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Investigating Transportation Policies to Reduce Air Pollution in Hong Kong

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submitted to the Faculty of
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Submitted to:

Professor Constance Clark (advisor)
Professor Zhikun Hou (co-advisor)

In Cooperation With
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Abstract

This report, sponsored by Friends of the Earth (Hong Kong), examined the current transportation policies in relation to air pollution in Hong Kong. The transport policies of several cities including Seoul, Singapore, and Rome were examined in relation to reduction of congestion and air pollution. The pedestrians were surveyed and observations of traffic patterns in Hong Kong were made, then the team recommended a reevaluation of the bus system, several limited traffic zones, and several changes to the cross-harbor tunnels.

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Executive Summary

This project, sponsored by Friends of the Earth (Hong Kong), examined the current transportation policies that affect air pollution in Hong Kong. The overall goal of the project was to provide policy recommendations with the purpose of improving air quality.

The project team began by examining Hong Kong's current policies in relation to transportation and air quality. The major types of air pollution in the city, and the differences in air quality around public and private housing were also examined. The general political system in Hong Kong was briefly examined, along with a summary of the Department of Transportation's plan to improve the public transport system, in relation to both improving the efficiency of the system and reducing the environmental impact of the public transport system as a whole. The Clean Air Plan for Hong Kong was also summarized, and points toward Hong Kong's intention to improve air quality, although the majority of the plan has not yet been implemented throughout the city.

The project team went on to examine several case studies in large cities worldwide that implemented plans to improve their own transport systems to relieve congestion and reduce air pollution. For example, Beijing suffers from rapidly deteriorating air quality both from increased congestion and from the use of coal as a primary source of fuel. The city was able to vastly improve the situation when it prepared for the 2008 Olympic Games with new laws to reduce vehicle traffic during peak hours and by using natural gas for fuel, but it reverted to coal after the games. Shanghai created a multi-scenario plan to combat an increasing population in regard to traffic volume, but does not have the physical space required to combat the increase in demand. Singapore introduced an Electronic Road Pricing system in an effort to reduce congestion during peak hours in high traffic areas.

This system was largely successful and reduced congestion by 17% in some of the most trafficked areas. Seoul revamped its bus system, creating dedicated bus lanes to cut down on congestion and updating the buses themselves to run on natural gas, which greatly reduced the volume of air pollution created by their public transport network. Rome introduced Low Traffic Zones, with the aim of reducing traffic around the most popular areas of the city. These zones were effective in reducing vehicle traffic while having little impact on tourism. London attempted to create Air Quality management areas, but was unsuccessful due to a lack of coordination between regional and national authorities. They were more successful in creating Low Emission Zones, although these zones only applied to commercial vehicles. Political obstructions to improving air quality in the United States and Australia were also examined. These problems represent issues that can be met while making realistic policy recommendations to be adopted by the Hong Kong government.

The team discussed observations in several sections of the city, and encompassed several key ideas. The team made several observations of the bus system, including redundancies in routes and the overabundance of buses. Taxis were observed to ignore drop off zones and to crowd streets looking for passengers. Commercial vehicles were observed to clog the parking zones in highly populated areas and to block traffic while unloading during rush hours. The cross harbor tunnels were also observed, and were seen to have significant congestion problems near their toll plazas.

The project team made recommendations to Friends of the Earth for policies that could reduce air pollution in Hong Kong from transportation. These recommendations were devised through surveying the local population about their general transportation usage and opinions of air quality, and by identifying areas of high traffic congestion and poor air quality. This data was combined with an acquired knowledge of both city traffic data and pollution data. The most current Hong Kong policies were also further examined with some access to the Hong Kong Department of Transportation while in the city. Those policies were compared with the case studies' policies and were further narrowed down to several important recommendations. With data on public knowledge, traffic congestion and transport usage, and regional pollution data, the team was able to make informed policy recommendations to the sponsor.

The team drafted several recommendations for the city to reduce congestion and therefore improve air quality. It was first recommended that the bus system be reevaluated. This includes the creation of bus interchanges, a redesign of bus routes, and the creation of a dedicated bus lane. It was next recommended that the city enforce limited traffic zones in the Central, Mong Kok, and Causeway Bay districts. These zones would limit the activity of taxis, commercial vehicles, and at times buses in their borders. The team also recommends several changes of the cross harbor tunnel system, including an equalization of tunnel tolls and several changes surrounding the toll plazas.

1. Introduction

Air pollution is a problem that has been growing in the world since the dawn of the industrial revolution in England. Factories belching smoke and other pollutants became a normal sight as air quality in industrial nations took a downturn. Greenhouse gas and hydrocarbon pollutants cause smog and have very negative effects on both global environments and human health. Pollution concentrating in population centers in the United Kingdom, the United States, and other developed countries has resulted in the deaths of thousands of people annually due to visibility problems, respiratory illnesses, and the development of cancer (Bernard, et al., 2000). These events, and evidence pointing to environmental problems, prompted many nations to enact legislation forcing their factories to reduce their environmental impact on air quality (Parrish, et al., 2009).

In addition to creating environmental standards and requirements for the manufacturing sector, legislation has set lofty goals for fuel mileage on cars. Before the advent of the catalytic converter, vehicles were releasing immense quantities of carbon monoxide and other pollutants into the air (Carslaw, et al., 2011). With the passing of legislation and the newly added catalytic converters, the amount of air pollution released was drastically cut. While this first step towards pollution control was effective, there is much more work to be done due to the amount of sources of air pollution.

Transportation, even after the efforts to reduce its impact, remains one of the largest sources of air pollution in the United States and many other nations. City traffic in many countries remains an enormous contributor to air pollution (Costabile, et al., 2006). However, many countries still have not yet taken steps toward reducing air pollution of any kind, with large repercussions being felt in manufacturing giants like China.

China has been an industrial power since the 1970s and has been growing dramatically in recent years; they currently have one of the largest economies in the world. As China's production totals have increased, so has its pollution output (Chan, 1992). As China's economy continues to grow, its air quality becomes worse as a result. Both from factories and transportation, the nation has been releasing significant amounts of pollution with very tangible effects. Many cities, including Beijing and Shanghai, have seen smog float down to ground level, reducing visibility significantly and creating health hazards. Recently, the pollution has reached a point where visibility was reduced to near blinding levels in the city of Harbin (Armstrong, 2013). The increase in air pollution has created problems in daily life, and it is considered a dangerous situation regarding potential respiratory problems. Unfortunately, the Chinese government has not been successful in continuing the enforcement of policies introduced in 2008 to reduce air pollution during the Beijing Olympics (Lin, Burkitt, 2013). In large cities especially, where there are thousands of small vehicles and other forms of public transport, the people are in dire need of new safety measures (Wang, et al., 2010).

Hong Kong is home to more than seven million people, and is known as the "Pearl of the Orient" with its blend of British colonial history and traditional Chinese values. Hong Kong's economic prosperity took off in the 1970s and still continues to grow. Although Hong Kong's Mass Transit Railway System (MTR) is one of the most efficient underground subways in the world, the city still faces a problem above ground: traffic congestion. Although a large percentage of people utilize the MTR, there are still a significant number of vehicles of varying types filling the roads of the city. Due to close packed skyscrapers and tall residential buildings, which create "street canyons," vehicle pollution is trapped due to limited ventilation. The vehicle pollution, both public and private, is able to build in concentration; this results in serious health risks for not only pedestrians, but all citizens of the city.

The Government of Hong Kong has developed a Clean Air Plan in March 2013 (Hong Kong, Environment Bureau, 2013) detailing various problems, solutions, and policies to be put into place. The goals of this plan include improving public health, enacting air quality management systems, targeting emission sources from roadside, marine, and power generation locations, and regulating mobile machinery. Some specific examples include completely switching to zero-emissions buses by 2017 and new legislation requiring bus operators to use the most efficient buses in terms of low exhaust emissions. Additionally, in order to encourage people to drive hybrid or electric vehicles, Hong Kong has built over 1000 EV charging stations in new and existing private properties.

Although Hong Kong has made an effort to promote clean energy resources, the problem of air pollution still exists in part because of poor transportation management. Transportation management consists of road planning, low emission efforts, public transport prioritization, electronic road pricing system, and all other aspects of a city's transportation network. Hong Kong has many possible options to consider in improving transportation management to lower congestion in the city, especially in a close examination of the public bus system and a reorganization of traffic moving through the cross-harbor tunnels. Congestion is a significant contributor (Chan, 1992) to roadside air pollution as idling cars choke the roads and emit pollutants in concentrated areas; thus, improving the public transport system and traffic patterns on the most highly travelled streets will have a positive effect on the reduction of congestion in high trafficked areas.

One of Hong Kong's environmental organizations, Friends of the Earth (Hong Kong), is also investigating the effects of air pollution caused by poor transportation planning. They advocate better air quality by pushing the government to enforce stricter policies toward cleaner air and to inform the public of the effects of air pollution. One of Friends of the Earth (Hong Kong)'s campaigns is called "Take a Brake," which is a low carbon-emission initiative encouraging residents to drive less and to adopt environmentally-friendly driving habits.

This project consisted of two primary parts: the investigation of the current conditions in Hong Kong and the research of other cities and their solutions to transportation management issues. The first goal was to explore other major cities similar to Hong Kong and analyze their policies for bettering transportation management in relation to reducing overall congestion and the effectiveness of these policies. The second goal was to analyze congested neighborhoods and business sectors in Hong Kong and to interview pedestrians affected by air pollution in each of the surveyed areas. Furthermore, the causes for congestion and elevated air pollution in the different neighborhoods were addressed. Through the comparison of successful policies in other large cities and the condition and needs of various areas in Hong Kong, the ultimate objective of this project was to formulate policy recommendations to better manage transportation in order to reduce air pollution within Hong Kong.

2. Background Chapter

2.1. General Combustion Mechanism and Health Concerns

Gasoline and diesel fuels are the most common fuels utilized by cars, and their combustion produces several gaseous byproducts. In general, combustion is the exothermic reaction of any chemical with excess oxygen. Gasoline and diesel are mixtures of various hydrocarbons and chemicals containing carbon, some examples of which are alcohols and ketones. These chemicals all combust in a similar manner with a general equation of:

$$C_xH_xO_x + O_2 \rightarrow xCO_2 + xH_2O$$

Combustion is rarely a complete process, as the fuel source can oxidize to a state that is not maximally oxidized, or can over-oxidize itself to a less stable state. While hydrocarbon combustion mostly yields carbon dioxide and water, many other products–such as carbon monoxide, various volatile organic compounds (VOCs), and particles of solid-state organic compounds–can form. Nitric oxides can also be formed through a side reaction to the combustion itself.

One of the main products of combustion is carbon dioxide, which is one of the most significant greenhouse gases contributing to global warming. While carbon dioxide can be a risk to the environment in general, carbon monoxide is a much more significant threat to pedestrian health. It is generally formed in the incomplete combustion of hydrocarbons, where the fuel does not completely oxidize into carbon dioxide before passing as a gas. It is well known that carbon monoxide is poisonous in high concentrations, and most homes in the United States are equipped with a carbon monoxide detector to warn occupants of rising concentrations. Exposure to low amounts of carbon monoxide for long periods of time poses other threats, such as headaches, nausea, and memory loss (Fawcett, et al., 1992).

Volatile organic compounds (VOCs) and particulate matter (PMs) are also common airborne pollutants created by the combustion of fuels. VOCs are chemicals such as acetone and formaldehyde that exist in a gaseous state in the exhaust from vehicles. These chemicals can cause respiratory problems, and in extreme cases, cancer (Ware, et al., 1993). PMs are small particles of solids that are caught in the aerosol of vehicular exhaust. Like VOCs, these compounds can also cause respiratory problems when inhaled.

Nitrogen oxides (NO_x) are chemical byproducts from vehicles that form in side reactions to the main combustion reaction. Because combustion is a largely exothermic reaction, excess energy can cause nitrogen gas in the air to react with airborne oxygen in an air-breathing engine. The nitrogen gas oxidizes to form NO_x, which is then released into the atmosphere as a gas. NO_x can have incredibly negative effects on health when it enters the respiratory system. The oxides react with water or ammonia to create nitric acid, causing respiratory system problems and worsening already existing respiratory conditions. (Bernard, et al., 2001)

Traffic congestion can have a profound impact on roadside air quality and thus pedestrian health. Studies have found that idling cars produce 200% more nitrogen oxides, 300% more hydrocarbons, and 400% more carbon monoxide than cars moving at normal highway speeds (Sjodin, et al., 1998).

2.2. Current Hong Kong Trends in Vehicle Usage and Pollutant Release

As the socio-economic developments of Hong Kong led to further pollution throughout the city, the environment of Hong Kong has gone further and further into disrepair. In order to effectively analyze the current pollution situation within Hong Kong, a number of areas were researched to form a base point for future applications. These areas include the city's current transportation trends, specific information regarding transportation's relationship with pollutants, the effects of private vs. public housing, current government policies on air quality in Hong Kong, and a number of case studies in regard to solutions put in place by governments globally to combat their respective issues of transportation management. Recent measures declared by Hong Kong can be found in the city's Environmental Report of 2011, the Clean Air Plan of March 2013, and New Air Quality Objectives by 2014. This background chapter will look at the proposals in the Clean Air Plan as well as transportation management policies instituted in other cities around the world, including Beijing, Shanghai, Singapore, Seoul, the United States, Rome, Australia, and London.

While there are a number of sources of pollution in Hong Kong, the transportation sector holds the largest concern. Firstly, there are a number of older vehicles populating the city that add to the air pollution; however, these vehicles are difficult to replace due to economic constraints. These vehicles are also often directly linked to the number of independent business owners in the city; thus, any forced replacement of these vehicles directly affects their financial welfare. Furthermore, it is projected that the number of vehicles within Hong Kong will only grow in the coming years (*Business Monitor International*, 2013) and the dominant part of Hong Kong's auto market is and will continue to be private vehicles. Additionally, the number of commercial vehicles is expected to increase due to government offered subsidies, which attempt to incentivize the replacement of old diesel-powered vehicles. To counter the increased demand, public campaigns seek to discourage the use of personal vehicles while simultaneously encouraging the use of public transportation (Chan, et al., 1992). However, private vehicles are a symbol of status and wealth in Hong Kong, so any attempt to remove them faces cultural obstructions.

By the end of June 2013, the Hong Kong government had collected data on various aspects of the city's transportation system. Public systems (railways, trams, buses, minibuses, taxis, and ferries) are used approximately 12.2 million times every day. (Hong Kong, Transport Dept., *Hong Kong: The Facts*, 2013) Additionally, there are 464,595 licensed private cars, which account for 70% of all registered vehicles at the time of the study. In total, there are 318 licensed vehicles for every kilometer of road, comprising about 70% of the total number of vehicles on the road, (Hong Kong, Transport Dept., *Hong Kong: The Facts,* 2013). Particularly noteworthy congestion occurs as vehicles cross Victoria Harbor via the three cross harbor tunnels: the Cross-Harbour, the Western, and the Eastern. Data regarding these tunnels can be found in the tables below. In Table 2, it is important to note percentages of vehicle types going through the tunnels and the concentration of traffic differences of each one.

Tunnel	Construction Begin	Opening Date	Franchise Expire	Current Owner	Connections	Daily Average	Toll Range
Cross Harbor	1969	Aug-72	30 year franchise agreement Turned over on 8/31/1999 due to termination of franchise	Government	Hung Hom to Causeway Bay	118,000	$8-$30
Western	1993	Apr-97	30 year franchise agreement 2023	Western Harbour Tunnel Company Limited	West Kowloon to Sai Ying Pun	60,000	$90-$500 $25-$140 after concessionary
Eastern	1986	Sep-89	30 year franchise agreement 2016	New Hong Kong Tunnel Company Limited	Quarry Bay to Lam Tin	71,000	$13-$75

Table 1: Background information regarding the three main cross-harbor tunnels. All dollars are in Hong Kong dollars. (Hong Kong, Transport Dept., Toll Rates of Road Tunnels and Lantau Link, 2013)

	Date									
Daily Average	Oct-13	Sep-13	Aug-13	Jul-13	Jun-13	May-13	Apr-13	Mar-13	Feb-13	Jan-13	Jan-Oct Average
Cross Harbor Tunnel											
Total Vehicle #	117,658	114,653	114,683	114,160	115,691	116,577	116,580	119,294	118,051	118,913	116626
% Private Cars	68.00%	67.60%	66.70%	66.40%	67.40%	67.00%	67.20%	67.90%	71.20%	67.00%	67.64%
% Goods Vehicle	22.00%	21.90%	22.50%	22.70%	21.90%	22.20%	21.90%	21.50%	18.60%	22.50%	21.77%
% Bus	10.00%	10.50%	10.80%	10.90%	10.70%	10.80%	10.90%	10.60%	10.20%	10.50%	10.59%
Western											
Total Vehicle #	64121	62903	62465	60748	61075	60723	59768	61348	56,122	60,290	60956.3
% Private Cars	77.20%	77.10%	77.10%	76.50%	77.30%	77.20%	77.30%	78%	78.40%	76.80%	77.29%
% Goods Vehicle	12.40%	12.70%	12.70%	12.90%	12.30%	12.20%	11.90%	11.40%	10.50%	12.30%	12.13%
% Bus	10.40%	10.20%	10.20%	10.60%	10.40%	10.60%	10.80%	11%	11.10%	10.90%	10.58%
Eastern											
Total Vehicle #	72,768	72,985	72,031	71,262	72,065	71,612	70,002	71,194	70,219	723.16	64486.116
% Private Cars	78.90%	79.00%	78.60%	78.20%	79.00%	78.90%	78.80%	79.40%	82.00%	78.60%	79.14%
% Goods Vehicle	16.30%	16.20%	16.80%	17.00%	16.20%	16.20%	16.20%	15.70%	13.30%	16.50%	16.04%
% Bus	4.80%	4.80%	4.60%	4.80%	4.80%	4.90%	5.00%	4.90%	4.70%	4.90%	4.82%

Table 2: Comparison of the daily average of vehicles and vehicle type percentage for January to October of 2013 for all 3 cross-harbor tunnels (Hong Kong, Transport Dept., Toll Rates of Road Tunnels and Lantau Link, 2013)

As of the end of April 2013, franchised buses comprised up to 40% of the traffic flow in busy sectors within Hong Kong. (Hong Kong, Environmental Protection Dept., *Retrofitting Franchised Buses with Selective Catalytic Reduction Devices,* 2013) In order to describe the details of the franchised and non-franchised bus fleet, the company name, routes, bus counts, daily passengers, and average fares of the various bus companies can be found in Table 3 below. This can give insight on the bus system as a whole and identifies the extent to which each company operates in different areas of Hong Kong. In addition to the buses operated by the five major bus companies, a number of Public Light Buses (commonly called minibuses) operate within the city. Red-roof light buses are able to operate anywhere (excluding areas with special limitations) and the driver sets the route and fare. On the other hand, green-roof light buses operate on fixed routes and fixed fares. The bus counts are further augmented by non-franchised buses that provide services for tourists, students, employees, and residents. Both red- and green-roof light buses have a maximum capacity of 16 passengers, public buses have a maximum capacity around 100 passengers (actual capacity varies by model), and non-franchised buses have a capacity between 40 and 60 (varies by model). Data about both minibuses and non-franchised buses can also be found in Table 3.

Company Name	Routes	Bus Count	Daily Passenger Count	Average Fares ($)
Kowloon Motor Bus Company (1933) Limited	312 Kowloon + New Territories 60 Cross Harbor	3,777	2,590,000	3.1-12.9 Urban 1.9-45 New Territories 8.4-35.6 Cross Harbor
New World First Bus Services Limited	50 Hong Kong Island 33 Cross Harbor	722	493,000	3.2-9.8 Hong Kong Island 3.4-10 Kowloon+ Tesung Kwan O 8.4-35.6 Cross Harbor
City Bus Limited (Network 1)	61 Hong Kong Island 1 New Territories 29 Cross Harbor	772	565,000	2.5-10.6 Hong Kong Island 9.3-32.2 Cross-Harbor
City Bus Limited (Network 2)	19 Airport/North Lantau + Urban	170	69,000	3-48 Airport/North +Urban
Long Win Bus Company	19 Airport/North Lantau + New Territories	167	88,000	3.5-30.9 Airport/North Lantau + New Territories
New Lantao Bus Company	22 Lantao 1 New Territories	108	63,000	3.1-43
Red Public Light Buses	Variable	1263	348,200	Variable, unfixed
Green Public Light Buses	71 Hong Kong Island 78 Kowloon 197 New Territories	3087	1,508,800	Variable, fixed
Non-Franchised	-	7057	-	-
Total Count	607	17,123	3,868,000	-

Table 3: Bus companies and their general route information (Hong Kong, Transport, Dept., *Buses*, 2013)

There are 15,250 urban, red taxis, 2838 New Territories, green taxis, and 50 Lantau, blue taxis that carry approximately 1 million passengers each day. Urban taxis operate throughout Hong Kong with the exception of Tung Chung Road and southern Lantau. New Territories taxis operate in the northeastern and northwestern parts of the New Territories. Lantau taxis operate on Lantau Island and Chek Lap Kok, excluding Discovery Bay. The fares of taxis are stipulated by law throughout Hong Kong. Urban taxis charge HK$20 for the first 2 kilometers, HK$1.5 for every additional 200 meters or 1 minute of waiting until the total is HK$72.5, and HK$1 per 200 meters or 1 minutes of waiting after that. New Territories taxis charge HK$16.5 for the first 2 kilometers, HK$1.3 for every additional 200 meters or 1 minute of waiting until the total is HK$55.5, and HK$1 per 200 meters of 1 minutes of waiting after that. Lantau taxis charge HK$15for the first 2 kilometers, HK$1.3 for every additional 200 meters or 1 minute of waiting until the total is HK$132, and HK$1.2 per 200 meters of 1 minutes of waiting after that.

