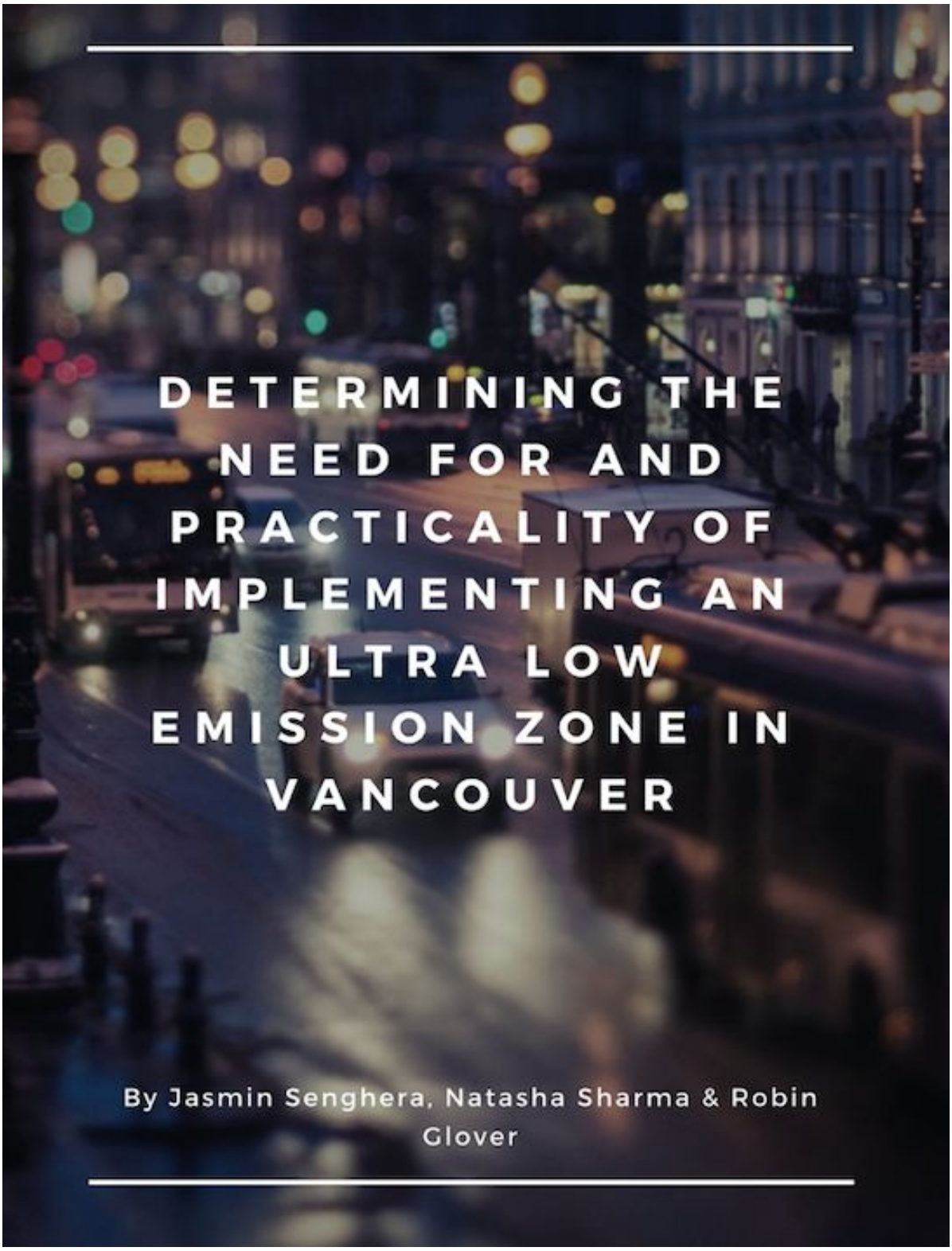
DETERMINING THE NEED FOR AND PRACTICALITY OF IMPLEMENTING AN ULTRA LOW EMISSION ZONE IN VANCOUVER
By Jasmin Senghera, Natasha Sharma & Robin Glover

Table of Contents

Abstract

The Ultra-Low Emission Zone (ULEZ) is a zone consisting of strict vehicular emission standards with a toll charge of £12.50 per day in central London, implemented in April of 2019 (Greater London Authority, 2019b). This zone was implemented on the basis that NO_2 is associated with increasing prevalence of respiratory problems in addition to premature deaths (Walton et al., 2015). So far, the ULEZ has had tremendous success as between April and June of 2019, there was a 24% decrease in NO_2 in Central London and a 10% decrease in Inner London (Greater London Authority, 2019a). In Canada, approximately 10,000 people die prematurely on a yearly basis due to air pollution and there is a 5% increase in risk of mortality in moving to urban centres such as Vancouver as explained by Michael Brauer, a professor and researcher in occupational and environmental health (Uguen-Csenge, 2019). Given these statistics and the success of the ULEZ in London, this project was proposed to determine the need, practicality, and potential location of an ULEZ based on NO_2 concentrations in Metro Vancouver in 2014. This study shows that the Robson Square and Kitsilano air monitoring stations experience exceedances of 1ppb over the 2020 annual NO_2 standard and that the differing geographic and demographic features surrounding these stations require more research to determine where the ULEZ should be located.

Description

We are urban planners that have been asked to determine whether an ultra low emission zone may be necessary in Metro Vancouver and where the best location for that zone may be. This research project was inspired by the ULEZ adopted in London in April of this year, which has reduced NO_2 emissions by a third (Greater London Authority, 2019a). We will conduct this research project by mapping annual NO_2 concentrations of the air quality monitoring stations in Metro Vancouver in the year of 2014 and subsequently conducting a rigorous analysis on the areas surrounding the air quality stations that exhibit the highest NO_2 concentrations to determine the need for an ULEZ. The analysis will consist of mapping demographic features such as percentage of the population above the age of 65, median total income of households and total population density in the locations of these air quality stations to determine the practicality of implementing this zone. This census data will allow us to deduce the percentage of elderly residents and population density that are vulnerable to high NO_2 concentrations. The median total income of households will illustrate if the area with high NO_2 concentrations are dominated by people who earn generously or earn less, and thus, may or may not be able to afford ULEZ's toll charge and adapt to the change. Furthermore, geographic aspects such as roads, schools, rapid transit lines, bikeways, greenways, schools, and electric vehicle charging stations will also be taken into account to pinpoint the ideal location and the feasibility of this ultra low emission zone in Vancouver.

