Future Transport in Lambeth

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WPI

Lambeth

Future Transport in Lambeth

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Abstract

Air pollution in London is linked to thousands of deaths every year. This project aimed to aid the Lambeth Council in promoting emissions-based cashless parking payments and integrating smart city technology to maintain revenue, influence future policy, and reduce air pollution. To accomplish this, we analysed existing data, spoke with Council employees, and surveyed and interviewed residents. Combining the ideas of electronic parking payment and smart city technology, we created a web application to demonstrate how applying smart city technology to parking could reduce air pollution. We found that most residents would be willing to adopt an electronic parking payment method for lower prices, although a cash-based alternative in local businesses would be widely accepted.

Executive Summary

Background and Objectives

Air pollution is the single greatest environmental health risk, contributing to an estimated 7 million deaths every year and causing illness to millions more (Vidal, 2015). In the city of London, it is illegal for hourly levels of nitrogen dioxide air pollution to exceed 200 micrograms per cubic metre more than 18 times annually (Forster, 2017). However, just five days into 2017 the Mayor's office was forced to declare a state of alert after it was found this yearly limit had already been breached on Brixton Road in the London Borough of Lambeth (Forster, 2017). Lambeth, home to one of the highest concentrations of air pollution in the city, tasked us with investigating possible solutions for their community.

The Lambeth Council requested that we focus on the local transportation sector as it relates to air pollution. The Council has incentivised the use of low emissions vehicles by offering discounted parking permits since 2011 but would now like to implement emissions-based pricing for short term parking. Problems arise however, as the pay and display machines currently in place are too outdated to identify the emissions level of the parked vehicles or even offer more than one standard price.

The Lambeth Council is also planning to use a system called PayPoint to process parking payments. PayPoint can be used as a cash and card alternative, where the user can pay for parking from a local convenience store. There are currently 350 PayPoint locations throughout the Borough. However, these locations are not currently configured for parking transactions, instead only handling bill payments and other services. With the ability to collect data from Pay by Phone transactions, the Council is also excited for the opportunity to integrate smart city technology into the community. Smart cities are ideally meant to better integrate utilities, optimising their performance, so the community as a whole can save both money and resources, diminish health and pollution problems, and improve general functionality. This can allow information to be shared between different public services, ideally optimising one's time in the Borough and allowing more educated policy development.

The overall focus of this project was to provide recommendations to the Lambeth Council promoting cashless parking payments and integrating smart city technology in the Borough to cut costs and reduce air pollution. To achieve this goal, we developed four objectives:

1. Assess the current state of parking payments in Lambeth
2. Investigate public response to potential developments in parking and transportation
3. Project future motor vehicle and smart city technology trends
4. Use our research to prototype an example smart city application

Methods

As we worked to fulfil the overall goal of the project, we used four distinct methods: data analysis, observation, surveying the public, and interviews. Once we began working with the Council, our first task was to analyse national census data and annual Borough reports to recognise trends that relate to car usage and air pollution. We mainly analysed citizens' primary travel methods, the availability of cars in each household in the Borough of Lambeth, population density, as well as energy consumption by motor vehicles. We then used documents more specific to Lambeth to gain an understanding of trends within the Borough. We additionally examined the use of smart city technology in similar locations to determine the feasibility of integrating such technology in the future of the Borough. This allowed us to project future technology trends in Lambeth concerning both parking and transportation in general.

Based upon reputable accounts on the success of direct observation methods, we resolved to better understand patterns and behaviours of those residents who park in Lambeth by shadowing two Civil Enforcement Officers (CEOs) who monitor parking in the different wards to get a sense of what they experience every day. This observation helped us assess the current state of parking in the Borough of Lambeth and allowed us to gain a better understanding of the effectiveness of various parking payment methods, especially cash and Pay by Phone.

We developed a survey to assess residents' views concerning air pollution, car usage, and the Pay by Phone parking payment method. Prior to releasing the survey, we pre-tested it with our sponsor to gain feedback concerning possible improvements. Through the information obtained in this survey, we gained a general view of the public's opinion regarding air pollution, parking payment methods, and future transportation in the Borough.

To further build and expand our knowledge of the Lambeth parking system, we interviewed residents and the Council employees of the Borough concerning the current state of parking and existing initiatives. From the analysis of the Council interviews, we were able to obtain in-depth knowledge on the background of the current parking initiatives, the current status

of the parking system, as well as car usage and smart city technology. From the interviews of residents, we could learn about their opinions concerning air pollution, technology, and circumstances that discourage them from using Pay by Phone.

After being exposed to both the Council's plan to implement a 100% electronic parking payment system and their interest in integrating smart city technology in the Borough, we began to consider ways to combine these ideas. We concluded that a portion of the data collected by the Pay by Phone application could also be used to give both the Council and residents real-time information concerning parking locations in the Borough. Using this idea as a foundation, we created an example web application for the Council to demonstrate how smart city technology could be used in the scope of parking.

Results

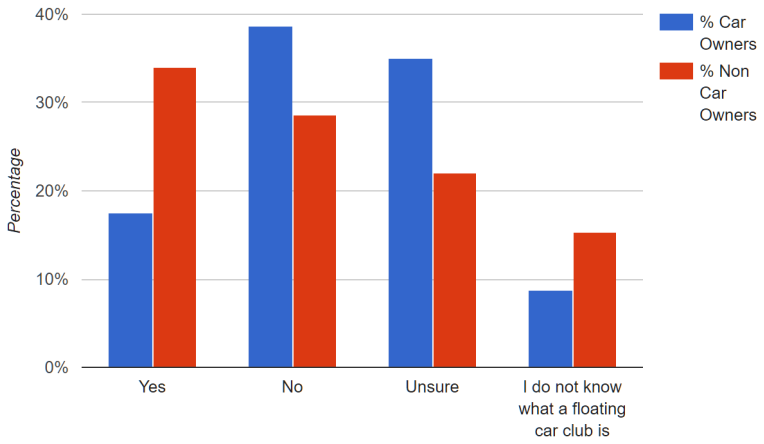
Of the 82 survey respondents who owned cars, 49 regularly parked in the Borough. When these individuals were asked about their preferred payment methods, a majority (59.2%) preferred the Pay by Phone method. This finding reflected the raw data supplied to us by the Council on payment methods in the Borough. When asked why they preferred their payment method of choice, a majority of survey subjects indicated that convenience was a main factor, regardless of what method they used. When asked, 60% of survey subjects who preferred cash or card payment methods stated that lower prices when using Pay by Phone would encourage them to switch, and 30% responded that an improved mobile app would encourage them to switch. However, no subjects stated that emissions-based pricing would encourage them to switch to Pay by Phone.

Some of the residents interviewed were aware how Pay by Phone worked but were still opposed to switching from their primarily cash payments. However, they were very interested in the concept of PayPoint, where there would be a cash option available at kiosks or local businesses.

Regarding the use of smart city technology, interviewees generally supported data collection through mobile applications, although two were opposed to "strengthening the government by allowing them to view any more information, even if it was anonymised." People were almost equally supportive of the Borough-supported floating car club concept. However, while non-car owners were in favour of personally using floating car clubs in the

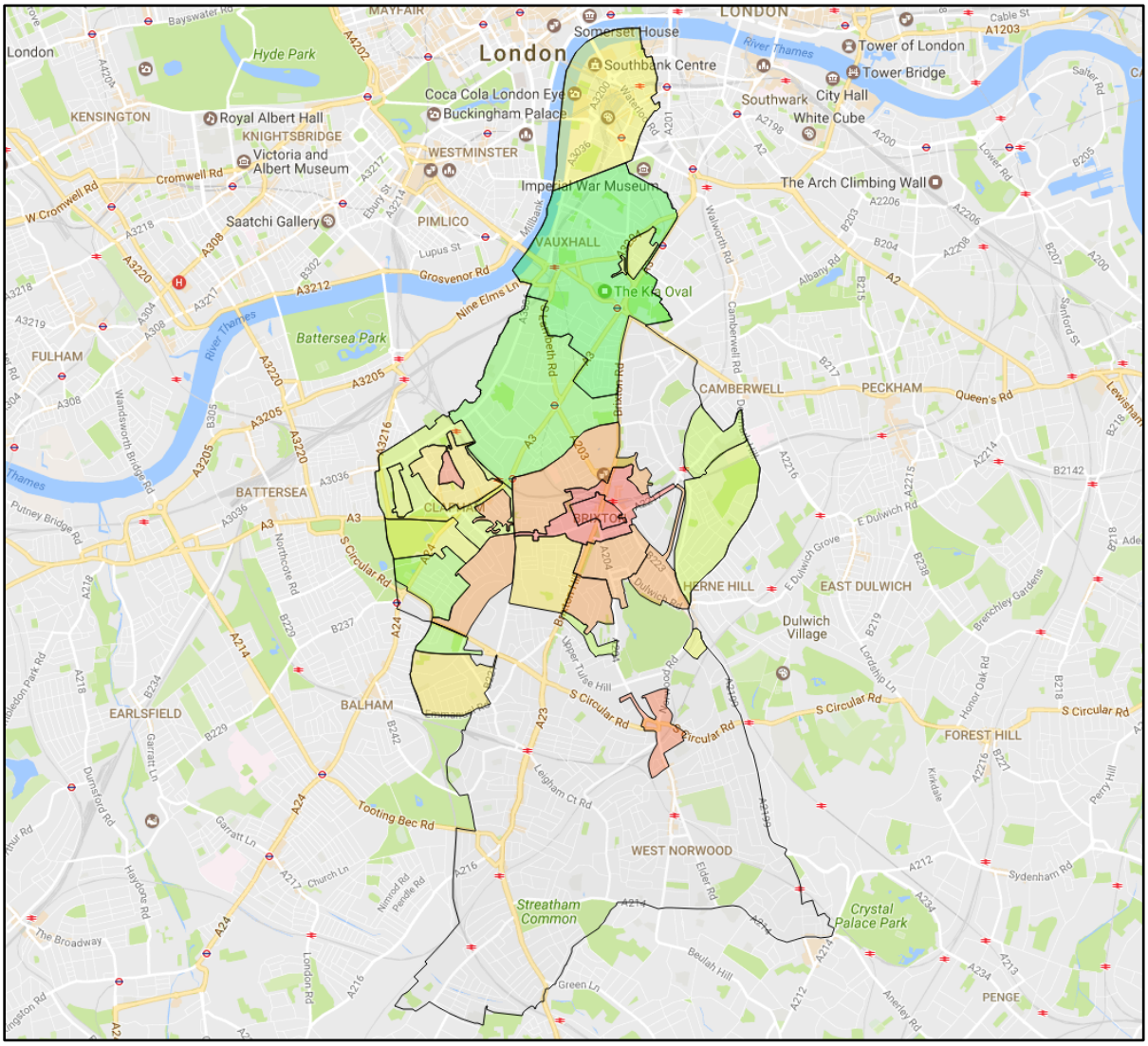
future, car owners showed more passive support, generally saying in interviews that while it is a good idea, they would not consider getting rid of their personal vehicles.

Figure 1. Likelihood of Floating Car Club Adoption by Vehicle Ownership



Finally, we created an example app to demonstrate how smart city technology could be used to enhance parking in the Borough for both cars users and the Council. It allows users to view available parking in the Borough through an interactive map and allows the Council to set emissions-based prices in real time (see Figure 2). The app can be accessed here: https://lambeth17.herokuapp.com

Figure 2. Interactive Map of Lambeth Parking Zones



Our application has three modes: 1) a user mode for car users, 2) an administrator mode for the Council, and 3) an edit mode for development and demonstration. User mode allows car users to view available parking within the Borough, highlighting parking locations based on their occupancy. Areas with available parking are highlighted in green, while areas without are highlighted in red. Administrator mode allows the Council to set emissions-based prices in real time and set estimated capacities for each parking location. Edit mode allows developers to demonstrate zone level changes and create new parking locations.

Recommendations

The crux of our work was ultimately to guide the Council on the best next steps regarding the future of transportation in Lambeth. Separated into short-term and long-term recommendations, we offered guidance with regards to the following:

Short-term Actions

1. We first recommended the Council prioritise the elimination of pay and display machines in favour of Pay by Phone and PayPoint locations throughout the Borough to implement an emissions-based pricing scheme. The machines proved to be overwhelmingly unpopular amongst both Council employees, who found them to be a cash sink that would never generate enough money to justify their maintenance, as well as residents, who felt they sometimes malfunctioned. The PayPoint system will serve as a cash and card alternative for users who are not able or willing to use Pay by Phone.
2. PayPoint has the potential to carry with it many of the same benefits to the Council that Pay by Phone does. There is no cost to adjust prices, with the increased price of using cash ideally counteracting the cost to the Council of using the Pay by Phone and PayPoint third-party services. We recommended that the Council require users to register for PayPoint using information similar to Pay by Phone. This integrates the two systems together, allowing the Council to enforce emissions-based pricing for all users.
3. Some members of the public are either unaware of the Pay by Phone method or uninformed concerning its functionality. We recommended that the Council take actions to raise awareness of the Pay by Phone payment method. We suggest that pay and display machines, and in the future PayPoint locations, be equipped with revised graphics showing visual instructions on how to use the Pay by Phone system, including the app, text, and call functionality.
4. We recommended that the Council contact the developers of Pay by Phone to request an update to their application to reflect the data-sharing ideas presented in the example application. If Pay by Phone is not willing to extend their app, we recommend that the Council ask Pay by Phone to create a way to access relevant data or consider a change of parking payment contractor.

Long-term Actions

We imagine the app to be the platform from which Lambeth could truly start building smart city technology and big data collection. The benefit of having the bulk of the population linked into an online service is the ability to use data and information to further improve the experience of living in the Borough. Future policy decisions can be better derived by focusing more on real-time, consistent data collected via systems such as our smart city app to model behaviour of people in the Borough with a limited scope of information. We believe that if Lambeth commits significant resources to looking at large data sets in this manner, predicting future trends will become universally more accurate.

The Council should seek to integrate floating car club contracts as a source of revenue. Mutually beneficial contracts with these companies can provide Lambeth residents with convenient travel options and grant the Council a source of revenue comparable to those of parking permits as well as control of the types of cars on the street. This would then allow the Council to limit air pollution in the Borough using low-emissions or electric car club vehicles.

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Chapter 1: Introduction

Air pollution is the single greatest environmental health risk, contributing to an estimated 7 million deaths every year and causing illness to millions more (Vidal, 2015). While natural air pollutants do exist, human activity in the past several decades has drastically increased the rate of production. According to global data acquired in 2010, the transportation sector contributed 14% of all greenhouse gas emissions, ranking as the fourth top economic sector in this regard (EPA, n.d.). Furthermore, this percentage significantly increases when the scope of interest is limited to urban areas, where there are larger concentrations of motor vehicles.

In London, it is illegal for hourly levels of nitrogen dioxide to exceed 200 micrograms per cubic metre more than 18 times annually (Forster, 2017). However, just five days into 2017 the Mayor's office was forced to declare a state of alert after it was found this yearly limit had already been breached on Brixton Road in the London Borough of Lambeth (Forster, 2017). Those regularly exposed to air pollution of this magnitude are subject to an increased risk of respiratory infection, nervous system impairment, and cancer, ultimately leading to what is estimated by the World Health Organization as a decrease in life expectancy of approximately 11 years (World Health Organization, 2017). With over 4,000 air pollution related deaths reported in London in 2008 alone, and the situation only worsening since, there is an abundance of pressure to address the increasing levels of pollutants (Greater London Authority, 2013).

The most logical approach to decreasing air pollutants is to limit their primary source. In major cities, it is estimated that roughly 80% of air pollutants are produced by fossil fuelled personal vehicles (Greater London Authority, 2013). Therefore, if citizens transitioned to using either low-emission or electric vehicles, air quality and by extension quality of life, would increase.

The London Borough of Lambeth, home to one of the highest concentrations of air pollution in the city, tasked us with investigating possible solutions for their community. By examining the 2011 Census as well as annual surveys conducted by the Borough, we gathered relevant information to project future trends in car usage and ownership, allowing the Council to be better informed of the effectiveness of their policies.

As one of the Council's responsibilities is managing parking in the Borough, they have been incentivising low emissions and electric vehicles at the local level by offering discounted parking permits for those vehicles. However, there is currently no way for emissions-based

pricing to be implemented for short-term parking. Pay and display machines currently in place are too outdated to identify the emissions level of the parked vehicles or even offer more than one standard price.

The Council has recently been focused on increasing popularity of the Pay by Phone system, which allows residents to pay for parking electronically with their mobile device through an app or by text. In addition to being easily programmable to feature emissions-based payment, this method costs much less to maintain, does not occupy space on the sidewalk, and cannot be broken into. Despite these apparent benefits, there has been hesitation in some parts of the Borough, with overall 20-30% of individuals still paying with cash (Fawcett, personal communication, 2016). The Council members seek to understand the reasons for this hesitation and the best ways to implement a complete shift to Pay by Phone, eliminating the parking machines entirely. Additionally, the Council must be sensitive to the needs of residents who are unable or unwilling to use mobile payments.

With the ability to collect data from Pay by Phone transactions, the Council is also excited for the opportunity to implement smart city technology into the community. This allows information to be shared between different public services, ideally optimising one's time in the Borough and allowing more educated policy development. By researching present smart city initiatives around the globe, as well as gauging public perception via a survey and interviews, we showed both the potential and feasibility of these technologies in the future of Lambeth transportation and recommended how best to go forward with plans to make the Borough a "smarter" place.

Chapter 2: Literature Review

This chapter first explores how air pollution is driven by private motor vehicles. It then pivots into defining smart cities and how specific smart city plans have tried to alleviate transportation issues, while improving quality of life. The chapter concludes with a discussion of the current state of transport in Lambeth and how the Council can impact the future of transportation with a focus on current parking initiatives.

2.1 Transportation and Air Pollution

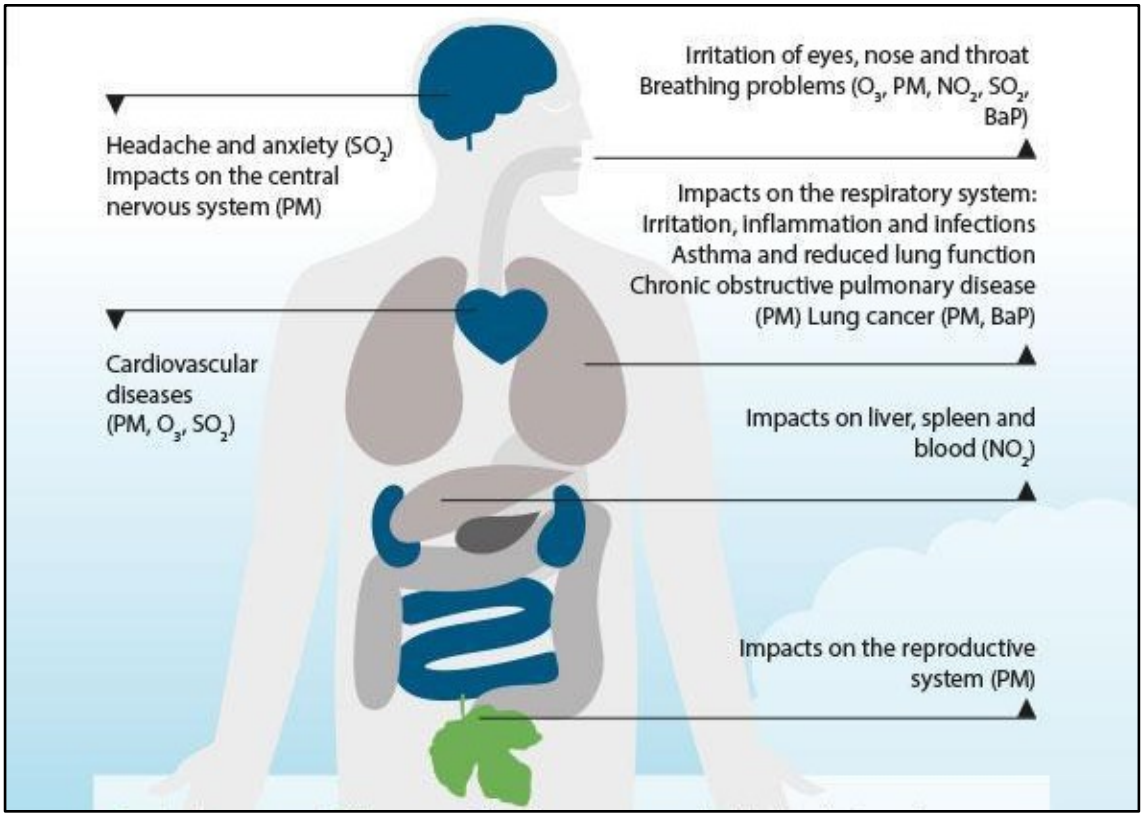
Cities have created a high concentration of economic activities which rely heavily upon transportation systems. With increasing population and motorisation in the last few decades, cities today are faced with unprecedented stress on their infrastructures, giving rise to issues such as congestion, air pollution, and road safety. These act as barriers to optimised transport and inhibit the quality of life for residents.

2.1.2 Air Pollution

The World Health Organization classifies air pollution as "...contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the nature characteristics of the atmosphere" (WHO, 2017, para.1). Emissions from the transport sector, particularly from motor vehicles, are significant contributors to this, generating carbon monoxide, nitrogen dioxide, sulphur dioxide, and small particulate matter (Falcocchio & Levinson, 2015). Their engines alone are responsible for producing 60% of carbon monoxide emissions, while wear on tires and brakes contribute small particulate matter (Akimoto, 2003; Greater London Authority, 2013).

This high level of pollution emission is detrimental to both human health and the environment. When an individual inhales NO_2 pollution, an immune response is triggered causing widespread damage. However, when one inhales small particulate matter (solids less than 10 micrometres in diameter), the impacts is substantially greater, with holes being torn in the irritated lung tissue making infection and cancer much more probable. Figure 1 illustrates the different ways in which this impacts the human body and inhibits one's quality of life (Greater London Authority, 2013).

Figure 1. Effects of Air Pollution
(Adapted from Scottish Environment Protection Agency, n.d.)



These effects are particularly alarming, as it is estimated that by 2050 nearly 70% of the global population will live in urban areas (Akimoto, 2003). This urban population growth and increase in motorisation will lead to an increase in exposure to air pollution, resulting in a significant escalation of premature mortality and respiratory illness. World Health Organization (WHO) findings estimated that carbon emissions are responsible for approximately 2 million premature deaths annually worldwide (Govinda R. Timilsina & Hari B. Dulal, 2011). Poor air quality also increases respiratory ailments, increases the risk of life-threatening conditions such as cancer, and burdens the healthcare system with substantial medical costs (Akimoto, 2003).

In Beijing alone, the annual number of motor vehicle registrations has increased from about 300,000 to 3,500,000 between 1989 and 2008. Air pollution from transportation was not only the primary cause of 3,413 deaths in 2004 in Beijing but was also responsible for 16,030 cases of acute bronchitis, 4,900 cases of chronic bronchitis, 598 cardiovascular hospital admissions, and 19,159 cases of asthma attacks (Falcocchio & Levinson, 2015). Other studies

also indicate that exposure to pollutants results in an increased risk of developing allergies (Krzyzanowski, 2005).