The MTR and Airport Express networks comprise a total of 84 stations that carry 4.34 million passengers per day. The route length of the main MTR system is about 175 kilometers with standard class adult fares ranging from HK$3.5 to HK$55. Furthermore, the MTR operates the 35.2 km Airport Express connecting the city with the Hong Kong International Airport and the AsiaWorld-Expo with adult fares ranging from HK$5 to HK$100. Additionally, the MTR also utilizes a Light Rail network in the northwest New Territories that contains 36.2 kilometers of double track with 68 stops, 141 single-deck light rail vehicles, and fares ranging from HK$4.5 to HK$6.5. The Light Rail is used by approximately 464 000 passengers each day (Hong Kong, Transport Dept., *Hong Kong: The Facts, Transport,* 2013).

As of December 15th 2011, there was a statutory ban placed against idling motor vehicle engines within the city of Hong Kong. The ordinance comes into play when any motor vehicle stays stationary while operating an internal combustion engine for more than three minutes within any continuous sixty-minute period. The idling prohibition involves all roads and car parks in Hong Kong all year long and results in a HK$320 fine unless certain exemptions apply. Some exception examples include any bus with a passenger in it, vehicles stationary due to traffic conditions, drivers during extreme weather warnings, a taxi at a taxi stand, or the first two Green or Red minibuses at a stand. (Hong Kong, Environmental Protection Dept., Mobile Source Group, 2011)

These transportation trends within Hong Kong must be examined as extensive research has demonstrated that traffic congestion increases vehicle emissions that in turn degrade local air quality. Furthermore, studies have shown that these emissions are directly affecting the health conditions of drivers, commuters, and individuals living near major roads (Zhang, et al., 2013). Vehicles have been found to be a major source of air pollutants, including carbon monoxide (CO), carbon dioxide (CO2), volatile organic compounds (VOCS), hydrocarbons (HCs), nitrogen oxides (NO_x), and particulate matter (PM) (Zhang, et al., 2013). And as previously mentioned, idling vehicles produce more pollutants than moving vehicles. So while sheer traffic volume does have an impact on roadside air quality, the number of vehicles on a roadway with freely flowing traffic does not have nearly as significant an impact as the number of vehicles on a congested road. If a particular roadway becomes congested, pollutant concentrations will not only rise in respect to each individual vehicles emissions, but also due to the overall duration that each vehicle is forced to stay on that road.

Congestion occurs when traffic volume exceeds road capacity and is commonly measured as a percentage of free-flow speed (Zhang, et al., 2013). Congestion results in a lowered average speed, increased travel time, and increased exposure to air pollution. Additionally, congestion "diminishes dispersion of vehicle-related pollutants since vehicle-induced turbulence depends on vehicle speed" (Zhang, et al., 2013). Namely, the lower speeds increase the concentration of pollutants on the roadway. Furthermore, congestion leads to fluctuating driving patterns, such as stops, starts, slowdowns, and speedups. These fluctuations have been found to increase the emissions of a car as compared to cruising conditions. In order to show these effects, (Sjodin,, et al., 1998) demonstrated a 400, 300, and 200 percent increase in CO, HC and NO_x emissions respectively with congestion (average speed of 20.93 km/hr) as compared to free-flow conditions (average speed, 62–70.84 km/hr) (Zhang, et al., 2013). Studies such as this display the need for action to be taken against congestion such that the number of air pollutants is minimized for the sake of public health. A study by Zhang K, et al. (2013) mathematically demonstrated the effects of congestion in terms of increasing health risks of drivers on freeways and arterial roads as well as individuals working or living near these roads based on an incremental analysis of traffic data. Figure 1 below summarizes this data and shows that the overall health risk to roadside pedestrians increases exponentially as traffic volume increases linearly on main roads during rush-hour times, which is when congestion is most likely to occur. This study concludes that congestion has a direct result on roadside air quality and thus poses health risks to pedestrians. The results note that analysis of traffic data, including NO_2-NO_x relationships, changes in travel, road type, and exposure location (Zhang, et al., 2013), is very important to the creation of informed transportation policies for the sake of traffic and air quality management.

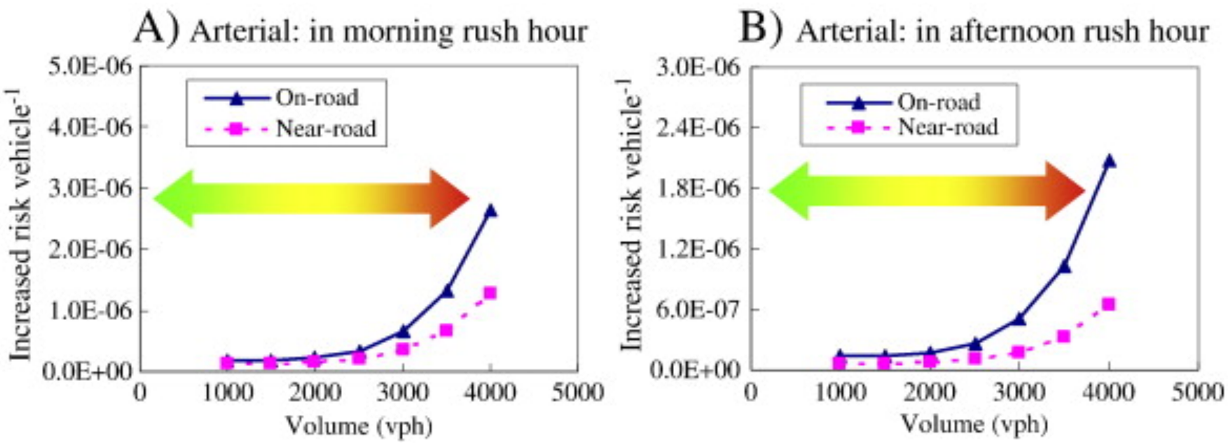

Figure 1: Incremental air pollution risks per vehicle versus traffic volume for upper bound mortality in the arterial scenario (Zhang, et al., 2013)

With the business culture of Hong Kong reinforcing the consumption of fossil fuels, the government is attempting a number of policy changes to combat the air pollution. However, continuous measurements of air quality in the city indicate that these policies often have little or no positive impact on pollution levels. The World Health Organization ranked Hong Kong 559th out of 566 cities in air quality in 2012 (Li, 2013). It was estimated that there were 3,000 premature deaths and more than seven million hospital visits as a direct result of pollution (Li, 2013). One of the biggest sources of the low air quality found in the city is a result of carbonyl pollution (Ho, et al., 2011). Carbonyl pollution is primarily a result of vehicular emissions and can have carcinogenic effects as well as being responsible for ozone formation at ground level. These measurements were carried out at several high vehicle traffic areas in Hong Kong and Kowloon, with two locations in the Outer New Territories. It was found that formaldehyde was the most common pollutant, with acetaldehyde a close second. No significant differences were observed in the areas where diesel vehicles outnumbered gasoline powered vehicles. Additionally, concentrations of formaldehyde were found to be much higher in the summer than in the winter, which is caused by some effects of atmospheric temperature (Ho, et al., 2011). On the other hand, summer monsoons bring winds up from the Pacific Ocean and winter monsoons bringing winds from Mainland China; thus, overall pollution concentrations are generally worse during the winter months (Hong Kong, Environmental Protection Dept., Mobile Source Group, personal communication, 2014)

In relation to the carbonyl study, the Environmental Protection Department has set up an Air Quality Monitoring Network around Hong Kong that monitors the air pollution health index of various regions as well as major contributing pollutants (Hong Kong, Environmental Protection Dept., *Hong Kong's Environment: Air,* 2013). Furthermore, it was found that the pollutant levels are higher in downtown areas as ventilation is limited by tall buildings, creating "street canyons" (Hong Kong, Environment Bureau, 2013 and Ho, et al., 2011). The presence of street canyons led to additional encouragement of government policies in order to reduce the entrapment of pollution within these sectors. Current pushes also extend to hybrid/electric tax incentives, hybrid/electric bus subsidies, a 2020 emission reduction plan, and the early retirement system (Hong Kong, Environmental Protection Dept., Mobile Source Group, personal communication, 2014)

Research in June 2012, titled "Differential exposure of the urban population to vehicular air pollution in Hong Kong" (Fan, et al., 2012), analyzed the influence of socio-economic conditions in relation to the effects of vehicular air pollution. Furthermore, this study served to analyze the difference between public and private housing and their respective transportation pollutant amounts. Approximately half of the population of Hong

Kong resides in public housing provided by the government with the rest in private housing. In order to estimate the pollution exposure, an Integrated Modernization Management Information System air dispersion model was developed in which the mean concentrations of CO, NO_x, SO_2 and PM_{10} were determined. The results from the model included a notable difference between those living in the government provided housing and privately owned housing as well as displaying the socio-economic differences within the city.

A portion of these conclusions can be seen in Figure 2, which demonstrates the relationship between Social Deprivation Index and Annual mean PM_{10}. A Social Deprivation Index (SDI) is a quantitative analysis of education, economic inactivity, occupation, tenancy, crowdedness, and median monthly household income of residents in a particular building group. An SDI value greater than zero indicates a more socially deprived building group while an SDI value less than zero indicates a less socially deprived building group. The study notes that the relationship between SDI and any specific pollutant would show trends very similar to PM_{10}.

Pollution from private housing generally increases as social deprivation (as defined by the study) increases; but pollution caused by public housing is about the same for all values of the SDI index. Since public housing is managed by the government, this study is evidence that the government's efforts to keep air quality in check can be successful and that government oversight can have a positive impact on the welfare of its citizens.

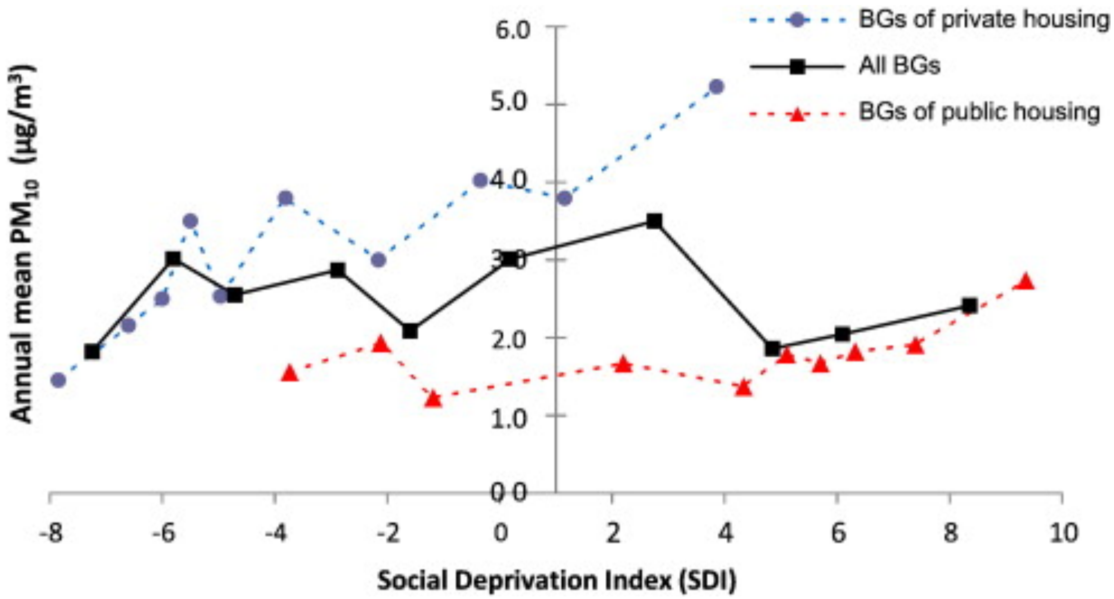

Figure 2: Annual mean PM_{10} concentration by SDI deciles in researched building groups (Fan, et al., 2012)

2.3. Hong Kong's Transportation Measures to Reduce Air Pollution

Since the 1997 turnover from Great Britain to China, Hong Kong has operated as an autonomous Special Administrative Region (HK SAR) of the People's Republic of China (PRC). However, the People's Republic of China controls all foreign affairs and the defense sector of Hong Kong. The Basic Law, Hong Kong's constitutional document, guarantees autonomy for 50 years and the government led by a Chief Executive and an Executive Council (Hong Kong Government, Legislative Council, 2013). The Chief Executive acts as the leader of the Hong Kong government and is elected by an election committee, comprised of people appointed by the PRC. The Chief Executive is responsible for "implementing the Basic Law, signing bills and budgets, making decisions on government policies and issuing Executive Orders" (Hong Kong Government, Legislative Council, 2013). The Executive

Council assists the Chief Executive in policy making. The Council consists of 15 principal officials and 14 non-official members. All members are appointed by the Chief Executive. The Legislative Council is the law-making body of the government system. The Judiciary is independent from the legislative and executive divisions of the government, with unbiased courts. There are 18 District Councils with 507 members - 412 elected, 68 appointed, and 27 ex officio members. These councils partake in improvement projects and advocate for cultural and community activities in their districts. Lastly, the main Administration consists of 12 policy divisions and 61 departments and agencies. The Secretary for the Environment oversees the Environment Bureau and Environmental Protection Department. And the Secretary for Transport and Housing oversees the Transport Department. Both Secretaries report back to the Chief Secretary for Administration. This administration is ultimately responsible for the departments and the policies that would be utilized to solve the growing environmental problem within Hong Kong.

Air pollution in Hong Kong is mainly due to the expansion of industrialization along the Pearl River Delta (PRD), shown in Figure 3, roadside air pollution, and because Hong Kong and Macau share the same air-shed and are industrial zones, local dispersion is weak. Hong Kong is located in the Pearl River Delta estuary and, due to the air circulation caused by the land-sea breeze between the sea and landmass of the PRD, Hong Kong is trapped in an area where wind flow is weak. Therefore, Hong Kong is unable to escape air pollution and must rely on technological advances to better its air quality. Several pollution policies are currently in place:

- Incentivized switching taxis and buses to liquid petroleum
- Incentivized program to put filters on automobiles and replace older cars

- Funding development of cleaner technology
- Compelling ships to switch to cleaner fuels while berthed at ports in the Pearl River Delta (Li, 2013).
- Targeting Hong Kong-owned factories in Guangdong to adopt cleaner production practices (Li, 2013).

Figure 3: Pearl River Delta Air Quality Monitoring Stations (Hong Kong, Environmental Protection Dept., ***Hong Kong's Environment: Air,*** **2013)**

The Transportation Department of Hong released the Environmental Report of 2011 in order to discuss the current objectives of the department as well as their progress regarding their goal to provide an environmentally friendly transport system. At the time, they were responsible for the implementation of five government policies regarding transportation progress: Planning and Development, Licensing of Vehicles and Drivers, District Traffic and Transport Services, Management of Transport Services, and Transport Services for People with Disabilities. One specific point is the implementation of more efficient means of interchanging public transport. This interchange would allow the better use of transportation for the public by utilizing a number of modes. Additional points include the reworking of bus routes and the provision of park-and-ride facilities and bikes parks. Some environmental objectives include the limitation of high emission buses, emission tests of all private and commercial vehicles, and the suggestion of alternative fuel sources. Finally, the report states the desire to utilize advanced technology to create more efficient uses of road space. This technology includes digitally provided transportation technology, real time traffic information, and the expansion of the Area Traffic Control system. Through the government publicizing their desires and actions, a careful account can be created that determines how effective their suggested changes were and what things need to be worked on in a different manner currently (The Government of Hong Kong Special Administrative Region, 2011).

The Clean Air Plan for Hong Kong was developed in March 2013 by Hong Kong's Environment Bureau in collaboration with the Transport and Housing Bureau, Food and Health Bureau, and the Development Bureau to prioritize the need to reduce air pollution and improve Hong Kong's air quality. The plan is the reduction of emission of $S0_2$, $N0_X$, RSP, and VOC by 25%, 10%, 10%, and 5%, respectively. Hong Kong is currently in the process of switching to zero/low emission buses and private vehicles. There are already more than 1000 charging stations in Hong Kong. However, clean technology is not enough to substantially reduce air pollutants. According to the Clean Air Plan, the Hong Kong government plans to introduce the following transport management solutions (Hong Kong, Environment Bureau, 2013):

- Low Emission Zones - In areas with high population, only the “cleanest” buses may drive through this area to reduce people’s exposure to pollution.
- Franchised bus routes rationalization - The government plans to rationalize bus routes to a more efficient system, however any changes must gain the public’s approval. The Environment Bureau and Environmental Protection Department will present the air quality benefits from bus route rationalization.
- Cross-harbor tunnels usage rationalization - Another solution is to adjust the tolls of the three road harbor crossings to redistribute traffic congestion. Not only will it improve air quality but also traffic flow.
- Vehicle inspection and maintenance - All commercial vehicles must pass the Transport Department’s roadworthiness test for licenses to be renewed. Commercial vehicles are mostly diesel or LPG-powered. Private cars, which are mostly run by petrol, must also pass the roadworthiness test for license renewal if the vehicle is over 6 years of age.

Figure 4: Traffic Congestion in Wan Chai during evening rush hour (Courtesy of Adria Fung)

The Hong Kong government, in 1987, created the Air Quality Objectives (AQOs), under the Air Pollution Ordinance to set limits on the seven main air pollutants: sulphur dioxide, total suspended particles, respirable suspended particles, nitrogen dioxide, carbon monoxide, photochemical oxidants, and lead (Hong Kong, Environmental Protection Dept., *API and air monitoring background information,* 2006). However, these AQOs will be replaced by the proposed new AQOs and were put into force in 2014. Hong Kong's current air quality cannot meet the expectations of the past AQOs due to excessive vehicle emissions and the regional smog concern. In June 2007, the Hong Kong Environmental Protection Department commissioned Ove Arup & Partners Hong Kong Ltd. to conduct a study and review of the AQOs and development to a long-term air quality strategy for Hong

Kong. In conclusion, ARUP proposed a framework for an effective air quality management (ARUP, 2009):

- Establishment of new AQOs
- Development and implementation of control measures
- Monitoring of air quality
- Identification and assessment of air pollution problem areas
- Research and education promotion
- Periodic review of the progress and the AQOs

These measures will target the following areas (ARUP, 2009):

- Cutting emissions from power plants by increasing the proportion of natural gas from the current 28% to 50% or more
- Advancing the earlier replacement of more polluting vehicles
- Further tightening the control of emissions from vessels and other sources
- Introducing suitable traffic management measures to reduce roadside emission
- Expanding rail/tram network
- Promoting energy efficiency.

Therefore, in January 2012, the HK Environmental Protection Department proposed the adoption of new AQOs. In terms of transportation management, the government has proposed these strategies (Hong Kong, Environmental Protection Dept., *Air Quality Objectives,* 2012):

- Early retirement of aged/heavily polluting vehicles
- Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards

- Wider use of hybrid/electric vehicles
- Low emission zones
- Car-free zone/pedestrian scheme
- Bus route rationalization
- Retrofit Euro II and III franchised buses with selective catalytic reduction devices to reduce their NO_x emissions
- Introduce a more stringent regime to control emissions from petrol vehicles through remote sensing equipment

Figure 5: Hong Kong's Public Buses (Oriental Model Buses, 2012)

Clean transportation management is a long-term effort that requires support from the government, public, and affected businesses. Although Hong Kong has conducted studies and proposed solutions, action needs to be taken in order to fully transition the city to a sustainable city. In reference to this proposal, a non-profit organization must take certain steps to aid in the motivation of these actions. In order to improve air quality through transportation, a non-profit organization would work with the Special Administration Region and their declarations through the use of lobbying for stricter regulations on air policy and transportation measures. Additionally, while proposals can be initially introduced, it is important for the government to continuously monitor the situation by enforcing regulations, an occurrence that can be encouraged by the lobbying and additional proposals. Furthermore, bills can be passed through the Legislative Council to condition these types of problems. In order for a non-profit environmental organization to help pass a bill, there are two methods to call upon. In the present case, our project responds to the Environmental Protection Department and Transport Department. The proposal would be sent to the respective departments through the enquiry email. If there is no reply, the proposal can be sent to the head of air policy division. The second method is to pass a bill with a Legislative member in the Council. (Chai, 2013) For permanent long-term solutions to be put into place, government regulations must be enforced and non-profit organization must reinforce these regulations if Hong Kong is ever to be sustainable.