Methodology

Acquire

In terms of the process of retrieving the datasets, we used a wide variety of sources. The raster data for Census Canada cartographic boundary files which was used as the background layer was acquired from Statistics Canada. The total population, percentage of population above the age of 65 and median total income of households tabular data was also acquired from Statistics Canada. The air quality monitoring station locations and NO_2 yearly concentrations were acquired from DataBC. The public streets, schools, bikeways, rapid transit lines, greenways, and electric vehicle charging stations vector datasets were acquired from City of Vancouver.

Parse Filter

Prior to working with our datasets we began by downloading them all into a geodatabase. We then conducted a tabular join of the spatial and tabular census data for Vancouver (total population, % of population 65 years and older and median income) based on the CTUID and similarly, we conducted a tabular join of air quality station location data and NO_2 concentrations data based on the air station names. We also clipped several datasets (as mentioned below) to the buffers of each air station in order to be able to calculate things such as the number of schools included in each of the buffers.

Mine

To determine the air stations in Metro Vancouver that had annual measurements of NO_2 that exceeded the CAAQS (Canadian Ambient Air Quality Standards), we used the search by attribute command. The monitoring stations with the two highest recorded annuals NO_2 concentrations in 2014 were then selected and saved as a new layer to conduct the feasibility analysis. Firstly, two 1 km buffers were created through the planar method for each of the air stations and were named kitsilano_buffer and robson_buffer, respectively. We then clipped the schools, bikeways, rapid transit lines, greenways, and electric vehicle charging stations datasets to both of these buffers. The attribute tables of these clipped datasets were used to produce Table 2 so that we could determine the amounts and lengths of these geographic features.

Represent

All the layers were reprojected as NAD 1983 UTM 10 using the Arctoolbox Project command as the scale of the map fit within one UTM and the scale was large enough. In terms of the final maps produced, the first map was representative of the air monitoring stations in Metro Vancouver alongside their annual NO2 concentrations in 2014. For this map, we ensured that there was a basemap of Metro Vancouver included to provide an understanding of the

location of these air stations. We also ensured that the points representing the NO_2 concentrations were brightly coloured with special emphasis on the stations that had the highest NO_2 concentrations. Three separate maps were then created to depict a feasibility analysis of the ULEZ in Vancouver based on total population, percentage of elderly population and median total household income. To represent these census datasets, natural breaks were used alongside a red gradient, hence, higher densities were displayed in dark colours and lowest density in light colours. The 1km buffer layers surrounding the air stations were made transparent with a solid outline so that the underlying layers were viewable. Contrasting colours and thicker lines of the CoV datasets were chosen against the backdrop of the canada cartography, thus, highlighting schools, bikeways, rapid transit lines, greenways, and electric vehicle charging stations.

Table 1. Dataset of the layers and their sources, uses, entity/data model, attributes, and modifications

Layer name	**Source**	**Uses**	**Entity/data model**	**Attributes**	**Modifications**
Original: (lct_000b16a_e.zip lda_000b16a_e.zip) **Renamed:** Van_CT	- Statistic Canada, 15/11/2019	Background layer for clipping and merging tabular (total population, total income, age) and spatial data	Raster	CTUID< DAUID, CMANAME	- Raster to polygon - Merged spatial and tabular data - Changed projection to NAD 1983 UTM 10
Original: Air quality monitoring station locations **Renamed:** kitsilano_buffer and robson_buffer	DataBC, 15/11/2019	Air quality monitoring station locations in Metro Vancouver that monitor NO_2 and other gases concentration. The monitoring station is joined to the NO_2 concentration data	Table	serial_code, ems_id, Station_name, location, city, category	- Tabular join with NO2_Monthly_Averages.csv, field calculator, search by attribute, buffer - Changed projection to NAD 1983 UTM 10

Original: NO2_Yearly_Averages.csv	DataBC, 15/11/2019	NO_2 concentrations in ppb, recorded at different air quality monitoring stations in Metro Vancouver from 2009-2017. Used to determine the areas that require an ultra low emission zone	Table	Station_name, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017	- tabular join with air quality monitoring station locations table
Original: Public street **Renamed:** Roads_clip	City of Vancouver, 15/11/2019, DWG file	To determine the road's name in Metro Vancouver that are within the high NO2 concentration	Vector (line)	geom, hblock	- Clipped to kitsilano_buffer and robson_buffer - Changed projection to NAD 1983 UTM 10
Original: Education **Renamed:** Schools_clip	City of Vancouver, 15/11/2019, CSV file	Determine the number of schools in the areas with high NO2 concentration	Vector (points)	Addressm school_category, school_name, geom, geo_local_area	- Clipped to kitsilano_buffer and robson_buffer -Changed projection to NAD 1983 UTM 10
Original: Bikeways **Renamed:** bikeways_clip	City of Vancouver, 15/11/2019, CSV file	A green mode of transportation that can be used in the ULEZ to minimize NO2 concentration in atmosphere	Vector (line)	Unique ID, Bike Route Name, Street Name. Bikeway Type, Status, Length, Year of Construction, Direction of Movement, Street Segment Types, Geom	- Clipped to kitsilano_buffer and robson_buffer -Changed projection to NAD 1983 UTM 10
Original:	City of	A green mode	Vector (line)	Line, Geom	- Clipped to

rapid-transit-lines **Renamed:** Rapidtransitlines_clip	Vancouver, 15/11/2019, CSV file	of transportation that can be used in the ULEZ to minimize NO2 concentration in atmosphere			kitsilano_buffer and robson_buffer -Changed projection to NAD 1983 UTM 10
Original: Greenways **Renamed:** Greenways_clip	City of Vancouver, 15/11/2019, CSV file	A green mode of transportation that can be used in the ULEZ to minimize NO2 concentration in atmosphere	Vector (line)	Name, Geom	- Clipped to kitsilano_buffer and robson_buffer -Changed projection to NAD 1983 UTM 10
Original electric-vehicle-charging-stations **Renamed:** EVCS_clip	City of Vancouver, 15/11/2019, CSV file	A green mode of transportation that can be used in the ULEZ to minimize NO2 concentration in atmosphere	Vector (points)	Address, Geom, LOT_OPERATOR	- Clipped to kitsilano_buffer and robson_buffer -Changed projection to NAD 1983 UTM 10