The transportation sector is also a major contributor to global warming. The impacts of on the environment are record high temperatures, rising seas, and severe flooding and droughts (EPA, 2015). The US transport sector contributes nearly 30% of all US global warming emissions, more than almost any other sector (Krzyzanowski, 2005). The largest source of transportation-based greenhouse gas in 2006 was passenger cars (34%) followed by light duty trucks (28%) (EPA, 2015). These statistics are just part of a growing list of reasons reduction of emissions needs to be addressed now.

2.1.1 Traffic Congestion

Air pollution and traffic congestion are intertwined issues in today's world. Congestion in transportation systems occurs when demand for their use exceeds their capacity (Falcocchio & Levinson, 2015). The direct consequences of traffic congestion are longer and less reliable trip times, decreased mobility and accessibility, lower roadway productivity, and environmental impacts. These consequences not only directly influence air pollution, but also lead to increases in business costs and fuel consumption (Falcocchio & Levinson, 2015; Ahammad, 2013). As cities' growth in population and motorization outpaces investments in roads and public transportation, individuals in cities must adjust their schedules to consider expected traffic as these problems continue to grow.

In most cities around the world, if a commuter expects to arrive to work on time, he or she must depart 19 minutes early to account for traffic (Ahammad, 2013). The effects of serious congestion manifest themselves in many diverse ways. Unexpected delays from congestion increase the cost of transporting goods by 50-250% (Ahammad, 2013). Another consequence of congestion is injury; a study estimated that reducing congestion in the United States alone would prevent 287,200 crashes over a twenty-year period (Falcocchio & Levinson, 2015). In addition to injury from these crashes, time is lost due to collisions on the road. A single car crash involving injury typically takes 45 to 90 minutes to resolve, causing over 2,500 vehicle hours of delay. In 2010, congestion caused Americans to travel 4.8 billion hours more and purchase an extra 1.9 billion gallons of fuel. The value of wasted time, fuel, and truck operating expenses cost the US economy $101 billion for that year alone (Ahammad, 2013).

Transportation accounts for 53% of the total annual pollutants in the US, including 34% generated by highway vehicles (EPA, 2015). Congestion on highways alone has the potential to cause tremendous increases in the emission of greenhouse gases. It has been reported that traffic congestion in which vehicles stop and go frequently releases three times more pollution than free-flowing traffic (Ahammad, 2013). In 2007, highway travel contributed almost 80% of the 28,000 million pounds of carbon dioxide released worldwide. Vehicle emissions are lowest when vehicle speeds are uniform and moderate (Falcocchio & Levinson, 2015).

2.1.3 Types of Cars

Not all motor vehicles produce the same degree of air pollution. Looking at Table 1, we can compare emissions from the top three fuels used worldwide: petrol, diesel, and Liquefied Petroleum Gas (LPG).

Table 1. Emissions of Top Three Fuels
(Adapted from Advanced Motor Fuels, n.d.)

	Petrol	Diesel	LPG
CO, g/km	1.48	0.10	1.39
HC, g/km	0.13	0.02	0.10
NO_x, g/km	0.10	0.80	0.07
HC+NO_x, g/km	0.24	0.83	0.18
NO_2,mg/km	0.02	0.37	0.01
PM, g/km	0.006	0.046	0.005
CO_2, g/km	208.1	180.5	189.3
Fuel consumption, l/100km	8.86	6.78	11.74
NH_3,mg/km	17.3	0.9	50.6
SO_2,mg/km	8.9	3.7	2.8
N_2O,mg/km	3	7	3
OC/EC,mg/km	1.1/0.6	11.5/26.1	0.4/0.2

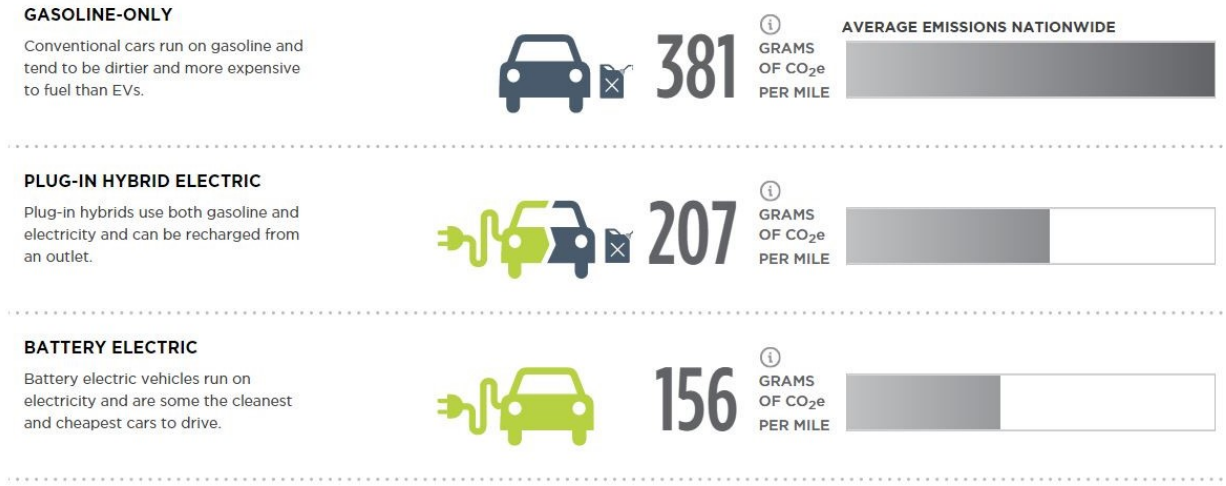
As LPG is a mixture of butane and propane designed to limit carbon and sulphate emissions, it is not surprising that it excels. However, it is more expensive than both petrol and diesel, which has limited its popularity. While it occupies a substantial amount of the market in some European countries outside of the UK, partially due to support from the EU, Australia pulled its last LPG model car in 2016, and only 1-2 % of US drivers have moved towards the fuel (Jones, 2016).

Petrol is of course the dominant choice because of its cheap price, but is found to be less efficient than diesel, while also generating much larger amounts of many air pollutants.

However, when it comes to small particulate matter and NO_x compounds diesel produces by far the most as they are often seen as the greatest threat in concentrated areas (Transport for London, 2013).

However, despite improvements in all three fuel technologies, both hybrid vehicles and electric vehicles ultimately outperform each of them with their limited impact on air quality. In figure 2, the ratio of carbon emissions between the different models can be viewed.

Figure 2. Petrol, Hybrid, and Electric Vehicle Carbon Dioxide Emissions
(Adapted from The Union of Concerned Scientists, 2015)



With the CO_2 production clocking in at 41% for purely electric vehicles when compared to standard petrol, and 54% when comparing the hybrid to standard petrol vehicles, there is no question as to which vehicles are best for the environment.

2.2 Smart City Technology

In an effort to more immediately diminish energy consumption, decrease air pollution, and improve quality of life in cities around the world, urban planners have been trying to integrate information and communication technology (ICT) and the Internet of Things (IoT) into their designs, a development aptly named smart city technology. Smart cities are ideally meant to better integrate utilities, optimising their performance so the community as a whole can save both money and resources, diminish health and pollution problems, and improve functionality.

2.2.1 Information and Communication Technology

Information and communication technology (ICT) is the natural progression after the boom of information technology (IT). ICT extends the focus of IT (storing, accessing, and processing data) to include unifying data through the use of communications technology, such as the Internet. This added focus on communication highlights how in today's world, data does not exist in isolation; in fact, connecting multiple datasets often allows one to determine more accurate trends and relationships. Being able to share data allows connections to be drawn that would have gone undiscovered if left to develop independently.

The European Union has promoted an initiative to help get European governments to optimise their energy consumption through in depth data analysis. Called DAREED, or the Decision support Advisor for innovative business models and use engagement for smart Energy Efficient Districts, its focus is to promote better energy usage policy making by encouraging governments to analyse their energy data to optimise their energy consumption (DAREED, n.d.). For example, DAREED aided the Cambridgeshire City Council in determining public venues to invest in by analysing and comparing each venue's assets and general energy consumption (KIT et. al., 2014). However, while this makes cities smarter, it does not promote the interaction between residents and their surroundings that characterise typical smart city plans.

2.2.2 Internet of Things

The missing link between ICT and a real smart city landscape is the Internet of Things (IoT). The term came into existence over the past two decades, describing the way in which everyday objects and systems could be connected and optimised by seamlessly transferring information between each other, creating a bridge between the physical world and the data world (Al-Shorbaji & Boulos, 2014). Much of the technology that goes into this bridge has existed for decades, including radio communication and various sensors, but has found a place under the Internet of Things umbrella due to its use in the simultaneous gathering and sharing of data (Hu & Ning, 2012).

A notable example of IoT technology in the modern world is Waze, a crowd-sourced GPS navigation application. The app incentivises users to add missing roads or map features, resulting in a fast development of accurate maps in locations of high use (Steele, 2015). Waze uses anonymous sensor data from smartphones to predict traffic in various locations and allows

its users to report events, such as accidents, congestion, and construction (Steele, 2015). Using this data, Waze predicts optimal travel routes, avoiding problematic areas. This strategy has been very successful; the app currently has about 65 million active users per month (Smith, 2017). The consumer-facing nature of this app directly benefits users while allowing the platform to collect valuable data. Furthermore, Waze began releasing its data to some city governments in 2013 (Olson, 2014). This data has been used to identify transportation issues and guide policy decisions, increasing transport efficiency and in turn benefiting city residents.

2.2.3 Benefits of Smart City Infrastructures

By 2050, the number of cars worldwide is expected to more than double from an estimated 1.1 billion to more than 2.5 billion (Gottbehüt, 2016). Rapid urbanisation and increased car ownership will only amplify the challenges of air pollution and people's demands for better public services. The need for cities to be more efficient and more environmentally friendly places to work and live will only become more pressing in the coming years. The only feasible way to accomplish this is through smart city initiatives. The main benefits of the integration of smart city infrastructure through ICT and IoT include sustainable energy consumption, increased mobility efficiency, and other substantial economic advantages (Stimmel, 2016).

Reducing energy consumption is among the modern city's major concerns. Resources such as fossil fuels, clean water and disposable land are becoming more limited as the world's population continues to grow (Gottbehüt, 2016). A smarter electrical grid, for that purpose, is a step towards smart energy consumption. Better networks and monitoring systems through IoT and ICT can be put in charge of energy generation, storage and consumption. In the US alone, a combination of big data analytics and IoT could help businesses and homeowners save over $1.2 trillion in energy costs (Mosannenzadeh, 2017).

A paramount aspect of smart city infrastructure is the forward-looking idea of implementing smart transport related technologies that tackle the rising challenges of growing population and increased demand in car usage. With current transport networks in place, these issues will consequentially lead to more global air pollution and traffic congestion. Large cities in general are responsible for approximately three quarters of greenhouse gases worldwide (Gottbehüt, 2016). Therefore, smart transport infrastructure must be integrated within traditional

transportation systems for maximum efficiency in mobility. Better traffic control, efficient road maintenance, and parking management can be achieved through IoT in the form of networked sensors (Batty et al.,2012).

2.2.4 Smart Parking

Smart parking is one way for governments and policymakers to continue to build on smart city initiatives (Miller, 2015). Parking plays a major role in contributing to congestion globally. Around 35% of cars driving on road in cities at any given time are looking for a parking space, and that directly contributes to traffic congestion issues (Kotb et al., 2016). In 2006, a study in France showed that 70 million hours were spent every year in France searching for parking, resulting in the loss of 700 million euros annually (Kotb et al., 2016). On average, commuters spend 20 minutes looking for parking spots; from this data, one can assume that a large percentage of global pollution and fuel waste is directly related to looking for parking (Kotb et al., 2016). Smart parking technology enables drivers to find a parking spot easily and quickly through the use of networked sensors in parking spaces. Knowing the location of the nearest open space reduces time spent cruising for a spot, increases efficiency in traffic flow, ultimately improving air quality.

While parking is part of the traffic congestion issue, traffic itself is a bigger issue (Batty et al., 2012). A better traffic management system through IoT can allow drivers to avoid traffic and minimise the number of stops at the traffic signals (Stimmel, 2016). Further modernisation through the use of smart road systems, including solar road lighting, magnetic charging for electric vehicles, and enhanced road signs, may further improve the efficiency and economic value of road travel (Stimmel, 2015).

A successful implementation of smart transport infrastructure can result in substantial economic benefits, increased transportation efficiency, and significant improvements in air quality. Globally, large cities could save $800 billion annually by simply installing smart transport systems (Gottbehüt, 2016).

2.2.5 Disadvantages of Smart City Infrastructures

The biggest concern regarding smart city infrastructure is an individual's privacy. With an IoT system in place, it is possible for one's every movement to be monitored with various sensors and devices collecting data both in private or public space (Miller, 2015). While privacy agreements protect individuals from companies misusing this information, stored data is still vulnerable to theft (Miller, 2015). Even if a company acts within their limitations, an individual breaking into the company's database could find data that he or she can personally use or sell to another criminal party (Vermesan et al., 2013).

Today, governments have the ability to listen to every telephone conversation, read every text message, and go through every email. Everything done online can be monitored, and with the potential for millions more sensors and devices to be connected to IoT systems, the potential for new data collection is near limitless. Ultimately, it is arguable that this is a trade-off, sacrificing one's privacy in return for all the benefits from the interconnectivity of the IoT (Batty et al., 2012). In addition to government monitoring, collected data of any form is open to exploitation and theft. Many individual smart devices may not necessary have the same level of security protection as more commercial systems, making these devices easy targets for hackers (Miller, 2015). While it may sound appealing to have virtually every device in the world connected through IoT systems, this interconnectivity creates a serious security risks. Some hackers may have even worse intentions than just stealing digital data; it could be an extremely dangerous issue if hackers gained control of the smart sensors in one's home, car, or city (Miller, 2015).

Smart city infrastructure can risk deepening the digital divide. A digital divide is defined as the gap between those who have access to ICT and those who do not. Although it has reduced over the last few decades as we become more of an information society, the issue persists today, disproportionately affecting older people, minority ethnic groups, those with lower levels of education and incomes, and those who live in geographically remote areas (Wong et al., 2009). People with disabilities also have considerably less access to technology compared to the general population in every country. Take the US for example, where 40% of the population without access to Internet broadband are people with disabilities (Thurston, 2016). The ability to use social media networks are key resources and skills needed by those seeking social and economic success, but those that stand to gain success are the often the same people that lack access

(Schweitzer, 2016).

As many major global cities start to integrate smart city technologies within their infrastructure, the digital divide will inevitably become a bigger problem. These implications will not just be individuals having mere access to technology. Within a nation, better quality access to IoT and ICT systems will be more accessible to the upper class. On a global level, factors like GDP, communication infrastructure, and investments in research and development influence the advancement of Internet distribution. Therefore, more developed societies are more prone to implement new technologies than less developed countries (Conceição, 2016). Those who are ahead in the ability to better navigate and process information will outpace people or nations with limited access (Schweitzer, 2016).

2.3 Examples of Smart City Initiatives

Many city governments have already recognised the advantages of this information sharing and have begun implementing IoT and ICT into the infrastructure of their cities. With the goals of collecting and presenting data to the public, improving transportation, and reducing air pollution, a number of innovative initiatives have cropped up around the world.

2.3.1 Zürich, Switzerland

Zürich is home to one of the most efficient and widely used public transit systems internationally (Nash & Sylvia, 2001). Paramount to its success is its transit priority program, which aims to increase the efficiency of road-based transportation through the use of IoT technology. Throughout the city, networked traffic signals coordinate to both regulate regional traffic to prevent congestion and give priority to buses, increasing the efficiency and attractiveness of public transit (Nash & Sylvia, 2001). This strategy has significantly increased the usage of public transit as a primary method of transportation; currently, approximately 44% of all residents use public transport in their commute to work, with an additional 19% biking for walking (Economist Intelligence Unit, 2009). The increased usage of public transit in addition to the traffic management systems greatly improve air quality, as fewer vehicles are left to idle in congested streets.

2.3.2 Copenhagen, Denmark

Copenhagen stands out as a progressive city concerning the integration of smart city technology and green transit. To reduce congestion and carbon emissions, the city restructured its traffic signal system, altering timings and adding sensors where appropriate (similar to Zürich). This initiative considers multiple modes of transportation, including cars, buses, and bicycles (City of Copenhagen, 2014). Copenhagen additionally favours bus transit by the incorporation of bus only lanes, which receive green traffic signals before other lanes. However, an array of more technical solutions exist. Each bus is equipped with a GPS system, which communicates with traffic signals in various locations; based on the relative position of a bus, each traffic signal coordinates a flow of green lights that will allow the bus to pass through very quickly, without adversely affecting other traffic patterns (City of Copenhagen, 2014). These initiatives increase the efficiency of both cars and buses, decreasing traffic congestion significantly, resulting in shorter travel times and significantly reduced air pollution.

2.3.3 Barcelona, Spain

Barcelona is one of the world's leading cities in smart technology and the integration of ICT and IoT. In 2012, the city began implementing a comprehensive set of smart city initiatives to improve the lives of its residents, save money, and reduce air pollution (Adler, 2016). A significant subset of these actions intend to improve transportation in the city, including some innovative parking strategies.

The Barcelona City Council, along with numerous private companies, are actively working to incentivise wide adoption of electric vehicles. Current policies include free city parking and the placement of charging stations throughout the city as well as significant discounts on electric vehicle registration taxes (Live, n.d.; BCNecologia, 2013). The city plans to further promote electric vehicles by deploying a fleet for use in the public sector (BCNecologia, 2013). In the long term, Barcelona intends for these initiatives to result in the wide adoption of electric cars, drastically reducing air pollution in the region.

The city has also made significant improvements to both public and private transit. Bus stops have been modified to include free Wi-Fi, real-time information concerning bus positions and arrivals, and resources for individuals concerning transit in the city (Adler, 2016). This aims to attract individuals to public transit in an effort to decrease emissions from privately owned

vehicles.

The most interesting initiative, however, is Barcelona's smart parking strategy. Using a connected network of sensors in the pavement of various roads, drivers can use an app to guide them to open parking spaces, where they may then pay for parking using that app (Adler, 2016). These resources have significantly decreased the time it takes to locate available parking, in turn decreasing congestion and air pollution from cars (Adler, 2016). This plan has been extremely successful, with 4,000 permits issued from the app daily after only one year of operation (Barcelona Service Press, 2014). These initiatives have allowed Barcelona to become one of the most technically advanced transportation cities in the world.

2.3.4 Singapore

Singapore's unique setting has allowed it to progress very rapidly with the integration of various smart city technologies. As a relatively small island, Singapore intends to connect every building to a network, implementing the first ever national information infrastructure (Mahizhnan, 1999). All new houses and government buildings are required to have built-in broadband connections (Mahizhnan, 1999). This lays the foundation for further integration of smart city technologies in the nation.

However, some of the most impressive ideas arise within Singapore's transportation system. Singapore's bus system utilises sensors in each bus, allowing the government to determine points of congestion, crowdedness, and locations that need more attention. This has resulted in a 90% decrease in crowdedness of buses in the city (Souppouris, 2016). Perhaps even more unprecedented is Singapore's plan for cars: by 2020, all cars will have government-mandated navigation systems, allowing the government to collect anonymous location data about each car on the road. The nation plans to analyse this data to find serious congestion points, assess average speeds, and obtain the most accurate view of transportation *ever* available (Souppouris, 2016). Although some of these ideas may not be reality yet, the nation of Singapore is working towards becoming the first 'smart nation' in the world.

2.3.5 London, England

Despite having some of the worst air quality in Europe, London is on the forefront of many smart city ideas, including a large focus on open transportation data. London is unique in

the way its transportation sector is divided; although some practices come under the control of the city's boroughs, many transportation issues fall under the jurisdiction of a greater government body, Transport for London (TfL). In recent years, Transport for London, the Mayor of London, and individual boroughs have all focused on making London one of the world's premier smart cities.

In 2013, the Mayor of London formed the Smart London Board, and it released a strategy for the implementation of smart city technology to improve the future of London and its residents (Greater London Authority, 2017). This document establishes a set of goals for the implementation of smart city initiatives to respond to the numerous issues created by a dramatically increasing population (Smart London Board, 2013). Although this plan encompasses all of London, a large focus is placed on transportation, as it dramatically impacts air quality, one of the Board's main concerns.

One of the focuses of this plan is the promotion of open transportation data. Through the London Datastore, Transport for London has created a number of open tools which allow third parties to use and analyse traffic data to improve how residents travel. A significant number of these tools are in the form of APIs, or application programming interfaces. An API is a defined set of protocols one may use when developing an application which communicates with another framework or application. The Transport for London Unified API consolidates a number of these APIs under one powerful open resource (Transport for London, 2017). Through this API, developers can gain access to a wide variety of data concerning the current state transport in London, including real-time bus arrival times, road disruptions, and tube line statuses (Transport for London, 2017). TfL intends for developers to use this API to create applications allowing residents to more intelligently perceive transportation in the city, helping commuters to take real-time events into account when planning their daily trips. TfL is also working on a journey planner API, which aims to provide developers with trip information specialised to London's transportation systems (Transport for London, 2017). Once completed, this API will provide resources to app developers of optimal routes in London considering real-time events. Although perhaps not present on the surface, the API initiatives of TfL show how smart city technology and open data can be used to benefit both app developers and residents. Transport for London intends for this data to be utilised to inform residents concerning travel decisions, attempting to reduce congestion and promote better air quality.

Other London transport initiatives come in a more conventional package, integrating IoT technology and ICT to provide commuters with useful information. A number of roadside message signs alert drivers of traffic incidents and road closings, and feeds from these signs can be accessed remotely via a live data feed (Transport for London, 2014). TfL also openly publishes data from 177 traffic cameras, allowing individuals to view the status of various roads in real time (Transport for London, 2014). London also features a number of displays accurately informing commuters when trains and buses will arrive (Transport for London, 2014). In 2016, the Mayor of London announced that certain bus routes will be converted to being fully electric, with a fleet of 51 electric buses the start of a plan to reduce the emissions of London's entire fleet (Mayor of London, 2016). Early in 2017, additional electric routes were added to supplement London's hybrid fleet of over 2,000 buses (Mayor of London, 2017). These electric buses include charging stations for riders' phones as well as displays informing riders of the next few stops as well as information concerning nearby tube stations (Mayor of London, 2016). These improvements significantly reduce emissions and provide incentives for riders to use public transit, further reducing air pollution. However, not all initiatives are on the city level. The Borough of Hackney, for example, monitors the usage of its bicycle paths to determine trends and make predictions about the future of cycling in the Borough (Hackney Council, 2017).

London aims to become a leading force in smart city technology and air quality by 2020 (Smart London Board, 2013). Its current technological initiatives provide a secure foundation for further development, and its strong focus on public engagement through open data allows for growth through the further integration of IoT technology. The condensation of complex transportation systems into simple developer-friendly APIs has allowed London to take the first steps into significantly reducing congestion, informing commuters in real time, and ultimately reducing air pollution.

2.3.6 General Smart City Guide

Each of these projects around the world require a series of urban planners who specialise in smart city building. As we continue to see projects grow in scope and develop over time, experts have created several guidelines on how to approach designing these initiatives. Interestingly, whether one looks at guides of what *not* to do, as seen in Adam Greenfield's "Against the Smart City", or pillars of what *to* do as seen in Dr. Larissa Suzuki's TED talk,

"What are Smart Cities?", they tend to maintain similar points.