2.4. Case Studies Providing Policy Examples

In order to determine how to better manage transportation practices, one needs to investigate similar models and their solutions to improve air quality through transport management. Models researched include those in Asia, Europe, and the United States.

The project team has compiled the key characteristics of the following case studies into a table, which can be found in Appendix K. The table briefly outlines the motivation and implementation of each policy researched, as well as the success and failures thereof, while the following section discusses various locations and their respective polices in more detail. Furthermore, Appendix K also quickly describes how each policy is applicable to Hong Kong; some of the most relatable policies are further examined in the Recommendations section of this paper.

2.4.1. Beijing

Like Hong Kong, one of Beijing's major sources of air pollution is from vehicle emissions (Zhou, 2009). Beijing, the capital of the People's Republic of China, is located in northern China. It is one of the political, cultural, educational, and economic centers of China, and is one of the most populous cities in the world. As the population increases, vehicle population in Beijing also increases at a rate of 15% every year (Fu, et al., 2011). However, vehicle owners are not switching to current emissions technology with hybrid or electric vehicles and the vehicle technology is equivalent to those in the 1960s and 1970s (Fu, et al., 2011). Many people are moving from rural to urban areas looking for job opportunities and better lifestyles in Beijing, causing private vehicles to be more concentrated in the city. With more private vehicles in Beijing, congestion and air pollution is building and air quality is deteriorating. Still, China's main source of energy is still from coal. Approximately 70% is energy in China comes from coal, with 21% from petroleum, 7% from renewables and nuclear, and 3% from natural gas (Fang, et al., 2009).

Figure 6: 11 days before the Olympics (AFP/Getty Images, 2008)

In 2001, Beijing was chosen to host the 2008 Summer Olympics. For the Chinese government, this was an important opportunity to make a positive impression on the global community. Therefore, the government felt the need to improve Beijing's air quality for participating athletes, spectators, and government officials. Traffic congestion and air pollution were two of the major challenges in planning the 2008 Olympics. The Beijing municipal government spent more than US$17 billion in an effort to implement aggressive efforts to reduce traffic, increase emission standards, and temporarily stop current construction projects before the games (Ju, 2009). The government enacted transportation control measures in preparation for the games: if the owner of a vehicle had a license plate ending in an odd number, they were banned from driving on the roads on even-numbered days and vice versa, 70% of government vehicles were not allowed to be operated, trucks can only be driven inside the "6th Ring Road" (shown in Figure 7) from midnight to 6 a.m., and majority of the vehicles with yellow environmental labels (labeling the vehicle as high emission) were banned from the city (Zhou, et al., 2009). Therefore, almost 2 million vehicles were pulled off the roads of Beijing. The government also decreased the use of coal, and instead used natural gas as their source of electricity. Researchers found that car emissions of black carbon, air pollutants harmful to lungs and a global warming compound, had decreased 33% from 2007 to 2008. Also, carbon dioxide had decreased 47% and carbon-based micro-particles had decreased 78% (Wang, et al., 2009).

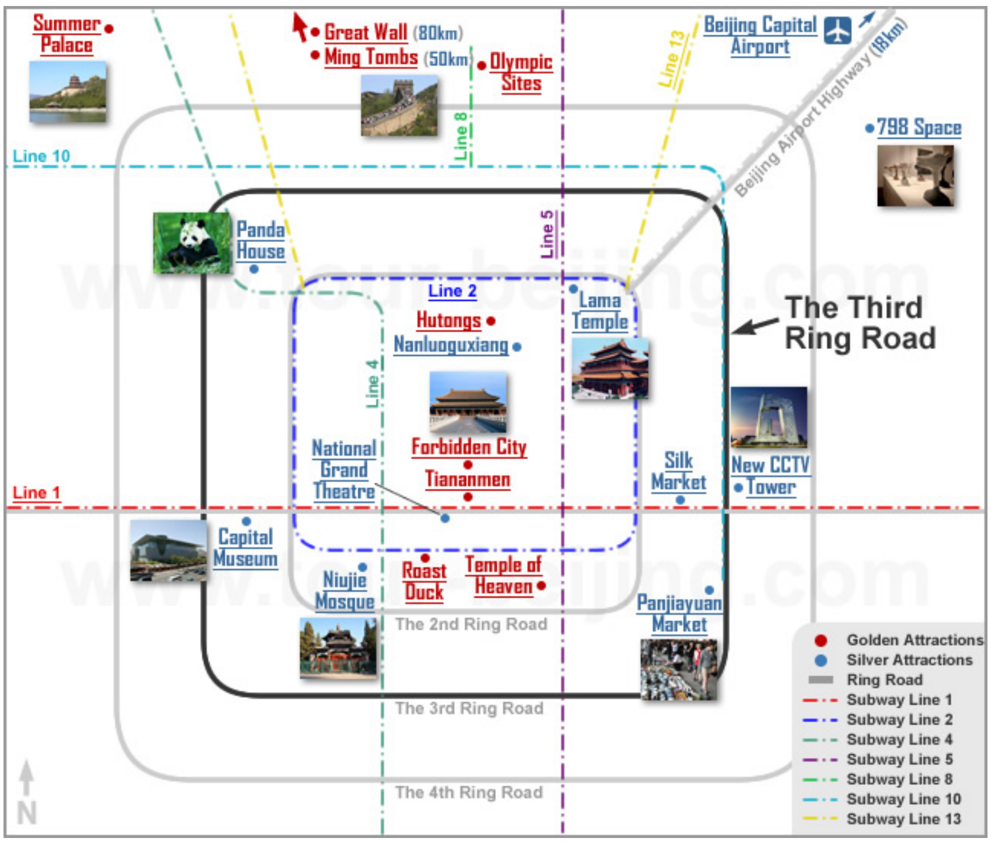

Figure 7: Beijing's Ring Roads (Beijing Bus Tour, 2013)

With such an aggressive plan as the Beijing Municipal Government employed, it seems as though any nation can significantly reduce vehicle emission within a year. However, from the data in Figure 8, one can see that pollution levels have drastically risen in the days leading to the event. Although these traffic interventions put on by a communist-regulated municipal government are motivating the city to continue this pattern of improvement, measurements taken in January 2013 show levels of air pollutants physically smaller than the US Embassy's equipment can measure. China still has a long way to go to be within standards of acceptable air quality; they have reverted back to burning coal as their primary source of energy. If the Hong Kong SAR Government is able to take these policies and enforce strict regulations, Hong Kong will be to enter a sustainable era.

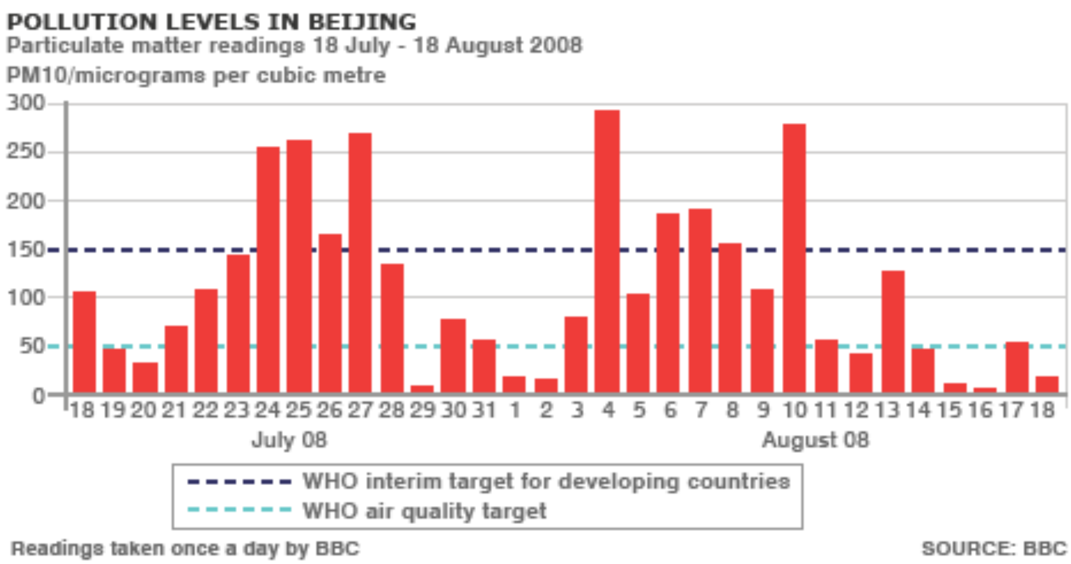

Figure 8: Pollution during the 2008 Olympics (BBC, 2008)

Recently in the weekend of January 14, 2014, pollution levels in Beijing skyrocketed to severe warnings. The city has issued its first "'orange' fog warning" (Lin, Burkitt, 2013) due to low visibility. This caused the government to take a step back to reevaluate and find ways to improve air quality. Government officials were told to reduce vehicle usage; in response, Beijing is now considering applying a congestion fee for car owners, a policy efficiently enacted in London. The city's plan is to keep less than 6 million licensed vehicles on the road by 2017 (Yu, 2013). This policy is part of Beijing's five-year plan to improve air quality through transportation, factories, and other pollution-emitting systems. The government will also ban outside city vehicles from entering the 6th ring road starting in 2014. Currently, vehicles from outside provinces are banned from entering the 5th ring road during only rush hours. Beijing will plan to spend US$280 billion to reduce pollution in the city (Yu, 2013).

2.4.2. Shanghai

The sudden increase in travel demand in Shanghai is due to its population and economic growth. The majority of the population growth consists of "non-registered migrants who come from rural areas to search for employment opportunities" (Shen, 2002). The economic and income growth has allowed more citizens to enjoy the luxuries that only the wealthy had access to such as taking the mini-bus or taxi. Now, more citizens travel greater distances for a wide variety of goods and services. The average travel time and distance has increased, and the number of people walking has decreased as many are using other modes of transportation. Also, the economic growth is allowing government corporations and businesses to purchase private automobiles. With Shanghai's current population reaching nearly 15 million, traffic volume has substantially increased.

The Shanghai municipal government plays a role in improving the overall transportation system even though it cannot directly affect the population or economic growth. The municipal government can influence the social travel behavior by taking into account the travel distance and increase in vehicle registration; therefore, the government is able to plan and introduce policy changes. If the government is able to change travel behavior, this action will lead to a change in travel demand. A study done by researchers depicts four different scenarios by changing the population growth and mode split, which is the percentage of the population using a specific type of transportation, and seeing the change in travel demand.

Scenario	Population Growth	Mode Split	Avg. Travel Distance	Travel Demand
1	Steady growth rate at 2.5%	Constant	Constant	Increase by 30%
2	Steady growth rate at 2.5%	Constant	Increase by 0.3 kilometers/year	Increase by 70%
3	Steady growth rate at 2.5%	Increase bike trips by 0.5%, increase non-transit motor vehicles by 1%, and increase walking trips by 1.5%	Constant	Increase by 150%
4	Steady growth rate at 2.5%	Increase bike trips by 0.5%, increase non-transit motor vehicles by 1%, and decrease walking trips by 1.5%	Increase by 0.3 kilometers/year	Increase by 300%

Table 4: Demand for road capacity in Shanghai (Shen, 2002)

By changing factors influenced by travel demand, one is able to see that if population growth is the only factor increasing exponentially, travel demand will continue to grow (Table 4). However, due to limited resources, the government will not be able to meet this demand. Because the government owns urban land in China, bureaucrats have a strong influence to regulate travel behavior. The government has a stronger authority in decision-making. However, strong authority does not necessarily mean being able to regulate policy changes. It is important for any government to develop a plan to design policy actions that is suitable for the population. Hong Kong's population has been growing significantly in recent years, so it is important for its government to take these factors into account when deciding policies in order to insure their longevity.

2.4.3. Singapore

Singapore is an exceptionally large city situated on a relatively small island. Naturally, this geography creates problems when attempting to expand an already expansive transportation network. The building of new roads is limited by the space available on the island, so the city turned to the construction of a Mass Rapid Transit (MRT) system. While public transport remained important and effective in the Singapore transportation network, many citizens preferred to own their own vehicles. The number of people purchasing new cars created a boom of private vehicle ownership, which in turn congested the already cramped streets.

Singapore's government tried a variety of policies to reduce overall congestion on their roadways. Beginning with additional registration fees (ARF) in 1972, they attempted to reduce new car ownership by increasing the fee on registering a car. While ARF's were successful in the beginning, the early success did not carry for a long period of time. The city next tried an area licensing scheme (ALS) which limited access to the Central Business District (CBD) by requiring a special license. This restriction worked initially, even seeing a drop in traffic of 45% (Goh, 2002), but began to fail when a larger number of people began to work in the CBD. After the MRT was introduced in 1987, the city implemented a Vehicle Quota System (VQS). The quota system limited vehicle purchases to just 3% of the expanded road systems, reducing the number of new cars on the road by 41,000 from 1990 to 1993 (Goh, 2002). Singapore next attempted an Off Peak Car Scheme (OPC), which set to lower car taxes and registration fees based on lower car usage. Ultimately, the OPC was unsuccessful, as people would rather have access to their cars than save a relatively small amount of money. Finally, the city implemented a Road Pricing Scheme (RPS) in 1995 and Electronic Road Pricing (ERP) in 1998.

An RPS is simply a system of tolls that affects high traffic areas in a city. When this system was first implemented in Singapore, it consisted chiefly of tollbooths in the entryway to the highest traffic areas. Attendants were required to man these stations, and tickets were handed to each driver passing through them, while the drivers themselves had to pay with the correct change each time. The system, while it was able to reduce traffic on some main roads and net a large sum of revenue for the city, resulted in many side routes backing up just as the main roads used to. Despite the side road traffic and some other minor setbacks with the system, road pricing systems were considered a success in Singapore.

Building on the success of the RPS, Singapore implemented an Electronic Road Pricing system to attempt to further decrease congestion and streamline the process for the general public. The system worked by placing a device on the dashboard that reacts to sensors placed in high trafficked areas. Payment would take place through a CashCard that could be stocked with money, and "filled" at many places throughout the city. Passing through a checkpoint without a CashCard would incur a fine of $40, and driver information would be taken through license plate cameras. (Goh, 2002) Almost immediately afterward, the system was declared to be a success. Traffic decreased by 17% in highly trafficked areas, and although overall revenue was down from the switch to ERP, the system remains in use, and is generally accepted to be a positive. Despite the success of the policy in Singapore, no other cities have taken up a pure ERP system, but Singapore has had great success in reducing congestion with the implementation of the ERP system in combination with a strong MRT system. With a lack of Road Pricing policies within Hong Kong, the government can look at the successes of these systems in cities such as Singapore. Although Hong Kong has been trying to encourage the use of public transportation and the replacement of older personal vehicles with more modern vehicles that contain "cleaner" technology, the government has not yet created a policy that actively deters the use of private transportation. Such a policy could prove to be effective in Hong Kong, as it has in Singapore and other global cities.

Figure 9: Electronic Road Pricing Gateway in Singapore (Mitsubishi Heavy Industries Group, 2014)

2.4.4. Seoul

Over the last 20 years, Seoul has gone through an economic boom, with the average per capita income rising to $12531 in 2002 from $351 in 1980. With the economic boom came an increase in private car ownership, causing significant increases in road congestion. The increased traffic on the roads in turn affected the Seoul bus system. The buses were no longer able to keep regular schedules, while the amount of air pollution and traffic accidents skyrocketed (Pucher, 2005). The metro system was able to take some of the slack for the wildly increased commuter traffic, but expansion of the metro put the city into enormous debt, with 80% of the city's total debt coming from the metro system (Pucher, 2005). The debt prevented the city from making any further expansions to the system, and instead turned to bus reforms to service their ever growing commuting needs.

Before the 2004 reforms, the bus system was largely owned by private networks and there was little government regulation. Only setting the fares for busing, the Seoul government had little impact on the irregularity of the bus schedules and the dangerous driving practices of the privately employed drivers. Each bus firm ran its own route, which may have covered area that was covered by other firms, creating inefficient routes. The private firms also encouraged "truly outrageous bus driving behavior". Bus drivers were known to engage in ridiculous actions, including; "To squeeze as many passengers as possible into a bus, bus drivers slammed on their brakes or suddenly and repetitively braked to jolt standing passengers further back into the bus. Bus drivers would recklessly race other buses to pick up passengers waiting at bus stops, but they deliberately avoided picking up elderly or disabled passengers to save time." (Pucher, 2005) These actions, in combination with an aging and out-of-date bus fleet led to a decline in passenger traffic.

In 2004, the city adopted new bus reforms that were able to improve the system for public use. The government turned the system into a "semi-public" system. (Pucher, 2005) Although the new system retained private firms running the buses, the government controlled the routes, schedules, fares, and overall system design. (Pucher, 2005) To prevent some of the reckless driving practices, bus companies are now compensated by total km travelled rather than by total passengers. Creating 400 set bus routes, with 4 color-coded route types (Figure 10) based on their range, allowed the city to make the bus system efficient while ensuring that every community had full access to the bus system. The new system also improved the dedicated bus lanes in the city, adding over 70 km of dedicated bus lanes. The addition of these bus lanes helped to alleviate the horrible congestion on the city's roads caused by the increase in private car ownership. All buses also now run on compressed natural gas, which helps to reduce their contribution to the city's air pollution totals.

Type of Bus	Numbering System
Blue Bus 	**3-digit number : Departure + Destination + Bus ID (0~9)** Example) 048 0: This bus starts from District Area 0 (Jongno, Junggu, Yongsan) 4 : 4: This bus heads for District Area 4 (Seocho, Gangnam) 8: Bus ID number
Green Bus 	**4-digit number: Departure + Destination + Bus ID (11~99)** Example) 1013 1: This bus starts from District Area 1 (Dobong, Gangbuk, Seongbuk, Nowon) 0: This bus heads for District Area 4 (Jongno, Junggu, Yongsan) 12: Bus ID number
Red Bus 	**4-digit number: 9 (Suburban Area) + Departure + Bus ID (00~99)** Example) 9112 9: The first number 9 means this bus serves suburban areas 1: This bus starts from Suburban Area 1 (Uijeongbu, Yangju, Pocheon) 12: Bus ID number
Yellow Bus 	**2-digit number: District + Bus ID (1~9) (1~9)** Example) 01 0: This bus circles District Area 0 (Jongno, Junggu, Yongsan) 1: Bus ID number

Figure 10: Chart detailing the differences in Seoul's color-coded bus system (Styrnsr, 2011)

The bus reforms were initially poorly received, with roughly 70% of passengers stating that they were dissatisfied and with roughly 60% of passengers saying that the changes were confusing. (Pucher, 2005) The initial dissatisfaction seemed to be a mere reaction to change as, within four months, satisfaction with the new system had risen to an incredible 90% of the passenger population. Not only did average bus speeds increase, but total passengers had increased by 14% over the four months. (Pucher, 2005) Further bus service expansions are planned, with the new system not only being cheaper than expanding the metro service, but being an equally integral part of the Seoul transport network. The work done by Seoul holds special importance in Hong Kong, as the environments of the two cities are extremely similar. Additionally, Hong Kong has extensively worked to improve its bus system; thus, its government can follow the footsteps of Seoul to better enact its policies and revise them.

2.4.5. United States

In the United States, pollution control policy faces major political obstructions. Over a two-year period, oil and gas lobbyists donated $15,078,146 to Republican members of Congress and environmental lobbyists donated $2,847,072 (Parnell, 2012). An even more difference exists in campaign donations, as shown in Figure 11 and 12 below. After a vote to force a faster review of the Keystone XL Pipeline, it was calculated that the members of Congress who voted 'aye' (234) had received $42 million in 'campaign contributions' from lobbyists for the fossil fuel industry, while those members of Congress who had voted 'nay' (193) had received only $8 million (Parnell, 2012). The fossil fuel industry tends to be resistant to policies that reduce their monopoly on energy generation, especially when such policies force sudden and dramatic changes. For example, the Clean Air Act–which was initially passed in 1970 but has undergone several adjustments since–requires power plant operators to install newer, "greener" technology when the plan underwent major upgrades, but could otherwise operate with older components. The Clinton Administration allegedly “reinterpreted” that to include routine maintenance, which meant that power plant operators would be forced to install the expensive upgrades to other systems because a turbine blade needed to be replaced or a cooling pipe had sprung a leak (Parnell). Sometimes installing the upgrades took a long time, and by nature, power plants only make money when they are operating. As a result, plant operators avoided replacing minor components, which in turn further lowered the efficiency and increased pollution of the plant.