Results

Primary NO_2 Analysis in Metro Vancouver

In the primary analysis of annual mean NO_2 concentrations in 2014 across all air stations in Metro Vancouver, it was discovered that the Kitsilano and Robson Square air monitoring stations had the highest recorded concentrations of NO_2. Both stations were recorded to have concentrations of 18 ppb, while the other Metro Vancouver air stations had concentrations ranging between 6-15 ppb. Thus, it was decided that the Kitsilano and Robson Square stations were the areas in greatest need of ultra low emission zones.

We decided to consider multiple aspects associated with each area in order to determine in which of the two locations an ULEZ would be most feasible and beneficial. Using census data, we considered the total population, the median total household income, and the percentage of the population 65 or older in each of the two areas. In addition to census data,

we considered the number of schools, the number of electric vehicle charging stations, and the length of public streets, rapid transit lines, bikeways, and greenways in both of the two buffers. Further mapping of these regions allowed for analysis of geographic features (greenways, bikeways, public streets, rapid transit lines, schools, and electric vehicle charging stations) and demographic (total population, the proportion of elderly population, mean household income) within these regions to determine the need for and practicality of implementing ultra low emission zone.

Geographic Features

In the geographic analysis it was discovered that the Kitsilano buffer region was void of electric vehicle charging stations, rapid transit lines, and greenways. The Robson Square buffer, on the other hand, contained eight electric vehicles charging stations, 4407 m of rapid transit lines, and 2601 m of greenways. In terms of bikeways and public streets, the Kitsilano buffer contained 7698 m of bikeways and 49950 m of streets while the Robson Square buffer contained 20966 m of bikeways and 48992 m of streets. For schools, both buffers contained six each. These values and lengths of geographic features are summarized in Table 2.

Demographic Features

When considering demographic data from census tracts, the Kitsilano and Robson Square buffers were quite similar and differ only by a small amount. In terms of the total population as highlighted by Map 2, Kitsilano and Robson Square appear to have the same population range with the only difference being that the Kitsilano buffer is comprised of a greater population overall. Similarly, when looking at the total household income as seen in Map 3, the range of income is the same, but overall the Kitsilano buffer consists of individuals with greater incomes. In regards to the percentage of the elderly population however, there does appear to be a larger discrepancy between the buffers. It appears that in the Kitsilano buffer, the percentage of the elderly population is generally between 10-15% while in Robson Square, the percentage is typically between 1-10%.

Discussion

Based on the Canadian Ambient Air Quality Standards, the target annual mean concentration of NO_2 for 2020 is 17 ppb. Both of the air stations located in Kitsilano and Robson Square recorded annual NO_2 concentrations that exceed this standard and therefore are located in areas where an ULEZ may be needed to reduce NO2 emissions. This ULEZ could help Vancouver in reaching the goals set out by the Greenest City 2020 Action Plan. Some of the Vancouver's Greenest City Goals that aim to help Vancouver become a leader in sustainability include clean air and green transportation. In terms of green transportation, Vancouver aims to make walking, cycling, and public transit the common forms of transportation (City of Vancouver, 2019). Implementation of an ULEZ would encourage people to reduce their use of

vehicles due to the toll and instead explore sustainable forms of transportation as Vancouver hopes to achieve. As for the clean air target, Vancouver aims to have the cleanest air out of all the major cities in the world (City of Vancouver, 2019a). This will only be possible if action is taken from governmental institutions to be stricter on pollutant standards which could be partially achieved by implementing an ULEZ.

When deciding whether to implement an ULEZ in either Kitsilano or Robson Square, many factors must be considered that may affect both the feasibility and potential benefits of these zones. Firstly, it is important to consider the demography of the population in the area when determining where to implement an ULEZ. In this analysis, we considered total population, percentage of elderly population, and median total household income as important demographic factors. It is clear that areas with a higher population of residents should be more strongly considered for the implementation of an ULEZ because there are likely more people exposed to pollutants. As more and more individuals are exposed to pollutants such as NO_2 there is a greater risk of premature deaths and respiratory problems (Walton et al., 2015). Based on Map 2, it appears that the Kitsilano buffer consists of a greater population overall, however both stations have the same range of population size. Thus, based on population density, both stations would be ideal candidates for implementation. However, based on the fact that Robson Square is at the heart of Downtown Vancouver and the financial district, it is likely that there are more people accessing this region that may not be living here and thus Robson Square may be a better candidate. The elderly population is particularly vulnerable to increases in air pollution (Viegi et al. 2009 & Goldberg et al. 2013). This is because lung function is naturally reduced during aging (Viegi et al. 2009) and because elderly people are more likely to suffer from chronic lung, heart, or circulatory conditions that may be worsened by exposure to increased air pollution (Goldberg et al. 2013). Given that Kitsilano consists of a greater elderly population in comparison to Robson Square, an ULEZ may be more necessary as the elderly population are more susceptible to the detrimental impacts of NO_2 exposure. Finally, it is important to consider the income of residents potentially located within an ULEZ because those with more financial resources will likely be able to adjust to restrictions on transportation with greater ease. For example, people with higher incomes are more likely to be able to afford an electric vehicle in order to abide by the vehicular emission standards. Additionally, it would be important to implement an ULEZ with a toll fee in a zone where people will be able to afford it as otherwise people with low-income will be unfairly penalized. Based on Map 4, the Kitsilano buffer does consist of slightly higher household incomes than in the Robson Square buffer. Yet, these values are not inclusive of those individuals entering these regions.

