, the AADT and speed values of the road segments could be changed to simulate the effects of this project’s flow improvement proposals: roundabouts and one-way streets. For the roundabout scenarios, speeds were made more even on the approach and slightly higher through the intersection. This models the fact that roundabouts reduce the number of cars stopping at intersections, as well as reduces the delay per car through an intersection. AADT remained the same for each road in each roundabout case, as it is not expected to change. One roundabout scenario involved placing the roundabout at the intersection of Franklin St. and Columbia St., and adjusting the speeds on those roads as such, while the other involved placing four mini roundabouts on the flanks of the main intersection. These mini roundabouts are located on Franklin St. and Rosemary St. at their intersections with Church St. and Henderson St.

The final scenario run was the one-way scenario, in which Franklin St. and Rosemary St. become a one-way couplet, with Franklin St. flowing eastbound and Rosemary St. flowing westbound. Each was given a speed of 25 mph (with 15 at the intersections) and the AADTs were summed together and then distributed 60%/40%, with Franklin St. retaining the higher percentage due to more traffic heading east. This is representative of what this study believes will occur in this case, as the one way streets will create more even, slightly faster speeds for almost the whole length of the line.

The last requirement for the study was to extract a rate from C-LINE so PM$_{2.5}$ concentrations could be estimated given any AADT and speed input. In order to do this, all the road features were removed from the map and created a single road feature to extract the rate from. A point on the map was chosen for reference so the same location’s value would be selected on each run, preventing outside influences from affecting the pollution value obtained. The effects of increasing AADT were measured first, followed by speed, and finally adjusting the fleet mix.

C-LINE was first run with an AADT of 7,000, a speed of 20mph, and the base fleet mix, and then the AADT was increased in steps of 1,000 up to a max of 12,000. The PM$_{2.5}$ concentration from each run was collected and placed in a spreadsheet, then a graph was created from the values. The slope of the line is the rate of change, which came to be an increase in PM$_{2.5}$ of 0.1166 $\mu g$ (about 10%) per 1,000 increase in AADT. Similarly, C-LINE was tested with AADT increases in steps of 100, from 10,000 to 10,500, and found PM$_{2.5}$ increased at a rate of 0.0115 $\mu g$ (about 1%) per 100 increase in AADT. This is comforting knowing that when the AADT change was decreased by a factor of 10, the PM concentration changed by a factor of 10 as well. A rate was derived from increasing the speed in steps of 5 mph as well, though it was slightly different since the relationship between speed and emissions is exponential. The largest drop is seen between the first three speeds: 5, 10, and 15 mph. From 5 to 10 mph, PM emissions drop 31% and from 10 to 15 mph, they drop 16%. From then on, with each 5 mph increase, PM emissions drop at an average rate of about 13-14%.
Deriving a rate from the fleet mix was a bit more tricky than simple AADT and speed adjustments. This project was interested in modeling real-world situations, such as a mass replacement of gasoline cars with electric vehicles (EVs). It also wanted to account for the situation in which the AADTs in Chapel Hill grow over the next few years as population increases. In order to model the replacement of cars with EVs, it was decided to simply remove a certain number of cars from the road. However since the AADT includes all vehicles, the number that were actually gasoline cars needed to be separated out. Using the fleet mix ratio for Chapel Hill of 90.7% gas cars, the proportional number of cars were found from total AADTs of 10,000-12,000 vehicles in intervals of 500. Next, the study was interested in what the new gas car AADT would be if EVs were to replace 10%, 15%, 20%, 25%, and 50% of cars on the road, so each calculated AADT was multiplied by each percent reduction, resulting in 25 new car AADT values. To apply this back to C-LINE, the difference between the original and new gas car AADTs had to be subtracted from the total AADT. For example, if the car AADT changed from 9,000 to 8,000, the total AADT would need to decrease by 1,000. There are now 25 AADT values, each representing a percent change in cars from a base AADT. Each of these 25 AADT values was plugged into C-LINE, and from them a PM concentration value was obtained at the same location. From these, it was determined that with each 5% decrease in cars on the road, PM decreases by 0.053 $\mu g$ (and with each 500 AADT increase, the rate increases by 0.003). At the same time, each 500 AADT increase results in a 0.053 $\mu g$ increase in PM (and for each 5% decrease in cars, the rate decreases by 0.003).
Methodology: i-Treestructure

Recommended Species

Using the i-Tre Specie Selector tool (see Figure 1), the proper location information for Chapel Hill in Orange County North Carolina, USA was entered. Then all of the air pollution benefits were given the highest ranking of 10. Air temperature reduction, carbon storage, and stream flow reduction were ranked with a number 9. The report produced was then saved as a PDF.

Tree Street Survey

On October 13th, data was collected on every street tree on Franklin Street from Crook’s Corner to Henderson Street. Measuring tape was used to find the circumference at breast height (approximately 4.5 feet off the ground) in inches of each tree. Additional information of tree species and estimated percent crown missing were also collected. Diameter at breast height in inches was later calculated from circumference. First, a new project was created in the Eco Tool by selecting a complete inventory rather than a sample inventory in Project Configuration. The population in Chapel Hill was entered as 59,635. The following specifications about the study area were made during Project Configuration: selecting urban area and choosing the pollution and weather year to be the most recent available in i-Tre (they must be the same year). The weather station that was closest to the study area on the map provided by i-Tre in the location tab of Project Definition was chosen. Under the Data Collection Options Tab the following data types were selected: Species, DBH, Land Use, Street Tree/Non Street Tree, Public/Private, and condition & percent dieback. This tool can be run with many more data categories, however DBH and species are required. Then, in the Land Use tab Commercial was selected as the land use category as that description best fit the specific section of Franklin Street studied. The data was uploaded as an excel file into the Eco Tool that was formatted using the import button under the Data tab. Two tree species that were not recognized by the software, and had to be changed to similar tree species. Pin oaks were then entered as northern red oaks and sawtooth oaks as willow oaks. The data was then analyzed by the software for a few hours before returning a full report.