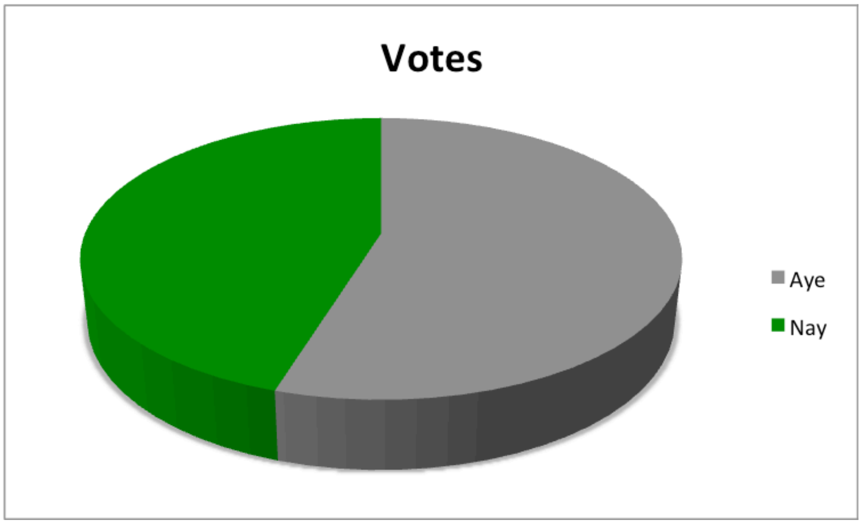

Figure 11: A comparison of affirmative vs. negative votes on a proposal to accelerate a review of the Keystone XL pipeline (Courtesy of Ryan Welch)

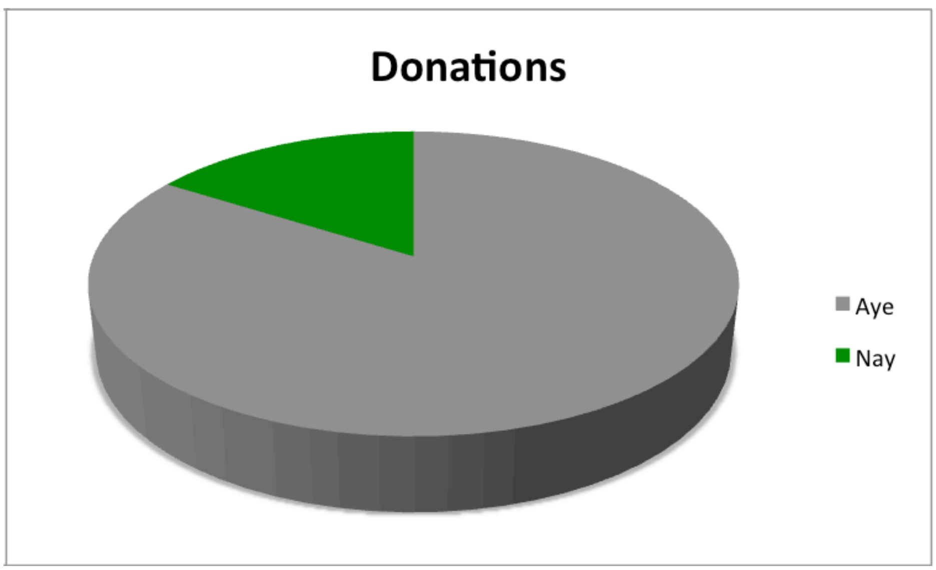

Figure 12: Donations made by lobbyists to members of congress who voted in favor vs. the donations made by lobbyists to the members of congress who voted against the proposal (Courtesy of Ryan Welch)

In an interview with WPI professor Suzanne LePage, we discussed American transportation policy and methods transportation engineers use to reduce city congestion and analyze traffic patterns. In general, traffic gravity models are used, which pinpoint the areas that traffic is the heaviest over a wide area (LePage, 2013). These models are required by the Clean Air act to be kept up to date in order to access any kind of federal transportation funding. Federal funding is also relegated based on state necessity, where the states will examine each traffic project, and assess its importance for limited funding. Apart from the requirements for funding through the Clean Air Act, San Francisco adopted a congestion pricing system, which did have some effect on the amount of congestion and air pollution produced by the city's transportation network.

In relation to Hong Kong, it was strongly recommended that the method to which Hong Kong enacts legislation be examined. Any amount of change must come from the Hong Kong government first, and that itself will likely not be furthered without public support. Through a series of public surveys, it can be determined how much air pollution actually affects daily life, and how far the citizenry would go to change the system. Although it is the job of the project team to make policy suggestions, it is important to understand what makes a realistic suggestion in the Hong Kong political environment.

2.4.6. Rome

In order to limit the pollution of private vehicles within Rome, the city implemented an updated Limited Traffic Zone (LTZ) policy in October 2001 (Talukdar, 2013). This zone covers roughly 5 km^2 and contains a concentration of government buildings, professional offices, artisan areas, a hospital, and major historical monuments (Rome Mobility Agency 2002). Due to the high vehicle flow within this zone, traffic and congestion were often a major problem. In 1994, the municipal police used to block the entrances to this area; however, these manual restrictions proved difficult to control and inefficient.

To combat this problem, the Limited Traffic Zone, seen below in Figure 13, utilizes an automated access control system as well as a flat fare Road Pricing Scheme. The objective of this system is to reduce overall congestion while providing a shift from private to public transport. Two major components of the policy are electronic gates for fee paying for access and parking as well as the distribution of annual permits for authorized personnel (Talukdar 2013). Residents of the zone may be granted permission free of charge while other users are sorted into categories. These categories would include differences in occupation need, emission standards, driving time necessities, and many other factors. As a result, this system includes a variety of means for vehicle identification and authorization that is dependent on the vehicle category. Various differences with this categorization system can be observed by the varying subzones within the LTZ, such as the "Emission Constraints" zone displayed in Figure 13. The LTZ utilizes a number of technological systems to identify vehicles in the different pre-determined categories.

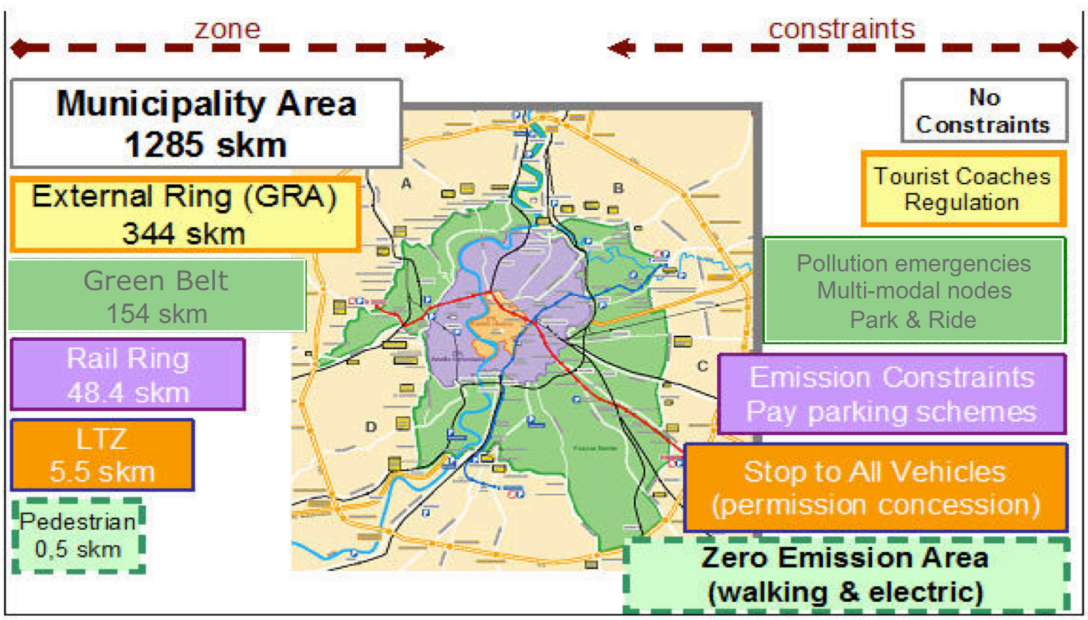

Figure 13: Map detailing areas of Limited Traffic Zone in Rome (Curacao, 2007)

This identification can be done with an On-Board-Unit that can secure high-speed transactions via micro transponders; thus, fares can be taken from an electronic purse automatically (Rome Mobility Agency 2002). Vehicles that do not include this on-board system can be monitored by Optical Character Recognition (OCR) or Video Enforcement System SIRIO (Rome Mobility Agency 2002). With OCR, the license plate of vehicles are analyzed and compared with listed authorized plate numbers. In order to avoid privacy concerns, these images are destroyed directly after passing unless the vehicle is found in violation. The LTZ policy has proven successful in demand management with a 20% reduction of car traffic during restriction times, which usually last from 6:30 am to 6 pm weekdays and 2pm to 6pm Saturdays (Talukdar, 2013).

Unfortunately, over 70,000 vehicles enter the Limited Traffic Zone per day, with 20% of these illegally whether it be on purpose or a result of lack of knowledge (Rome Mobility Agency, 2002). Furthermore, handling special cases such as foreigners, handicapped, and other exceptions has become a key issue for the success of the system. Additionally, the management of the disabled has proved the most difficult as national laws require free transit in any areas for vehicles with disabled personal as drivers or passengers (Rome Mobility Agency, 2002). The Limited Traffic Zone is still maintained today and has earned much more understanding and following. Rome furthered the application of the LTZ by reworking their public transportation and further encouraging its use. As there are a number of locations with Hong Kong that has significantly more pollutants than others, the idea of a limited traffic zone is very applicable. Due to population densities, business travel, and tourism, congestion can be found at various places, which adds to the overall pollution of the area. If Hong Kong were to follow Rome's policies, certain problem areas could be limited based on personal authorization. With the government taking an active role in certain areas, the people of those areas could ultimately be helped through the reduction of travel at certain points.

2.4.7. Australia

Australia began addressing climate change and air pollution with the Hawke government in the mid 1980's. While no legislation was enacted under Hawke, dialogue about the issue began with the creation of NSESD (Australian National Strategy for Ecologically Sustainable Development). The strategy led the way for talks on Australia's position on climate change, and developed a rudimentary plan to tackle the issue.

After Hawke, the Keating government took control, where a "no-regrets" position was taken. The approach determined that Australia would not attempt to end its reliance on fossil fuels, but instead attempt to make the usage of fossil fuels more efficient, both in reduction of emissions and in cost to the government. The strong influence held by coal companies in the Labor party prevented the government from limiting the industries and from aligning with the EU on issues of climate change. Despite the decision not to reduce use of fossil fuels, the Keating government was still supportive of the UN treaty on climate change (Firvosa, et al., 2012).

To further add to the ambivalence of Australia on the climate change issue, the newly elected Howard government of 1996 refused to ratify the Kyoto Protocol, which in combination with the United States' refusal to ratify prevented the Protocol from taking effect. The protocol would have required some limiting of emissions, and other articles, which would have harmed the coal and oil industries, causing the government to fear serious economic distress (Firvosa, et al., 2012). Within the leadership of the Howard government, no real legislation was enacted to control air pollution except the National Greenhouse and Energy Reporting Act, which required the reporting of greenhouse gas emissions annually from energy firms.

In 2007, the Rudd government took office with the goal of enacting climate control legislation. They began by ratifying the Kyoto Protocol and attempting to pass the Carbon Pollution Reduction Scheme (CPRS). The CPRS was unable to be passed, chiefly due to criticism from all sides, and general inactivity on the side of the government. Some said it would have no effect on carbon emission levels, while others were too worried about possible effects on the economy. It was noted that as much as 97% of the funds raised would find their way back to fossil fuel producers or have no effect on air pollution reduction. Again, the coal industry stepped in to oppose the bill, claiming that it posed a threat to the Australian economy and could raise unemployment further. All in all, the CPRS was scrapped, and no decision was made to enact any legislation on reducing air pollution and fight climate change. Although there are talks about a possible "carbon tax" and other minor measures, the government under Gillard seemed to lean towards "business as usual" (Firvosa, et al., 2012). These movements found in Australia can be related back to the political difficulties of immediately adoptable policies within Hong Kong. The failures of the legislation in Australia can be utilized by activists within Hong Kong as evidence against hastily making decisions regarding transportation and pollution without proper insight.

2.4.8. London

The introduction of the Environment Act 1995 in the United Kingdom centralized overall air pollution management by organizing everything under one authority–the Act itself–where previously, administration had been split between multiple government organizations. The Act established the Local Air Quality Management framework, which defines the traits of Air Quality Management Areas (AQMAs). Section 82 of the Act puts local authorities in charge of measuring the air pollution in their respective regions and identifying any locations that fall under the criteria for AQMAs, then reporting their findings. The Act also requires the local authorities to create an Air Quality Action Plan upon identifying an AQMA. Similar policies exist in New Zealand and South Africa (Olowoporoku, et al., 2011). The Clean Air Act in the United States charges the local/state governments with air quality measurement as well as making it their primary responsibility to resolve high-pollution areas. On the other hand, the Environment Act 1995 only requires that the local bodies work "in pursuit" of achieving air quality goals in such a way that fills the gaps of national actions.

When the process of identifying and resolving AQMAs began in 1998, it was expected that only a few regional governments would identify AQMAs, and that those areas would exist in densely populated cities. However, that optimism faded quickly. By 2008, AQMAs had been reported by 61% of regional authorities in England (excluding the 33 local authorities in the Greater London Area, which all reported at least one AQMA–many of which included the entire administrative region). Over 90% of all AQMAs were caused by excessive road transportation emissions (Olowoporoku, et al., 2012). The European Union has tightened emission standards, including the use of catalytic converters, but a 2011 study (Carslaw, et al., 2011) for the Department for Environment, Food, and Rural Affairs (DEFRA) shows that air quality has not responded to these sanctions as had been expected, and has in fact increased in some large cities. It is theorized that the growing population of motor vehicles in Europe outweighs the advances in pollution reduction policy (Olowoporoku, et al., 2012).

A government review of the Local Air Quality Management framework stated that a major contributor to the lack of progress in reducing air pollution–aside from road traffic–

was the disconnect between diagnosing air pollution problems and resolving the identified problems (Olowoporoku, et al., 2010). Furthermore, in several cases, the required solutions are beyond the capabilities of the local administration, but do not fall within the scope of a higher authority. Overall, the Local Air Quality Management process and the subsequent Local Transportation Plan failed due to low expectations of air quality concerns, poor organizational planning before and during execution, and, perhaps most notably, a lack of sufficient funding from top-level government. The government of Hong Kong can learn from the failures of London in order to exemplify the methods that should not be followed once legislation is passed. While viewing the potential benefits of pushing for such powerful legislation, it is important to consider the repercussions should the legislation not work out, and how to avoid such an occurrence from happening in the first place.

London also incorporated Low Emission Zones (LEZ) in February 2008 to encourage heavy polluting specialist vehicles (such as buses and coaches) to switch to low emission vehicles. The LEZ covers most of Greater London (Figure 14), where signs around the area tell drivers that they are entering the zone (Figure 15). As there are no tollbooths or barriers within the LEZ, cameras around the area will capture the license plate as each vehicle drives through the zone. The data is used to compare against the database of registered low emission vehicles. If a vehicle does not meet the emission standard, the daily charge is 100 euros for large vans and minibuses, and 200 euros for buses, coaches, and other heavy vehicles. Payment can be made online through the United Kingdom government site. By August 2008, 96% of heavy vehicles affected by the LEZ were compliant with the low emission standards compared to the 70% in 2007 (Transport for London, 2008). However, the LEZ is only limited to large vehicles and there is no restriction on private automobiles. Hong Kong's 2013 Clean Air Plan included a proposal of a Low Emission Zone, but in order for such a policy to be effective in Hong Kong, it must include all vehicles, public and private.

Figure 14: Map of border of the LEZ covering Greater London (TfL, 2008)

Figure 15: LEZ sign (Dan Kitwood/Getty Images, 2012)

2.5. Summary

As industry and transportation throughout the world has grown significantly in the past 50 years, the environment has suffered greatly due to a complete lack of planning to keep it safe. As a result, cities such as Hong Kong have developed increasingly unhealthy conditions that seem to only get worse. While the government of Hong Kong has been releasing certain goals such as the Clean Air Plan and the New Air Quality Objectives that generally map out plans regarding the improvement of the pollution of the city, there has been a history of proposed solutions failing not only in Hong Kong, but many other locations around the world. For true improvement to occur, concrete policies must be enacted and enforced. Successes such as the Electronic Road Pricing of Singapore, the reformed bus system of Seoul, and the Limited Traffic Zone of Rome should be examined to see how and why certain ideas are successful and others are not. Failures such as the proposed legislation of London and Australia represent how policies can fail with effective government management despite the best intentions. Evidence of the effectiveness of government interference with pollution factors can be seen in Shanghai and the United

States, whether it be with Shanghai attempting to take into account long term goals or the United States only looking at the short term. Through utilizing the information gathered by governments, departments, and agencies all over the world, the issues found in Hong Kong can be better managed and more effectively solved. To truly solve the problems with transportation pollution in Hong Kong, a number of resources must be taken in so that the best solution can be found and used. Various transportation measures implemented in other cities will be used in comparison to Hong Kong's current situation through a number of factors, such as average travel time, population data, pre and post pollution indexes, and analyzing the sources of congestion. By creating a way to categorize this data, a systematic approach can be made that organizes effective methods that best match a specific area. This approach can then be used to efficiently propose policy measures that would provide the most useful solution. To augment this form of process of elimination, local residents will also be interviewed to obtain the urban information that would be associated with the statistical data. By efficiently narrowing the list of transportation measures that can be executed, a guideline can be utilized in future problem areas.

3. Methodology

The goal of this project is to be able to provide viable proposals for changes to transportation policy in Hong Kong that will improve roadside air quality in the city. In order to achieve this goal, we first strived to specify a few specific locations that we would focus on, and then we collected as much data on traffic conditions, air quality, and public opinion as we could.

Data for this project was collected from a range of fieldwork. Initially, the team surveyed various areas around the city in an effort to identify problem sites for traffic congestion in both the busiest hours of the day (8:00 to 10:00 AM and 5:00 to 7:00 PM) and non-business hours (12:00 PM – 2:00 PM). These periods helped to show how the analyzed areas built up with the increase of traffic during highly populated time periods, namely “rush hour” and "lunch hour.” In addition to utilizing the suggested areas from Friends of the Earth and local residents, the team determined which areas are truly congested by a combination of quantitative vehicle counts with relation to number of lanes in an area and a qualitative assessment of the average speeds of the cars moving through the site.

Transportation data was obtained from Causeway Bay, Mong Kok, Sham Shui Po, Central Tsim Sha Tsui, The Cross-Harbour Tunnel, the Eastern Harbor Tunnel, and the Western Harbor Tunnel. This data was primarily done in pairs in order to most effectively count the passing vehicles over a particular area. The areas chosen for analysis was chosen based on general observations of traffic and the potential for problems to arise from a variety of sources, including merging, pedestrians, traffic lights, multiple intersections, shopping areas, highway entrances/exits, and reducing lanes. This particular form of data was taken from main roads primarily such that differences in time periods would be most effectually evident. Data taken included a count of private vehicles, commercial vehicles, "large" buses, "light" buses, and taxis as well as an estimated average speed based on timing over a predetermined distance. Other factors collected were stoplight durations, idle durations, and any accident or breakdown occurrences. The quantity and route number of empty buses was also noted after immediate observation of a large number of empty in-service buses in populated areas.

In addition to the data for main roads, we also took observational data of multiple smaller streets in given areas. For locations such as Central, Causeway Bay, and Mong Kok, it was not just the main roads where congestion occurred only, but also side, intersecting streets. As a result, the average speeds, idle times, and generally vehicle type percentage was obtained for a number of side streets over an entire sector for the different time periods.

Determining the air quality of an area is not something that can be done by merely assessing the area, but is something that must be assessed by quantitative measurements of various pollution concentrations in the air. While quality assessments done by the group or by local residents may play a part in the team's data entry, concise entries were necessary. In order to most effectively form a consistent air quality assessment, the numerous Air Quality Stations around Hong Kong are used in parallel with the obtained vehicle data. By comparing the number of vehicles, the time of day, the type of vehicles, or the average speed of a particular area with the pollution indexes, general trends could be found that can provide evidence of transportation factors directly relating to pollutant count. As these indexes can be found online on the Hong Kong Environmental Protection Department's website and are updated very frequently, every piece of vehicle field work could be directly correlated to pollutant numbers. Through the utilization of these trends, the previous research put into potential transportation policy emplacements could be sorted into which particular areas would most benefit from policy changes.

Although data was available for many areas, the project team focused only on the Central, Causeway Bay, and Mong Kok roadside stations. This data is reported as the Air Quality Health Index, which was put into place by the Environmental Protection Department (EPD) beginning on December 30th 2013. It operates on a 1 to 10 rating system through the analysis of NO2, O3, SO2, CO, PM10, and PM2.5. The data for every area was obtained on a daily basis in order to show pollution trends depends on the time of day for the purpose of demonstrating the pollutant health risks were a direct result of the variable of traffic. Additionally, the specific pollutant data was obtained of the closest AQHI station for time periods where traffic data was obtained.

Following field assessments of problem site locations, the project team interviewed the locals to gauge public opinion of the effect of air pollution on their daily lives and commutes. Surveys were collected in Central, Causeway Bay, and Mong Kok where pedestrian concentration was highest. One of the primary questions that needed to be asked was a measure of how people in the city view pollution, not only the possible dangers, but whether they recognized the problem at hand. It is entirely possible that knowledge of decreasing air quality was not well publicized, which could be detrimental to passing any form of legislation. The survey also included a question for age, to better understand the generational differences in understanding of the air quality issue. While it is likely that most people surveyed will live in the city, a generational gap can have profound effect not only on a person's understanding of the air quality problem, but on how they would believe the problem should be approached. By analyzing the experiences gained from people living through different governments as well as vastly different economic situations can give insights into how legislation or policy change can be approached from a public opinion standpoint.