Secondly, in order for an ULEZ to be successfully implemented, there must be sufficient access to green modes of transportation in the area. Types of green transportation may include walking, biking, taking rapid transit, bussing, or driving an electric car. In this analysis, we determined the relative accessibility to green transportation by calculating the number of electric vehicle charging stations and the lengths of rapid transit lines, bikeways, and greenways

contained within each of the buffers. Between the two buffers, only the one located at Robson Square contained electric vehicle charging stations, rapid transit lines, and greenways. While both buffers contained bikeways, the Robson Square buffer contained more than twice the length of bikeways than the Kitsilano buffer. Therefore, an ULEZ located in the Robson Square buffer would have much greater access to green transportation than an ULEZ in the Kitsilano buffer. Additionally, both of these buffers contain 8 schools each. This indicates that there are a lot of children that can become susceptible to the health impacts of NO_2 exposure. Schoolchildren are of particular concern as their bodies are still developing, and air pollution can hinder this development (World Health Organization, 2019). This further highlights the need for a ULEZ in these areas in order to reduce NO2 emissions that may harm the children in the area.

Overall, based on the research and analysis conducted, this report recommends implementing an ULEZ in Vancouver. Implementing this zone aligns with the CAAQS (Canadian Ambient Air Quality Standards) to reduce the annual NO_2 concentrations below the standard of 17 ppb and it aligns with Vancouver's Greenest City Goals to promote green transportation and clean air. Furthermore, this zone will assist in preventing premature deaths and health issues associated with long-term and short-term NO_2 exposure. In terms of the location of this zone, this report was unable to make conclusive recommendations. Based on the demography of the areas encompassing these air stations, it appears that the Kitsilano region would be ideal for the ULEZ as there appears to be a slightly greater population density, a greater proportion of the elderly population, and higher income owners that in the Robson Square region. This indicates that there are more people that could be susceptible to the detrimental health impacts of NO_2 in this area. These findings also depict that the fees of the ULEZ may be more appropriate in Kitsilano as Robson Square appears to consist of more low-income owners who may be adversely penalized due to this zone. However, these census statistics don't include values for individuals working and accessing these regions and thus, based on demography no clear conclusions can be made on an ULEZ location. In terms of geographic features, it is clear that the Robson Square region is better equipped for the transition to an ULEZ due to the presence of greenways, electric vehicle charging stations, rapid transit lines, and greater length of bikeways. Nonetheless, further research and analysis should be conducted to determine the ideal location and boundaries of an ULEZ in Vancouver

Error & Uncertainty

Although the datasets for the geographic analysis were obtained from the City of Vancouver's open data portal where data is accurate due to features such as survey accuracy, there can still be errors. The school's dataset from COV was based on data from the BC Ministry of Education extracted in 2009. While it may be unlikely that new schools have been implemented in the Kitsilano and Robson Square regions of Vancouver since then, this dataset is still dated and potentially inaccurate. The transit lines, greenways, electric vehicle charging

stations, and public streets datasets were also mentioned to be approximate on the data portal as survey accuracy is used sometimes and often locations of transit lines and greenways are approximate (City of Vancouver, 2019b).

For the yearly NO_2 datasets, the data was retrieved from a GitHub site where it had already been sifted through and organized for analysis. Therefore, human error may have been introduced to the data while processing which may have resulted in misplaced or incorrect values. Also, this dataset had many values missing which is why this report focuses on 2014 and not a more recent year. The dataset on the air quality monitoring stations was also problematic as, upon conducting the tabular join between the monitoring stations and air quality data, there were air stations included that did not have any air quality data and there were some air stations included that no longer operate. This is likely attributable to the dataset being last updated in 2016.

In regard to the census data, the main types of errors include coverage errors where people may be missed or double-counted and sampling errors resulting from the long-form questionnaire of the 2016 census (Statistics Canada, 2019). Another issue of uncertainty that can arise from census data is the modifiable areal unit problem in which census data is aggregated over census administrative areas, thus, the results are based on these boundaries which may not be ideal to view the geographical distribution of population. Hence, MAUP may interfere with the visualization of the population, elderly population, and household income data in the demographic analysis. Another error and uncertainty in the census data can be seen on Maps 2-4 in the census tract to the left of the Robson Square air monitoring station in which there is no data. Upon looking closer at this area, it appears that it consists of shops, restaurants, hotels and car rentals. However, there are high-rises in this area that comprise of rental apartment units. Thus, it appears that there are some inconsistencies in the census that could be affecting this analysis.

Another element of error and uncertainty is based on the user. It could be highly likely that in the process of clipping, changing projections, and selecting we made a mistake and introduced error to our analysis. It is also important to note that in selecting certain datasets and aspects of this project, we made some assumptions that may not have been ideal to make, therefore, introduced uncertainty to this analysis. For example, this analysis is conducted based on NO_2 concentrations in 2014, which was a year of intense forest fires that could have been the main drivers for the exceedances over the CAAQS. Additionally, in making the buffers around the air stations, 1km was arbitrarily chosen as a buffering length. If a greater length was chosen, then maybe there would have been more conclusive results for choosing the ULEZ location.

Further Research/Recommendations

As highlighted in the discussion, while there is a clear need for an ultra-low emission zone in Vancouver, more analysis must be done to determine where this zone would be located

and how exactly it would operate. In order to make these conclusions, research needs to be conducted on a larger scale around the air monitoring stations. The ULEZ in London encompasses the entirety of Central London which includes a large portion of the River Thames, multiple metro stations and several main roads as seen in Figure 1. Thus, it would be useful to do an analysis on an area comparable to the London ULEZ in Vancouver to determine if, based on this greater area, there is a greater need for this zone and how feasible this expanded area may be. Alongside looking at a greater area, it would also be important to look at pollutants such as VOC's (volatile organic compounds) and PM (particulate matter) to determine whether their concentrations exceed the CAAQS and whether there is a large discrepancy between Kitsilano and Robson Square. Given that there is a lot of research surrounding the health impacts of $PM_{2.5}$ in the Lower Fraser Valley in particular, there may be an opportunity to advocate for the need of an ULEZ on this basis. Another aspect that could require more research is traffic; given that central London has always been known for congestion, the ULEZ made a lot of sense on that front. Thus, it would be beneficial to analyze statistics in traffic to determine if there is a discrepancy between the two stations and how the patterns change throughout the day. Knowing these variations throughout the day will help in determining whether this zone should be in operation 24 hours a day, 7 days a week like the one in the UK or whether there should be a time set for operation. It is also recommended that alongside this research, public consultations should be introduced to determine how people may feel about the implementation of this zone.