Future Projection for Franklin Street

To predict the effect of trees being planted in front of Carolina Square and in replacement of trees with poor condition quality a separate project in the iTree Eco Tool was started. The same background information as previous selected was specified in Project Configuration. In order to model the replacement of trees, the ones determined in the lowest condition percent provided by the Eco tool were removed from the data set. Then a random number generator was used to select the species from the list of seven recommended species to add to the excel file that was later uploaded to the
Methodology: i-Tree

project. All new trees were added with the media DBH of the existing tree population (12 inches). It was determined that 21 trees could be planted outside of Carolina Square when construction was completed and the same process indicated early was used to add these trees to the data set. Instead of following this procedure, it is recommended that the town look into the forecast tab in order to project the model into the future. Information as to the year when these trees could be planted was unavailable (when Carolina Square construction will be complete), therefore this function of the Eco Tool wasn’t used.

140 W Pocket Park Modeling

First, the Street Address of interest, for this situation 140 W Franklin Street, Chapel Hill, 27514, USA was entered in the i-Tree Design tool. A polygon was drawn around a portion of the building which holds Crepe Traditions in order to find out energy efficiency data and the most desirable places to plant the trees in the park. Using this icon on the top of the map display screen, click on every corner of the building to draw the polygon and double-clicked to finish drawing. Moving onto the second drop down menu on the left hand side labeled 2. Place Trees. The species “Ginkgo” and the median tree diameter for Franklin street (12 inches) was entered along with “Excellent” tree condition and changing “Tree exposure to sunlight” as necessary for its placement. 10 trees were placed as seen earlier in the report. Then move on to 3. Estimate Benefits where 10 was entered for years in order to track tree growth and benefits. iTree then produced a comprehensive report in which the value of the trees planted can be seen in reference to air quality, energy efficiency of the building, carbon sequestration, and storm water retention.
Methodology: BenMAP

In order to evaluate the benefits related to public health and the economic feasibility of the potential policy recommendations, this study applied a health and environmental assessment model developed by the US EPA known as the Environmental Benefits Mapping and Analysis Program — Community Edition (BenMAP-CE). Figure 1 shows the mechanism of the BenMAP model (Davidson).

A standard concentration-response function that relates changes in air pollution exposure to health impacts by quantifying the incidence of pollution-related adverse health events was a key factor to determine variation in health impact:

\[ \Delta y = \beta e^{\Delta P M} \left(1 - e^{-\beta P M_0} \right) = y_0 \left[ 1 - \frac{1}{1 + \exp(\beta \times \Delta PM)} \right] \]

where \( \Delta y \) is the change in the health events, \( y_0 \) is the baseline incidence rate for the health impact, the unitless coefficient fraction beta (\( \beta \)) is a coefficient derived from the relative risk (RR) associated with a change in exposure, \( \Delta PM \) is the estimated change in PM exposure concentration, and POP is the exposed population (Ding et al.). Since this study aimed to evaluate health and economic benefit within a local area, Chapel Hill, all the inputs were specific to Orange County. In this study, all-cause mortality was chosen as the health endpoint representing the health effect of policy recommendations. Similarly, for the aforementioned concentration-response function, a beta value for all-cause mortality related to change in \( PM_{2.5} \) concentration was chosen (Krewski). Table 1 on the next page describes all the data input in this study.

Mortality rates were collected from Center of Disease Controls and Protection for the year 2014. The baseline \( PM_{2.5} \) concentration was generated from US EPA air quality statistics. Both modeled decrease in \( PM_{2.5} \) from C-LINE and estimated decreases from the literature were input as \( \Delta PM \). Since most of the impact on \( PM_{2.5} \) from policy evaluation was available as a percentage, a percentage rollback was performed. Due to the fact that this study was performed on a very small local scale, aggregation of results was not conducted. Mortality change as well as economic benefit were specified to Orange County. In order to evaluate economic benefit brought by the change in mortality, a Unit Value of Statistical Life of $5.5 million per death case, developed the US EPA, was applied (Dockins et al.).
Methodology: BenMAP

There are several assumptions made in this study while implementing the cost-benefit function, as well as running the model, that might have affected calculation. The adverse health effect of PM$_{2.5}$ was considered equal, in spite of existing differences among formation mechanisms of different types and sources of PM$_{2.5}$. The beta value, which represents the correlation coefficient between PM$_{2.5}$ concentration and premature mortality, was obtained from an epidemiology study that has done experiments in 116 U.S. cities by Krewski et al., one of the default set in the BenMAP software. If other EPA standard health impact functions were used from other epidemiology studies using different samples, the beta value would have been lowered by a factor from 2 to 3.

References:

Centers for Disease Controls and Protection.2014. CDC Wonder Data Report. Available at: https://wonder.cdc.gov/controller/datarequest/D76;jsessionid=DFD47FB1F2611CB7367C2AC7970DD0D7


Kenneth Davidson, Aaron Hallberg, Donald McCubbin & Bryan Hubbell (2007) Analysis of PM2.5 Using the Environmental Benefits Mapping and Analysis Program (BenMAP), Journal of Toxicology and Environmental Health, Part A, 70:3-4, 332-346, DOI: 10.1080/15287390600884982 Available at: http://dx.doi.org/10.1080/15287390600884982


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