By asking local people about their commute speed and mode of travel, the project team determined the degree to which high congestion and increased air pollution affect their daily lives. As we worked to demonstrate that high congestion directly correlates to a decrease in air quality, a knowledge of commute speeds and traffic volume could give the team a good idea of how much people feel that congestion contributes to the issue. Asking about mode of travel was able to give the team information of the necessity or want for reforms in the public transport or private transport sectors. For instance, if an overwhelming percentage of citizens are using public transportation for their commute, policy suggestions for private travel may be less prudent. With data collected from vendors in different parts of the city, and varying degrees of air quality, the team can gain some insight into the effect of air quality on pedestrian traffic.

Interviews are conducted with professionals from emission testing centers, the Environmental Protection Department, and traffic engineers. The project team can evaluate the public and private businesses' priority of improving air quality through transportation. The team will investigate whether steps are being taken to encourage low emission vehicles, reduce the number of vehicles on the road, and more to reduce air pollution. The team has read a number of reports put out by the Hong Kong government suggesting changes to improve air quality, however implementation sluggish. By interviewing professionals from both the government and private firms, the team will have a better understanding on where companies stand to reduce air pollution. Surveys and interview questions are located in Appendix B.

While in Hong Kong, it was imperative that the project team investigated the current state of air quality policy in the city. Finding information about the subject on the Internet proved difficult, but in conjunction with easily accessible governmental information and a contact who spent time working within the Hong Kong Department of Transportation, the team was able to better understand the problems. Having a solid understanding of Hong Kong's air quality plan allowed the team to compare Hong Kong to other large cities in the world that have pursued similar steps to improve traffic congestion and/or air quality in general.

After identifying locations that are sources of pollution-causing traffic, the project team classified each location based on the following characteristics: geographic location, average variation in pollution over 24 hours, traffic causes (poor road design, poor traffic signal timing, high pedestrian traffic, and other causes to be determined by field study), public opinion of the traffic and pollution, and other factors that were identified during field study. Each location was then matched with the most appropriate solution based on the pre-departure research of air quality management and traffic management policies implemented in other cities. If no solution is readily apparent for a location, the team considered the characteristics of that location and designed a solution based on previous research and accumulated knowledge.

4. Results and Observations

The fieldwork of this project mostly encompassed the survey of general public opinion and knowledge of air quality in Hong Kong and of observing traffic patterns in the most highly trafficked areas in the city. After the collection of 500 surveys, the project team was able to draw several conclusions regarding public opinion of air quality, and was able to determine on which areas to focus our efforts. By the direction of our survey results, we spent the majority of our time observing traffic patterns in Causeway Bay, Mong Kok, and Central districts, and came to several conclusions regarding the current states of the public bus systems, road-side interactions, and driving patterns. Both main roads and side road areas were observed, each presenting with different issues. We also took observations at each of the cross harbor tunnels, and drew several conclusions about their relative traffic densities and the causes of these conditions.

4.1. Survey Results

An important method of policy determination is the collection of people's opinions of the need for change. Surveys were conducted to illustrate public opinion of problems with the transportation management in the city. Surveys were mostly conducted in Causeway Bay due to the amount of foot traffic, and surveys were taken from residents and tourists aged 18 to 80 with a target sample size of 500. Respondents were asked to gauge air quality in Hong Kong and general information about their use of public and private transportation. The pedestrian survey is included in Appendix B, and their responses and graphs are included in Appendix E and F. Compared with the actual population distribution in Hong Kong, the collected survey distribution is favored towards the younger age group

(18-24). The actual population distribution shows a higher percentage in the 45-54 year range. Even though the survey respondents do not match the actual population distribution, the overall transportation policies, when enacted, will have a direct effect on the younger ages, who will be able to provide both a strong and important opinion in implementation. The table below depicts the number of male and female respondents in each age group.

	18-24	**25-34**	**35-44**	**45-54**	**55-64**	**65+**
Number of male respondents	100	74	20	16	15	8
Number of female respondents	142	42	14	8	5	5
Total	242	116	34	24	20	13

Table 5: Gender distribution of survey response by age group. (Courtesy of Adria Fung)

When asked to rate Hong Kong's air pollution on a scale from 1 to 5, where 1 represents good air quality and 5 represents bad air quality, most people responded with an average of 4. When asked for a rating of whether certain areas in Hong Kong had higher pollution than others, the average response was 3.75, showing that most of the population asked, believes that Hong Kong has an air pollution problem. The average for the second question is slightly lower because 28 people out of 500 responded with 1, signifying that the air pollution problem is everywhere and not just concentrated in a few areas. However, data from the AQHI (Air Quality Health Index) shows that there are a higher number of pollutants in certain areas, such as Mong Kok and Causeway Bay.

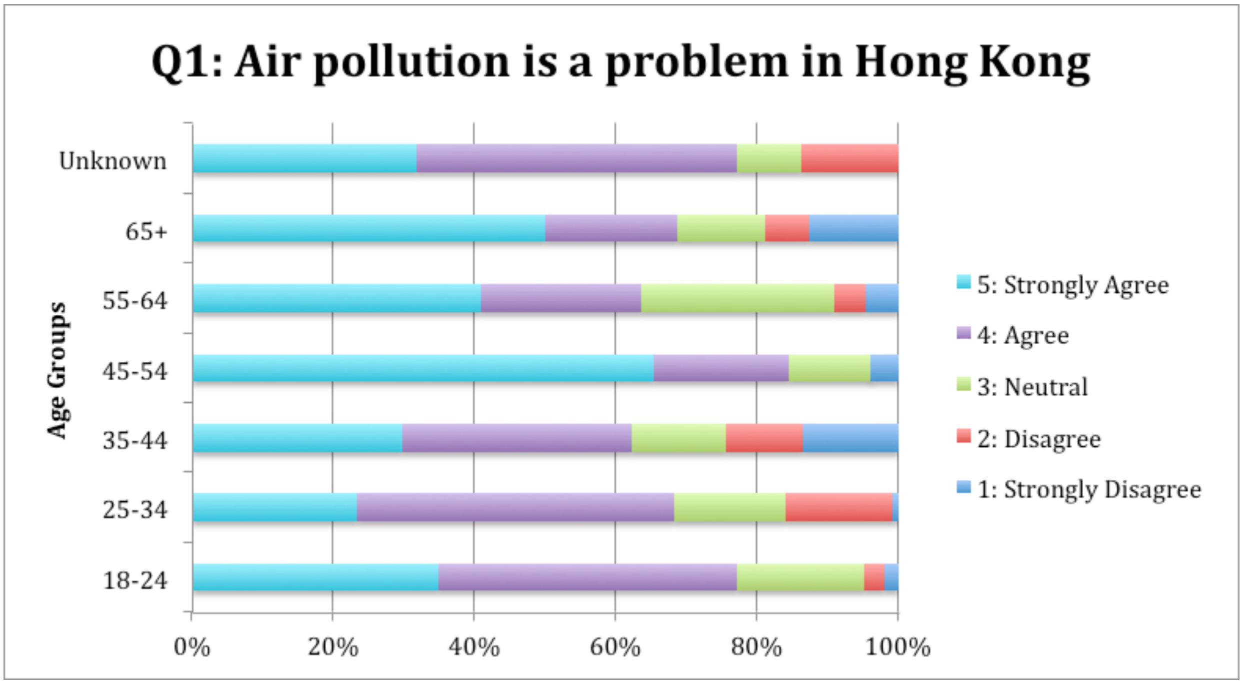

Figure 16: Distribution of answers for question 1 of the survey by age group. (Courtesy of Ryan Welch)

Question 3 asks if vehicles cause pollution: true or false. 421 people responded with true and 77 people responded with false. The highest percentage of those surveyed who responded with false were in the 25-34 age group, where 20% in that group answered false. This observation strongly illustrates a lack of public understanding of how pollution is produced, and it can be extrapolated that some people may be hesitant to introduce changes in traffic patterns based upon environmental concerns.

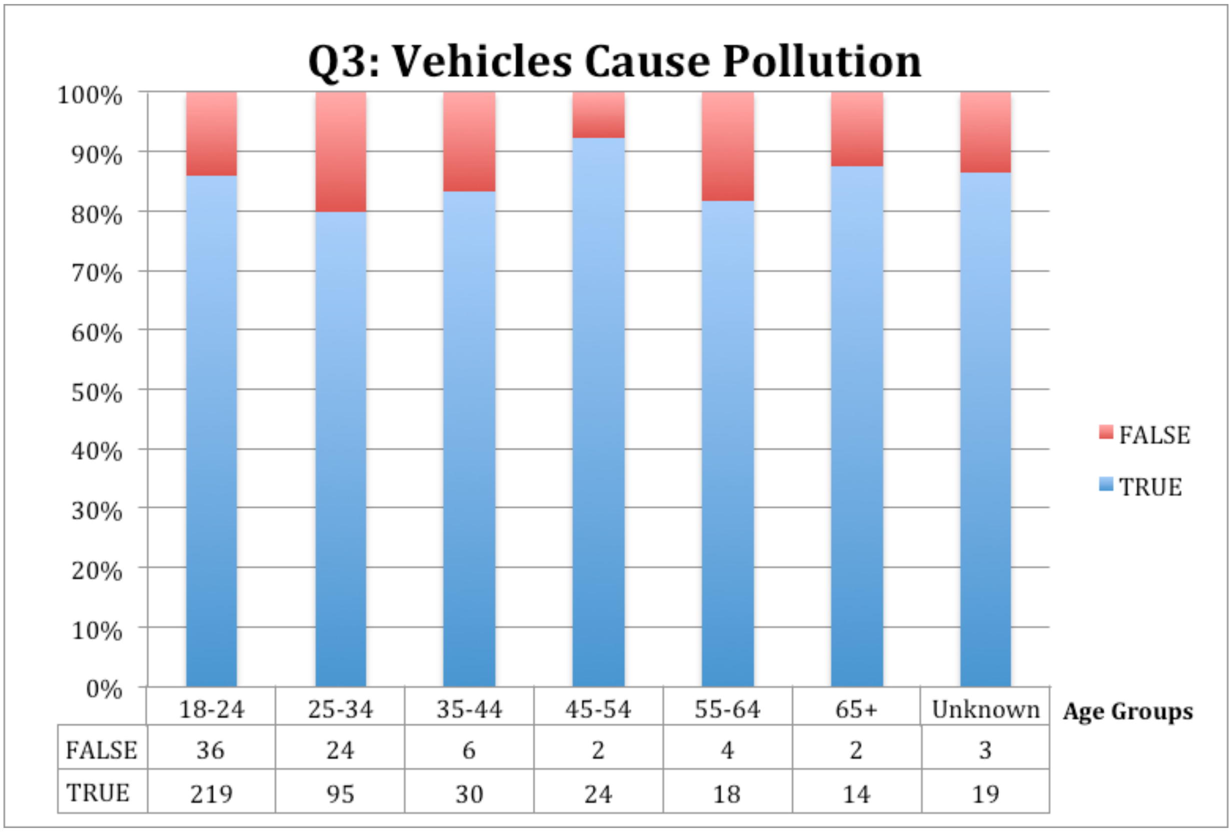

Figure 17: Distribution of answers for question 3 of the survey by age group. (Courtesy of Ryan Welch)

Question 4 asks the primary mode of transportation used in each respondent's everyday commute. 287 people answered MTR, 168 answered public bus, and 13 responded with private car. In the 55-64 age group, a higher percentage of people answered that they take the public bus than those who answered that they take the MTR. While the older demographic favors the public bus, the prevalence of MTR use in younger age groups shows that the MTR is a very popular mode of transport in Hong Kong when compared to the public bus or private vehicles.

Question 5 asks how much time is spent traveling every day. On average, each respondent spent about 2 hours traveling every day. The highest average time is 2.67 hours in the unknown age category, the second highest average is 2.39 hours in the 23-30 age category, and the lowest average time is 1.32 hours in the 55-64 age category.

The survey was designed to gauge public opinion of Hong Kong's air quality in respect to transportation. The results gave the team insight into the generally negative opinion of the city's air quality, while showing that a sizeable percentage is unaware of vehicle's effects on air pollution. The results of the transport questions illustrate the importance of the public bus system to a large quantity of people in the city. This population proves that the bus system is worth examining while providing a warning that such a large population may not be receptive to change. The final question provided insight to public opinion on traffic distribution in the city. A large majority of people answered Central, Mong Kok, and Causeway Bay, leading the team to focus on traffic in those specific areas. The survey proved not only a useful gauge of public opinion, but was useful in directing the focus of the recommendations and the project itself. In addition to the inferences derived from each question, the survey as a whole suggested the need for further public education regarding air pollution, transportation policies, and vehicular emissions.

4.2. Air Quality Health Index

On December 30th 2013, the Hong Kong Government released a new system for the evaluation of air quality called the Air Quality Health Index or AQHI. Based on a combination of the concentrations of airborne pollutants and several other factors, the system calculates a number between 1 and 10 with 10 being high risk to health by air pollution. If the system calculates a number higher than 10, a 10+ is then given. The stations used to measure AQHI are found around Hong Kong, with three specific roadside stations at Causeway Bay, Mong Kok, and Central. These sensors are specifically placed to measure roadside air pollution. The project team tracked the readouts of these stations to examine them for average AQHI at each hour interval over the month of January. These averages were able to provide insight into the effect of rush hour on air quality and the relative severity of air pollution in each area (Appendix K).

The month of January showed the same relative trend for each day; beginning at midnight, AQHI levels are at a relatively low number, and climb to more dangerous numbers after 8:00 in the morning. The trend takes a slight dip at about 13:00, indicative of a lunch rush lull in traffic density. The air quality trend gets consistently worse over the course of the day before peaking at about 19:00, and eventually dropping in the late night/early morning to begin the day again. This data points to an 8:00 rush hour that brings an immediate rise in AQHI, and another rush hour where the data peaks around 18:00 or 19:00. These rush hours were further supported by the high and low comparisons in each area, which consistently showed a jump at the 8:00 hour, and would either jump or have their highest values between the hours of 18:00 or 19:00.

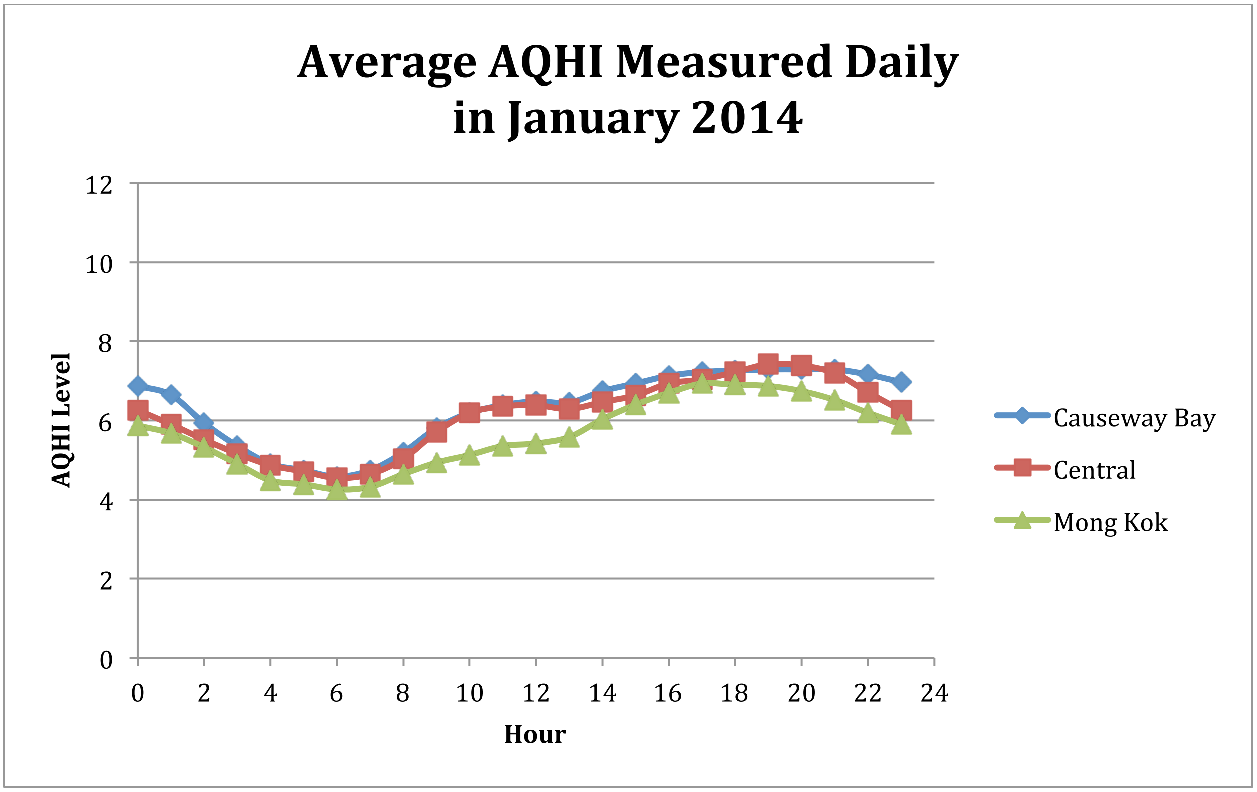

Figure 18: Average AQHI levels for every hour in January 2014 (Courtesy of Ryan Welch)

The trend displayed by AQHI is able to confirm the rush hour times because of the connection between air pollution and congestion. As congestion built in the city during rush hour times, air quality would get to its highest levels and jump to incredibly unhealthy levels at and around these rush hours. As congestion dissipated, and the rush hours ended both in the middle of the day around lunch and at the late hours of the day, the AQHI value would either make a dip or fall to the lowest values of the day. This correlation provides a direct link between air quality and congestion. With the knowledge of each rush hour, the project team observed several aspects of the transportation system during these times, beginning with the city's bus system.

4.3. Observational Data on Bus System

In Causeway Bay, Mong Kok, and Central, the bus system spawned a large number of problems for the main roads, often creating or prolonging congestion. One of the most apparent issues with the buses was their sheer number. During some ten-minute observation periods, over 50 buses could be observed moving through certain areas of the city, as seen in Appendix H. This heavily affects traffic flow due to the fact that double-decker buses in general take up a large amount of physical space, and while mini-buses exist in some areas, they simply do not cover large areas or routes. Further exacerbating the problem, many public and light buses were filled with less than 20% of their maximum capacity during all hours of the day, effectively wasting space on the roads with each bus that was not closer to full capacity.

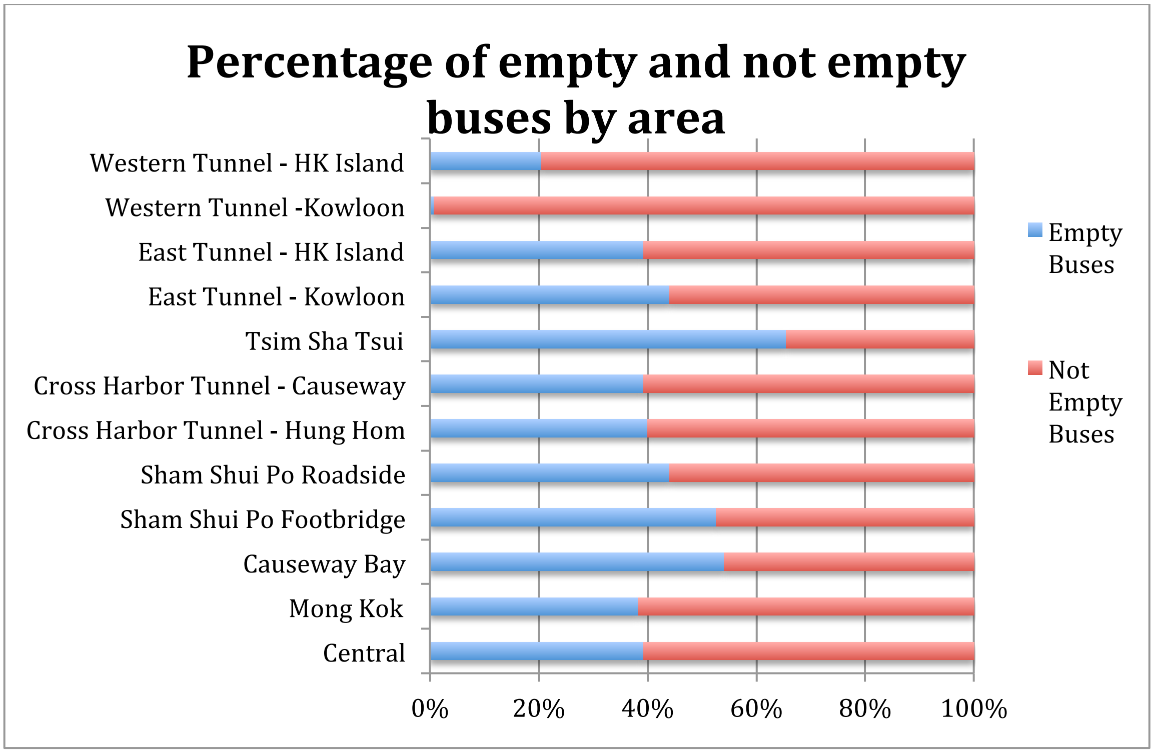

Figure 19: Graph of the percentage of empty buses observed per area (Courtesy of Ryan Welch)

Empty buses were often observed all over the city, to such an extreme where, in Central and Mong Kok, empty buses averaged 39% and 38% respectively, of the total number of buses moving through the area. Causeway Bay saw a much higher fraction of empty buses, averaging 54% of total buses moving through the observed areas. Each of these areas is highly trafficked by pedestrians, which results in more frequent usage of public transportation. In other observed areas, the percent of empty buses still remained high. For example, when observing Salisbury Road of Tsim Sha Tsui, bus emptiness reached as high as 65.5% during the recording time periods (Figure 19). Although this data is observational, it points towards a problem in the placement of current bus routes and in the number of buses servicing them.