Appendices

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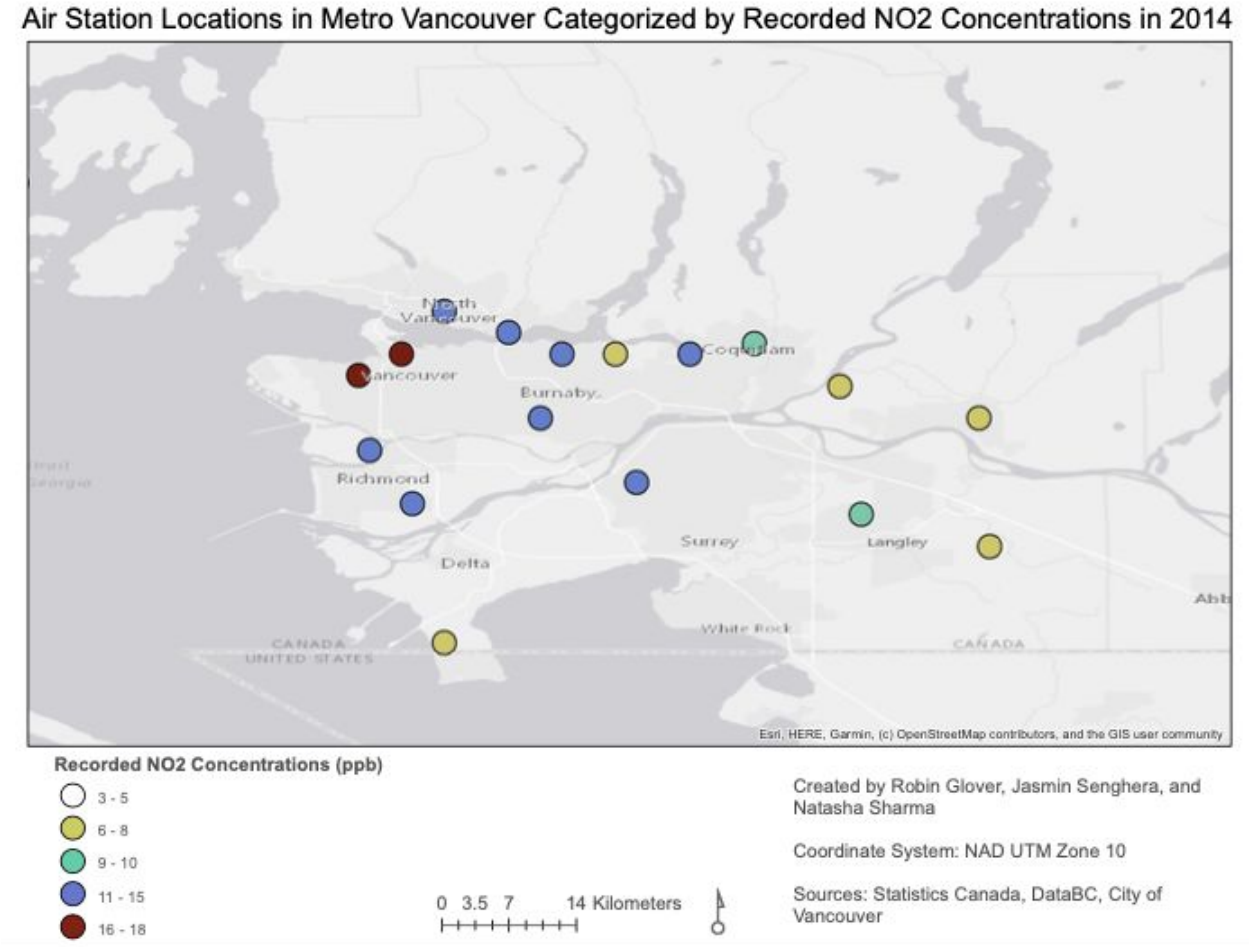
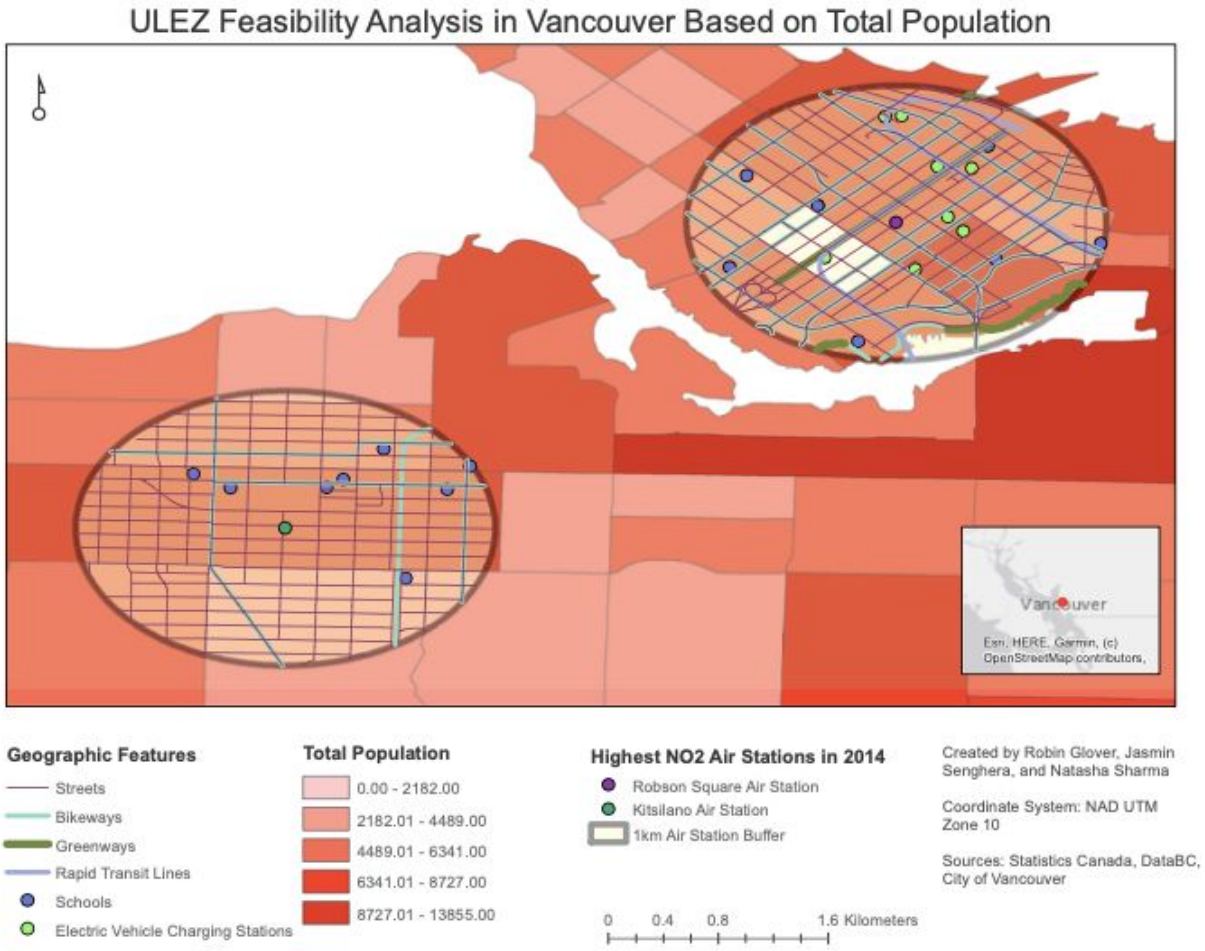
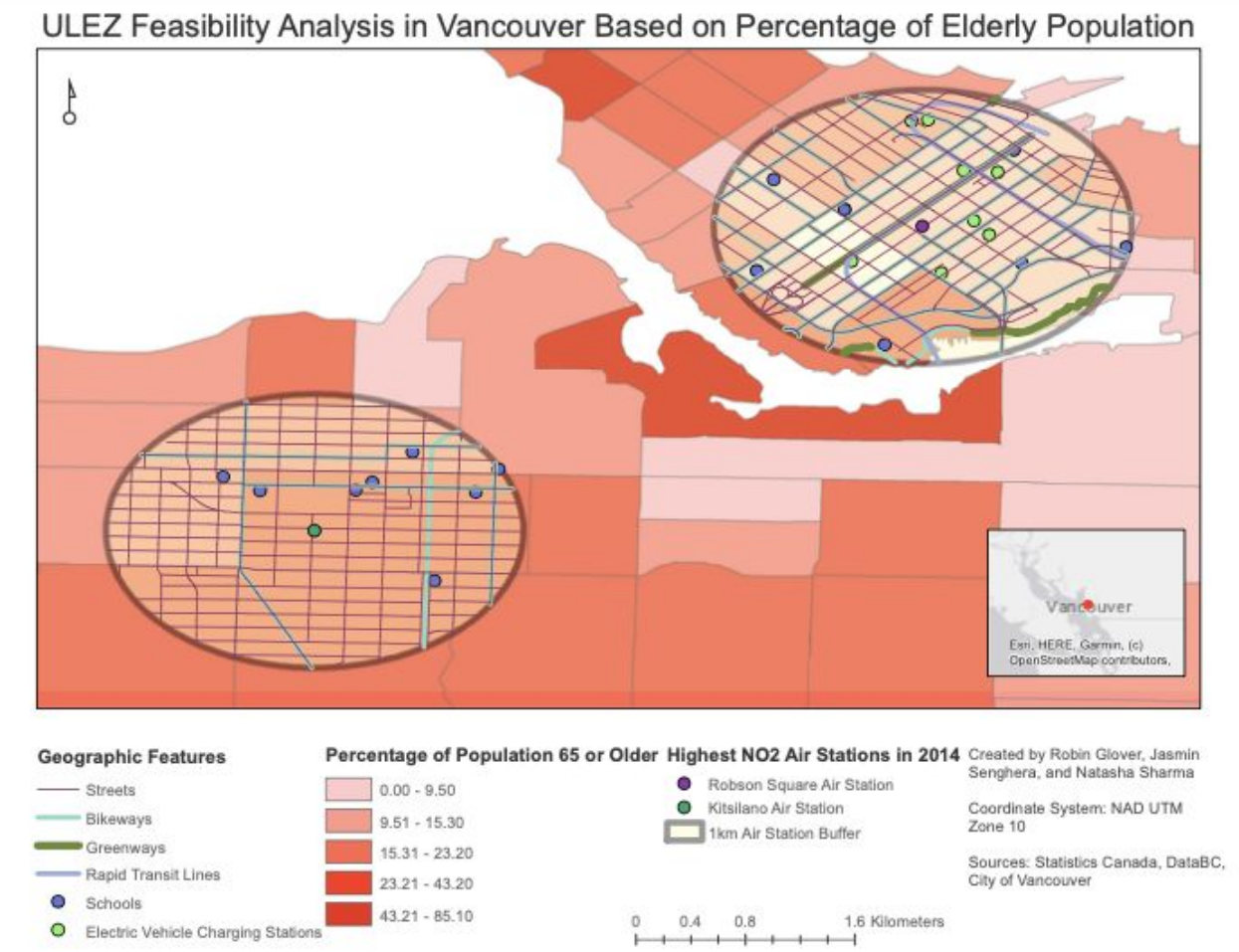
Maps & Figures