First, experts recommend that smart city plans operate on a feasible timeline. Although it may be simple to make a prediction or develop a strategy that will take 30 years, it is often very difficult to see either of these come to fruition (Greenfield, 2013). Plans are suggested to be realistic, made so that they can be implemented in a reasonable amount of time, so the person developing the plan knows they will be there to see it implemented (Greenfield, 2013).

Second, smart cities need to clearly serve the people. When a governing body sees the opportunity to use data to make decisions, it is often driven to adjust the city's behaviour to solely cut costs and reduce energy consumption. While this could be a side effect of using smart city technology, a city ultimately serves the people. Therefore, experts suggest that there must be visible benefits to all residents (Suzuki, 2014).

Third, experts suggest that smart city technology actively include human interaction (Greenfield, 2013). This stems from the idea that personal interaction with smart city technology allows users and government bodies to judge effectiveness and make improvements when necessary (Suzuki, 2014).

Finally, smart cities need to allow for adjustments. As with any technology, adjustments and updated must be made, and the body maintaining whatever smart systems are in place must prepare to make these changes (Suzuki, 2014). This prevents the technologies in use from becoming obsolete.

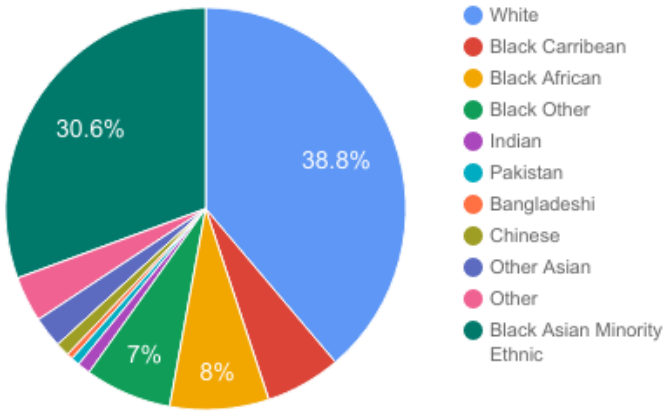
2.4 Introduction of Lambeth

Located in central London with its northern point on the Thames, The London Borough of Lambeth has been a part of the city's history for hundreds of years, gaining its borough status in 1889 (see Appendix A, Figure 1). Today, Lambeth is primarily a residential district with a population of 318,000 people, the eighth largest borough population in London (Lambeth Council, 2016). In the north of Lambeth resides a business district and tourist attractions such as the London Eye in Waterloo, and gradually gives way to increasingly residential districts to the south in wards like Brixton, and further southward in Streatham. The local wards are thickly settled, mostly with working age people between the ages of twenty and forty-four (Lambeth Council, 2016).

Lambeth has gone through drastic gentrification in recent years, with the community

remodelling itself to better suit the lifestyle of the increasing amounts of younger people. Long-time residents recall when Brixton, a historically population dense ward in Lambeth, was predominantly known as a Caribbean immigrant community, but over the last few decades it has given way to districts containing chain restaurants and other similar businesses. Today Brixton's population has shifted to a more diverse setting with residents from many different backgrounds, while the Caribbean population has settled below 5% (Lambeth Council, 2015; Wheatle, 2016). Figure 3 illustrates the current population diversity of Lambeth, using data from the 2016 State of the Borough.

Figure 3. 2015 Lambeth Population by Ethnic Group
(Adapted from Lambeth Council, 2016)



Lambeth's history as an immigrant community, and its evolution to a young working class residential borough has cemented it as one of the more liberal boroughs in London. During discussions with the lead commissioner of the Council, Mr. John Bennett, he stated that because of these liberal tendencies, the residents of Lambeth as a whole are more willing to take an active role in the community and care about social issues (J. Bennett, personal communication, Feb 13, 2017).

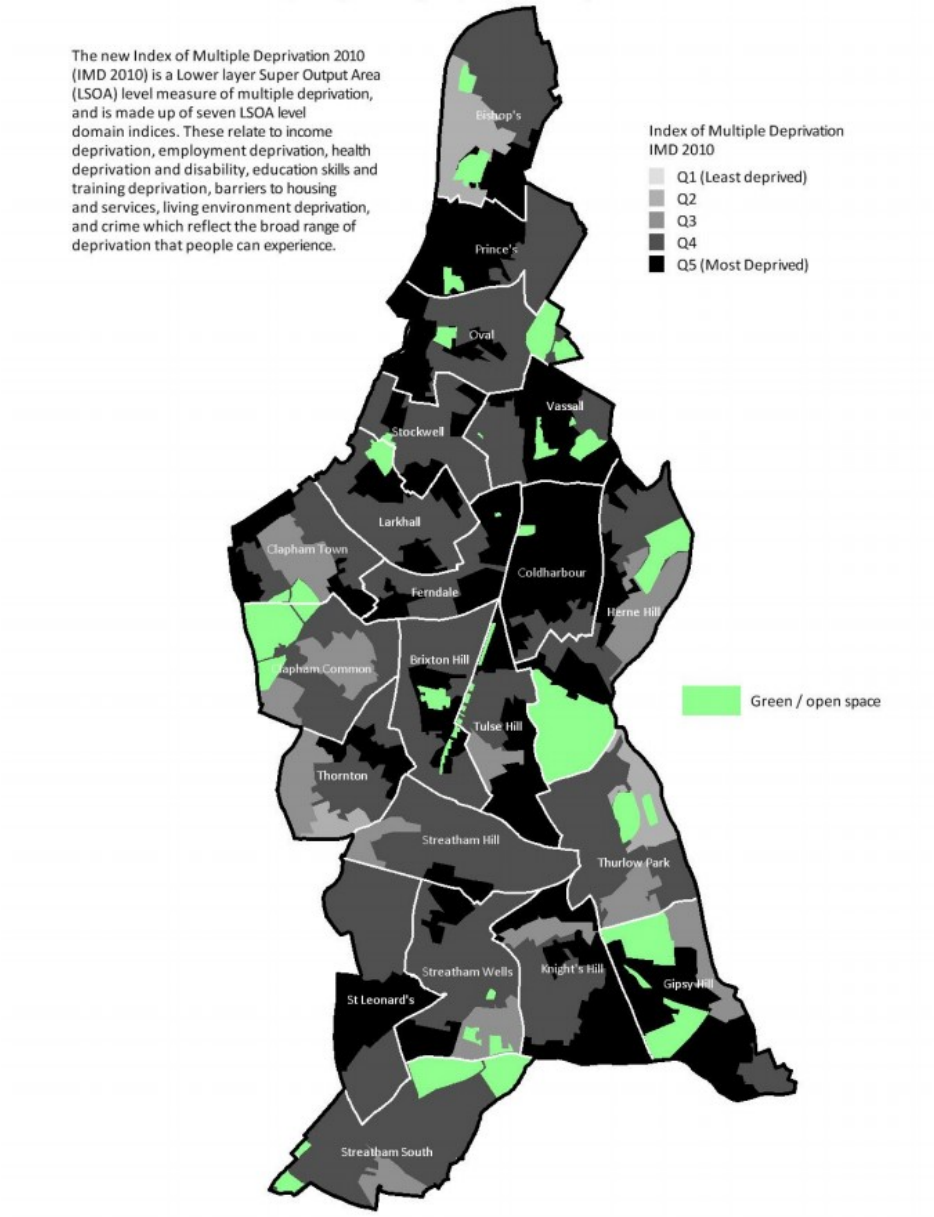
However, their engagement is not always in favour of action, as there exists some resistance to the various waves of change in Lambeth's wards. With residents' nostalgia for the unique character of wards such as Brixton during their youths, there is also a resentment for the what the area has become. Their recollections of Brixton depict how the Caribbean population brought a particular life to the local community with rich music, Jamaican groceries and a stable

presence of small business (Hill, 2015). Many of the concerns being expressed by the local population relate to property only being affordable for citizens in the middle to higher class, which seems to force locals out of their businesses and home communities while inviting in a new wave of business chains. As a result of the increase in construction and transformation of businesses and housing, residents have begun to speak out against the effects of local gentrification (Hill, 2015). Most notably, the hashtag #savebrixton has gained traction on Twitter, as a way for the citizens of Brixton to call for the preservation of their neighbourhoods' identities.

However, protests have not always been this peaceful. In 1981, the ward of Brixton was the stage for a three-day riot that started as a result of questionable police activity, attempting to curb the crime that had spiked as a result of increased unemployment in the Borough. Despite events such as these, Lambeth has undergone a noticeable shift in its nature. Today, while safety and crimes rates are still a primary concern of the Borough's citizens, public surveys have shown that these concerns have reduced in severity over the past few years (Lambeth Council, 2015). This is most likely due to the rapid decrease in higher priority crime throughout Lambeth, with the 2014 State of the Borough recognizing an 8.8% drop from 2013 (Lambeth Council, 2014).

In 2010, Lambeth was rated the 14th most deprived location in England. The Borough has seen a positive trend in the last six years, moving to the 22nd most deprived in the country, while being ranked as the 8th most deprived borough in the city of London (Lambeth Council, 2016). The wards of Lambeth containing areas classified as "severely deprived" in various categories are shown in Figure 4.

Figure 4. Index of Multiple Deprivation (IMD) in Lambeth
(Adapted from Lambeth & Southwark Public Health Intelligence Teams, 2015)



Data shows that the deprivation throughout Lambeth is not in fact spread evenly, but is instead concentrated in several "pockets" (see Figure 4) (Lambeth Council, 2016). While the bulk of the Borough is changing for the better, the growing population emphasises these pockets and more clearly demonstrates the transit inconveniences associated with larger amounts of people. As the populace is growing, the cost of housing has increased, contributing to many working age Londoners opting to rent or take out mortgages and loans on homes, as opposed to pursuing property ownership. Along with these changes, local surveys have determined 85% of

residents to be content with the conditions in their neighbourhoods, with 53% of residents stating that their neighbourhoods are experiencing change for the better (Lambeth Council, 2016).

2.4.1 Transit and Air Quality in Lambeth

While Census records indicate that only about 8.6% of individuals in Lambeth primarily travel via automobile, the narrow and intricate structure of Lambeth's roads results in debilitating traffic, rendering intra-borough travel in peak hours especially difficult (Office for National Statistics, 2011). However, this does not deter the residents of the Borough from using the roads and rails, with an estimated 60% of the total number of residents in Lambeth commuting via public transit (Bennett, 2016). This is a factor which demonstrates clearly that a majority of Lambeth's residents are primarily workers, though their places of work do vary. Only 28% of all residents both live and work in the Borough, whereas 26% of the population commute outside of the Borough to work elsewhere in the city of London (Bennett, 2016).

The inefficient flow of traffic during the busy hours of daily travel is catalysed by limited access to the London rail, inhibiting residents from reaching destinations within the Borough. Though there exists a variety of stations providing access to overground and underground rails, these places become flooded with commuters over the course of the day. Some residents have limited means of accessing the underground, such as in the Streatham wards as well as an area known as Norwood, both in the south of the Borough. People who do not have ease of access to these rails are forced to rely on options such as bus routes, which have a north-south focus instead of east-west (Lambeth Council, 2011). When citizens in certain areas do not have their travel needs readily met, their freedom of choice over which transport methods they use are impacted.

A combination of regularly congested transportation and the uneven distribution of transit access throughout the Borough has resulted in various concerns within the Lambeth Council, the greatest of which is the impact on air pollution. The governing body estimates that the local transport sector contributes to a quarter of a million tonnes of greenhouse gases via automobiles (Lambeth Council, 2011). In January of 2017 the London Mayor's office was forced to announce a toxic air warning, after breathability throughout the city was deemed too poor, and warned citizens with existing respiratory problems to limit their time spent outside (Forster, 2017).

While the overall alert could be blamed on the culmination of decades of poorly

controlled pollution in London, the impacts of this air quality have been made apparent. In 2013, the Greater London Authority published a study on air quality specifically in Lambeth, where it was found that 139 people died prematurely in 2008 from exposure to small particulates in the atmosphere (Greater London Authority, 2013) (see Appendix A, Table 1). The total number of fatalities is actually higher than the city's average per borough, where it is estimated that roughly 4,200 individuals throughout London died. A concerning 7.7% of deaths in Lambeth and a decrease in life expectancy by 11 years can be attributed to long term exposure to small particulate matter, with similar values in all of London (see Appendix A, Table 2).

This exposure to particulates is also estimated to have impacted thousands of individuals in non-fatal ways, which is of particular concern to the people of Lambeth. The same 2013 study reinforced the idea that deprivation and air pollution are often found in similar locations due to a phenomenon called environmental inequality (Greater London Authority, 2013; Fecht et al., 2015). This is partially that the impacts of air pollution on those who are not as affluent is much more severe due to the lesser availability of healthcare, which makes them less able to work and continues a cycle of deprivation (Fecht et al., 2015). Due to the pockets of more impoverished citizens found in Lambeth, these individuals are more at risk than others in more economically stable communities.

2.4.2 The Lambeth Council and Parking

The Lambeth Council regards air pollution to be a pressing issue, however any direct influence that the Council has over the main contributing factors is limited. Many of the roads on which buses travel are under the jurisdiction of Transport for London, and the Council can only seek to petition TfL as well as the Mayor's Office to enact meaningful change. The members of the Council do, however, have direct power over transportation in the form of a main source of revenue for the Borough: parking (J. Bennett, personal communication, 2017).

Current parking policy in the Borough dictates that residents are eligible to purchase a parking permit, allowing them to park in the Controlled Parking Zone (CPZ) in which they reside (see Appendix B, Figure 1). The pricing for these permits is currently based on carbon dioxide emissions in g/km for motor vehicles, dividing them into six bands. The first band includes vehicles with the lowest emissions, while the sixth includes vehicles with the highest emissions. The vehicles in these bands tend to be electric and diesel, respectively. Occupying the remainder

of the bands is a mixture of hybrid and petrol vehicles of varying levels of carbon dioxide emission. The following table shows the pricing for a parking permit, given the various band levels. This table is representative of CPZs outside of congestion zones, where the prices for each band reduce by about £13.

Table 2. Emissions-based Permit Pricing (Outside Congestion Zone)
(Adapted from Lambeth Council)

Lambeth Permit	New Charges - from 21 Feb 2011 M = months			
Band	**Annual**	**6m**	**3m**	**1m**
1	£0	£0	£0	£0
2	£117.00	£61.45	£33.70	£15.20
3	£149.50	£78.00	£42.25	£18.45
4	£175.50	£91.00	£48.75	£21.15
5	£234.00	£120.90	£63.70	£26.00
6	£260.00	£133.25	£69.90	£27.65

If an individual parks in a CPZ without a valid permit for that CPZ, resident or otherwise, they must pay a fee to use that space. This fee is paid using the “pay and display” machines that line the pavements of Lambeth (see Figure 5).

Figure 5. Pay and Display Machine in Lambeth

A person using this machine can pay for the parking space for an increment of time using cash, a card, or a Pay by Phone method. Each machine has a unique location number that users of Pay by Phone must input to indicate where their car is parked. These machines have proven themselves to be quite difficult for the Council, as they are outdated, with many accepting only cash due to their age, and will require reconfiguring to accept the new pound coin entering circulation in March 2017. This reconfiguration would cost the Council a total of approximately £150,000 for all the machines in the Borough. Not only are the pay and display machines causing clutter on the pavement, but they are prone to theft and vandalism as well as requiring constant maintenance (N. Fenton, personal communication, 2017).

Thus far, the Council has made a number of attempts to investigate the elimination of the pay and display system. One of these attempts involved a trial period in December 2016, where 15 pay and display machines were left incapable of accepting cash in favour of Pay by Phone to observe the response by users. The trial resulted in a steady increase in the usage of the Pay by

Phone method during that time period. Another method of saving on costs for the Council is to simply allow pay and display machines to go unrepaired when they break down, so long as there is a functioning machine nearby that could be used with equal ease. One of the more established plans to address this matter is to retain a fraction of the existing machines based on location and frequency of use, while phasing out the remainder of the machines, thereby limiting the amount of reconfiguration required to a more reasonable amount (P. Fawcett, personal communication, 2017).

In the midst of the Council's plans to mitigate the costs of this transition, they have determined that the ideal situation is a complete conversion to the Pay by Phone system. Users can make calls, text, or use a mobile app to make their parking payments, eliminating the need for cash or cards that would necessitate a machine. Many parts of Lambeth, such as Waterloo, already have a large majority using this mode of payment, while places such as Brixton still rely on cash payments. With widespread adoption of the Pay by Phone method, the Council could easily enforce an emissions-based pricing system on short-term parking similar to that of their permit-based parking scheme. This would allow the Council to encourage all short-term parking users to use lower emissions vehicles, therefore reducing air pollution in the Borough. The Lambeth Council is also planning to use a system called PayPoint to process parking payments. PayPoint can be used as a cash and card alternative, where the user can pay for parking from a local convenience store. There are currently 350 PayPoint locations throughout the Borough. However, these locations are not currently configured for parking transactions, instead only handling bill payments and other services. The inclusion of parking payment functionality in PayPoint could take about 3 months and would cost the Council around £10,000. At the time of writing, the Lambeth Council is seeking to understand car users' reasons for preferring cash and card payment methods to Pay by Phone. The Council also wishes to identify possible ramifications of eliminating pay and display machines in the Borough in favour of a completely Pay by Phone system.

The Council is also looking to integrate the use of floating car clubs in the Borough. Floating car clubs are ideas similar to Zipcar, where operators provide access to one-way shared vehicles to members, and one can end the car reservation by parking within a specified company operating location. London as a whole currently has a total car club membership of 135,000. A member can simply reserve cars online or by smartphone app, unlock the car with their

membership card, and drive off to their destination. The Council is interested in floating car clubs to help address problems concerning population growth, traffic congestion, and air quality through reducing car ownership and encouraging the use of sustainable forms of transport. Delays from congestions currently cost about £4 billion in London, and it is estimated that by 2031, population of London will reach over 10 million, only increasing congestion (Transport for London, n.d.). The Lambeth Council views the float car clubs approach as one of the solution to addressing these challenges. However, at the time of writing, the Council is unsure of residents' views concerning floating car clubs, and they believe this will largely determine the feasibility of implementing such a plan.

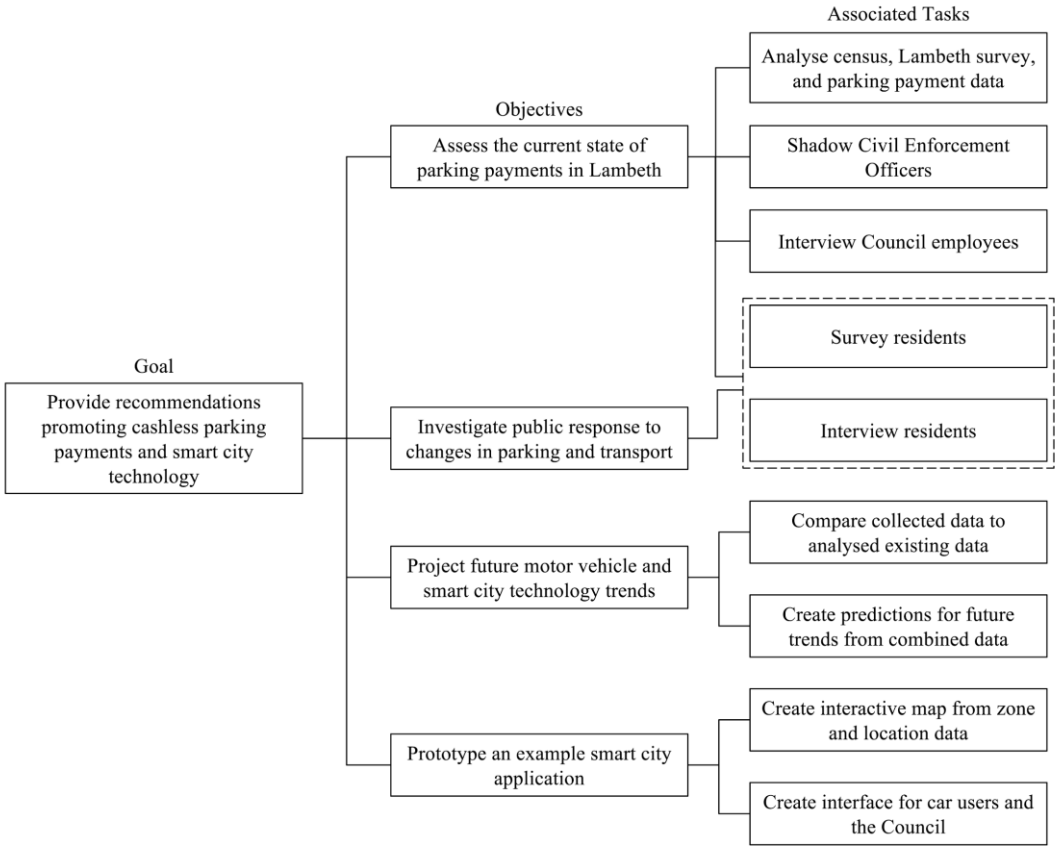
Chapter 3: Methods

The goal of this project was to provide recommendations to the Lambeth Council promoting cashless parking payments and how this could facilitate the integration of smart city technology in the Borough to cut costs and reduce air pollution. To achieve this goal, we developed a strategy divided into four objectives:

1. Assess the current state of parking payments in Lambeth
2. Investigate public response to potential developments in parking and transportation
3. Project future motor vehicle and smart city technology trends
4. Use our research to prototype an example smart city application

This section introduces and discusses the methods used to achieve this goal, including data collection and analysis techniques implemented in Lambeth. Figures 6 shows the associated tasks for each of the objectives (see Appendix C, Figure 1 for an approximate timeline for these tasks).

Figure 6. Objectives and Associated Tasks



3.1 Shadowing Civil Enforcement Officers (CEOs)

Direct observation is a method of collecting qualitative data utilised in many disciplines, and has proven to be particularly useful when evaluating transportation systems (Strambi, 2010). Based upon this we used similar methods to better understand patterns and behaviours of those residents who park in Lambeth, shadowing two Civil Enforcement Officers (CEOs) who monitor parking in the different wards to get a sense of what they observe every day.

This observation helped us assess the current state of parking in the Borough of Lambeth and allowed us to gain a better understanding of the effectiveness of various parking payment methods, especially cash and Pay by Phone. This method of data collection was meant be informative and exploratory, allowing us to build our background knowledge concerning the Lambeth parking system and other relevant issues.

We shadowed the CEOs during the third week of data collection, choosing to split between two locations in Lambeth, one known to favour Pay by Phone and the other cash, to best understand the difference in resident behaviour towards different payment options from the CEOs' viewpoint. Observing the CEOs at two different location gave us ideas to why one location has wider adoption of one payment method over the other and knowing these reasons were used along with direct responses from the resident interviews when we were developing our recommendations about the immediate impact of short-term parking changes on the residents. Waterloo in the north of Lambeth was chosen as the majority of people (86%) parking there already use Pay by Phone, while Brixton in the south of Lambeth was selected because people there still favour the cash based pay and display machines.