Despite the smaller number of passengers, full sized double-decker buses were still used, occupying an unnecessary amount of space in relation to the fact that a number of buses traveling all over the city were generally under capacity, their significantly larger size in comparison with other vehicle types was strongly highlighted. While this problem was less prevalent in Mong Kok due to the enormous amount of red-topped Mong Kok light buses, the other two addressed districts were filled with double decker buses. Within our observed locations, each area contained at least one major motorway that contained similar bus issues. While Central and Causeway Bay were primarily filled with double decker buses, Mong Kok had a large number of both double decker and red-top light buses.

The overabundance of buses would block traffic as they attempted to stop at a bus stop, thus creating a long line of buses in the travel lanes as they waited to access their passengers. Large numbers of buses would approach the same stop at the same time, causing backups into all lanes of traffic, and at times entirely halting traffic flow on the road. This action was commonly observed on Nathan Road in Mong Kok, Yee Wo Street in Causeway Bay, and Connaught Road Central where the stops were both poorly placed on roads and overly visited by different bus routes. Many of these bus stops line the sides of main roads, especially Nathan Road south from Mong Kok, Hennessy Road in Causeway Bay, and Des Voeux Road in Central, (Appendix J) where many stops are spaced right next to each other, causing even more of a backup during rush hour, as many buses with overlapping routes attempt to stop in similar areas. These stops are sometimes no more than a bus length apart, causing backup between buses trying to access bus stops that were technically different.

During the observational walk of Causeway Bay, a particular situation was noted on Hennessy Road, via a footbridge overlooking the road. At one bus stop, four buses were all attempting to pick up passengers with a fifth approaching. The fifth bus was unable to enter the area due to the sheer number of buses already there, which then was paralleled by a sixth and seventh bus approaching the same stop. Due to the inability to pull over, two of three possible lanes were completely stalled while passengers slowly got on the buses initially observed. More buses then arrive in the area, some of which still attempting to approach the bus stop. This incident results in fifteen different buses stopping at the one bus stop over the course of about three minutes with all three lanes being blocked for two minutes and two lanes for an additional minute and a half (Appendix H.3). While this event occurred specifically in Causeway Bay, this type of situation was observed at various bus stops all over the city.

At the cross harbor tunnels, bus stops are also placed directly before tunnel toll plazas, which cause congestion directly before the already crowded toll plazas. Similar to the crowded bus stops on main roads in the city, these bus stops commonly back up into the main travel lanes, slowing traffic as it tries to pass the toll plazas on the Kowloon side. This effect caused significant backups in one of the only two Autotoll lane options, paralyzing that area of the toll plaza. While the current structure of the bus system is causing increased congestion, the taxis and commercial vehicles create similar situations that also lead to higher congestion.

Figure 20: Vehicles merge into Cross-Harbour Tunnel entrance (Courtesy of Derek Tsaknopoulos)

4.4. Observational Data on Taxis and Other Commercial Vehicles

4.4.1. Taxis

Many of the major problems observed with taxis and commercial vehicles were formed out of bad driving practices. It was commonly observed to see large numbers of taxis idling on the side of the road waiting for passengers, or letting people off in the middle of the road. These taxis would choke already crowded roads, and would block the flow of traffic by driving or stopping erratically at the prospect of picking up a new passenger. Taxis were often observed to drop off passengers directly at bus stops, which would prevent buses from approaching and inadvertently back up traffic. Several instances were observed in which a taxi driver would unload passengers in areas that are specifically designated as no-pull-off zones. In small numbers, this would not have caused too significant of a problem, but taxis make up a significant percentage of total traffic number, as seen in the charts of Appendix H over various observed areas.

The applicability of a Limited Traffic Zone such as in Rome over the various locations in Hong Kong is directly dependent upon the infrastructure of the area and the type of vehicles causing congestion. Electronic gate systems would prove effective only when private and commercial vehicles are the most problematic, as the public transportation is generally exempt. Furthermore, careful analysis of these gates would be required so not to simply divert traffic to another road that would potentially handle the congestion worst. Furthermore, the zones that could be established within Hong Kong could relate very similar to those of Rome. Authorization systems would be extremely effective in terms of the allowance of parking in certain areas and what types of vehicles were allowed at certain times. These systems could be applied to specific problematic roads and could be customized to suit the immediate environment. This would also play a part in emission controls, as the specified zones can also be limited to certain emission parameters, supported either through an inspection validation or remote sensing. While every part of Hong Kong has its own individual characteristics that must be considering in the creation of a limited traffic zone, in comparison to the complexity and size of that established in Rome, each has the potential to institute at least some portion of the example zone in Rome. In order to analyze the specific applicability, potential zones were examined for Causeway Bay, Mong Kok, and Central through the evaluation of the individual regions during observation walks.

4.4.1.1. Causeway Bay

In Causeway Bay, taxis would often take up bus stops at inopportune times, specifically on the problematic Hennessy Road. Additionally, extreme counts of taxis were found in the area surround Time's Square (Appendix H.3). While the structure in Times

Square maintained a taxi loading area with an attendant, the 8 taxi spots were heavily outweighed by the extreme number of taxis in the surrounding area, as seen in Figure 21.

Figure 21: Taxis line up outside of Times Square (Courtesy of Mark Mantell)

4.4.1.2. Mong Kok

In Mong Kok, taxis would pick up or drop off wherever they saw fit. For example, a particular bus stop on Nathan Road was taken by an unloading taxi, resulting in dangerous swerving of passing vehicles in an attempt to avoid it. At a different bus stop on Nathan Road later in the day, a taxi almost caused an accident with the following buses when it abruptly stopped at a bus stop to load a passenger. Additionally, despite two of three lanes being taken by parked vehicles on Portland Street, various taxis began to load and unload passengers in the one remaining lane despite the vehicles behind them. In another instance, taxis were observed overloading taxi stands in an effort to pull over to pick up passengers. These actions were especially prevalent on Portland Street, where taxis attempting to pull over would be in such numbers that they would actually back up into the natural flow of the road (Appendix H.2 and J.3).

4.4.1.3. Central

In Central and Sheung Wan, most congestion stemmed from a simple excess of vehicles in the area. Additionally, on side roads such as Hillier Street, Queen's Road Central, and D'Anguilar Street, it was observed that a large percentage of these vehicles were taxis, contributing to the higher congestion of the overall areas (Appendix H.1). Taxis would also continue to pull over at will, blocking the flow of traffic. On Connaught Road Central, undeniably the main road of Central, taxis attempting to pull over caused erratic driving and congestion in three of the four possible driving lanes at one particular taxi stand (Appendix I.3).

4.4.2. Other Commercial Vehicles

Commercial vehicles appear to be even worse offenders than taxis in many areas, as their driving practices cause even more strife in crowded streets and have a much greater effect on blocking traffic. Commercial vehicles will often fill every parking zone on side streets, or even go so far as to double park to unload their goods. Doing so forces taxis, private vehicles, and other commercial vehicles to hunt for other spots, slowing traffic flow to a crawl as each car slows to attempt to fit into the spots they can find. Commercial vehicles have also been seen to crowd around bus stops, forcing buses to wait for the vehicle to move to pick up passengers. Furthermore, commercial vehicles crowd already narrow roads to load and often unload at the busiest times of the day, causing an already strained system to clog entirely. Commercial vehicles were observed to park in no-parking zones during rush hour, forcing main roads down to just one lane for traffic flow.

Figure 22: The van has stopped in the middle of the road to unload, blocking all traffic for almost 3 minutes. (Courtesy of Derek Tsaknopoulos)

4.4.2.1. Causeway Bay

In Causeway Bay, commercial unloading was a pronounced problem causing intense congestion in the areas surrounding the Sogo shopping center. Particular streets of interest include Lockhart, Jaffe, Cannon, and Gloucester. On Lockhart Road, multiple commercial vehicles filled the street and sidewalks with numerous boxes, blocking not only vehicle travel, but pedestrian as well (Appendix I.1). On several occasions, with only a limited number of lanes of available, an unloading commercial vehicle was observed blocking all lanes of travel, bringing traffic flow to a halt as it attempted to parallel park or unload directly in the travel lane. Jaffe Road in particular was almost entirely filled with unloading commercial vehicles, where in one instance all lanes of movement on both Jaffe and Cannon were blocked for over 50 seconds by an extended parallel parking job.

Cannon Street saw levels of congestion due to the combination of high traffic flow and extensive unloading of commercial vehicles. Gloucester Road contained possibly one of the worst levels of congestion anywhere in the city. While this was due to a number of factors, one factor involved the rampant ignoring of "No unloading" signs in certain areas the complete blocking of traffic by said unloading commercial vehicles, as seen in the picture below (Figure 23).

Figure 23:A van blocks all lanes of travel on Lockhart Road (Courtesy of Mark Mantell)

4.4.2.2. Mong Kok

In Mong Kok, vehicle unloading would cause congestion throughout the entire area. Streets such as Portland, Dundas, Hamilton, and Sai Yueng Choi South saw heavy unloading during highly trafficked times in terms of both other vehicle and pedestrian traffic (Appendix I.2). Particularly in Sai Yueng Choi Street South, commercial vehicles would weave in and out of the high number of pedestrians taking part of the various markets in the area. This was notable as commercial vehicles were the only observed form of vehicle in the immediate area. Throughout the observed areas, commercial vehicles contributed to the lower speed of traffic flow as they slowly hunted for parking space on the already crowded streets.

4.4.2.3. Central

In Central, commercial vehicles were not as evidently problematic as in Mong Kok or Causeway Bay; however, they still engaged in the same bad driving habits. On Connaught Road Central, a commercial vehicle attempted to avoid pulling over into a bus stop by double parking right in front of it, thus blocking traffic in the lane despite a clearly visible "24 hour No Unloading" sign (Appendix I.3). Throughout the observed areas, commercial vehicles highly contributed to the heavy flow of traffic on the streets of various sizes. While their loading practices were not as extreme of a problem in these cases, their driving practices were a result of clogged roads and locations that are not designed to handle large vehicles or large volumes of vehicles.

4.5. Observational Data on Parking

The parking practices in the city cause problems for traffic flow regardless of vehicle type. Many of the more travelled side streets have cars lining both sides of the road, and in some instances, the entire road would be double parked on both sides, as seen in Figure 24. It is common to see roads that are designed to have two or three lanes of traffic be reduced to barely one as a result of excessive parking, resulting in numerous vehicles struggling to move through the narrow passageways. Often times, the struggling traffic will back up a long line of vehicles at an intersection and force them to make dangerous turns due to lack of vision. These bad driving practices and clogged roadways made currently existing problems caused by traffic volume considerably worse.

Figure 24: Double parking on Walnut Street in Tai Kok Tsui (Courtesy of Adria Fung)

4.5.1. Causeway Bay

Congestion in Causeway Bay involved the competition of all vehicle types for parking spots and was amplified by a number of vehicles already clogging the streets. On Jaffe Road and Cannon Street, vehicles were forced to engage in dangerous driving practices as they directly competed with unloading commercial vehicles and stationary vehicles. Additionally, many vehicles had difficulties turning due the proximity of parked vehicles to the intersection (Appendix I.1). Double parking was also a major issue on roads such as Lockhart and Hennessy. On both of these roads, two of the three possible lanes of traffic were blocked by a variety of vehicle types. This included various stationary vehicles in the side lanes while fighting buses, taxis, and commercial vehicles in the primary travel lanes.

4.5.2. Mong Kok

Mong Kok had the most distinct parking problems when compared to the other observed locations. While commercial unloading was undoubtedly a problem, it was the commercial vehicles that simply sat stationary for immense amounts of time without any sign of activity that were a more extreme problem (Appendix I.2). Additionally, high numbers of taxis and red minibuses often lined the streets, minimizing the traveling spaces of many roads without conducting any business whatsoever. The clogged streets would result in extensive double parking and cause vehicles to slowly search for a parking spot, as there was not a single option left in most areas. Roads such as Portland, Changsha, Dundas, Hamilton, Sai Yeung Choi South, Shan Tung, Fife, and Soy were all parked to 100% capacity by empty commercial vehicles, loading commercial vehicles, taxis, or red minibuses. This caused high congestion levels in the immediate area which overflowed to the more highly travelled streets.

Figure 25: The van parked to deliver a suit, blocking most of the only travel lane. While the taxi could fit, the truck that came a few seconds later blocked until the van moved (Courtesy of Derek Tsaknopoulos)

4.5.3. Central

While parking problems in Central were not as widespread as in Causeway Bay or Mong Kok, existing obstacles were dramatically highlighted due the naturally higher traffic flow of the area. Connaught Road Central saw double parking in certain stretches and intense lane blockage in others (Appendix I.3). Queens Road Central also saw parking in certain areas, seriously inhibiting traffic flow down the corridor. During the evening, parking complications became even more evident. For example, Pottinger Street saw extensive double parking resulting in very slow moving traffic. This traffic then backed up the length of the road and causing additional driving difficulties on the merge onto the street via Queen's Road Central. The merging lane of Queen's Road Central then backed up far enough to negatively affect the straight lane. Traffic volume in the area was high, but was only stressed in areas where the roads were clogged with over parking.

4.6. Observational Data on the Cross Harbor Tunnels

The cross harbor tunnels also presented many problems that led to high levels of congestion. First and foremost was the enormous difference in the price of each tunnel. For a private car, the toll for the Cross-Harbour Tunnel costs $20, the Eastern tunnel costs $25, and the Western Tunnel costs $55. (Hong Kong Transport Dept., 2013) With the toll of the central Cross-Harbour Tunnel costing less than the other two, drivers are more much more inclined to utilize it over its Eastern and Western counterparts. The Eastern Tunnel toll costs more than the Cross-Harbour Tunnel toll and sees less traffic in comparison. The Western Tunnel toll is considerably more expensive than both the Cross-Harbour and Eastern tunnels and sees almost no traffic or backup of any kind, pointing to a correlation between price of tunnel and traffic volume.

The congestion at the Central Cross-Harbour Tunnel is far worse than the congestion at the Eastern and Western Tunnels, and this congestion is partially caused by overcrowding of the toll plaza as well as the structure of the toll plaza itself. In order to view the problems with the toll plaza first hand, observations were made through a ride-along of the cross harbor route 118. During this bus ride, heavy back-ups occurred in the toll plaza bus stop that resulted in extensive idle durations as well as a direct impact upon the flow of traffic well before the toll plaza. The eight lanes leading up to the toll plaza merge into two at the tunnel entrance, leading to slow and dangerous merging by all vehicles attempting to use the tunnel. The side lanes were observed to have the worst problems, as buses in these lanes would wait until the last moment to merge and end up waiting for long periods of time to continue through the tunnel. As congestion built up by the tunnel's entrance, the traffic would back up far behind the toll plaza, leaving the entire area essentially in a standstill, as seen in Figure 26. When crowding at the tunnel entrance was not a significant issue, a great volume of cars would still line up before the toll plaza itself that backs up far into the streets leading up to it.

Figure 26: Vehicles line up before the toll plaza at the Cross-Harbour Tunnel (Courtesy of Mark Mantell)

While the toll plazas of all three cross-harbor tunnels are all equipped with automatic electronic tolls called Autotoll, each toll plaza has only two Autotoll lanes–one on each side of the plaza. Most vehicles do not have the in-vehicle unit necessary to use the Autotoll, and instead use the manual booths, creating longer backups. As we observed the toll plaza at the Cross-Harbour Tunnel, we observed both types of toll lanes becoming clogged. The cash lanes slowed to a crawl as each driver had to stop to pay before attempting to move into the crowded car funnel. The Autotoll lane also slowed to a crawl as such a large number of drivers looking to use their Autotoll were crushed into one lane. The crowding in each lane type persisted in the Eastern tunnel when similar congestion was achieved around the tunnel entrance. The Western tunnel on the other hand was so under-utilized that congestion never formed in any capacity, as shown in Figure 27.

Figure 27: The un-congested Western Harbor Tunnel (Courtesy of Adria Fung)

5. Recommendations

5.1. Recommendations for the Bus System

The team has determined through the collection of observational data that the Hong Kong public bus system is a main offender in the creation of traffic congestion. Seoul, South Korea is an example of a city that tackled issues in their bus system and many of the ideas included in its reconfiguration can be used in Hong Kong as well. When comparing the bus systems of Hong Kong to the old bus system of Seoul, it is plain to see how Seoul's solutions can be applied in Hong Kong. Both scenarios have very similar franchised bus schemes and share a number of similar issues that need to be addressed. Two of Seoul's main solutions were the implementation of a dedicated bus lane and switching control over bus routes and fares from individual companies to the city government. The dedicated lane separated buses from the main traffic flow, helping the buses to keep a more accurate schedule and reducing congestion. Putting a single body in charge of route planning also greatly increased the efficiency of the bus system as a whole by reducing redundant routes and forcing bus drivers to utilize safer driving practices. These policies were successful for Seoul, and while they were initially rejected by a majority of the populace, after just a few months the changes were accepted as a positive change by 90% of citizens (Pucher, 2005). After observation of Hong Kong's bus system, the team recommends the adoption of these policies to Hong Kong's specific needs.

With the current number of buses on the road in Hong Kong, a dedicated bus lane would help to measurably reduce congestion. Currently, buses must fight with the rest of the traffic flow to travel between stops, and they sometimes block traffic flow as they vie for space to move over to a bus stop. A dedicated bus lane would allow buses to stop at will without risk to other drivers on a crowded road and would also help prevent reduction in traffic flow speed when multiple buses arrive at the same stop. Therefore, lanes of traffic would not have to stop and wait when the buses attempt to pull over. While some roads do not have the physical space necessary to implement a dedicated bus lane, many of the main roads, including Nathan Road in Mong Kok, Gloucester and Hennessy Road in Causeway Bay, and Connaught Central St in Central, have plenty of room to include a bus lane while still having the capacity to accommodate other forms of transportation (Figure 28). The exclusivity of a bus lane would have to be tightly enforced, as impatient drivers would likely invade the bus lane to avoid congestion. Bus lanes could also include designated areas for taxis to pick up or drop off passengers when doing so would not seriously hinder the movement of buses. However, it is very important that taxis obey these passenger areas as serious problems can arise if stopping occurs in other unplanned locations.

Figure 28: Double-decker buses during evening rush hour on Hennessy Road, Causeway Bay (Courtesy of Adria Fung)

To complement the addition of a dedicated bus lane, the creation of several bus interchanges would also aid in reducing congestion. The creation of large-scale bus interchanges on Hong Kong Island, Southern Kowloon, and at various regions on the Kowloon/New Territories border would greatly simplify the bus system while helping to alleviate numerous route redundancies. While Hong Kong is currently pursuing a Bus Service Rationalization Scheme, progress has been generally unreported. Moreover, interchange schemes currently trend to affect routes in the New Territories as opposed to the very problematic areas of Kowloon and Hong Kong Island. (Hong Kong, Transport Dept., *Buses,* 2014)

As an example of redundant bus route, the bus route 970x runs from Sham Shui Po to Aberdeen with many stops in between and on several of the main roads on Hong Kong Island and Kowloon, including Pok Fu Lam Road and Nathan Road. The bus route was well travelled by commuters, and during an observational ride through the entirety of the route, it was clear how many other buses overlapped with this one route. As the bus travelled northward on Nathan Road, there were times when bus 970x was entirely surrounded by other buses. In another observational ride, bus 118 from Sham Shui Po to Siu Sai Wan was taken for the entirety of the route. When travelling from Sham Shui Po, the bus was mostly empty for almost the entirety of the route. In this direction, the bus was constantly crowded by the presence of other buses, and spent a significant amount of time attempting to approach highly travelled stops, such as the stop directly before the tunnel crossing in Hung Hom. Despite the number of buses, this ride remained empty, even at the crossing stop at Hung Hom. On the return trip, the exact opposite was observed, as the bus filled quickly in the early stops, but almost entirely emptied at the Hung Hom stop on the Kowloon side of the tunnel. From our observations, we concluded that most people who utilized this bus route were using it only to make the harbor crossing while the bus travelled empty for the remainder of the route. Routes like the aforementioned would benefit most from the addition of bus interchanges. Instead of one single bus route that sits empty for most of its trip, a shorter route could carry a large number of people to the interchange and allow each person to cross the tunnel and get on a bus to their final destination. This would reduce the number of buses on the road as redundant bus routes would be cut out entirely as shorter bus routes take their place. The overall reduction of buses on the road would help to reduce backups at the stops themselves and help to reduce strain on the road caused by overcrowding congestion.