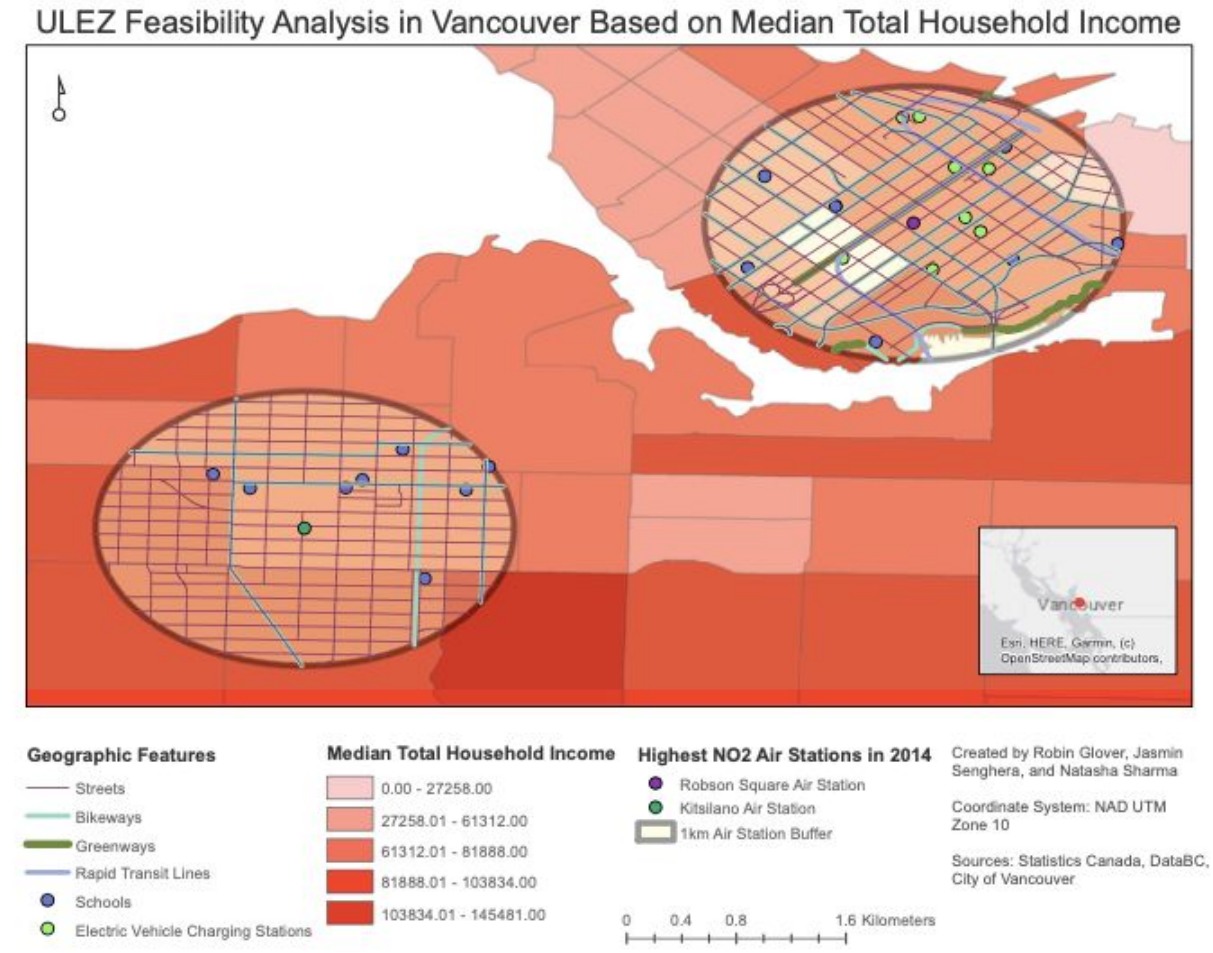
Map 1. Air monitoring station locations in Metro Vancouver categorized by recorded mean annual NO_2 concentrations (ppb) in 2014.