After getting in contact with the third-party company responsible for CEOs in the Borough, we were introduced to Zeka in Waterloo and John Uba in Brixton. We asked questions regarding the effectiveness of the Pay by Phone app and people's behaviour towards the different form of payments to CEO from each location. Observing the process a CEO must take to issue a parking tickets and hearing their experiences with residents concerning different payment methods gave us general information on how parking works in Lambeth and the differences that lead to more people using Pay by Phone in Waterloo than Brixton. More importantly, the conversations with the CEOs gave us information concerning the effectiveness of the Pay by Phone app from on both the CEOs' and their perception of how residents feel about this method.

This experience gave us a better idea of how those outside the Council view issues

regarding parking. We were able to form a preliminary assessment of resident's attitudes on the present parking payment options from these CEOs' perspective who have been interacting with the residents for as long as 16 years. We discussed and analysed these observations to draw conclusions concerning the current state of parking. Furthermore, gathering this information early also allowed us to modify questions for resident interviews based upon the issues we discussed, resulting in more useful responses later on.

3.2 Analysis of Existing Data

Transportation in London has been monitored for decades, with detailed statistics gathered in the census every ten years and the Borough reports annually. As we began working with the Council, our first task was to gain access to these records and recognise trends that relate to car usage and air pollution. Although the last census was performed in 2011, its extensive data still aided in our assessment of the current state of transportation, giving insights into car ownership trends and general environmental issues. We mainly analysed citizens' primary travel methods, the availability of cars in each household in the Borough of Lambeth, and population density. Additional data regarding energy consumption by motor vehicles over time allowed us to determine trends concerning the usage of both petrol and diesel cars. We then used documents more specific to Lambeth to gain an understanding of trends within the Borough. Each year, the Lambeth Council conducts a survey of approximately 700 residents, obtaining information concerning borough-wide issues and public satisfaction (J. Bennett, personal communication, Feb 13, 2017). We examined these surveys to determine public opinion concerning both transit and air pollution, while recording how these perceptions have changed in the past few years.

Regarding parking, the Lambeth Council has collected a significant amount of data concerning the usage of the cash, card, and Pay by Phone payment methods throughout the Borough. This data includes time series values of revenue from cash, card, and Pay by Phone for each parking zone in the Borough. We used this data to determine general trends in payment method usage in the Borough as a whole and to identify areas which have the highest resistance to Pay by Phone.

We additionally examined the use of smart city technology in similar locations to determine the feasibility of integrating such technology in the future of the Borough. This

allowed us to project future technology trends in Lambeth concerning both parking and transportation in general.

The conclusions drawn from this data allowed us to build on our understanding of the state of transportation and parking in Lambeth. We extended this analysis by conducting our own set of surveys and interviews, providing a more in-depth assessment of pertinent transportation issues.

3.3 Survey on Parking and Car Usage

We developed a survey to assess residents' views concerning air pollution, car usage, as well as the future parking and transportation initiatives. Prior to releasing the survey, we pre-tested it with our sponsor to gain feedback concerning possible improvements. We then distributed this survey in four ways; first, we cooperated with the Lambeth Council to write a blog post on their website "Love Lambeth", which was tweeted by the Lambeth Council. Second, we posted a link to our survey on a number of Lambeth Facebook groups and on various other social media platforms. Third, we distributed several flyers throughout the Borough, primarily in Brixton and Waterloo. Each flyer contained a short link to our survey as well as a QR code, and was attached to pay and display machines in the area and placed others on parked cars windshields. Lastly, we had the link to our survey distributed to a pre-set e-mail alias used by the Council to generate survey responses in the past.

After obtaining consent, our survey asked residents questions concerning their opinions on air pollution in Lambeth (see Appendix C, Questions 1-3*)*. These questions were meant to determine both general public opinion and awareness of the current air pollution issues. Residents were asked to indicate the severity of air pollution in Lambeth, what they think its main causes are, and the level to which cars affect air pollution. These results together allowed us to gauge the public's view of air pollution in Lambeth. We utilised the results of this question to verify existing data, showing that residents perceive cars as the primary cause of air pollution in the Borough. Other responses allowed us to identify secondary contributions to pollution that the community believes are significant.

The survey then asked residents various questions concerning car ownership and parking in Lambeth. Individuals who paid for parking in the Borough on a regular basis were asked to indicate their preferred payment method and their rationale behind this choice. From these

questions, we gained an understanding of the thinking behind the use of each available payment method. People who did not use Pay by Phone were then asked what would encourage them to use it (see Appendix C, Question 9). These responses allowed us to determine recommendations concerning how to perform a complete switch to Pay by Phone within the Borough while maintaining public satisfaction. In addition, this allowed us to compare our sampling of the public to the information the Lambeth Council collected on a larger scale regarding what percent are using which payment method.

The survey also queried individual's reasons for parking in Lambeth to gain an understanding of the public's primary uses of parking in a controlled parking zone (CPZ). All respondents were also asked if they would favour using a floating car club in the future. This was aimed to gain a simple understanding of the way such ideas are viewed with both car owners and otherwise.

3.4 Interviews of Council Employees and Residents

To further build and expand our knowledge of the Lambeth parking system, we interviewed Council employees and residents of the Borough concerning the current state of parking and existing initiatives. Collecting qualitative data helped us accomplish our first two objectives: to assess the current state of parking payments in Lambeth and to investigate public response to potential developments in parking and transportation.

3.4.1 Interviews with Council Employees

We interviewed employees working for the Council specifically involved in the implementation and advancement of existing transport and parking initiatives. This allowed us to develop a deeper understanding of the current state of parking in Lambeth and the status of past and existing parking initiatives from government officials' perspectives. We also obtained information concerning the Council's perspective on issues including air pollution, car usage, and ways the Council has approached transport problems in the past and plans for the future. These interviews were conducted starting the first week and concluded at the end of the third week. We interviewed a total of 5 Council employees, and each interview lasted from 20-45 minutes. The contact information of employees interviewed were obtained through our sponsor, Lead Commissioner Mr. John Bennett. Interviews took place in either Phoenix House or Blue

Star House in Lambeth. All interviews were recorded and either summary documents or transcripts were created (Appendix E).

Mr. Bennett introduced us to the Programme Director for Environment, Regeneration, Planning and Neighbourhood in Lambeth. In this meeting, we were provided with a very structured direction to the research aspects of our project. We addressed the Council's overarching goal to improve air quality and how the short-term emission based parking pricing initiative came on the agenda. We were additionally provided some direction regarding research areas relevant to our project and advised that we begin considering the potential for a Council-supported floating car club to be implemented in Lambeth. Through this discussion, we also arranged to talk to the Sustainability Manager for the Lambeth Council, where we addressed more specifically the Council's current and future plans for tackling air pollution, and the impact of air pollution the Borough has been monitoring.

We also interviewed three Council employees who were particularly involved in the current parking initiatives. These interviews allowed us to assess the current state of parking in Lambeth from the Council's perspective. The Regeneration Development Manager and the Senior Business Development Officer at the same time due to their close partnership, allowing us to see how both negotiations with third party partnerships have panned out as well as the potential developments being worked on. This was where we were first introduced to the PayPoint concept, where instead of machines, people parking in Lambeth would be directed to either a small business or a kiosk designated by a third party to pay for parking. To further test the feasibility of this idea, we opted to include it in our survey and interview questions to gauge how the public would respond to it.

From the analysis of these interviews, we were able to obtain in-depth knowledge on the background of the current parking initiatives as well as the current status of the parking system. Furthermore, these interviews provided information on potential car usage and smart city technology trends that the Borough of Lambeth as a whole is moving to in the future. Since they are all Council employees and dealt with surveying the residents, they recommended a number of locations where we could obtain the best survey responses. The qualitative data from these interviews was also used in conjunction with data from interviews and surveys of residents to draw parallel themes, helping us achieve the overall project goal.

3.4.2 Interviews with Residents

While survey results allowed us to obtain supplemental data to existing government documents, responses often lacked the depth that one may find in a one-on-one conversation. For example, if an individual was opposed to Pay by Phone because the app was too difficult to use, what about it was difficult to work? For this reason, we conducted a set of interviews with residents of Lambeth, where we asked specific questions to improve our understanding of the Borough's view on air pollution, car usage, and parking.

In our interviews with the Senior Business Development Officer and Regeneration and Development Manager, it was recommended that we scope out public venues, specifically the Lambeth Customer Centre in Brixton to find people willing to participate. In addition, we also attempted to get interviews in the Waterloo area, at both the Millennium Green, and Oasis Centre and Library. We obtained 18 participants for interviews, each individual taking approximately 10 to 20 minutes to talk with. Each interview was recorded with the permission of the participant and had a similar structure to the survey, allowing us to engage in follow up questions that supplied qualitative reasoning from each interviewee. Data collected from the interviews was analysed to identify themes and patterns regarding our overall goal.

After a brief introduction, where we explained our project goals, we asked residents about their experience with cars in the Borough, leading into if they own or have owned one while in Lambeth. This then evolved into a discussion on how they pay for parking in the Borough and why they opted for their preferred method. From here we introduced the possibility of future transportation technologies, such as smart city networking and other car-based advancements, like more support for electric cars and floating car clubs. We also queried individual's opinions concerning air pollution in Lambeth, including primary causes and how serious an issue they perceive it to be (see Appendix D).

3.5 Reaching Out to Smart City Experts

As we developed our smart city suggestions we often looked for guidance in papers written by experts in Urban Planning and Development who had experience working with the IoT technology. We were ultimately able to take away general themes of their research, but decided to reach out personally in an attempt to get their direct input on our project.

We sent e-mails to several researchers and professors that have either worked in the area

or at WPI in the hopes of beginning a discussion with regards to the direction we saw the project going. From these exchanges, we were also able to get their opinions on the potential smart city technologies that could be implemented in the Borough of Lambeth, particularly the smart parking idea. In addition, since these people are experts that have worked on smart cities for much of their career, their input helps legitimise our recommendations, satisfying our third objective.

3.6 Example Application

After being exposed to both the Council's plan to implement a 100% electronic parking payment system and their interest in integrating smart city technology in the Borough, we began to consider ways to combine these ideas. We concluded that a portion of the data collected by the Pay by Phone application could also be used to give both the Council and residents real-time information concerning parking locations in the Borough. Using this idea as a foundation, we created an example web application for the Council to demonstrate how smart city technology could be used in the scope of parking.

The main goal of the application was to accurately determine areas of available parking within the Borough, using just data from the Pay by Phone system and other raw data, while allowing the Council to set prices in real time. Each time a user begins parking on Pay by Phone, a signal is sent to the Pay by Phone server, indicating that a car has begun parking in a given location. This information could also be used to determine the number of cars parked in a given parking location. With this data and an estimation of the number of cars that could park within this location at once, one can determine if that location has available parking.

As the backbone of the app, we implemented a server application that contained data concerning each parking zone and some example parking locations. We designed the server to update each connected client whenever a zone or location was updated, providing users with real-time parking and pricing information. We created an interactive map of each CPZ in the Borough from existing Council records and maps (see Appendix B, Figure 1). Next, we added data specifying pay and display machines and their accompanying parking locations based on additional data from the Council. Finally, we constructed an interface for both car users, allowing them to park in a selected parking location, and the Council, allowing them to set emissions-based prices in real time. The product was a platform that allowed for the real-time

transfer of data concerning both available parking and pricing throughout the Borough.

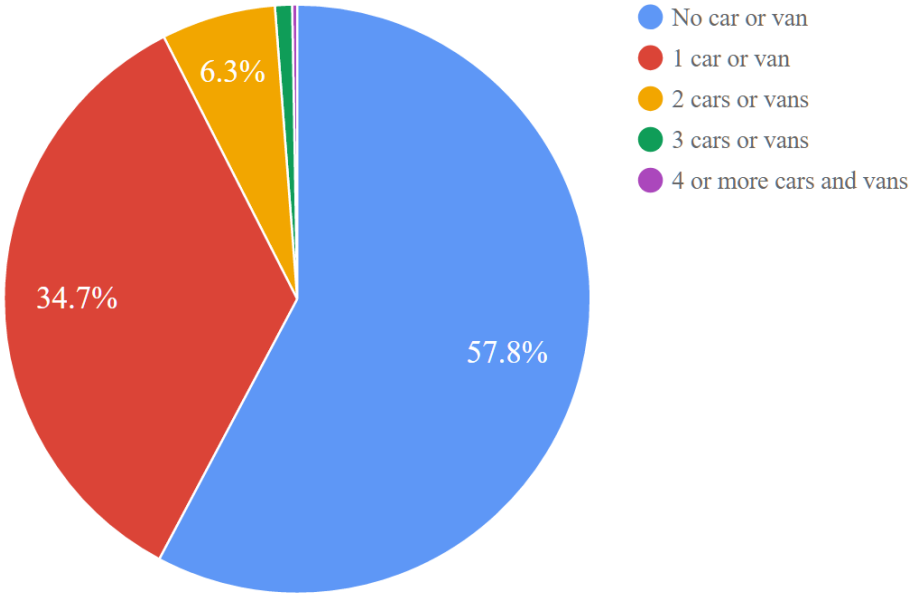
Chapter 4: Results

This chapter details the information gathered through our methods, organised as they pertain to the different themes of our research. Beginning with our analysis of raw data provided by the Council, it then proceeds to detail the findings from both our survey and interviews on the current state of parking, public opinion on potential future parking developments, and future car ownership and smart city technology trends. The section concludes by elaborating on the development process for an application meant to demonstrate smart city parking technology.

4.1 Conclusions from Secondary Data

Regarding current car ownership and usage, the 2011 Census data stated that about 58% of households did not own a car and about 35% own only one car. The remaining 7% own 2 or more cars (see Figure 7). Additionally, only around 7% of all residents use a car as a method of travel to work. The rest of the working population uses public transportation such as the underground, train, and bus or cycle to work.

Figure 7. Car and Van Ownership in Each Household in Lambeth



By analysing car usage in Lambeth, we found that in 2013 the primary vehicle types contributing to overall energy consumption were privately owned petrol and diesel vehicles. A summary of energy consumption by all vehicle types in Lambeth can be found in Figure 8 and Figure 9. The trends in energy consumption showed that while personal petrol vehicles are declining in overall contribution, diesel has remained mostly unchanged since 2008 and has even experienced an increase between 2002 and 2012.

Figure 8. Total Motor Vehicle Energy Consumption by Vehicle Type in Lambeth in 2013

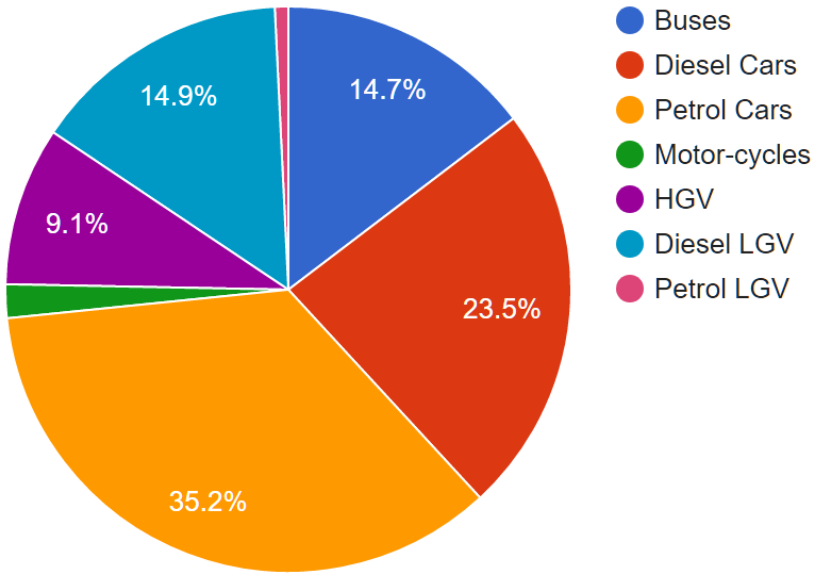
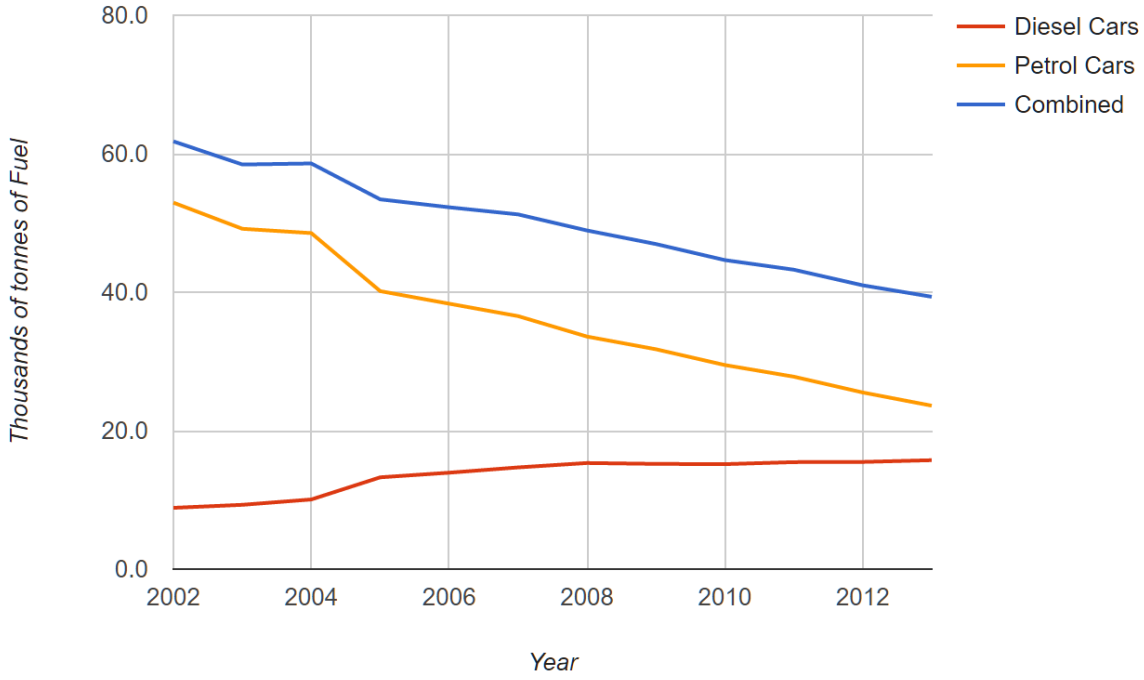


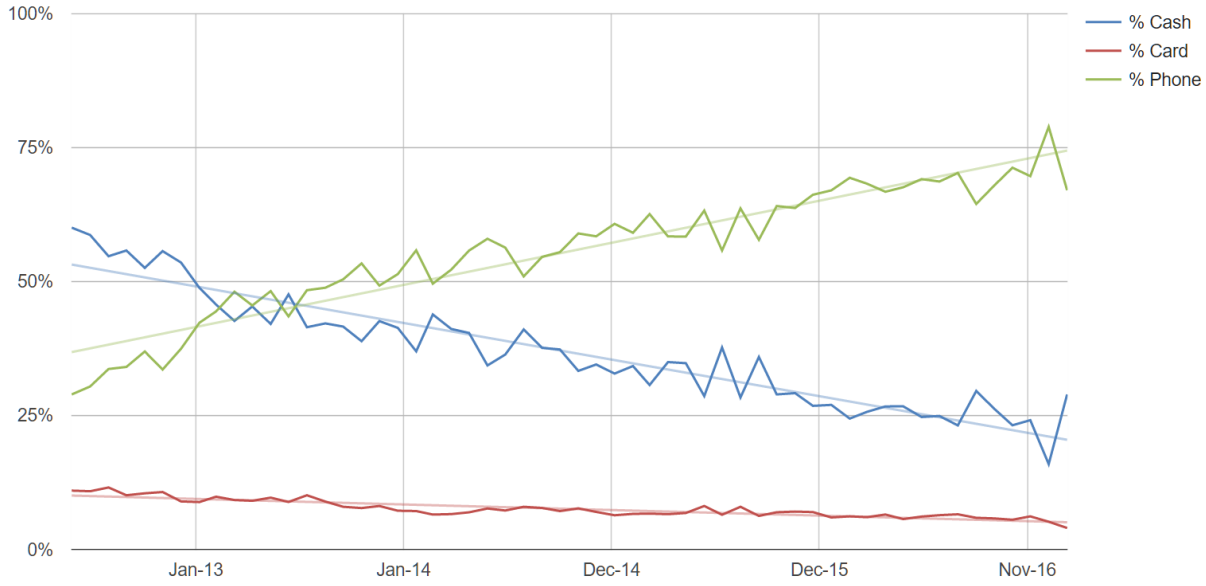
Figure 9. Energy Consumption by Personal Cars in Lambeth



To gauge individuals' openness to Pay by Phone, the Council conducted an unofficial experiment starting in early December 2016, removing 15 pay and display machines throughout the Borough. Their goal was to determine if the inconvenience of having to travel farther would incentivise the use of the mobile payment alternative. At the conclusion of the study in late December 2016, there was a 12% increase in Pay by Phone usage at the trial locations. It was also shown that the people making transactions during this trial period were mostly first time users of the Pay by Phone method, supporting the idea that many people are willing to change and embrace new technology for new payment methods when it becomes more convenient.

Usage of Pay by Phone has substantially increased in Lambeth (see Figure 10). However, it has been more widely embraced in some CPZs than others. As seen in Appendix G, Figure 1, as of January 2017, 85% of people parking in Waterloo process their parking payments through the mobile app, compared to 63% in central Brixton as seen in Appendix G, Figure 2.

Figure 10. Percentage of Card, Cash, and Pay by Phone usage



One of the Council's goals in removing the pay and display machines is to improve street environments and reduce clutter or obstructions generated by the machines. In the Lambeth Annual Surveys from 2014, 2015 and 2016, residents rated clean streets and crime reduction not only as the most important improvement in the Borough to make it a better place live, but also as the area most in need of improvement.

4.2 Current State of Parking and Air Pollution

Every interview with Council employees showed major concern over air pollution issues in Lambeth, demonstrating the Borough's commitment to improving air quality. Employees working on the current plan to remove the pay and display machines reported that aside from the savings generated by not having to maintain and upgrade the machines, the primary benefit from our project is the ability to establish an emissions-based short-term parking pricing system. Currently this is impossible as the machines cannot differentiate one car from another and can only process one price. However, the desire to encourage even visitors to use lower emissions vehicles is a priority in the Borough, particularly as the Sustainability Manager from the Health and Sustainability Department stated that "air pollution generally affects everyone but has an even greater impact on young children, older people with respiratory problems, and people who

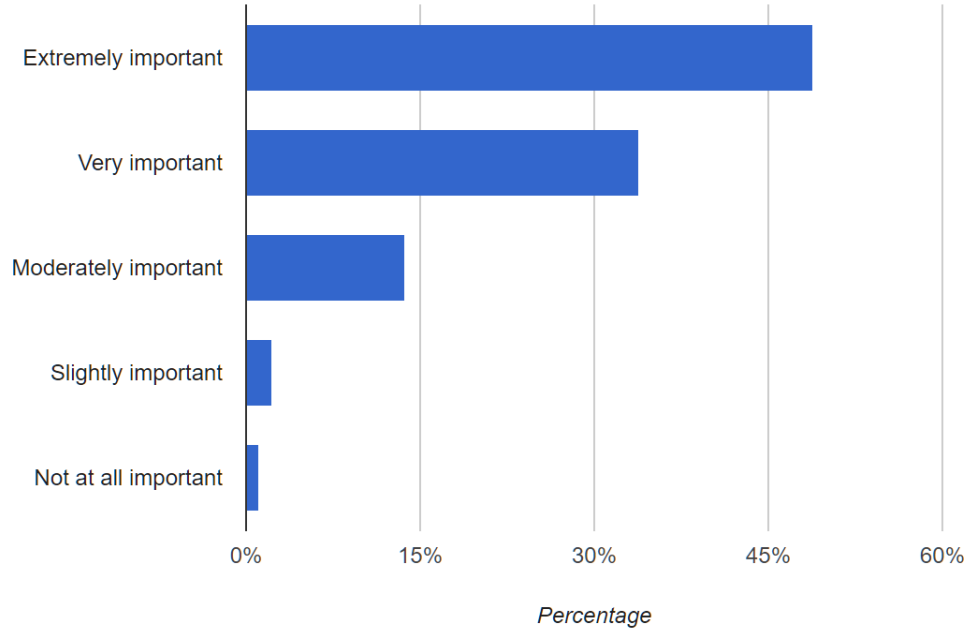
are living in poor conditions." With the downsides impacting all residents in Lambeth, a Council employee went on to say, "Air Quality is one of the major issues we're tackling, and we're evaluating if owning a car is a necessity or a luxury in Lambeth. If we treat it as a luxury, you have to pay for it, and when people are living in London you really don't need to own a car. Most people can't drive to work because there's no parking anywhere."