With a reevaluation of the bus system on a whole, the amount of buses on main roads can be significantly reduced. All bus routes would stem from bus interchange in highly populated zones such as Southern Kowloon and Harborfront Hong Kong Island, cutting out routes that service similar areas. For example, instead of many routes servicing Sham Shui Po by connecting it to Hong Kong Island, only one route would need to service it from the interchange. New routes could also be created to connect areas that are far apart but in the same area without the need for an interchange, like from Cheung Sha Wan to San Po Kong. These bus routes would continue to be important but would be created much more sparingly. In addition to the number of buses, there are a large number of stops in the same general area, especially on roads the size of Nathan Road in Mong Kok. While the amount of walking a person would have to do to reach a destination may increase, a reduction in total bus stops could help to alleviate congestion, and through that improve the air quality for pedestrians. It is important to note that while interchanges would benefit transportation as a whole, the access and facilities of these interchanges must be customized to match the needs of the population. The interchange system would be best for accessing the most population heavy areas, it still may be easiest to access less popular areas by use of the green topped light buses.

Some roads are too small for the large double-decker buses, and are better suited to access by light bus not only because of population, but also topography. Increased efficiency of the use of the light buses would both reduce overall bus volume on the roads and help in the general consolidation of the system. This concept not only ties into the idea of consolidation, but into another idea of limited busing zones. In some popular areas, buses make up a large fraction of road traffic where they can block the flow of traffic in the attempt to make their way into bus stops. In combination with a redistribution of bus stops and routes, the institution of areas that are forbidden to certain buses would help traffic flow and reduce a lot of congestion. One particular area specifically applicable is Causeway Bay, where large numbers of buses travel directly next to the Sogo shopping center and the pedestrian heavy area surrounding it. It could be beneficial to shift bus stops away from the pedestrian area and to the surrounding roads like Gloucester Road. While the walking time from the bus stop to destinations in Causeway Bay would slightly increase, congestion caused by backups at the bus stops would drastically decrease, improving the accuracy of the bus schedule and helping to streamline traffic flow and reducing idling. This is also related to the limitation of red top minibuses.

As the drivers of these buses are given completely free reign over their practices, they often congregate in areas with the best business potential (Pan, 2014). While on the surface this is beneficial for the passenger, it often causes significant congestion due the sheer number of these minibuses. As a result, red-topped minibuses must be considered in the evaluation of the bus system as a whole, including the possibility of utilizing green-top minibuses as an alternative.

Figure 29: Buses lining up in a row on Hennessy Road, Causeway Bay (Courtesy of Adria Fung)

5.2. Recommendations for Limited Traffic Zones

Addressing poor driving habits is difficult to resolve with a transportation policy, but a restrictive limited traffic zone can have a positive impact on congestion reduction in the busiest areas of the city. In Mong Kok, Causeway Bay, and Central, a limited traffic zone restricting commercial vehicles to certain times of the day would open significant amounts of space on the streets and improve overall traffic flow. One important aspect of this limited traffic zone would allow commercial vehicles to enter the limited traffic zone only during certain times of the day. This action was used by Beijing in preparation for the 2008 Olympic Games, where the government limited trucks to operating in the inner rings of the city only between the hours of midnight to 6 a.m. (Zhou, et al., 2009). Limited traffic zones were also implemented around the tourist areas and government buildings in Rome. These zones limited the entrance of vehicles by way of electronic toll gates and vehicle type restrictions. The Limited Traffic Zone, in combination with other new traffic and emission control policies, was successful in reducing the pollutant output of Rome.

In an interview with Eddy Chang (Appendix C.3), a researcher at the Jockey Club Heavy Vehicles Emission Testing Centre, the team discussed the importance of engine maintenance in relation to emission control. Poorly maintained engines have an increased negative impact on air quality, as they do not manage pollutant output as well as well-maintained engines. A Limited Traffic Zone will only be effective if implemented in tandem with a campaign for proper engine maintenance, as they are specifically designed to restrict the movement of high-emission vehicles.

5.2.1. Causeway Bay

A limited traffic zone in Causeway Bay would cover the area enclosed by the MTR exits and stretching up to Gloucester Road. This range would circle some of the busiest areas in Causeway Bay, ensuring that the side roads are not adversely affected by commercial vehicles during the peak hours of the day, instead relegating their operation to the earlier hours of the morning. Commercial vehicles are relegated to early morning as opposed to the evening because of the nature of Causeway Bay as a social area with increased pedestrian use during the mid-day and into the later hours of the evening. Observations on the side streets showed wide roads that were consistently choked by commercial vehicles unloading during peak traffic hours. This stood out not only in that it caused a complete and total blockage of traffic, but that the area was so choked already with commercial vehicles on the sides of the road, that it forced actions such as double parking and mid-street unloading by any other vehicles attempting to utilize the area. Roads lined with commercial vehicles were the norm in the area, with some streets left with no parking and on some occasions no room to drive at all. Additionally, taxi stands situated around the zone would need to be better spaced in relation to the newly worked bus stops, but would also need to be more strongly enforced. The existing taxi stands are well used, but the areas around them, and many other areas on the roads, will find themselves choked with taxis. Enhanced enforcement of taxi stands will help to keep the roads clear.

By limiting commercial unloading to only certain times when pedestrians and other transit systems are not in mass, the entire environment of Causeway Bay has the potential to improve. Specifically, roads such as Lockhart, Jaffe, and Cannon would benefit the most from this change. To augment the limited traffic zone, parking limits must also be enforced so as not to obstruct the streets with idle private or public vehicles, or other commercial vehicles simply sitting in valuable parking areas. This includes not only the limitation of parking near intersections, but the limitation of parking time in ensure the area can be actively used by more drivers looking for parking. By reducing the ability for commercial vehicles to clog the area, overall traffic should improve in the entire zone due to the distribution of vehicle counts over the course of the entire day. Additionally, by encouraging a flowing business sector in terms of parking, the overall speed of traffic should improve, reducing congestion. To summarize, the goal is to create an efficient in-and-out environment where people fulfill what they need to do in the area and remove themselves before causing any complications for other drivers.

Furthermore, the use of the electronic gates may be utilized to further improve traffic flow in the area. By encouraging the use of some roads and discouraging the use of others, the natural flow of traffic can be optimized and pushed towards corridors that best accommodate higher numbers. By limiting the flow into and out of the main Sogo area of Causeway Bay via Gloucester Road, the circulation of this major pathway may be improved for all drivers. Additionally, roads such as Leighton, which can handle a larger number of vehicles, is under-utilized, and can be stimulated through the use of electronic gates. While private vehicles were not a particular problem during observations, this system would also add control over their circulation as well.

5.2.2. Mong Kok

While Mong Kok is a less centralized area than Causeway Bay, a similar limited traffic zone could be utilized to the areas benefit. This zone would enclose an area surrounding Nathan Road and Argyle Street, and stretch to include all areas and roads that feed into the main Mong Kok artery, including Portland Street, Shanghai Street, Dundas Street, and Sai Yeung Choi Street South. These areas have large amounts of vehicle traffic on both the main roads and side streets, but suffer from the same problems observed in Causeway Bay, in that commercial unloading and uncontrolled parking significantly influence the circulation of vehicles around the entire area. Specifically, taxi stands need to be regionalized away from high traffic and have zero to low interactions with the varied bus stops and commercial centers. Due to the social environment of Mong Kok, commercial loading would be best pushed towards the early morning or early afternoon. The hours around lunchtime and from the evening rush hour onwards must be completely avoided so as to avoid the high pedestrian populations crowding the streets. A particular piece of note of Mong Kok is the popularity of the Ladies Market, which significantly adds to the amount of foot-travelers during the evening. This is further highlighted by extreme flows of vehicles down roads that simply cannot handle the loads being put upon them from the combination of traffic flow from other territories and outpouring side streets. As a result, the flows of specific streets must either be limited, or made extremely more efficient. Limitation can be achieved through the use of electronic gates; however, this is not as applicable as in Causeway Bay due to the crowded nature of the zone and the extreme number of winding streets. As a result, it is most effective to put much stricter policies into effect on these roads so as to completely allow steady travel throughout all times of the day. Through the complete limitation of parking and unloading on the side streets entering and exiting Argyle Road, the significant flow accompanying the road would become more efficient in conjunction with its already well working light system (Figure 30). Shanghai Road would benefit greatly from strict parking and unloading policies at all times of the day, as its high vehicle counts need to be allowed to operate freely.

Figure 30: Double decker buses blocking the adjacent lane on Argyle Street (Courtesy of Adria Fung)

5.2.3. Central

Central sees issues similar to those of each other area, but to a lesser extent. No-Parking zones were often observed being ignored, and commercial vehicles choked many side streets. The traffic along the main roads, while seeing an overabundance of bus traffic, was generally free-flowing, although blockages occasionally surfaced around bus stops (Figure 31). The limited traffic zone in Central would follow a similar theme as the other two in the limitation of commercial vehicles, although they would here be relegated to the very early morning, the early afternoon, or the very late night, so as to avoid the main hours of commuting workers. Additionally, the area around Lan Kwai Fong specifically should be avoided at night so as to avoid the active night life of the area. A limitation on taxis to side streets would also be prudent during certain times of the night, when taxis moving through highly concentrated areas of pedestrian traffic leads to small traffic backups and danger to pedestrians. Furthermore, parking bans must be enforced so as to allow the most complete flow of major pathways, like Connaught Road Central, Queen's Road Central, and Ice House St where parking caused direct issues with the circulation of traffic. Additionally, the flow of many roadways will be relieved with the reworking of the bus clogged Des Voeux Road Central. In order to limit the flow of certain areas, an electronic gate system could also be implemented. However, further research is required into the reasons for significant flow in certain directions and from where the sources originate.

Each of the proposed limited traffic zones has the potential to lower congestion in their respective areas, but their effectiveness hinges entirely on enforcement of the respective measures. This would include the enforcement of all parking and loading limits, as it was often observed that a string of hindrances would stem from one offending vehicle. Throughout all time spent in observation, very rarely were any traffic policemen observed. Despite observing many instances of illegal parking and frequent unsafe driving actions, never once did the team observe a traffic ticket issued for any type of violation. An increase in traffic policy enforcement would not only ensure that a new limited traffic zone is respected, but would also have a positive effect on reducing traffic violations throughout the city.

Figure 31: Morning rush hour on Connaught Road in Central (Courtesy of Adria Fung)

5.3. Recommendations for the Cross Harbor Tunnels

The traffic structures around the cross harbor tunnels are responsible for large amounts of congestion around their entrances and toll plazas (Figure 32). Each tunnel has very similar structures regarding the number of lanes approaching and leaving the tolls and entering and exiting the tunnels. These lane structures allowed many cars to move through the toll booths at once, but as more cars moved through, it became apparent that the tunnels were too narrow to accommodate such a large number of cars and backed up significantly. While this circumstance occurred at each tunnel, it was to a far greater extent at the Cross-Harbour Tunnel. Based on these observations, a restructuring of the toll plaza is highly recommended. As the tunnel entrance is only two lanes wide, six or eight toll lanes create too much confusion as vehicles attempt to merge into the narrow tunnel. Using a smaller amount of toll lanes with a quicker payment method would allow for more efficient merging and less backup after the toll plaza. While this would slow the passage of cars past the toll plaza, it will reduce congestion post-toll plaza.

To further combat the problem, Singapore's electronic road pricing method can have a positive impact increasing speeds through the toll plaza. Singapore utilizes an electronic road pricing system city-wide, where certain areas of the city have toll gates, where a car is charged using an electronic device in the car promptly upon driving under the gate. This system does not require vehicles to slow, and has a camera system in place to photograph cars that pass without paying the toll. While their electronic toll system is implemented in the center of the city, such a toll gate could be beneficial to the tunnel system of Hong Kong. It was noted that cars would back up in significant numbers behind the cash toll lanes, purely by the nature of paying at a cash lane, which requires each car to halt at the booth to pay the toll. In full rush hour, the cars extended in a line past the observers' sight range, and did not clear for the duration of the observation. While leaving one or two toll lanes as a cash/Autotoll hybrid lane would be beneficial to some drivers, any other lanes would be Autotoll only lanes that allow drivers to move through at a highly accelerated pace, using only an electronic device to scan into the tunnel. Faster movement through the toll plaza will streamline the tunnel entrance process and reduce congestion around the entrance. The increased speed moving through the toll plaza will also counteract the reduction in lanes, allowing for a similar number of vehicles moving through the tunnel, while doing so without congestion before entrance. Through the implementation of both solutions, the process of merging would become quicker and safer, greatly minimizing the time between the approach of the toll booths and the entrance of the tunnel.

While the traffic structure around the entrance to the Cross-Harbour Tunnel had a strong hand in creating congestion, the overall tunnel system in the city pushes more cars toward the Cross-Harbour Tunnel than to the other options, exacerbating the congestion problems there and sparing the other two tunnels. Both the Western and Eastern tunnels are owned by separate corporations, and each sets the toll separately from the government owned Cross-Harbour Tunnel. The owners of the Eastern tunnel have a higher set toll than that set for the Cross-Harbour Tunnel, and the Western tunnel is set considerably higher than either other tunnel. Naturally, this price difference shifts many more commuters toward the Cross-Harbour Tunnel, causing an unbalanced build-up of cars at this center tunnel. The Hong Kong Government is currently investigating methods to redistribute traffic, which can be helped by simply equalizing fares. While the fares would not have to be identical, bringing the numbers closer to one another would help persuade drivers to move their morning commutes to the less crowded Western and Eastern tunnels. This issue should also be strongly considered in the reworking of the bus routes over the tunnels. Lowering the toll, however, is not entirely controlled by the government's discretion. Each of the two tunnel-owning corporations has a controlling stake in each tunnel, and ultimately has control over the tunnel's administration. Despite the freedom of the tunnels to set their own prices, it is worth noting that an equalization of the tolls would have a positive effect on reducing congestion around the tunnel entrances. As the Western and Eastern tunnels could seemingly handle a much larger traffic flow via the observations made, it is most evident that the toll rationalization is one of the scenarios for relieving congestion in the Cross-Harbour tunnel. In order to proceed with such a concept, market analyses and comprises must be made with the varied companies so that advancements can be made in a timely manner.

Figure 32: Exiting lane to Causeway Bay of the Cross-Harbour Tunnel (Courtesy of Adria Fung)

6. Conclusion

Through the determination of the direct effect of vehicular emissions with air pollution throughout Hong Kong, various transportation policies were researched that would potentially improve overall roadside air quality in the city. These policies were selected through the general demonstration of problem areas via observational studies that emphasized the need for additional research into particular problems as well as providing specific suggestions in certain circumstances. By observing traffic at various times and places and comparing it to pollutant counts via the AQHI system, it was apparent that increased vehicle usage resulted in decreased road-side air quality. Furthermore, this emphasized the importance of vehicle count on pollution and congestion, as not only did more vehicles contribute negatively to emission numbers, but higher vehicle counts correlated with higher AQHI values. Coupled with these observations, informal surveys of both residents and visitors to the city concluded that people did indeed see a problem with pollution in Hong Kong and that certain areas were considered worse than others. This information coincides with the fact that congestion and vehicle types were contributing factors on air quality. Based on these conclusions, the team observed the current bus system, the bus-taxi relationship, the cross harbor tunnels system, current emission standards, and more specifically the areas of Mong Kok, Causeway Bay, and Central.

The bus system was found to be poorly managed and overly saturated in its current state. Recommendations include the adjustment of entire routes, bus stop counts, entire bus counts, the "Red Light Bus" system, adaptable bus fares, and the incorporation of a bus lane. These changes are proposed in line with the method used by Seoul, South Korea, which was a highly successful example of a reworked bus system through the use of dedicated bus lanes and the reevaluation of bus routes. Due to the scope of the proposed solutions, the only apparent method to begin improvement would be to follow Seoul's lead and have the government of Hong Kong take a direct approach and analyze all areas under all companies at once. While the Bus Rationalization scheme has already been placed in Hong Kong, it is strongly recommended that the process and extent of the scheme is expanded greatly.

While the bus systems are addressed, the relationship of various bus types with taxis can be advanced as well. As the number of taxis in comparison to the number of potential passengers is within acceptable ranges, their driving habits are the concerns that must be directly addressed. Due to the competing nature of buses and taxis, problems arose around the pickup and drop-off of passengers. Through the regulation of bus stops and bus counts, buses and taxis will compete less for areas to pull over. Furthermore, the location of where taxis may interact with passengers must be limited, as it was generally observed that these interactions caused direct threat to many other vehicles in the road and contributed to congestion as well.

As extensive congestion was observed around the entrances of the cross harbor tunnels, it was apparent that certain issues need to be addressed. While the Autotoll system is in place at all three tunnels, it is often far too over congested by drivers due to the limited number of Autotoll stations. This would frequently result in longer wait times as compared to the regular tolls during rush hours. One particular solution is the incorporation of "dual" tolls that would provide both auto-toll and regular payment options. As every toll lane would become congested during certain hours, the development of an overhead payment system would decrease wait times due to the lack of need to slow down for booth payment.

Another observed problem in relation to the harbor crossings was the location of a bus stop at the toll system on either side. This bus stop would be often crowded with far too many routes, resulting in a back-up that would affect lanes approaching the tolls. This extreme bus count would also interfere with the merge between the tolls and the tunnel entrance. Finally, an issue was found between the governing systems of the three tunnels. As only one of the three is owned by the Hong Kong government, two tunnels are unregulated and have cost far greater than the tolls for the government tunnel. This causes a surge of vehicle using the government owned Cross-Harbour tunnel, resulting in extensive congestion due to extreme over-capacity.

A number of individual problems accompany particular areas around the city. Through the distribution of our surveys and observations of the city, it was determined that Mong Kok, Causeway Bay, and Central had some of the most widespread congestion issues. While congestion is a problem in other areas of the city, this project has concentrated on these particular three. Through observations of these locations, limited traffic zones were established that contain particular transportation solutions that address problematic roadways. Observed issues include commercial vehicle usage, bus stop locations, taxi interferences, parking issues, and unregulated road usage.

Suggested facets of a limited traffic zone include the re-evaluation of the flow of buses through populated areas, the enforcement of parking bans, and the division of taxi pick-ups and bus stops. Potential policies also include the creation of time bans regarding commercial vehicle usage with loading/unloading, and the limitation of particular road usage through an electronic billing system. This billing system would address all vehicle types, but most importantly personal vehicles due to the fact that other suggestions do not influence them significantly. The billing system in particular is in the line of policies enacted by Singapore and Rome, where the government instituted an electronic toll system for the busiest parts of the city.

While each of these changes has the potential to induce a reduction of congestion and an improvement of air quality, one change alone will not entirely fix the problem. The use of multiple policies, including limited traffic zones, public transportation improvements, and electronic road pricing is exemplified in Rome, Italy. The usage of a combination of policies in Rome was successful, reducing congestion in their most trafficked areas. Each proposed recommendation in tandem will have a significant and lasting effect on reducing both congestion and roadside air pollution in the city. If only some of the solutions are attempted, the other observed sources of congestion will still have a significant negative impact on air quality.

Furthermore, in addition to initial enforcement, prolonged dedication to the measures would be required. A need for commitment to the changes proposed is a result of a likely aversion to change in the general populace. Taxi and commercial vehicle drivers may feel that their businesses are being infringed upon, private vehicle drivers may feel that their driving freedoms are being taken away, and pedestrians may be confused as to the new locations of bus stops. However, it is for those points that the problems regarding transportation arose originally, and public opinion will warm to policies that both reduce congestion and improve air quality. For the sake of the air quality and the greater welfare of the city as a whole, changes must be made that will require time to adjust.

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8. Appendices

Appendix A. About our sponsor

Friends of the Earth (Hong Kong) was established in 1983 as a charitable organization to "become an environmental leading advocate for a sustainable future." It is one of Hong Kong's "most prominent green groups." Their mission is to:

- Focus on and protect our environment locally and regionally
- Offer solutions to help create environmentally sustainable public policies, business practices and community lifestyles
- Engage governments, business and society

Friends of the Earth (Hong Kong) currently has more than 12,000 members and 51 participating corporate "Earth Partners". Friends of the Earth (Hong Kong)'s organization structure includes the Board of Governors and Staff Members (FoE, Organization Structure).