Map 2. This map depicts the area extending 1 km from the Vancouver Robson Square and the Vancouver Kitsilano air monitoring stations categorized by total population based on the 2016 census data . This map also includes the location of schools, streets, bikeways, greenways, rapid transit lines, electric vehicle charging stations, and total population. The purpose of this map is to provide a visual of the feasibility of the ULEZ in Vancouver based on proximity to and presence of the features mentioned previously.



Map 3. This map depicts the area extending 1 km from the Vancouver Robson Square and the Vancouver Kitsilano air monitoring stations categorized by the percentage of the elderly population from the 2016 census data . This map also includes the location of schools, streets, bikeways, greenways, rapid transit lines, electric vehicle charging stations, and total population. The purpose of this map is to provide a visual of the feasibility of the ULEZ in Vancouver based on proximity to and presence of the features mentioned previously.



Map 4. This map depicts the area extending 1 km from the Vancouver Robson Square and the Vancouver Kitsilano air monitoring stations categorized by median total household income data collected in 2015. This map also includes the location of schools, streets, bikeways, greenways, rapid transit lines, electric vehicle charging stations, and total population. The purpose of this map is to provide a visual of the feasibility of the ULEZ in Vancouver based on proximity to and presence of the features mentioned previously.

Table 2. The number of schools and electric vehicle charging stations and the length of public streets, rapid transit lines, bikeways, and greenways encompassed by the 1 km radius extending from the Robson Square and Kitsilano air monitoring stations.

	Kitsilano Station Buffer	Robson Square Station Buffer
Electric Vehicle Charging Stations	0	8
Schools	8	8
Public Streets (sum)	49950 m	48992 m
Rapid Transit Lines (sum)	0	4407 m
Bikeways (sum)	7698 m	20966 m
Greenways (sum)	0	2601 m