Our interview with the Program Director for Environment, Regeneration, Planning, and Neighbourhood in Lambeth revealed the Council's hope is that "private car ownership will considerably decrease over the next several decades, and by promoting floating car clubs and car sharing as the main method of traveling, we can limit the number of cars on the road and ensure the majority will be low emissions or electric vehicles." By signing third party companies to run floating car clubs in the Borough, they could essentially replace the revenue formerly generated from parking with contracts with private car companies to run floating car clubs from designated parking spaces throughout the Borough, allowing the government to limit air pollution without diminishing their revenue.

We obtained 191 survey responses, 174 of which were usable. Approximately 38% of survey subjects lived in Lambeth, and 47% owned cars. About 69% were White, 14% were Black / African / Caribbean / Black British, 6% were Asian, and the remaining 11% were either other ethnic groups or indicated that they preferred not to answer. About 60% of subjects were 35 and older.

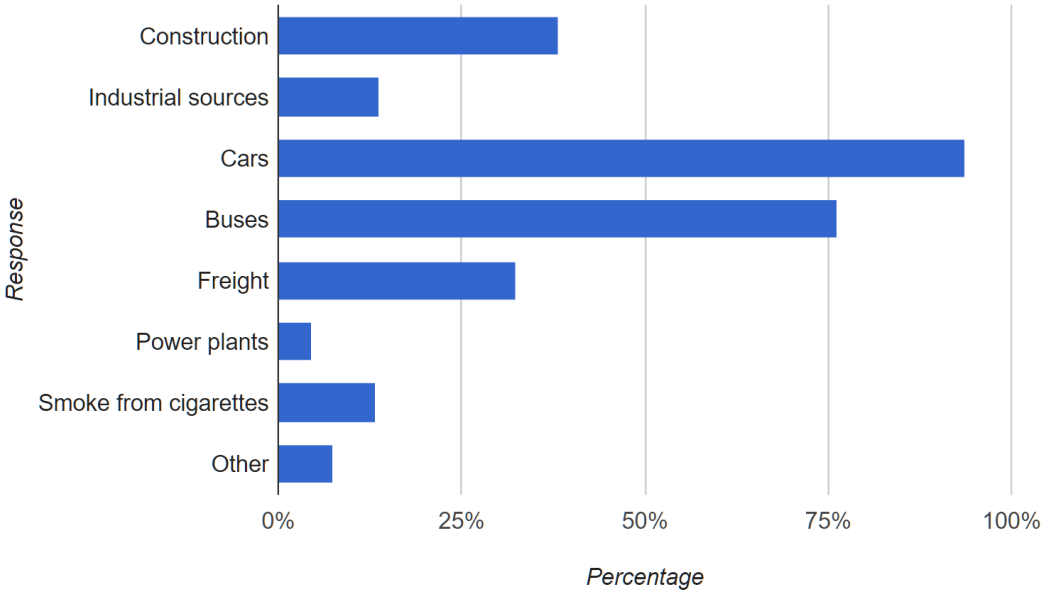
Residents generally agreed with the assessment that air pollution is an issue, with 49% of people surveyed feeling air pollution to be extremely important and 34% feeling it to be very important (see Figure 11).

Figure 11. How important of an issue is air pollution in Lambeth?



When asked to state the primary causes of air pollution in Lambeth, responses showed the most common answers among people to be cars, buses, and construction (see Figure 12). Interestingly, these results differed very little between those who owned cars and those who did not.

Figure 12. What do you think are the primary causes of air pollution in Lambeth?

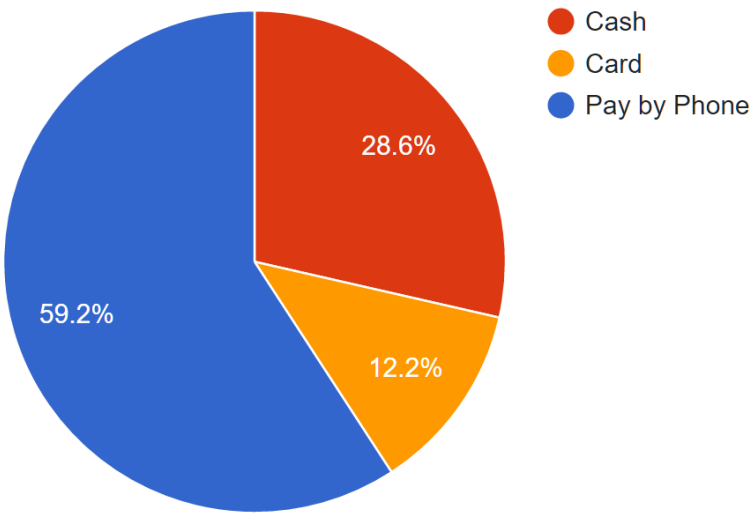


Note: Subjects were permitted to choose multiple responses

During our informal interviews with residents, the opinions expressed generally followed those demonstrated in the surveys, with many agreeing air pollution is a significant issue in Lambeth. However, despite expressing optimism many remained unsure of what changes could be implemented, with one interviewee saying, “I believe everyone thinks it’s an issue, especially with the new mayor, but what else are people going to do? I’m not getting rid of my car.”

Of the 82 survey respondents who owned cars, 49 regularly parked in the Borough. When these individuals were asked about their preferred payment methods, a majority (59.2%) preferred the Pay by Phone method. About 28.6% of people preferred cash, followed by 12.2% preferring card (see Figure 13).

Figure 13. Preferred Payment Methods of Car Owners Who Park in Lambeth



Speaking with the Civil Enforcement Officers (CEOs) responsible for enforcing parking rules and restrictions, we found that some users of the Pay by Phone app experience functionality issues. One stated, “Civilians complain all the time, ‘The app does not work, it does not recognise my location’ and they show me and it doesn’t work. It is better than the machines which don’t work, but the Council should have two methods that work.” The CEOs believe PayPoint to be a very effective solution, particularly since it offers integration with the application used with Pay by Phone, allowing them to work easily on a single platform.

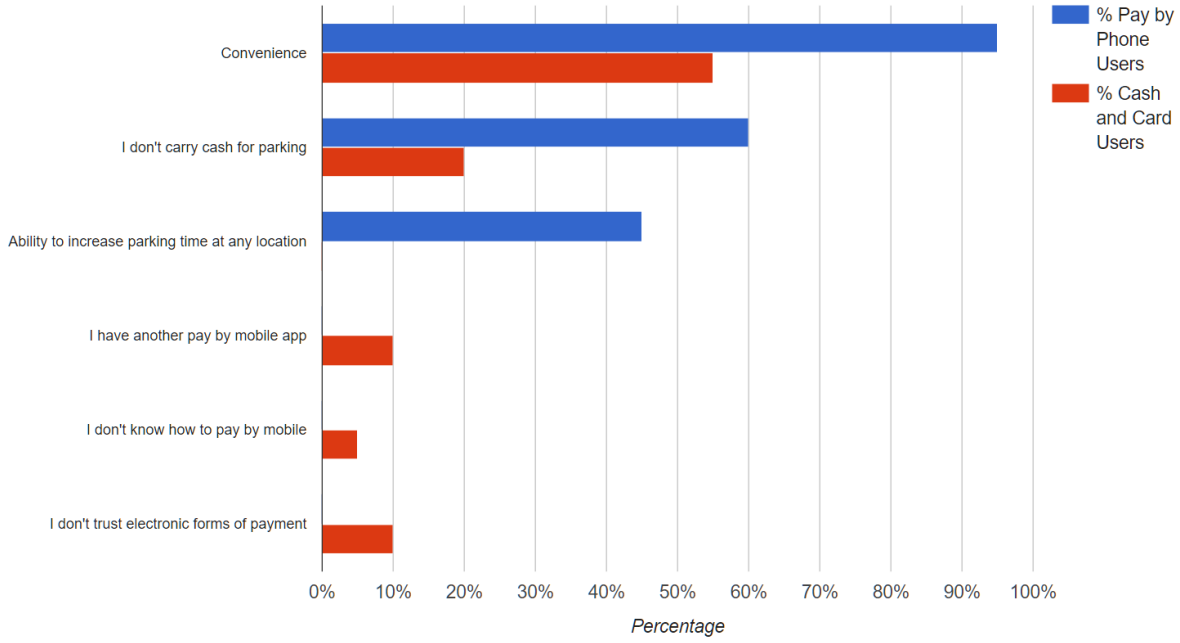
Additionally, they stated that they would not have to bother with machines that break or tickets that might be obstructed from view. However, the general consensus among interview subjects and CEOs was that finding a parking spot in Lambeth, and central London in general, is very difficult.

4.3 Public Opinion on the Future of Parking

In this section, we discuss people's opinions concerning the future of parking payments in Lambeth. Survey subjects in this section were comprised of the 49 individuals who both owned a car and regularly parked in Lambeth.

When asked why they preferred their payment method of choice, a majority of survey subjects indicated that convenience was a main factor, regardless of what method they used. Figure 14 illustrates the subjects' reasons for choosing their preferred method.

Figure 14. Reasons for Preferred Payment Method



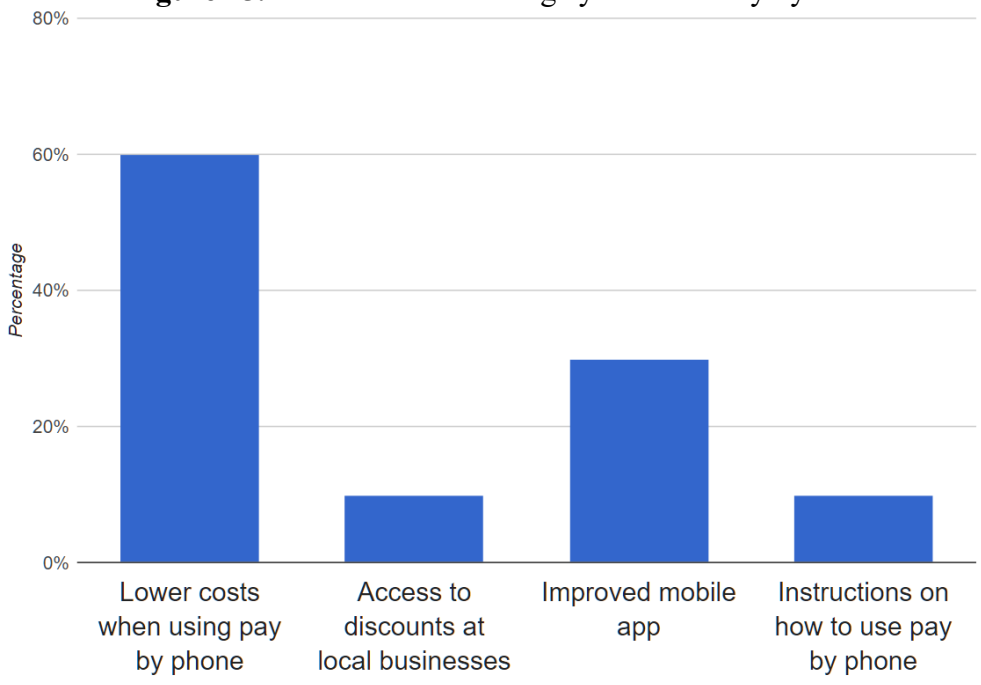
Note: Subjects were permitted to choose multiple responses

No survey subjects indicated that they did not have a mobile phone or debit / credit card. Other responses included the following statements:

- Other areas may only accept cash, and therefore it is safer to always pay with cash (2 subjects)
- Machines rarely accept card payment (2 subjects)
- Exact change is not always available to pay by cash

When asked, 60% of survey subjects who preferred cash or card payment methods stated that lower prices when using Pay by Phone would encourage them to switch, and 30% responded that an improved mobile app would encourage them to switch. However, no subjects stated that emissions-based pricing would encourage them to switch to Pay by Phone. A number of subjects indicated that other things would encourage them to use Pay by Phone; however, none of these subjects indicated what these methods were. A summary of individuals' responses can be seen in Figure 15.

Figure 15. What would encourage you to use Pay by Phone?



Note: Subjects were permitted to choose multiple responses

Similar to our survey results, some interviewed residents admitted that they would switch if Pay by Phone was made cheaper than the cash or card options or if updates were made to remove some of the apps faults, such as not recognizing several locations in the Borough and making instructions clearer. Additionally, responses from these interviews stated that educating residents on app navigation and making them aware of payment via mobile app would encourage them to convert to the mobile payment method. One resident said that their reason for not using Pay by Phone was, "I don't want to have to call someone every time I park, I just want to use my cash and be done with it." When asked to explain, they were unaware that you could pay via text if using a simple mobile phone, a trend that appeared several times.

Even those who knew how Pay by Phone worked were often still opposed. However, they were very interested in the concept of PayPoint, where there would be a cash option available at kiosks or local businesses. Residents were very accepting of this method in replacement of pay and display machines.

4.4 Future Transportation Strategy

The public response to the future of transportation varied. We interviewed 12 people in the greater Waterloo area and 11 at the customer centre in Brixton. We found that all of them were very receptive to both electric and low emissions cars albeit with some reservations.

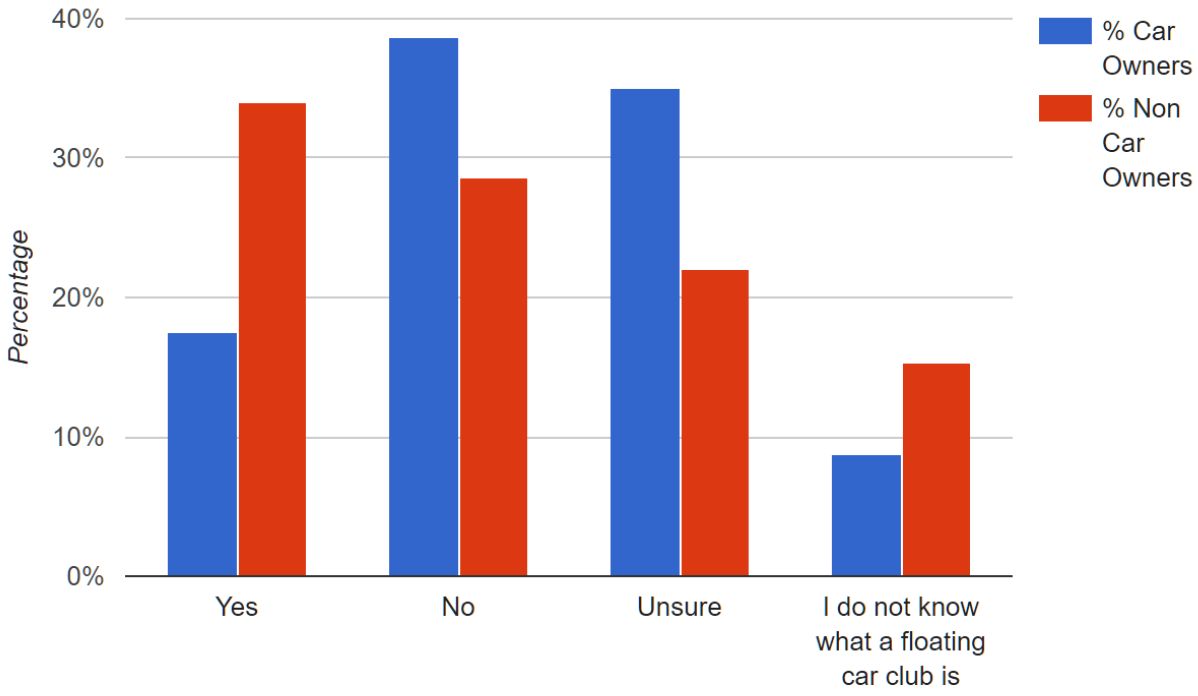
There remain few charging points in the Borough, which generates some concern for those who would like to use an electric or plug-in hybrid vehicle as their primary mode of transportation. This in conjunction with the fact that electric vehicles are more expensive than a standard petrol or diesel car makes car owners more hesitant towards these options.

Regarding the use of smart city technology, interviewees generally supported data collection through mobile applications, although two were opposed to "strengthening the government by allowing them to view any more information, even if it was anonymised." As long as the Council stays transparent with how they are utilizing the information and there are clear benefits that will be provided to the public, most residents felt that gathering anonymous data could be very beneficial to the Borough.

People were almost equally supportive of the Borough-supported floating car club concept. However, while non-car owners were in favour of personally using floating car clubs in the future, car owners showed more passive support, generally saying in interviews that while it

is an innovative idea, they would not consider getting rid of their personal vehicles. Only 17.5% of the car owners said they are open to using floating car clubs, while about 34% of non-car owners would take advantage of the service (see Figure 16).

Figure 16. Likelihood of Floating Car Club Adoption by Vehicle Ownership

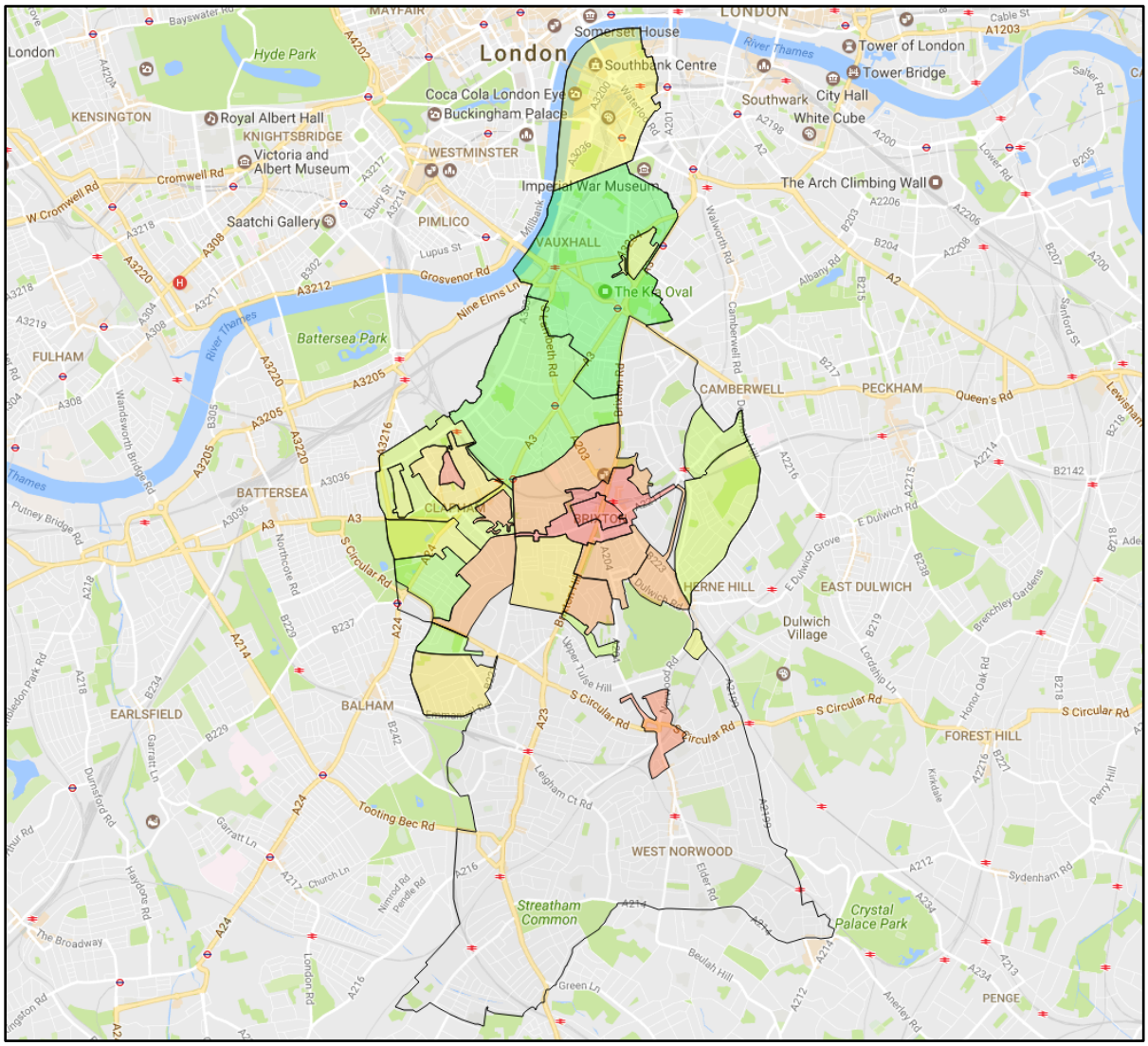


4.5 Example Application

We created an example app to demonstrate how smart city technology could be used to enhance parking in the Borough for both cars users and the Council. It allows users to view available parking in the Borough and allows the Council to set emissions-based prices in real time. The app can be accessed here: https://lambeth17.herokuapp.com

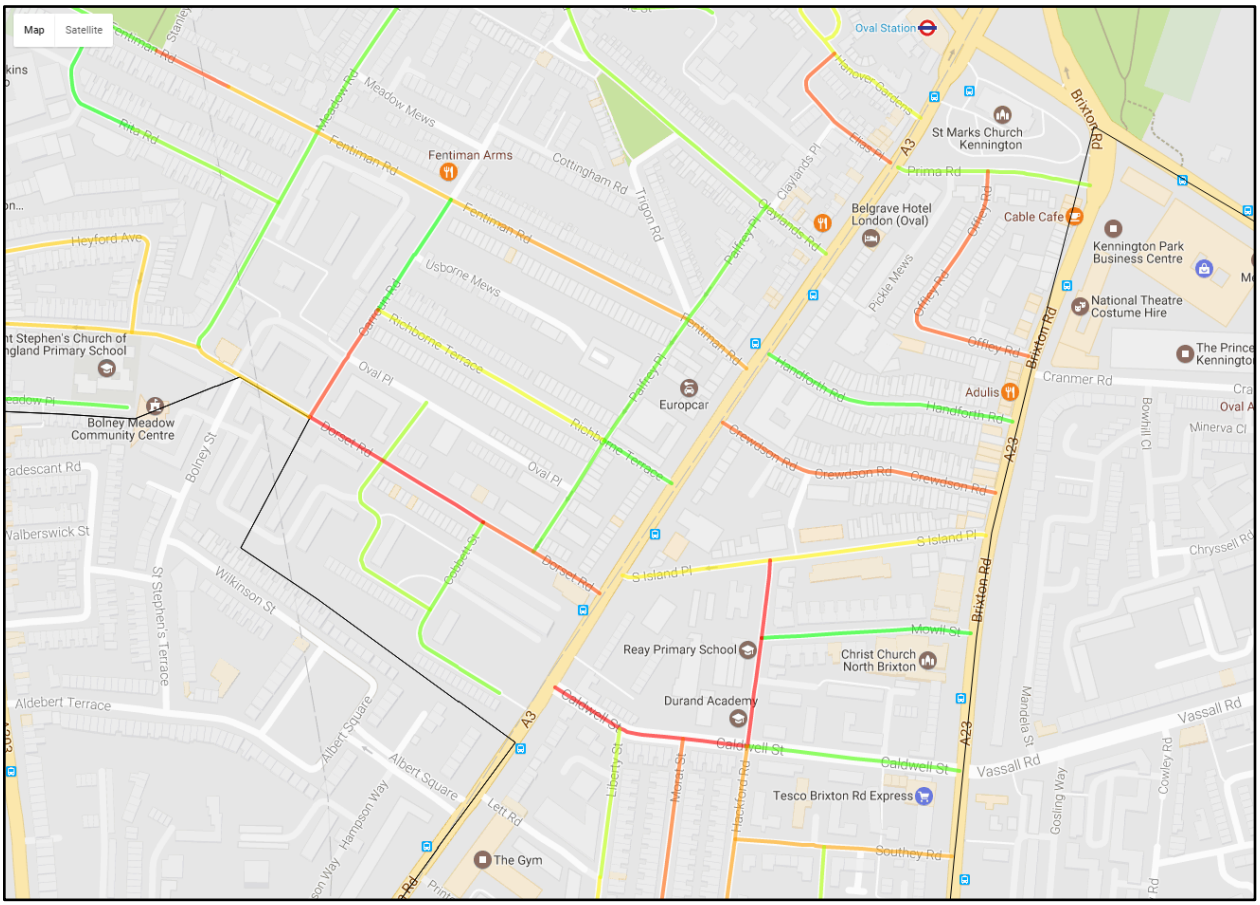
Our application has three modes: 1) a user mode for car users, 2) an administrator mode for the Council, and 3) an edit mode for development and demonstration. When opening the app in all modes, an interactive map of Lambeth is displayed with each CPZ highlighted to show the current state of parking. Colours range from green to red, indicating the probability of finding available parking in each zone. For example, a green zone is below parking capacity and has ample available parking, while a red zone is at capacity and has very scarce available parking. Figure 17 below demonstrates this zone highlighting.