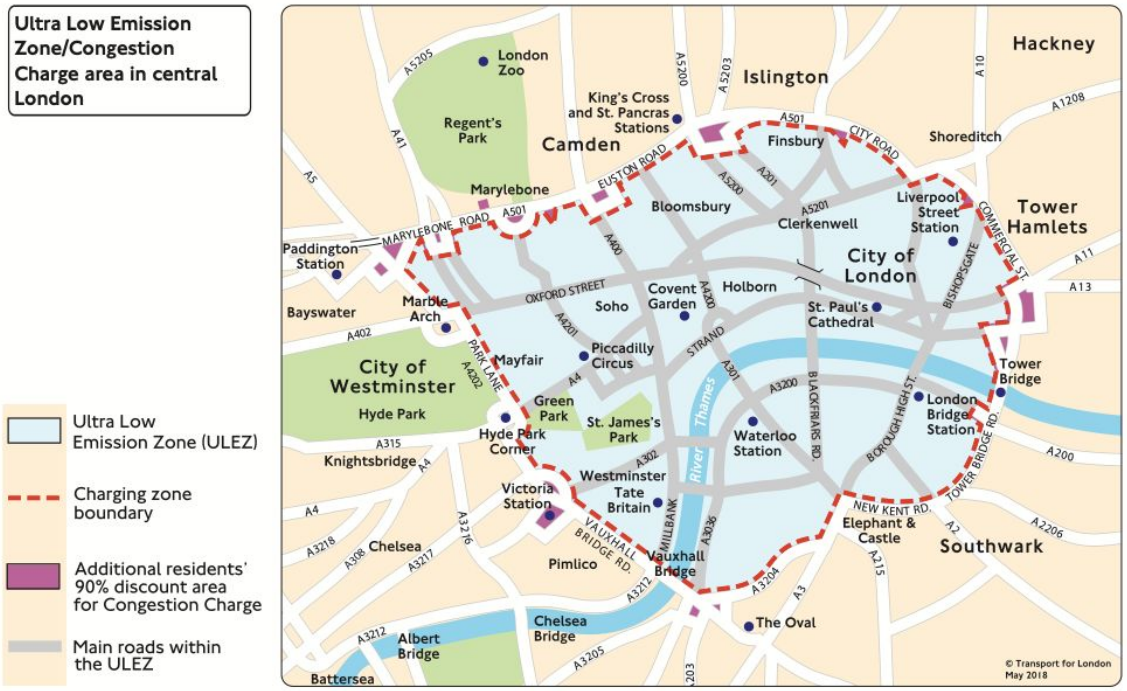
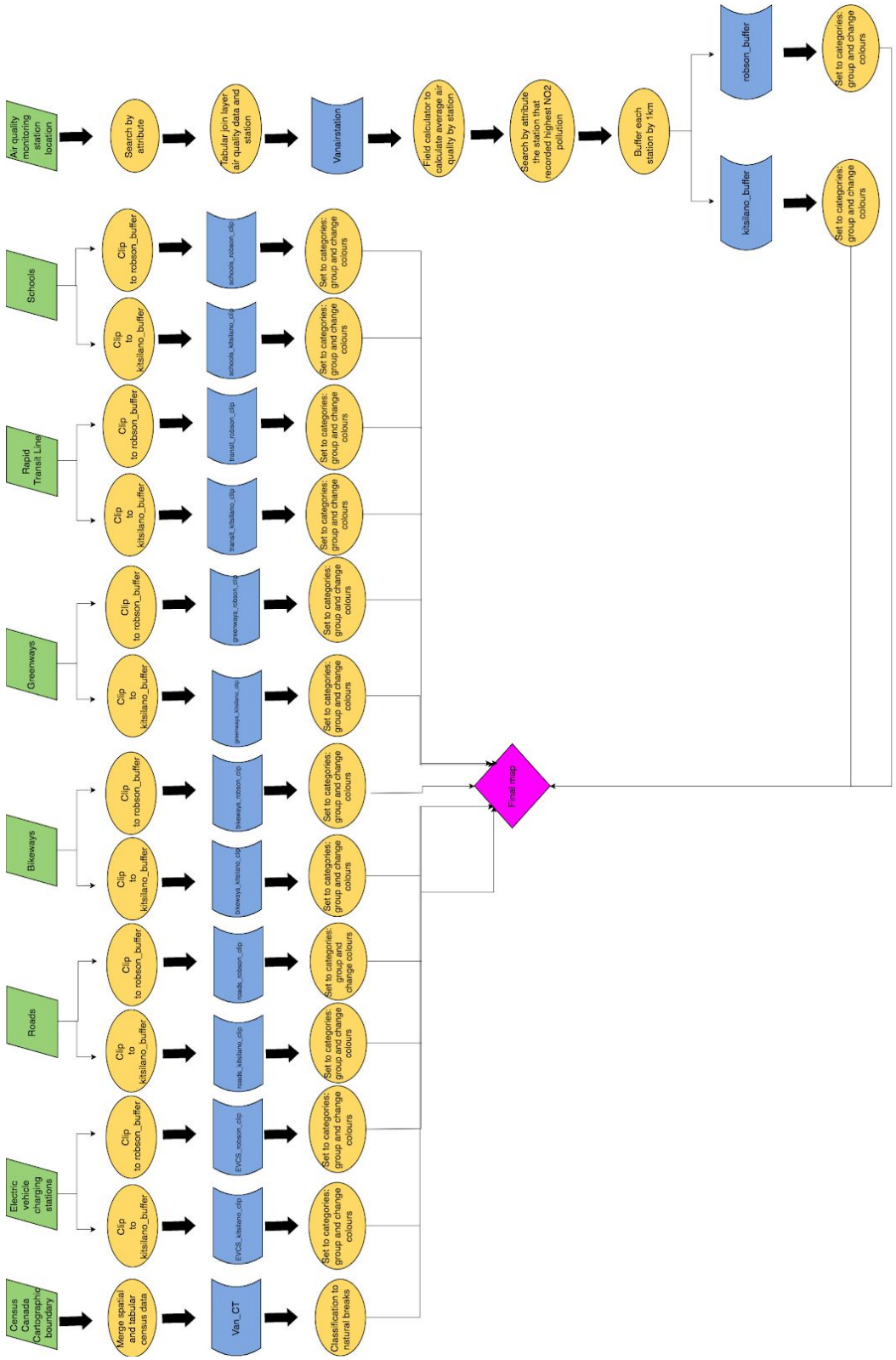


Figure 1. A map of London's Ultra-Low Emission Zone (Transport for London, 2018).

Flowchart


Air quality monitoring station location
Search by attribute
Tabular join layer air quality data and station
Vanairstation
Field calculator to calculate average air quality by station
Search by attribute the station that recorded highest NO2 pollution
Buffer each station by 1km
robson_buffer
kitsilano_buffer
Set to categories: group and change colours
Census Canada Cartographic boundary
Merge spatial and tabular census data
Van_CT
Classification to natural breaks
Electric vehicle charging stations
Clip to kitsilano_buffer
Clip to robson_buffer
EVCS_kitsilano_clip
EVCS_robson_clip
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Rapid Transit Line
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transit_robson_clip
Schools
schools_kitsilano_clip
schools_robson_clip
Final map