Figure 17. Zone Highlighting in Example Application



When zoomed in, the application removes the zone highlighting to colourise individual roads that are associated with Council parking locations. The app highlights these roads similar to zones, showing areas with available parking in green and areas without available parking in red, with a continuous colour gradient in between. Figure 18 below shows an example of this colourisation in Kennington.

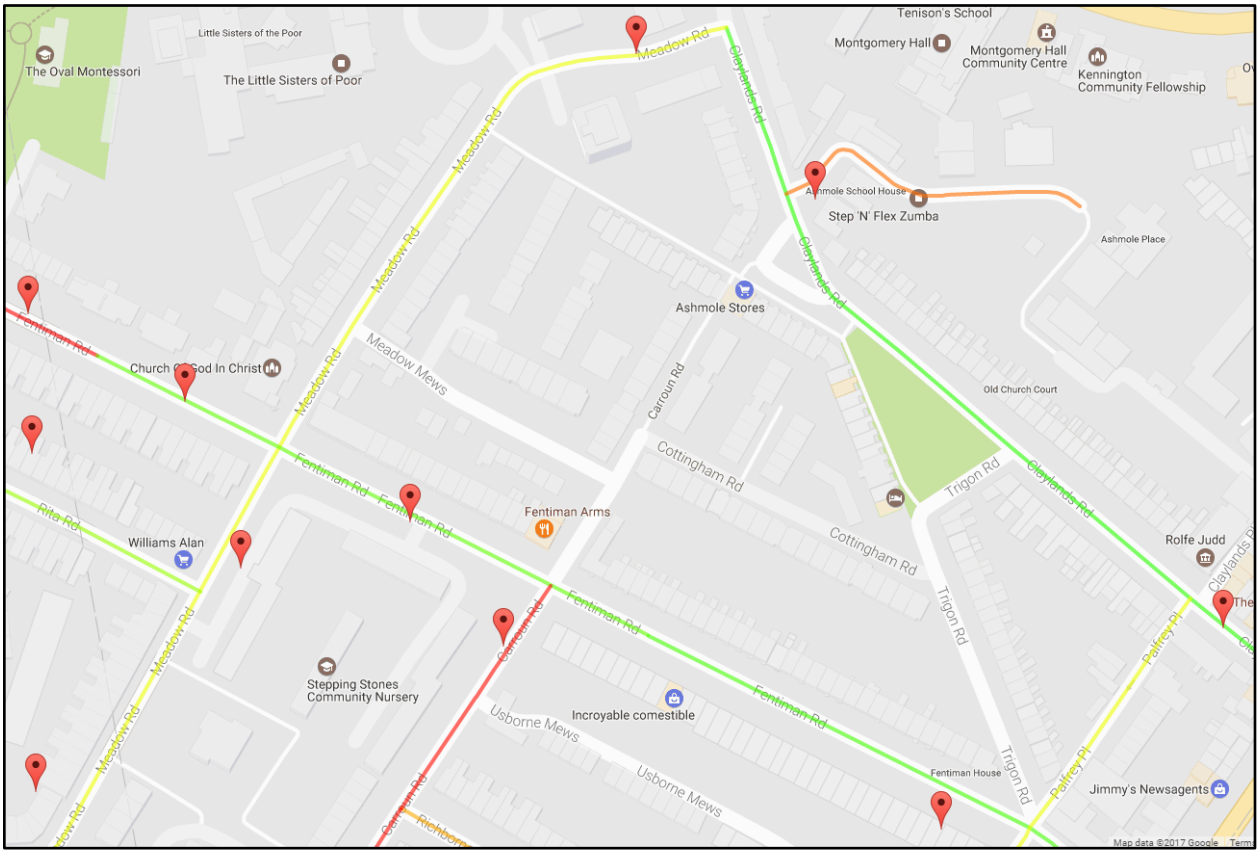
Figure 18. Street Highlighting in Example Application



Both zone and street level highlighting function using a defined set of capacities for each parking location in the Borough. A capacity is an estimation of the number of cars which may park in a given parking location at once. From this, a zone's capacity is the sum of the capacities of all of its parking locations. In addition to its capacity, each zone contains a numeric field indicating the number of cars currently parked there, referred to as the current occupancy. When fully implemented, this number would be determined from a Pay by Phone database containing the number of cars currently parked in given location; however, in this case we generated a random set of values as a demonstration. A location or zone's colour is derived using the ratio of the current occupancy to the capacity. Numbers closer to zero represent colours closer to green, while numbers closer to one represent colours closer to red. When more users park in a certain location, the current occupancy increases, and the location's colour changes. Additionally, when users leave or their time runs out, the current occupancy decreases, also altering the location's

colour. With these changes occurring in real time on both the server and client side, this app provides users with a real-time map of parking in the Borough. Users in all modes are given the option to show pay and display machines throughout the Borough, as can be seen in Figure 19 below. In the future, this functionality could be extended to show PayPoint locations.

Figure 19. Pay and Display Machines in Example Application

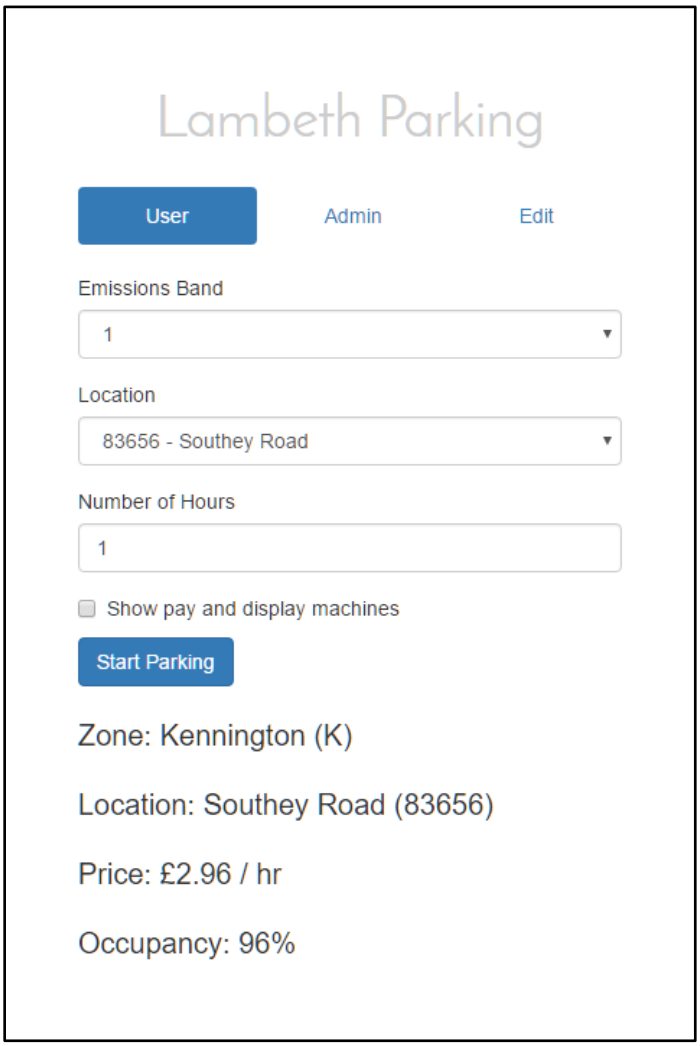


4.5.1 User Mode

In user mode, users are given the ability to change the emissions band of the car they are using. When fully implemented, this will be set automatically based on one's vehicle registration data. Mousing over or tapping on a CPZ displays the name and price of that zone, and a list of possible parking locations is updated to reflect that zone. The user may select a specific parking location by clicking on a street that is managed by the Council or selecting it from the list. Once a location is selected, the app displays that area's location name, number, and price, and provides the user with an option to begin parking after selecting the number of hours they wish to stay for.

Figure 20 below shows an example configuration.

Figure 20. User Mode Parking Interface

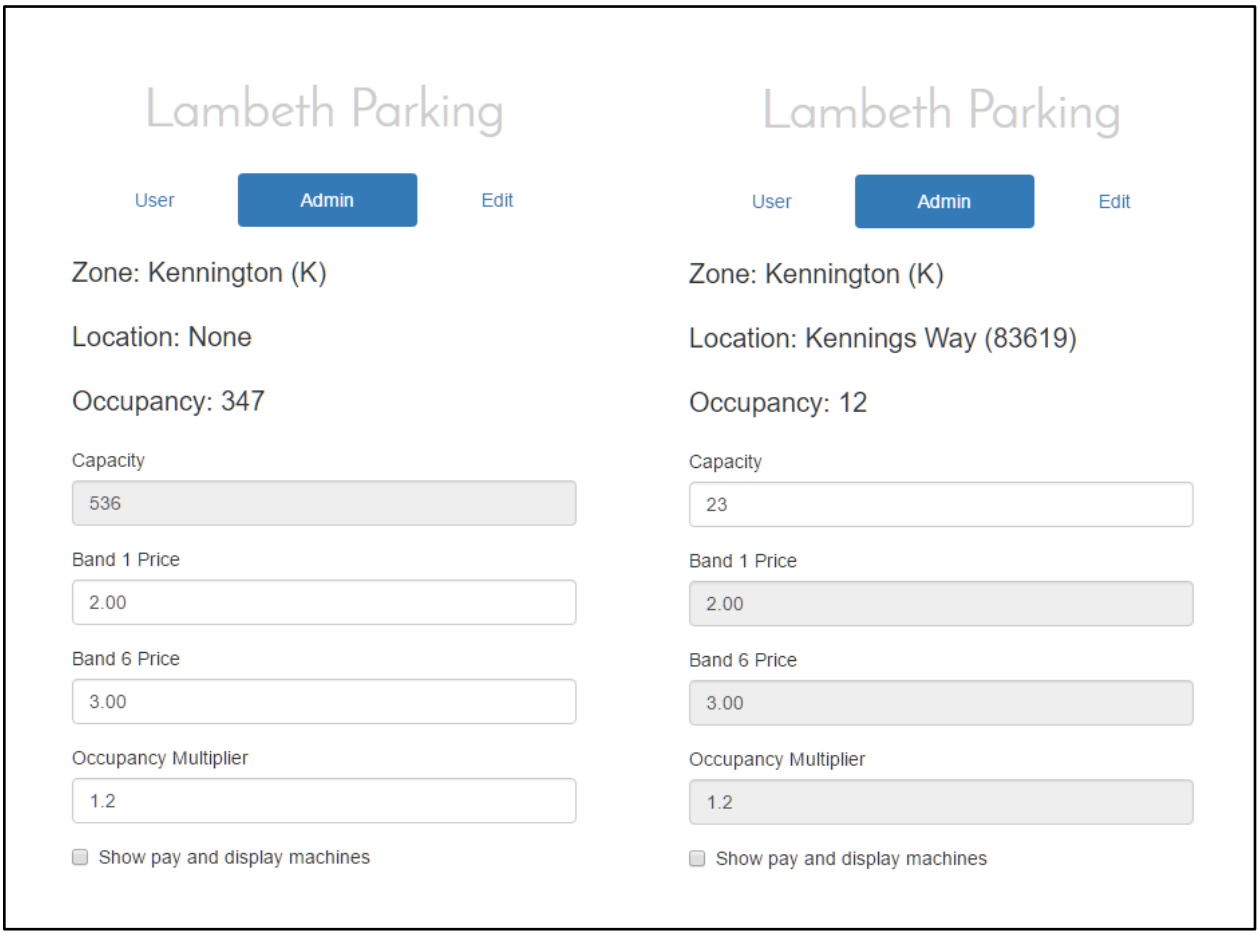


Once the user clicks the ‘Start Parking’ button, a timer appears, showing their remaining parking time. Additionally, a signal is sent to the server, which increments the current occupancy of the selected parking location. The server then updates all other clients with the increase in occupancy. Once the user’s time runs out, this number will be decremented, showing that the user has left.

4.5.2 Administrator Mode

Administrator mode allows the Council to set prices, change estimated capacities, and configure extensive pricing options. Although the map display is identical to that of user mode, the interface allows administrators to edit various qualities about both zones and locations. For example, when a zone is selected, an administrator has the ability to edit prices. In this example application, an administrator may set two emissions-based prices: one for Band 1 vehicles (with the lowest emissions) and one for Band 6 vehicles (with the highest emissions). Vehicles in these bands will be charged these values, while vehicles in intermediate bands will be charged an amount representing a linear interpolation between these two values according to their band number. Additionally, an administrator may alter an 'occupancy multiplier' for each zone. A zone's occupancy multiplier is a number greater than or equal to one, indicating how much the price of a parking location increases as it becomes closer to filling its capacity. An occupancy multiplier of 1 indicates no change in price as the location fills up, while an occupancy multiplier greater than one indicates that the price will be increased by a factor of that number at full capacity. When an administrator selects a parking location, however, the app provides options to alter the location's capacity, while the ability to change prices is removed. This allows the Council to alter capacities to more accurately represent parking in the Borough. Figure 21 shows an example of administrator mode with both a CPZ and location selected.

Figure 21. Administrator Mode Interface



Note: CPZ selected on left and parking location selected on right

4.5.3 Edit Mode

The final mode of this application allows the user to create new location data and perform actions for demonstration. When a user clicks on a road, a path is created. The user may click on various other points to create a new parking location. Once this path is completed, the user can input the location number, name, and CPZ associated with the new location. The location is then presented in a standardised form that may be added to the existing data. Additionally, a user in edit mode may change the current occupancy on an entire CPZ for demonstration purposes; this action simply increments or decrements the current occupancy of each parking location within the zone to reflect a zone-wide change.

Chapter 5: Discussion and Recommendations

In this chapter, we first discuss the analysis of findings and what this could mean for the Council and residents of Lambeth. Second, we provide step-by-step recommendations that the Council could act upon. Finally, limitations and future research are presented.

5.1 Parking, Floating Car Clubs, and Smart Cities

This section will discuss the information we gathered regarding the different actions we believe the Council should be considering, including Pay by Phone, floating car clubs, and smart city technology.

5.1.1 Pay by Phone Payment Method

As the majority of people are already using Pay by Phone to pay for parking, with many of the current cash payment users likely convert with a reduced price, the Council's goal to obtain 100% adoption of Pay by Phone and get rid of every pay and display machine seemed very feasible. Because many people said they are more likely to begin using Pay by Phone if the price is reduced, the same effect could be accomplished by increasing price when using a cash based option. The data from our survey and interviews imply that most of the resistance toward Pay by Phone is less because the users are inhibited by their circumstances, but more so out of comfort and familiarity. This means that the Council could disincentivise the cash and card methods to encourage the people to adopt the Pay by Phone options. However, the groups of people who may be limited by circumstances, such as the lack of a smartphone or a restrictive text and data plan, must be taken into consideration. Residents such as these might show some resistance, as they would be paying more to use a cash method instead of using limited texts or data to pay for parking, and the Council must be sensitive to the needs of these people.

This idea of reducing convenience to catalyse a change was ultimately supported by the unofficial experiment conducted by Lambeth's parking department, which showed that a number of cash users switched to Pay by Phone after the removal of certain pay and display machines. However, some resident interviews showed that the people who continued to pay by cash despite the reduced number of machines were less likely to ever embrace paying via a mobile service. This was either because of a distrust of electronic payment or because they lacked a smartphone and found the pay by text option to be too much of a hassle. These results were also linked to the

fact that some people were not aware of the mobile app or text payment methods. This means that the Council could raise awareness of the availability and benefits of both the mobile app and text payment options.

Implementing PayPoint throughout the Borough could accommodate the people who do not own compatible phones or simply prefer to use cash or card. Even with a slightly higher cost, many of the people we spoke to felt this would be beneficial to implement alongside an increased push for mobile payments. This sentiment was shared by the CEOs, who supported the idea that the PayPoint system could be incorporated into the same interface as Pay by Phone, allowing them to better keep track of who is abiding by parking laws.

In addition, it would allow the Council to maintain constant revenue even if a percent of all transactions went to the company running PayPoint. Despite being a cash or card option, PayPoint has the potential to carry with it many of the same benefits to the Council that Pay by Phone does. There is no additional cost to the Council to adjust parking prices in the Pay by Phone system. If the Council additionally requires individuals to register with the service upon first use, requiring the same information as Pay by Phone, they could seamlessly implement emissions-based parking prices across the two services.

5.1.2 Car Ownership Trends and Floating Car Clubs

We determined from both survey responses and interviews that the majority of non-car owners would be interested in using floating car clubs in the future, while individuals who own cars remained more apprehensive towards the new program. As of the 2011 Census, the number of Lambeth households who own a car or a van was approximately 44%. This number could decrease in the future, given that many of the individuals we interviewed said they got rid of their cars due to the difficulty and cost of maintenance and parking in the Borough. This trend of people deciding against car ownership could continue as population in the city continues to grow. We predict that people without cars will turn towards floating car clubs or car sharing programs when they need a personal vehicle, since they do not have to deal with the hassle and costs of maintaining a car. Therefore, although private car ownership could decrease in the future, there will still be a demand for personal vehicles that can be satisfied by a floating car club, which in turn could fulfil the revenue requirements of the Council, despite decreases in private car parking.

Additionally, our results showed people were very open to owning an electric or low emission car. This means the Council could encourage the residents who want to own cars to use electric cars by providing incentives. Moreover, the Council could enact programs to disincentivise the use of diesel vehicles, as they remain a significant portion of Lambeth's fuel energy consumption and therefore a serious contributor to air pollution. To this point, the Council would be able to negotiate contracts with sponsored floating car clubs to exclusively provide all electric or low-emissions cars. Through wide use of low emissions and electric cars, there could be a major impact to improve the air quality.

5.1.3 Smart City Parking Application

The application we developed can be integrated into the existing parking and payment system to benefit both the Council and the public. The real-time nature of this app allows the Council to set and alter prices with respect to emissions, occupancy, and other factors quickly and easily. This can save the Council from the expenses of updating pay and display machines while also providing extra revenue from high-emissions vehicles. Car users can use this application to find available parking within the Borough quickly, reducing both the time spent looking for an available spot and general traffic congestion. This in turn could decrease the overall traffic congestion within the Borough.

The implementation of an app similar to our example would require only minor extensions to the functionality of existing Pay by Phone application, and no additional data is required from car users. This app could be implemented either by fully integrating with the Pay by Phone system or by establishing a simple database to store capacities and occupancies.

5.1.4 Future Smart City Technology in Lambeth

Beginning with emissions-based parking, Lambeth has the opportunity to gather information and make informed decisions to influence the direction of future transportation in the Borough. Though no one said emissions-based parking would incentivise them to use Pay by Phone in our survey responses, ultimately this action would benefit all residents by incentivising cleaner vehicles. Interview results showed that people's opinions on vehicles and their contribution to air quality was largely negative, so even if some car owners are unhappy with this plan, the public response should overall be more positive.

In interviews, when we elaborated on our idea to develop an app that could provide real-time information of parking availabilities near their destination, the potential to improve parking efficiency was widely accepted. Therefore, if the Council can successfully implement an app that provides real-time information for parking, the app not only makes parking a much more efficient process, but it can also collect data on parking demands in various locations for the Council to develop localised parking policies and initiatives.

These characteristics closely adhere the guidelines detailed in our Literature Review, in the works of smart city experts Dr. Larissa Suzuki and Mr. Adam Greenfield, where the requirements regarding implementing a smart city initiative were separated into four key points: it must have a clear time frame, allow outsiders to interact with it, be adaptable to changing environments, and ultimately serve the people. As the current app plan was made with the intention of near immediate use, to make parking easier for people driving in the Borough, easy user interaction, and easy interface updates, it fits each of these goals. Our hope is that if we can help Lambeth establish this foundation with the right guidelines, future concepts will also be implemented in a similar manner.

5.2 Recommendations

The crux of our work is ultimately to guide the Council on the best next steps regarding the future of transportation in Lambeth. Separated into short-term and long-term recommendations, we offer guidance with regards to the following:

1. Short-term actions, taking the form of the Pay by Phone application and emissions-based payment for short-term parking, and
2. Long-term changes, with a major focus on using the Pay by Phone application to gather data to make better policies

5.2.1 Short-term Actions

1. We first recommended the Council prioritise the elimination of pay and display machines in favour of Pay by Phone and PayPoint locations throughout the Borough to implement an emissions-based pricing scheme. The machines proved to be overwhelmingly unpopular amongst both Council employees, who found them to be a cash sink that would never generate enough money to justify their maintenance, as well as residents,

who felt they sometimes malfunctioned. The PayPoint system will serve as a cash and card alternative for users who are not able or willing to use Pay by Phone.

2. PayPoint has the potential to carry with it many of the same benefits to the Council that Pay by Phone does. There is no cost to adjust prices, with the increased price of using cash ideally counteracting the cost to the Council of using the Pay by Phone and PayPoint third-party services. We recommended that the Council require users to register for PayPoint using information similar to Pay by Phone. This integrates the two systems together, allowing the Council to enforce emissions-based pricing for all users.
3. Some members of the public are either unaware of the Pay by Phone method or uninformed concerning its functionality. We recommended that the Council take actions to raise awareness of the Pay by Phone payment method. We suggest that pay and display machines, and in the future PayPoint locations, be equipped with revised graphics showing visual instructions on how to use the Pay by Phone system, including the app, text, and call functionality.
4. We recommended that the Council contact the developers of Pay by Phone to request an update to their application to reflect the data-sharing ideas presented in the example application. If Pay by Phone is not willing to extend their app, we recommend that the Council ask Pay by Phone to create a way to access relevant data or consider a change of parking payment contractor.

5.2.2 Long-term Changes

We imagine the app to be the platform from which Lambeth could truly start building smart city technology and big data collection. The benefit of having the bulk of the population linked into an online service is the ability to use data and information to further improve the experience of living in the Borough. Simply using the data of where people are parking, we have demonstrated the possibility of being able to direct drivers toward areas with the most available parking.

Future policy decisions can be better derived by focusing more on anonymised real-time data, collected via systems such as our smart city app to model behaviour of people in the Borough. The scope of this data can be limited, including only parking location and vehicle type information. For more information on how mobile phone data can be used to make predictions,

see the following paper that shows a model for crime hotspots in London that is roughly 10% more accurate than analysing census data:

Bogomolov, A., Lepri, B., Staiano, J., Oliver, N., Pianesi, F., & Pentland, A. (2014, November). Once upon a crime: towards crime prediction from demographics and mobile data. In *Proceedings of the 16th international conference on multimodal interaction* (pp. 427-434). ACM.

We believe that if Lambeth commits significant resources to looking at large data sets in this manner, predicting future trends will become universally more accurate.

The Council should seek to integrate floating car club contracts as a source of revenue. Mutually beneficial contracts with these companies can provide Lambeth residents with convenient travel options and grant the Council a source of revenue comparable to those of parking permits as well as control of the types of cars on the street.

5.3 Limitations and Future Research

5.3.1 Data Collection

Though we have been able to draw solid conclusion from our research, there remain gaps requiring further work to fill. The largest of these is the size of our interview and survey samples. To start, we only shadowed two CEOs in two CPZs, which means there were other viewpoints from those officials, their colleagues, and potentially other situations we did not get to see in our observations. While we are confident in our survey results, particularly after finding that the percent of individuals that use Pay by Phone when compared to card or cash in Figure 6 mirrored the Council's Borough-wide information, we only obtained 191 survey responses, of which 174 were usable. In a borough populated by roughly 300,000 individuals, this is not a large sampling of the population. In the same vein, we feel that a larger volume of interviews could have provided more confident conclusions on the behaviours and opinions of the residents.

Our survey was also distributed online, skewing it towards those who have Internet availability. In reality, only 89% of Lambeth households have direct access to the Internet (Lambeth Council, 2016), meaning that the rest of the population, those most impacted by the digital divide, are less represented in our data. Interestingly, our interviews suffer from the reverse case. As we performed most meetings at the Customer Centre, typically populated by people unable or unwilling to fill out paperwork online, we mostly interviewed individuals who

did not have access to smartphones and heavily favoured paying by cash. A similar situation became apparent in Waterloo, where it was difficult to find interviewees who were both car owners and therefore users of parking payment. Despite these limitations, there were very consistent results in both surveys and interviews, showing that the opinions we were looking with regards to smart cities and car usage are likely to cross socioeconomic barriers, but this requires more evidence to confirm.

Finally, although many survey and interview subjects who paid by cash or card indicated that lower prices when using Pay by Phone would encourage them to switch, we did not collect data concerning the actual price difference that would cause this switch. This is an excellent opportunity for future research, as we believe determining this price difference would allow the Council to successfully incentivise the use of Pay by Phone, while maximizing revenue.

5.3.2 Example Application

Although the example application shows promise, there are several factors that impact its effectiveness. The first and most notable concern is that this system only works effectively if almost all parking transactions are sent through the Pay by Phone database, which in turn signals changes in current occupancy. Therefore, with pay and display machines still frequently used, implementing this app immediately would prove unsuccessful. However, if the Council eliminates nearly all of the pay and display machines in favour of both Pay by Phone and PayPoint, the frequency of non-electronic parking will significantly decrease, increasing the effectiveness of the app.

Perhaps the most considerable concern regarding this application is the presence of permit-based parking. Permit holders do not need to pay for parking, and therefore there will never be a record of permit-holding cars parked in a parking location. This will significantly skew the current occupancy of parking locations, leading to inaccurate data in the application for both users and the Council. However, we believe the Council could solve this problem by altering the current occupancy of each parking location using a heuristic technique. Over a period of time, the Council could observe the number of permit-holding cars parked in each parking location at specific times of the day and week, potentially through CEOs. Over time, an average number of permit-holding cars can be determined for each parking location for various times. After this period of data collection, the current occupancy of a given parking location can

be determined by adding both the current number of cars parked using electronic payment and the estimated number of permit-holding cars for that day and time. Although this method does not promise perfect accuracy, it can help to alleviate the issue.

The final limitation proposed by the example application in coordination with the current Pay by Phone system lies in the time accuracy of the data presented. For example, a car owner may leave his or her parking spot early, before their parking time runs out. In this case, their car is still marked as present in parking location, leading to misleading occupancy data. Although this may be insignificant for one car, there may be instances where multiple cars leave before their time runs out, making an area of available parking seem occupied. The inverse is also true; if multiple vehicles overstay their time, an area of occupied parking will be shown as available. Although it is difficult to account for cars overstaying their time, it is possible to decrease the first occurrence by incentivising the use of a 'finish parking' function. Once a car user is prepared to leave their parking spot, they can indicate that they have finished parking in the app. As an incentive, users who use this function often could be given recurring one-time parking discounts based on usage. In the future, the app could be configured to use geolocation to infer when a car user has left his or her parking location.

5.3.3 Contacting Experts

With regards to getting in contact with outside experts (either companies who would be open to floating car clubs or Smart City urban environment planners) we found very little success. We were able to watch several lectures, read theses, and even attend a seminar featuring people who could help lend credibility to our recommendations, but our attempts to begin a dialogue were unsuccessful. We did gain insights from their research but were unable to get their opinion on the work we were doing.

5.4 Conclusion

Our project ultimately sought to have a meaningful impact on the prevalent air pollution problem in Lambeth. We found that this would be possible through exploration of the Pay by Phone method introduced to us by the Lambeth Council. By conducting surveys and interviews among the Council employees and residents, we found that the Borough would respond well to a widespread implementation of an augmented Pay by Phone app in place of the current pay and

display machines, supplemented by a PayPoint system. An app such as this can allow the Council to enact an emissions-based pricing scheme, incentivising the use of electric and low emissions vehicles in Lambeth. Added functions also provide the opportunity for the Council to perform real-time pricing alterations, as well as supply regularly updated parking availability to users. Through the use of this app and apps like it, Lambeth can continue to embrace more smart city technologies which will conduct similar data collections in real-time, allowing for accurate representations of behaviour in the interest of developing policies which can further impact air pollution. We believe that our recommendations to the Lambeth Council provided a unique framework which will help them work toward these goals using a tangible and practical approach.

5.5 Reflections

5.5.1 Sam Carley

Arriving in London, the only part of our project that was certain was census analysis, everything else had more or less been a guess. However, when we were ultimately given a concrete platform to work on, parking and smart city development, we hit the ground running. Finding ways to merge these two ideas was particularly fun. It was funny, because when I started talking about big data collection early on, I had no idea Connor was already brainstorming ideas for a model application. Furthermore, working with the Borough employees and our sponsor John Bennett was a terrific experience where we learned not only what's really important when developing a government proposal, but all the nuances of work in Lambeth. Overall my favourite take-away was how useful they found our involvement with their work; it gives me a greater appreciation for local government work.

5.5.2 Tsering Dolma

Over the course of this project, I have gained experience and skills that can help advance my professional career and expand personal growth. Academically, I was able to improve my writing, presentation, and teamwork skills. The project definitely challenged my thinking process and broadened my critical thinking abilities. The most challenging part of this project in the beginning was working well with the team members. Listening to one another with respect, understanding team members' thought processes, and compromising played a major role in the

successful completion of this project. Although our project had a rough start with no clear project focus, we were able to adapt as a team and strive for a goal that was tangible yet had an immediate impact on the current and upcoming Council policies. Additionally, my time in London and working with the Lambeth Council has given me knowledge of how the local governments functions as well as the opportunity to immerse myself in the culture of London. At the conclusion of the project, the most rewarding feeling was when our sponsor and the Council employees were very pleased with our deliverables. Furthermore, I have gained some great friendships through this process. I wouldn't have gotten to know these people if it wasn't for this project.

5.5.3 Timothy Jones

At the conclusion of the IQP process, I find that among the aspects of the project most prominent to me is the way in which I came to enjoy the city of London and the people who inhabit it. Having the opportunity to work with such dedicated and welcoming colleagues was a true privilege, and being exposed to the many subcultures within London was an eye-opening experience. I found myself loving the city, its history, its food, and most notably its theatres. This project site cultivated in me a respect for the United Kingdom and its citizens, as many of those who we met extended their kindness toward us the moment we met them. At the end of this journey, the people I have to thank the most are my group members, Connor, Sam, and Tsering. Through the initial evolutions of our project and the hours spent working, they were there with me combating the stresses with British sweets, weekly visits to the Kennington Cafe and its owner Halil, and several working nights spent singing songs from the 1990s. I have them to thank for pushing me to reach my potential on this project, and I could not have done this without them. I am very proud to have been a part of the Lambeth Squad.

5.5.4 Connor Weeks

At the start of this project, we lacked a significant goal, and this resulted in numerous disagreements. However, as we began to focus on parking and smart city technology, our workflow dramatically improved. Throughout the course of this project, I not only learned valuable skills about teamwork, research, and local government, but I also gained an amazing set of friends. It has been a pleasure to work with such passionate individuals, and I thank them for

their intellect, insight, kindness, and humour. It was also very exciting to be able to use some of our more technical skills in this social project to great success, although I still learned a lot about issues I had not previously considered. Finally, this project allowed me to experience London, something I am truly grateful for.

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Appendix A: Lambeth Tables and Figures

Figure 1. The Borough of Lambeth in the City of London

(Adapted from Wikimedia Commons, 2016)

Figure 2. Nine Lambeth Focus Area with Air Quality Monitors

(Adapted from WHO, 2017)

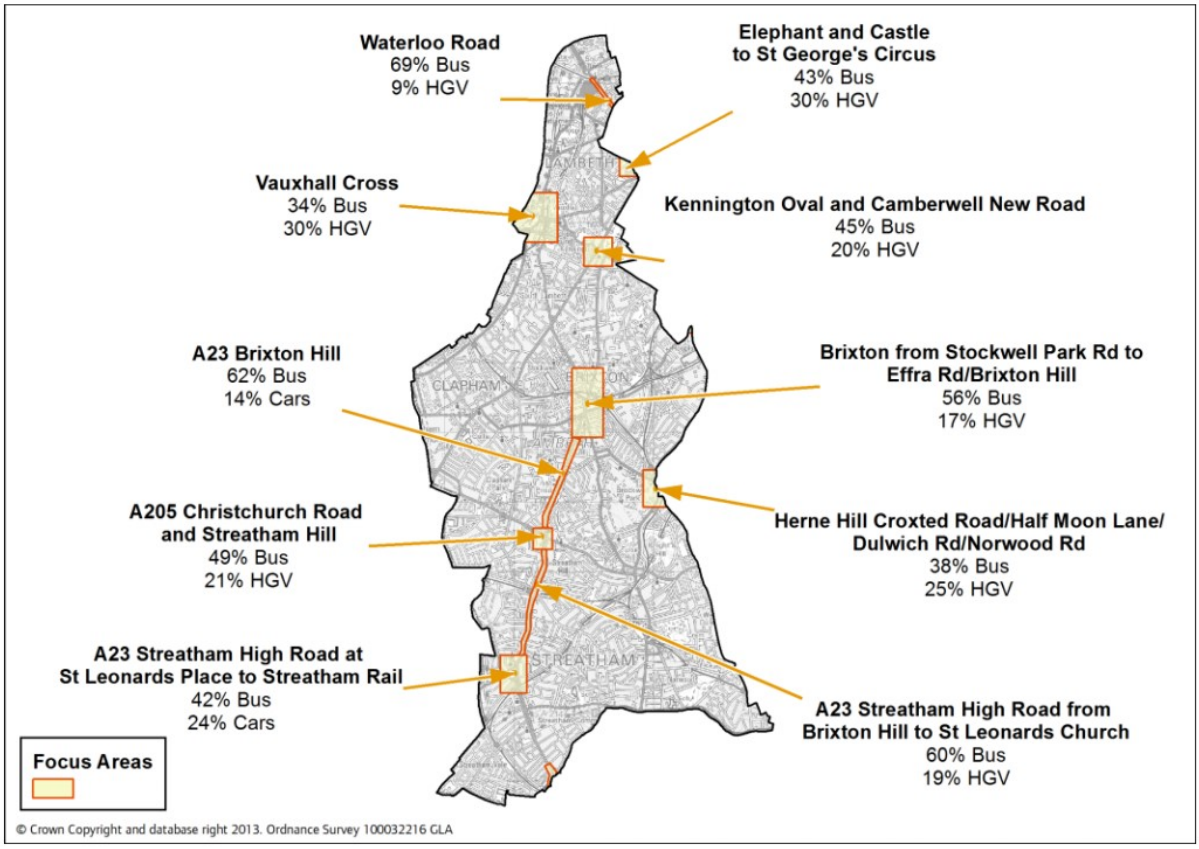


Table 1. Number of deaths attributed to exposure to pollution in 2008 in wards in the London Borough of Lambeth

(Adapted from WHO, 2017)

Ward	Total Population	Annual deaths attributable to exposure to PM2.5
Bishop's	10,003	5
Brixton Hill	13,734	7
Clapham Common	13,706	6
Clapham Town	14,564	7
Coldharbour	15,493	7
Ferndale	14,518	7
Gipsy Hill	14,598	7
Herne Hill	13,039	6
Knight's Hill	14,688	7
Larkhall	15,775	7
Oval	13,873	7
Prince's	12,575	6
St. Leonards	13,423	6
Stockwell	14,491	7
Streatham Hill	14,372	7
Streatham South	14,335	7
Streatham Wells	14,093	7
Thornton	13,426	6
Thurlow Park	12,497	6
Tulse Hill	14,389	7
Vassall	14,191	7
Total		139

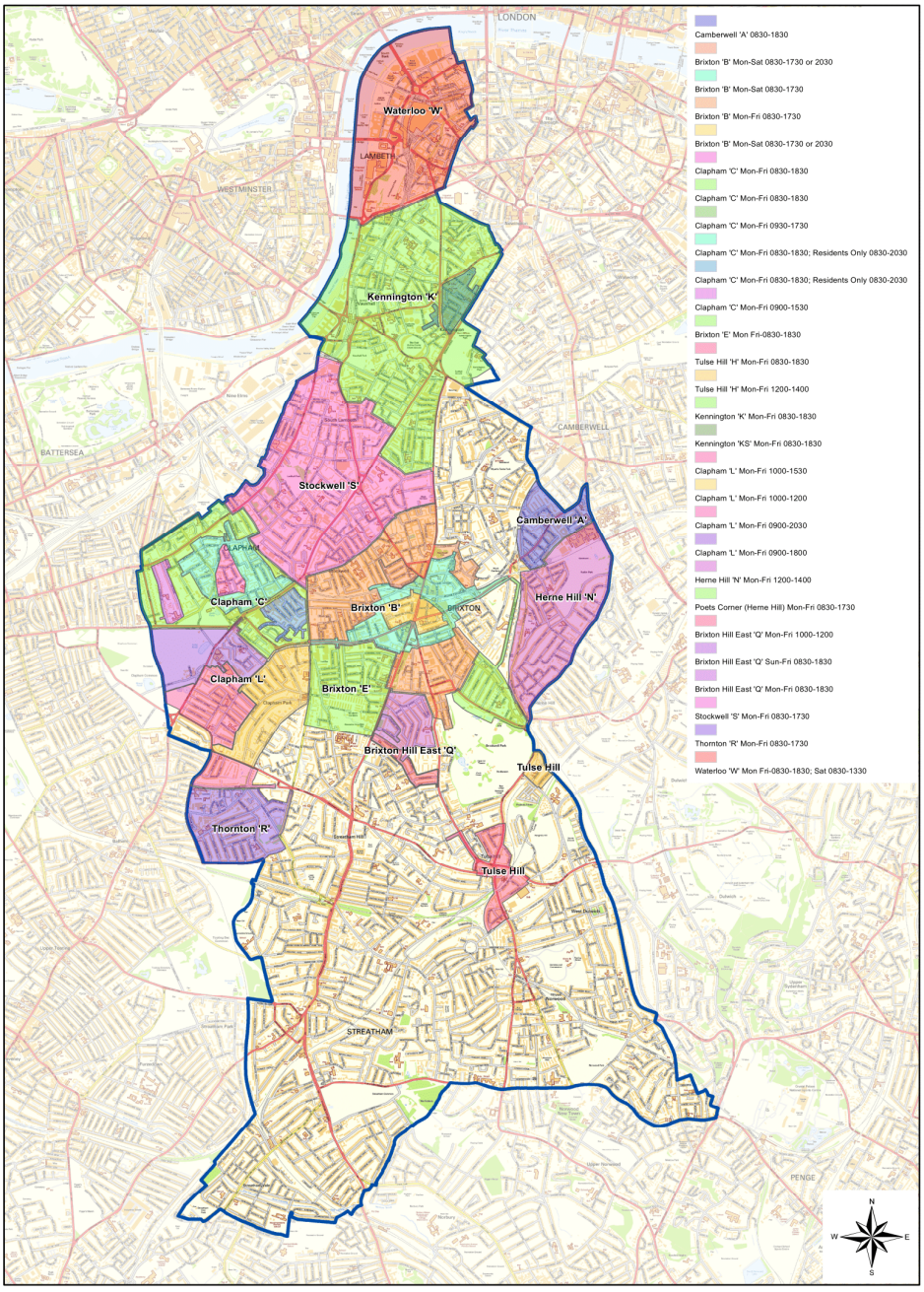
Table 2. Percentage of mortality attributable to long term exposure to pollution (Adapted from WHO, 2017)

Local Authority	Fraction (%) of mortality attributable to long term exposure to PM2.5
Bromley	6.3
Havering	6.3
Harrow	6.4
Sutton	6.4
Croydon	6.5
Hillingdon	6.5
Bexley	6.6
Enfield	6.6
Kingston upon Thames	6.7
Barnet	6.8
Richmond upon Thames	6.8
Merton	6.9
Redbridge	7
Barking & Dagenham	7.1
Haringey	7.1
Hounslow	7.1
Brent	7.2
Ealing	7.2
Greenwich	7.2
Lewisham	7.2
Waltham Forest	7.3
Wandsworth	7.3
Newham	7.6
Camden	7.7
Lambeth	7.7
Hackney	7.8
Hammersmith and Fulham	7.9
Islington	7.9
Southwark	7.9
Tower Hamlets	8.1
Kensington and Chelsea	8.3
Westminster	8.3
City of London	9

Appendix B: Lambeth Controlled Parking Zones

Figure 1. Lambeth Controlled Parking Zones (CPZs)

(Adapted from Lambeth Council, 2015)



Appendix C: Timeline of Events

Table 1. Timeline of Events

	Pre-Arrival	Week						
		1	2	3	4	5	6	7
Meet with Sponsor		x	x	x	x	x	x	x
Pre-test Resident Survey and Interviews		x						
Analysis of Existing Data	x	x	x					
Interview Council Employees	x	x	x					
Shadow Civil Enforcement Officers				x				
Survey Residents			x	x	x			
Interview Residents					x			
Analyse Survey and Interview Data					x	x		
Project Future Smart City Trends in Lambeth						x	x	
Develop Example Application			x	x	x	x	x	
Recommendations and Deliverables							x	x
Final Presentation								x

Appendix D: Survey Questions

Thank you for agreeing to participate in this study conducted by the Worcester Polytechnic Institute's Lambeth Interactive Qualifying Project. The aim of this survey is to understand habits and thoughts regarding transportation. Your participation in this study is voluntary and you may stop at any time. Results of this survey will be kept confidential and will not be attributed to you in any way. Results of this survey will only be released in aggregate and with no personal identifying information.

For questions regarding the research study, please contact our advisors, Prof. Adrienne Hall-Phillips (ahphillips@wpi.edu) or Prof. Josh Rosenstock (jrosenstock@wpi.edu). For questions regarding your rights as a research participant, contact the Human Research Protection Program at Worcester Polytechnic Institute, Worcester, Massachusetts, USA (irb@wpi.edu).

If you consent and are ready to participate in this survey, please click below to start the survey and indicate your consent to participate. By agreeing you are verifying that you are over the age of 18.

- ❑ I agree to the above conditions

1. In your opinion, how important of an issue is air pollution in Lambeth?

Not at all Important	Slightly Important	Moderately Important	Very Important	Extremely Important
1	2	3	4	5

2. What do you think are the main causes of air pollution in Lambeth? (Check all that apply)

- ❑ Construction
- ❑ Industrial sources/manufacturing facilities
- ❑ Private Cars
- ❑ Buses
- ❑ Delivery Vehicles
- ❑ Population growth
- ❑ Power plants
- ❑ Smoke from cigarettes
- ❑ Waste disposal

3. Do you believe cars are a significant cause of air pollution in Lambeth?

Not Significant	Slightly Significant	Moderately Significant	Very Significant	Extremely Significant
1	2	3	4	5

4. Do you own a motor vehicle (car or motorcycle)?

- ❑ Yes
- ❑ No

5. Do you have a valid parking permit for the Borough of Lambeth?

- ❑ Yes
- ❑ No

6. How often do you park in a Lambeth controlled parking zone?
   - ❑ Everyday
   - ❑ Several times a week
   - ❑ Once a week
   - ❑ Once every couple weeks
   - ❑ Rarely
   - ❑ Never

7. What method of parking payment do you most often use?
   - ❑ Cash
   - ❑ Card
   - ❑ Pay by phone

8. Why do you prefer this method over other options?
   - ❑ Convenience
   - ❑ I don't carry cash for parking (if Pay by Phone was selected for question 8)
   - ❑ Ability to increase parking time at any location (if Pay by Phone was selected for question 8)
   - ❑ I have another Pay by Phone app (if cash / contactless was selected in question 8)
   - ❑ I don't know how to pay through mobile (if cash / contactless was selected in question 8)
   - ❑ I don't have a mobile phone (if cash / contactless was selected in question 8)
   - ❑ I don't have debit or credit card (if cash was selected in question 8)
   - ❑ I don't trust electronic form of payment (if cash / contactless was selected in question 8)
   - ❑ Other_____

9. What would encourage you to use Pay by Phone?
   - ❑ A lower cost when using Pay by Phone
   - ❑ Access to discounts at local businesses
   - ❑ Emissions-based pricing for Pay by Phone
   - ❑ Different mobile app
   - ❑ Improved app support
   - ❑ Instructions on how to use Pay by Phone
   - ❑ Other_____

10. What kind of car do you drive?
   - ❑ Standard Petrol
   - ❑ Diesel
   - ❑ Hybrid
   - ❑ Electric

11. (If question 10 is answered Petrol or Diesel) What is the size of your vehicle's engine?

- ❑ 0 - 0.5 L
- ❑ 0.501 - 1 L
- ❑ 1.001 - 1.5 L
- ❑ 1.501 - 2 L
- ❑ 2.001 - 2.5 L
- ❑ 2.501 - 3 L
- ❑ Unsure

12. (if question 4 was answered yes) When you park, what are you doing in Lambeth?

	Rarely				**Always**
	1	**2**	**3**	**4**	**5**
Commuting	1	2	3	4	5
Business	1	2	3	4	5
Education / Taking someone to school / college	1	2	3	4	5
Shopping	1	2	3	4	5
Transporting Others	1	2	3	4	5
Personal Business	1	2	3	4	5
Leisure (Meeting friends, going to see movies/plays, hiking)	1	2	3	4	5

13. In the future, do you see yourself using a floating car club (where you do not have to return the car back to the same location)?

- ❑ Yes
- ❑ No
- ❑ I don't what a floating car club is.

14. Which age group applies to you?
- ❑ 18-24
- ❑ 25-34
- ❑ 35-44
- ❑ 45-54
- ❑ 55-64
- ❑ 65-74
- ❑ 75-84
- ❑ 85+
- ❑ Prefer not to say

15. What is your ethnic group?
- ❑ White
- ❑ Mixed / multiple ethnic groups
- ❑ Asian /Asian British
- ❑ Black / African / Caribbean / Black British
- ❑ Other ethnic group
- ❑ Prefer not to say

16. Do you live in Lambeth?
- ❑ Yes
- ❑ No

Appendix E: Summaries of Interviews with Council Employees

Notes from Interview with Raj Mistry
Date: March 23th, 2017
Time: 10:00 PM
Location: Blue Star House, Brixton
Team Members in Attendance: Sam Carley, Tsering Dolma, Timothy Jones, and Connor Weeks
Guests in Attendance: Raj Mistry, John Bennett

- Transport for London data available online
- Car Manufacturing information
    - Providing services as well as vehicles, looking to increase tech
- Car Club
    - Club in a specific bay, you pick it up and drive it, return it
    - Floating: pick up the car, drive it, leave it anywhere
- Electric vehicle charging points
    - Charging electric cars via lamp posts
- Looking to clean the cars up, but there will be changes in ownership, leasing, etc.
- Data
    - Residents
    - TfL
    - What is the private sector doing?
        - How are they going to continue growing without large manufacturing?
        - Compare these projections or plans to existing ones
    - GLA
        - Represent service areas, take a look at their plans as well
    - AIR QUALITY
        - Particulate matter above CO2
        - 112 deaths per year due to particulates in Lambeth
        - TfL working on reducing diesel vehicles
        - Borough looking to charge diesel owners more for ownership
        - Active lobbying of TfL and govt.
        - Will act as the “wrapper” for our data
    - Public Health
        - Environment Team across central and local govt, separate from Health teams
        - Overlap due to air quality, catalysed by particulate data
        - Public health officials have announced the air quality in a state of emergency
        - Who is being primarily affected? Children, adults, pregnant women

        - Those most affected are usually children and elderly
        - Air quality through the eyes of public health should act as a medium for our data
- Technology
    - Linking technologies for a customer experience
    - Available online, BMW was involved
    - Event that Neil attended (parking spot locator)
    - In the future, this car is interesting but the goal is reduced car ownership with self-driving cars that function using your schedule
    - Tesla website, try ordering a car, self-driving option available for purchase (extra 3000 pounds)
- Questions for Raj
    - Smart City folks
        - They'll have information on some car manufacturers
        - This info is also available online
        - Say we're from Lambeth Council investigation service delivery options
    - Interviews and Surveys
        - "Brilliant" - Raj
        - Revenue burden falls on the parking machines
        - North of the Borough has high retention of PbM
    - British Telecom
        - New telephone booths in NY
        - Double sided LED with a phone in between
        - Negotiating to refresh what they have right now
        - Provide this product for London, in the next 3 or 4 months
    - Main Contributors
        - Construction caused a breach in Vauxhall
        - Creating new buildings and Tube stations
        - Caused large spikes near construction sites, probably the worst contributor
        - Andrew Round, head of sustainability
            - Ensuring air is cleaner
            - Has many contacts for data on air quality
            - Will be happy to see us
    - TfL
        - Healthy Streets
    - Duality
        - Balancing air quality with revenue
        - Business models will hopefully shift from parking based income to leasing land and space to manufacturers
        - Speak to BMW and ZipCar, they've approached the Council on leasing

        - Floating CC: Parking their cars in resident spaces
        - They can park in the resident spaces, but they need to pay a premium, probably a larger amount
        - Also talking with Wandsworth, Westminster, other boroughs
        - Hopefully shift will be gradual
        - Parking is Short Term
        - Medium and Long term, how these shifts will impact the existing systems
    - Self-driving cars
        - Many people are cautious, universally
    - New Cars
        - Will utilise API's
        - Tech will integrate systems instead of using phone and such for individual API's
        - Can fit into Long Term visions, how they are used now and how they can transition into the future
    - Park Bench
        - Solar Panel bench that charges phone and has wifi
        - Ugly in traditional parks, concerns about who will use them
    - Assets
        - Highway
        - Not many of the assets have interconnectivity, they don't serve each other
    - Public Health Focus
        - Only recently started noting dangers of diesel
        - Shifted the thinking around diesel engines
    - Cargo (?)
        - Air quality on lamp posts
        - Seen where and *when* spikes happen and use this data to make policy
        - 50 million pounds worth of projects on highway (currently)
            - Just by talking to people and seeing what they want
    - Chicago approach
        - Investments based on data
        - Limiting areas to just public transport
        - Combining air quality and accident data for policy changes
        - Interviewed by BBC a month ago about this system, find online
    - Plans
        - Public inspectors looking at roads and such
        - Looking for something they can wear to monitor air quality while working
        - "Mobile air quality monitoring solutions"
        - Being able to locate spikes will help enact some more specific policy

Interview with Henna Akram and Hannah Bennett
Date: March 24th, 2017
Time: 4:00 PM
Location: Blue Star House, Brixton
Team Members in Attendance: Sam Carley, Tsering Dolma, Timothy Jones, and Connor Weeks
Guests in Attendance: Henna Akram and Hannah Bennett

Henna Akram: Development manager, Three and half years of working with the Council,
Hannah Bennett: Senior Business Development officer, a year and a half with the Council, reporting and business analysis on parking permit ticket.

Parking service plan looking for ways to generate revenues, save and increase

- Work with the permit notices and ticketing, looking for opportunities for development in the field
- Parking Service Plan - ways in which they could generate income or save money
    - Working with repricing permit prices so there is surcharge for things
    - Congestion Zone charges cars in particularly congested areas to drive there
    - People here do not want to own a car
    - Virtual Permits
    - The Team is looking at it from a user experience point of view, ensuring parties are happy with new plan implementation
- New Contracts are being made with the individuals who print things/scan things for evidence - this is being phased out as we go more digital
- "Air Quality is one of the major issues we're tackling, and we're evaluating if owning a car is a necessity or a luxury in Lambeth. If we treat it as a luxury, you have to pay for it and when people are living in London you really don't need to own a car. Most people can't drive to work because there's no parking anywhere."
- TfL prices increased 18 percent for public transport, we need to increase the charges for cars to balance out.
- Infants and elderly people are going to be more impacted by our air pollution
- Using a car is for long distance, not short distances
- Customer satisfaction needs to be balanced with making Lambeth a healthy place to live. Who is penalised by our actions, who benefits. We need to have a fairly robust business plan for what we want to do. There's invariably going to be backlash
- We're no longer using CO2 as our standard when pricing permits, instead the 6 bands, also low emissions vehicles will no longer be entirely free. They used to say diesel vehicles was efficient until recently.
- Emissions-based visitor vouchers, for actual visitors to the Borough. If you pay by phone you could get a variable price depending on the vehicle.

- 11 to 6 pricing levels in the new structure, congestion zones will no longer have different pricing
- Sadiq Khan was the big push for air quality as opposed to Boris Johnson who was all about biking and alternative modes of transport. This brought about the greatest change in our approach to this problem
- Andrew Round is in Sustainability and equality, he's met Sadiq Khan a few times, a delightful guy.
- It's about educating people that it is not their right to own a vehicle, it is something you have to pay more for because it's a luxury. If you are a resident in a new building you cannot get parking.
- BMW smart car would flash up to you parking spaces that were available in line with the permit you have or size of your vehicle.
- Off Quoted Statistic - 30% of people driving in London are driving to find parking spaces
    - This is the connection between air pollution and parking, if you could be directed to a space immediately it would cut down completely on the hovering and stalling at low speeds just belching out air pollution
- They need to use estimations instead of using exact data→ likelihood instead
- Floating car club sound like a good idea

Interview with Ashley Brandon
Date: March 31th, 2017
Time: 2:00 PM
Location: Blue Star House, Brixton
Team Members in Attendance: Tsering Dolma and Connor Weeks
Guests in Attendance: Ashley Brandon

The interview started out with Ashley talking about her position or role in the short-term parking initiatives. She is the current environment performance and development officer focusing on providing good customer experience which deals with issuing parking permits, customer's interactions with the pay and display machines and handling parking ticket complaints. The end goal is to provide them with good quality service. She then talked about the how her role led into the promotion of Pay by Phone method because it is not just about providing good service to the resident but look for ways to cost efficiently run these services. Their reason for promoting the app and decommissioning the machines is because it is not cost efficient maintaining the machines. The machines get vandalised and broken into. Having to fix the machines all the time is not cost efficient and good customer service. Another reason for the Council to discourage people from relying on these pay and display machines is the new coin that came into circulation at the end of March. It would cost a substantial amount to upgrade these machines.

When asked about the drawbacks of the mobile app and impact it could have, she discussed about having the network down from time to time but that's very unlikely to happen since it functions properly 99.99% of the time. Another impact could be that no matter what some people don't trust in electronic form of payment and don't want to put their credit information at risk. There are also group of people who are in circumstances that wouldn't allow them to have easy access to the mobile app. In that case the Council must take the equality policy into consideration to meet everyone's needs.

She also discussed about changing people's perception of cash vs. credit card when asked about challenges that the team have faced dealing with current parking initiative. The Council's end goal of these various ongoing initiative is achieving higher air quality. For that reason, the Council must push ahead with the wider adoption of payment through mobile app. This will allow them to collect data that can be used to implement an emissions base pricing for the parking payment. This meant reaching out to the Lambeth residents effectively with regards to educating about the mobile app and advantages that comes with it particularly residents in central Brixton. The interview ended with a few discussion points on floating car clubs. She thinks that the system of the floating car clubs can help advance the Council's goal to improve air quality but one thing the Council has to consider for sure is the amount of the revenue the Council will lose if these cars have permit to park around the Borough.

Interview with Andrew Round
Date: March 31th, 2017
Time: 3:00 PM
Location: Blue Star House, Brixton
Team Members in Attendance: Tsering Dolma and Connor Weeks
Guests in Attendance: Andrew Round

Andrew Round is the current Sustainability Manager at Lambeth Council. The interview with him focused on the current Council's air quality action plans. Wide range of topics about air pollution, particulate matter, nitrogen dioxide, major sources of air pollution and various ongoing initiatives were discussed. He highly stressed on the fact that Lambeth is committed to reducing the exposure of people in the Borough to poor air quality in order to improve health and quality of life. The air quality plan has the guidelines and actions the Council will take to improve air quality in Lambeth and protect the residents from exposure to the main pollutants. air pollution particularly affects the most vulnerable in society including children and older people, those with heart and lung conditions and people who are from poor background.

He also discussed about major sources of pollution. These sources include boilers, building constructions, transport and highways. Road transport in particular is the main source of air pollution in Lambeth. The Council is continuing to encourage walking, cycling and low emission vehicles as a method of traveling. The delivery truck vehicles contribute 20% of air pollution in Lambeth. The Council is currently in the process of working with other boroughs like Southwark, Croydon, and Wandsworth to create a consolidation centre outside of London to efficiently deliver the goods and that will hopefully reduce the delivery trucks off the road.

By 2030, Andrew thinks that London will face traffic gridlock. Currently, the Council is trying to look into a system called virtual aid where a driver can reserve a parking spot and load the car at the destination instead of driving around looking spot, causing major traffic and wasting fuel cost and time. Additionally, he talked about encouraging the residents to cycle to work and students to walk to school.

The interview ended with discussing about the types of air pollution the Lambeth is most concerned about which includes nitrogen dioxide, PM_{10} and $PM_{2.5}$. Although all of these types have negative effects on human health, PM2.5 is more fatal. This particulate can pierce through skin and cannot be blocked by mask. While the Borough is required to monitor nitrogen dioxide and PM_{10}, the Council doesn't have any data on the health effects of $PM_{2.5}$. 9,500 Londoners dies each year from exposure to air pollution and at Lambeth level 112 residents die each year.

Appendix F: Interview Questions for Council Employees

1. How do you think technology impacts present and future transportation in Lambeth?
2. Do you believe that removing the ability to pay for parking with cash would have any significant impacts (also, specific impacts on demographic groups)?
3. How has air pollution affected public health in general (different age groups, etc.)?
4. What forms of air pollution have the most negative effects in Lambeth?
5. What has your department done to improve the air quality in Lambeth?
6. In the far future, what are your department's plans to reduce air pollution?

Appendix G: Notes from Resident Interviews

Resident 1

- Owns a car but has parking permit
- Never used Pay by Phone method before and pays by cash when needed
- Thinks that educating and raising awareness about the use of Pay by Phone method would help get people to use it.
- Reduce rate for Pay by Phone can also encourage them to use Pay by Phone

Resident 2

- Doesn't own a car but used to own one for running errands for the family.
- Thinks that the main cause of air pollution is delivery trucks and cars in general
- In order to make an effective change, the system and mindset of people have to change
- Floating club won't be effective: rich will continue with the luxury of driving cars and it would cause more crime and theft in the poor neighbourhoods/ lower middle class. He thinks it would cost more for the poor.
- Won't be owning a car anytime soon in the future.
- System has to be equal for it to be effective for all.

Resident 3

- Used to own a car to commute to work but got rid of it because it is difficult to find a place park and expensive to maintain it.
- Not in financial situation to own car in the future
- Electric car could be a potential solution to air pollution
- Current transportation system in London is just ok. Underground trains could be improved. Tubes get very hot and crowded in the summer times.
- Pollution is definitely an issue in Lambeth and main cause are traffic, heating system and boiler.
- Floating car club is a good idea and often uses zip cars to drive around.
- Thinks that car sharing should be widely used.
- Wishes for a day when there would be no car on the road.

Resident 4

- Used to own a car in the past for leisure activity but since he doesn't have the time and money to do those activity, he does not have car anymore

- Thinks that cars are major sources for the pollution along with heating and cooking (restaurants and cafes)
- Thinks that electric cars and car club/ car sharing is great ideas but probably won't use them.
- Travels by tricycle powered through electric.
- Strongly against the idea of the smart city: the idea of IoT and harvesting information gives more power and advantages to the government than doing service to the people.
- Hackers can get into the database and will use to influence the citizens. It is not safe.

Resident 5

- Doesn't own a car or use car club
- Air pollution is a serious issue in Lambeth
- Electric car is a good idea but haven't seen any charging point at all
- Not aware of smart city technologies

Resident 6

- Doesn't own a car mainly because parking is expensive
- Air pollution is not really a problem
- App is not working at all for them. The transactions through the app
- Electric cars are great idea but not enough charging point in the Borough
- Receptive to car club
- Smart city is great idea

Resident 7

- Owns car but doesn't drive in Lambeth because of the severe congestion
- Usually uses cash primarily because the phone is not reliable all the time. Sometimes it is out of battery or not having access to the phone data all the time.
- Pollution is quite an issue
- Would consider switching to electric cars only if there are perks for doing that. At the moment, it is too expensive.
- Renting out car is also expensive (car club)
- Doesn't feel safe about self-driving car. They are not reliable.

Resident 8

- Only works in Lambeth, will never drive in anywhere in Lambeth. It is economically

very inefficient and parking is a huge issue.

- Air quality has definitely improved comparing to the times in 90s
- Only uses car to travel outside of London
- Open to car club idea

Resident 9

- Lambeth resident, doesn't own a car
- Air pollution is generally an issue in London itself
- In the future, most likely rent to a car if he needs one instead of owning one.

Resident 10

- Doesn't live Lambeth
- Sold his vehicle because of the difficulty of maintaining and parking in Lambeth

Resident 11

- Owned a car
- Did not use Pay by Phone
- Had a parking permit in the Borough
- Usually avoids CPZs but uses cash when parking in them
- Stated that smartphones are too expensive and are not a necessity
- Had not heard of smart city technology but was generally open to the idea
- Would not use a floating car club; already owned a car and would be afraid of damaging a car club car
- "I believe everyone thinks it's an issue, especially with the new mayor, but what else are people going to do? I'm not getting rid of my car."
- Stated that air pollution is not very bad in Lambeth, not much of an issue

Resident 12

- Did not own a car
- Primarily use bus or rains
- Believed air pollution was a slight issue, since some medical conditions were worsened by air pollution
- *Very* supportive of the idea of a floating car club, since it is often too expensive to own a car
- Interested in electric cars, but stated they are not currently feasible since there are very

few charge points in the Borough. If there were more charge points throughout the Borough, would be willing to switch to electric.

- Strongly supports smart city initiatives

Resident 13

- Has never owned a car
- Very supportive of floating car clubs; great idea for those who just need to use a car once a week or similar
- Stated that parking in Lambeth is very difficult and must be improved
- Was not aware of smart city technology. It is very hard to find available spots.
- Very supportive of smart parking initiatives to make finding spots easier
- Viewed air pollution as a serious issue, although it has been improving recently

Resident 14

- Owned a hybrid car, but received no permit benefits due to engine size
- Lives in a CPZ
- Does not pay for parking a lot due to having a driveway
- Stated that Pay by Phone sometimes has errors when parking
- Stated that the app needs better instructions to be easier to use
- Stated that floating car clubs would be excellent for those who don't use a car regularly and great for reducing emissions
- Stated that air pollution is very bad in the Borough
- Not able to give up car, since it is needed for going to work and taking family to the hospital regularly

Resident 15

- Owns a car but tries not to use it often
- Pays via cash
- Stated that this method is used due to age, does not trust electronic forms of payment
- "I don't want to have to call someone every time I park, I just want to use my cash and be done with it."
- Very open to the idea of PayPoint as an alternative to pay and display machines
- Stated that air pollution is definitely a problem
- Very open to the idea of smart city initiatives

Resident 16

- Does not own a car
- Stated that air pollution is a serious issue in Lambeth, especially for children
- Very supportive of emissions-based short term parking payments
- Very supportive of floating car clubs as a way of using a car infrequently
- Was generally supportive of smart city initiatives, although stated some concerns about the amount of information given to the government

Appendix H: Interview Questions for Residents

Dear Resident,

The Worcester Polytechnic Institute London Interactive Qualifying Project team invites you to participate in an interview regarding information about your habits and thoughts regarding transportation. We intend to use the collected data to forecast future transportation trends. Your responses will assist our team to meet the needs of Lambeth Council.

In this interview, information about you will be collected. Information collected will be summarised in our IQP final paper, but will not include any identifiable information about our interview subjects. This will be kept confidential and anonymous.

This interview should take approximately 15 to 30 minutes to complete. Individual responses may be quoted in the final paper but no identifiable information such as name will be released. We fully commit to keeping all responses confidential and will only choose to use a direct quote if we feel it absolutely necessary. Because responses are confidential, there is no foreseeable risk to you. The interview is entirely voluntary and should any of the questions asked make you feel uncomfortable in any way, shape or form you can request to skip said question or stop the interview completely.

If you have any questions regarding the interview process or the information we intend to collect, please feel free to ask before the start of the interview, or send any lingering questions to gnbiqp@wpi.edu. For questions regarding the research study, please contact our advisors, Prof. Adrienne Hall-Phillips (ahphillips@wpi.edu) or Prof. Josh Rosenstock (jrosenstock@wpi.edu). For questions regarding your rights as a research participant, contact the Human Research Protection Program at Worcester Polytechnic Institute, Worcester, Massachusetts, USA (irb@wpi.edu).

If you consent to all the information provided above, please sign below.

Subject's Name (print): _____

Subject's Signature: _____ Date: _____

Questions required before proceeding: do you have a car, and do you have a parking permit in Lambeth?

1. (Only if individual has a car but not a permit) What are your main reasons for owning a car? How often do you park in the Borough?
    a. Do you have a preferred method of payment for parking? Why?
    b. What could get you to switch to Pay by Phone?
    c. In what ways would the removal of the pay by cash method affect you?
    d. Have you found any other problems with regarding parking in Lambeth?
2. What role do you think cars play in Lambeth's air pollution?
3. What are your thoughts on electric and low-emissions vehicles?
4. Do you see your travel behaviour changing over the next ten years?
5. What comes to mind when you think of a smart city?
6. How would you feel about interacting with smart city technology specifically in Lambeth?

Appendix I: Payment Methods Data

Figure 1. Brixton (B) Payment Methods Usage

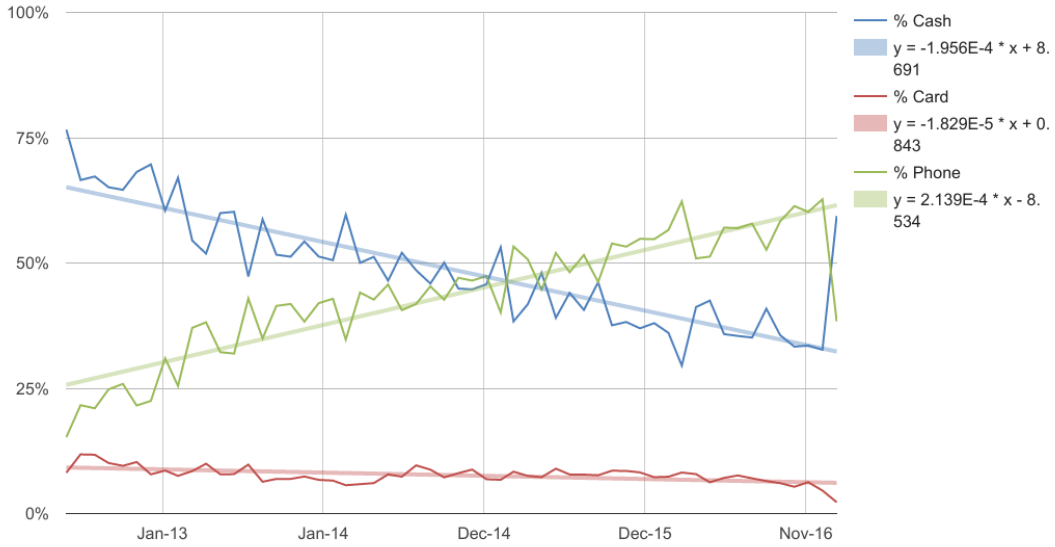


Figure 2. Waterloo (W) Payment Methods Usage