Dr. Vivian Wong	Chairperson
Prof. Carlos W. H. Lo	Vice-chairperson
Mrs. Astor Kam	Honorary Treasurer
Mrs. Karen Barretto	Honorary Secretary
Mrs. Mei Ng	Board Member
Mr. Daniel Cheng	Board Member
Mr. George Coombs	Board Member
Mr. Fred Ho	Board Member
Mr. Stanley Wong	Board Member
Dr. Howard Liu	Board Member
Ms. Jasminia Cheung	Board Member

Table 6: Friends of the Earth (Hong Kong)'s Board of Governors for 2013/2014 (FoE, Organization Structure)

Friends of the Earth (Hong Kong)'s initiatives are directed towards the focus of air, energy and climate, waste, and water. Their key approaches for clean air are (FoE, Air):

- Lobby the government to update the Air Quality Objectives to reflect modern air quality standards; and for a much faster phasing out of old polluting vehicles, enforce stringent air quality standards and do a proper environmental assessment on infrastructure projects so that the environmental costs can be determined and dealt with before the projects begin.
- Engage the public, and especially schools with our air pollution campaign to raise awareness of how air pollution harms young people and to urge the government to take action on this.

Their key approaches to promote energy efficiency and clean energy are (FoE, Energy & Climate):

- Lobby the government to offer demand side management solutions.
- Advocate for energy efficiency in buildings since they account for about 89% of the total electricity consumption in Hong Kong.
- Expose the hidden problem of light pollution which poses health threat to people, and increase public awareness of this issue.
- Engage the public, businesses, organizations and schools with our "Power Smart Contest" to promote the low carbon life style and business model.

Their key approaches to promote "full recycling" and avoid "zero landfilling" are (FoE, Waste):

- Lobby the Government to legislate on Producer Responsibility that obliges producers to shoulder their proportional environmental responsibility and this is exemplified by the taking back of used products and simplifying of packaging. We urge the Government to take on the measure of Waste Charging as an effective means to reduce overall solid waste.
- Engage the public and organizations through our Food Waste Campaign which prompted the private sector, such as supermarkets, to stop wasting food and distribute edible items to the needy.

Their key approaches to conserve water are (FoE, Water):

- We organize Plant a Tree, a regular tree planting project in the Jiangxi Province of China. In 2012, 15,000 trees were planted by volunteers from Jiangxi, Guangdong and Hong Kong

- In the villages surrounding the Dongjiang River source, we have on-the-ground programmes of building eco-toilets, distributing biogas, and ecological education for students and children.
- Sons of Dongjiang is a volunteer activity organized for the youth along the river in Hong Kong and the Guangdong province to reinforce partnership of upstream and downstream of the Dongjiang River. Volunteers can access a fund, "I Green Dongjiang", to carry out their actions that care for the Dongjiang. A Youth Summit for Water was set up by us to provide a platform for the exchange of ideas among the youth.
- We host the Green Pathfinder forum with keynote speakers from green groups, corporations and academics in the Pearl River Delta. They tour colleges and universities in the Guangdong province every year to address various issues related to environmental protection.

One of Friends of the Earth (Hong Kong)'s current campaigns for clean air is called "Take a Brake." This joint-initiative was started by Friends of the Earth (Hong Kong), World Wildlife Fund, and Green Power to encourage people to "drive less and adopt green driving habits." Another campaign, "Dim It", aims to reduce light nuisance and energy wastage. On the night of June 21, 2008, Friends of the Earth (Hong Kong) and more than 140 landmarks participated the first Asia lights-out night, with a focus to campaign for the reduction of light pollution. To promote the conservation of water, Friends of the Earth (Hong Kong) will host a hike called, "Water Challenge" on December 15, 2013. Funds raised from this event will be directed towards public education programs on water conservation and conservation projects along the Dongjiang water headstream.

The Interactive Qualifying Project team assisted the Friends of the Earth (Hong Kong) in researching the effects of transportation planning on air pollution and solutions to manage transportation to benefit the mission of the organization.

Appendix B. Potential Interview Questions

B.1. Potential Questions for Eddy Chang, Jockey Club Heavy Vehicle Emissions Testing and Research Centre

1) What types of vehicles are commonly tested in the heavy vehicle emission centre?

2) Which types of vehicles commonly have the largest pollutant emissions?

3) Are there significant differences between gas burning and diesel burning vehicles?

4) What do you think of pushing for stricter emission standards?

5) How often is each individual vehicle inspected?

6) Is there an incentive for low emission vehicles? if not, would having an incentive push for more people owning low emission vehicles?

7) What happens to a vehicle that does not pass the standard?

B.2. Potential Questions for Mobile Source Group, Environmental Protection Department

1) What are your thoughts on privately owned cross-harbor tunnels?

2) What are your thoughts on current air quality policy in Hong Kong?

3) Do you think that the current enforcement of air quality policy in Hong Kong is adequate?

4) Do you think that the current enforcement of transportation policy in Hong Kong is adequate?

5) What are the requirements for effectively proposing policy change?

6) How will the general public likely react to policies that work to reduce traffic congestion, especially policies that would rework bus routes?

7) How much of an impact does public opinion have on enacting policy changes?

Appendix C. Interview Notes

C.1. Interview with Wu Chai

- Hong Kong uses an Advisory Committee
  - Partly government officials
  - Just advise, no real say
  - Wu Chai only contacted for complaints
- Advised to email transportation department
- Wu Chai worked for Intelligent Transport System
  - Worked mainly in the construction process -> based on CS and ECE concepts
  - Info gathered by Poly U
    - Real time analysis
    - Created transport model to be reported back to DoT
  - Gives approximate amounts of travel time
    - avoid traffic jams
    - Choose new routes
    - Generally used in larger routes
- MTR only form of public transportation owned by government
- ITS not used by bus companies
  - No planning really
  - ~1000 Bus routes
  - 4 Big Bus companies privately owned
    - somewhat co-operate
- Unsure about taxi's
  - 3 types of taxis
    - 15200 red urban taxis
    - 2838 green new territories
    - 50 blue
  - Taxi number low compared to 8 million population
  - taxi licenses expensive
- Bicycle track interesting but not feasible
- Traffic laws
  - Drivers generally safe in HK
  - Police enforcement difficult
  - 15 marks on license lead to temporary suspension
    - 1st ?
    - 2nd ?
    - 3rd License terminated
  - Enforced by camera surveillance
    - operated by police
      - rule broken, photo taken
  - Current engine removal policies in place
    - Trade-in program and grants to encourage new engines

    - Feb 2014
    - Entire vehicles generally replaced over engines
- Economics up in 96, down in 2003, and back up now

C.2. Interview with Joey Pan

- Recommends attending a Transport Forum Meeting
- 3 Tunnels
  - Saves government money by subsidizing
    - Government pays into the tunnel for 20-25 years while a company runs it, then purchases it
    - Government doesn't need to worry about operation or staffing in early years of tunnel
- Congestion may shift to West tunnel if the toll drops
- Toll Booths
  - Very near to tunnel entrance
  - Sensors exist near booths to monitor number of cars in the tunnel
  - Environmental concerns can cause booths to shut down
  - There is not enough room in Hong Kong to make more space
  - Each Tunnel company sets the toll
- In the morning, electronic toll isn't congested, reverses for the afternoon
- Bus interchange system is useful
- Buses come very often
- 171 bus is widely used
- 117 has low demand
- Bus Company websites are a good resource
- Recommends to examine minibus system
- The routes of green-roofed minibuses are set by the government
  - Drivers are salaried
- Red-roofed minibus routes are set by driver
  - They have full control over their route to avoid wasting time
  - Always go to more populated areas
  - Money earned from fares goes straight to driver

C.3. Interview with Eddy Chang, Jockey Club Heavy Vehicle Emissions Testing and Research Centre

- Emission Testing Center
    - Opened a couple years ago
    - Certified last year
    - Set up via Donation/Charity
        - Jockey Club
            - From Royal Jockey Club (only government could gamble)
            - Jockey Club income goes to charity/organizations
            - Biggest contributor in HK
            - Children's Homes, Elderly Homes, etc.
    - Hong Kong government can't take direct action, too much interference
    - Had to move when university taken over
        - Tried to set up at Jung Gon Oh near Sai Com
            - Local council too dirty
            - Rejected proposal
- Government donates for day to day operation.
- All vehicles Right hand
- Emission measured to European standards
- Equipment
    - Mostly from England, some American, Some Austrian
    - 4 Testing areas
- US standards very varied from state to state
    - Cali very strict
- Hong Kong toughest standard in Asia
    - Euro 5
    - Trained people from Thailand/Malaysia
        - Euro1-2
    - Singapore Euro 4
- Hong Kong government invest heavily into pollution solutions
    - 10 Billion Environmental Fund
    - 3 Billion green testing
    - 15 Billion exchanging diesel
    - 30% subsidy for new vehicles
- Older Vehicles go to other countries though
    - Just moving problem
- Center is a Hong Kong government initiative
    - Teach vocational and research
    - No actual certifications given out
- Utilizing mobile emission collecting
    - American - Sensor Inc.
    - Austria AVL
    - Different types of collectors on different vehicles

        - Collecting for 3 years
        - Emission sensors and GPS for driving patterns
            - GPS from National Instruments
    - Vehicles recalibrated every month

- All researching after market devices
    - Filters, Catalytic converters, tail pipe additions, etc.
- Taxis and Light Buses LPG - not focus
- Test Taxi
    - 18 Simulations on taxi to measure emissions
    - Multiple twin parts - one working one not
        - fans, converters etc.
- For most part, not a visible PM problem in HK (already using clean gas)
    - Biggest issue NOx → Not visible
- Center is only for research and development - not an actual testing center
- Only 3 centers in HK
- People only get tickets if smoke visible really
- Utilize Dynamometer in testing centers and the Center
    - Loads up engine and connects to output
    - Can measure power
    - HV goes into Center
        - Loaded to different amounts
        - Throttled to different amounts
        - Measures smoke
        - Can be fooled
        - Doesn't account for habits - very set
- Transient Dynamometers more effective
    - can motor or absorb
    - sophisticated controller
    - Can load and simulate driving habits
        - Acceleration, deceleration, up-hill, down-hill, etc
    - 10x more expensive
- Euro scale
    - Startup
    - Urban <30 mph
    - Highway
- Center scale
    - 26 minute cycle
    - Variable
- Actually measures HC, NO2, NO, CO, CO2, and fuel consumption
    - no butane
- Georgia Tech
    - Remote Sensing via optical method
    - Opposed to direct sensing on exhaust
    - Laser scanning that determines chemical comp

    - Used in HK for last few years
    - Each tunnel has emission standards
    - American cannot use for legitimate means
        - Dispersion factor
- Desire to apply optical method to tunnel system
    - Closed environmental
    - Hope to prove statistically confidence
    - Used for Prosecution
        - Picture of license
    - "Approved" with follow up test
    - Collecting extensive data for have legislation pass
- Vehicle testing very secretive in most corporations
    - Needs more open facilities
    - Very expensive
- Double Decker Engine
    - Momentum and Torque
    - Alexander something motor
    - Only dynamometer engine cell in HK that size
    - Used by conservation society
        - researching fuel additives
    - Multiple Temperature controllers
        - Power Link
    - BG3
        - Measures PM
        - Costs 3 million
    - AVL
        - Fuel balance (very accurate)
    - PV=NRT
        - Temp very important factor
            - Fuel conditioning needed
    - Used Transient system for new cycles
        - Australian
        - Orange county
        - Manhattan
        - Custom Bus
        - Very easy to program new
    - Utilizes 45 minute cycle usually
- Toyota Diesel
    - Test biodiesel fuel usually
    - tests Diesel catalytic converters
    - Used small dynamometer
        - Only loads
        - No driving patterns
    - Engine Cell with steel bed
        - Very precise due to vibrations and misalignments

            - No driving cycle = less precautions needed
- Temp and Humid regulated in lab
- HV area
    - Fits largest vehicles in HK
        - Double decker
- Working with MIT, Germany, Heart Condition Units
- Rollers for testing
    - 48 inch diameter
    - Mustang Advanced Engineering (not very good)
    - Driving cycle on screen
        - Must be followed or failed
        - Robot used only in big corps
        - 26 minute cycle, 6 hour wait after fail
    - Analyzers fill bags, 1 per minute
- Desire reworked Annual inspections
    - Needs to be airtight to fight opposition
        - Hong Kong government not very powerful
        - Rich people
            - Ferrari guy going 104
    - Make people aware of proper maintenance
        - Poor maintained = 5 times more pollution
- Receiving new equipment from Hong Kong government
    - optical testers
    - Going to follow with extensive testing with all imaginable factors
    - Used for education
        - People and Vehicle repairers
- No public events, mainly commercial
    - Diesel main problem

C.4. Interview with Environmental Protection Department

- Roadside stations
    - PM10 42% PM2.5 31%
    - PM2.5 - monitored by 5 stations (4 general, 1 roadside)

    - Summer monsoon: winds from Pacific Ocean
    - Winter monsoon: winds from China

    - Clean Air Plan (Mar. 2013)
    - To achieve new AQOs by 2020
    - Broadly comparable to US, EU
    - Review every 5 years

    - Currently on Euro II, Euro III
    - Change to Euro V
    - Tax incentives for hybrid/electric vehicles
    - Subsidized trial of hybrid bus and electric bus
    - 300 million Pilot Green Transport Fund
    - 82,000 diesel commercial vehicles
    - Endorsed set of emission reduction plan by 2020
    - Emission reduction targets

    - Roadside station analysis
    - US EPA standards
    - Automatic calibration controller

    - Early retirement system
    - Phasing out DCE program
    - Incentive payment $1.5 billion (US)
    - 15 years for old vehicle
    - Into effect March 2014

    - Catalytic converters
    - LPG, petrol vehicles
    - Private, taxi, light bus
    - Emission test
    - Subsidized owners
    - Remote sensor to filter
    - Once caught, have to replace vehicle or license cancel

    - NOx increase
    - malfunction of catalytic converter

    - LPG -> butane -> ozone => NOx

- Low priority - policy
    - Bus rationalization, LEZ

- Transport department - meet w/ district council

- Encourage public opinion

- LEZ (phase 1) - only LE bus pass busy corridors (2015) Euro IV +

- EPD - public education programs
    - tightening LPG and Petrol

- Idling Law - not so much relieve air pollution
    - reduce nuisance on road

- Electric vehicle
    - charged by coal factories

- Wind Turbines
    - On Lamma Island
    - Power plant

Appendix D. Pedestrian Survey

D.1. Survey in English and Traditional Chinese

Age/年齡: ______

Gender/性別: (選一)　　男/M　　女/F

1) 香港存在空氣污染問題
Air pollution is a problem in Hong Kong.

非常不同意 Strongly Disagree	**1**	**2**	**3**	**4**	**5**	非常同意 Strongly Agree

2) 香港部分地區的污染問題比其他地區嚴重
Certain areas in Hong Kong have more air pollution than others.

非常不同意 Strongly Disagree	**1**	**2**	**3**	**4**	**5**	非常同意 Strongly Agree

3) 機動車是造成污染的原因
Vehicles cause pollution.

正確 不正確
True　　False

4) 你每天通勤使用的主要交通工具是什麼?
What is your primary mode of transport for your daily commute?

地鐵 MTR	公共汽車 Public Bus	私家車 Private Vehicles

5) 你每天通勤所需時間是多少?
How much time is spent in your daily commute?

6) 請列出兩個機動車交通量高的地區。
List two areas that have high vehicle traffic.

Appendix E. Survey Responses

Age	Gender	Air pollution is a problem	Certain areas in HK have more pollution	Vehicles cause pollution	Primary mode of transport	Time in daily commute (in hours)	Mong Kok	Causeway Bay	Central	TST	Other
18	M	4	5	T	Public bus	0.75			X	X	
18	F	4	4	T	Public bus	4.00		X	X		
18	M	4	5	F	MTR	1.50					
18	F	3	4	T	MTR	1.00					
18	M	5	4	T	MTR	2.00	X	X			
18	M	5	4	T	MTR	1.00	X	X			
18	M	5	5	F	Walking	0.50	X	X			
18	F	3	3	T	Public Bus	3.00	X	X			
18	F	4	4	T	Public Bus	0.75				X	Kowloon Tong
18	F	5	4	T	MTR	2.50			X		Tseun Wan
18	F	5	5	T	MTR	2.00	X	X			
18	M	3	3	T	MTR	0.50	X	X			
18	M	4	4	T	MTR	0.75		X			Hung Hom
18	M	5	5	T	MTR	2.00		X			Hung Hom
18	M	4	5	F	Private						
18	M	4	4	T	Public Bus	5.00				X	Admiralty
18	M	4	5	T	MTR						
18	F	4	4	F	MTR	2.00	X	X			
18	F	5	5	T	Public Bus	2.50	X			X	
18	F	5	5	T	MTR	1.00					Tseun Wan, Sha TIn
18	F	4	3	T	Public Bus	0.50					
18	F	3	2	T	Public Bus						
18	M	5	3	T	Public Bus	2.00		X		X	
18	M	4	4	T	MTR	3.00		X			Hung Hom
18	M	4	3	T	MTR	2.00		X		X	
18	F	4	3	F	Public Bus	don't live here					bu zhi dao
18	F	4	3	T	MTR						
18		3	4	F	Public Bus	0.25	X			X	
18	F	4	4	T	MTR	0.75					
18	M	4	2	T	MTR	0.50	X	X			
18	M	4	4	T	MTR	2.00	X	X			
18	F	3	1	T	Private Vehicle	2.00		X			
18	F	3	4	T	Public Bus	3.00	X	X			
18	F	2	3	T	MTR	5.00	X				Shatin
18	F	3	4	F	MTR	0.75	X			X	
18	F	5	2	T	Public Bus	3.00		X			Hung Hom
18	M	4	4	T	MTR	4.00	X			X	
18	M	3	3	T	MTR	0.75					I don't know
18	F	3	5	T	MTR	3.00		X		X	
18	F	4	2	T	MTR	0.50	X		X		
18	F	4	4	T	MTR	0.50	X	X			

18	F	5	4	T	MTR	3.50		X			Hung Hom
18	F	4	4	T	Public Bus	2.00	X			X	
18		4	4	F	MTR	7.00	X	X			
18	F	5	4	T	MTR	5hr	X			X	
18	F	5	3	T	MTR	4hr	X	X			
18	M	4	4	T	MTR	2hr	X	X			
18	M	4	2	T	MTR	0.5hr	X	X			
19	M	5	4	T	MTR	1.00	X	X			
19	M	5	5	T	MTR	1.00	X	X			
19	M	5	4	F	MTR	3.00	X				Wan Chai
19	F	4	3	T	Private	2.00	X	X			
19	F	4	3	T	MTR	2.50	X	X			
19	F	4	5	T	Public Bus	2.00	X		X		
19	F	4	3	T	Private	0.50	X				
19	F	4	4	T	MTR	0.50	X			X	
19	M	4	3	T	MTR	2.00	X	X			
19	M	4	4	T	MTR	0.50	X			X	
19	M	4	4	T	Public Bus	8.00	X	X			
19	M	4	5	T	MTR	4.00				X	Admiralty
19	M	5	3	T	MTR, Public Bus	1.00		X			Hung Hom
19	F	4	4	T	MTR	0.50	X	X			
19	M	4	4	T	MTR	2.00	X	X			
19	F	4	4	T	MTR						
19	F	3	2	T	Public Bus	0.25	X	X			
19	M	4	4	T	Public Bus	0.75	X	X			
19	F	5	4	F	Public Bus	4.50	X				Admiralty
19	F	4	5	T	MTR	1.00	X	X			
19	F	4	5	T	MTR	3.00			X		Tseun Wan
19	M	3	5	T	Private Vehicle	0.50					
19	F	4	4	T	Public Bus	0.25					
19	F	3	3	T	Public Bus	5.00	X				Admiralty
19	F	5	5	T	Public Bus	4.00					
19	F	1	1	F	MTR	everyday	X		X		
19	F	5	5	T	MTR	4.50		X			Hung Hom
19	M	3	5	F	MTR	4.00	X	X			
19	F	4	2	T	MTR	1.00					Bus, Taxi
19	F	4	2	T	Public Bus	3.00					Kowloon Tong, Wan Chai
19	F	4	4	T	MTR	4.00	X	X			
19	M	3	5	T	MTR	1.50		X	X		
19	F	5	2	T	MTR	1.50		X			Admiralty
19	F	4	1	T	MTR						
19	M	3	1	T	Public Bus	0.50	X		X		
19	M	4	3	T	MTR	3.00	X	X			
19	F	4	2	T	Public Bus	0.75		X	X		
19	F	5	4	T	MTR	2.00	X	X			
19	F	4	4	F	MTR	2.00					
19	F	5	5	T	Public Bus	1.50	X	X			
19	M	5	5	T	Public Bus	2.00	X	X			
19	F	4	5	T	MTR						

19	F	4	4	T	MTR						
20	M	3	1	T	Public bus	3.00	X			X	
20		5	5	T	MTR	8.00	X			X	
20	F	5	4	T	MTR	1.00	X	X			
20		5	5	T	Public bus	0.75		X			
20	M	4	3	T	Public Bus	1.00				X	Wan Chai
20	F	4	4	T	MTR	2.00					
20	M	2	5	T	Public Bus						
20	F	5	4	T	MTR	2.00	X			X	
20	M	5	5	T	MTR	1.00	X		X		
20	F	4	3	T	MTR	1.00					
20	F	5	5	T	Public Bus	0.50	X	X			
20	M	4	4	T	MTR	2.00	X				Kowloon Tong
20	F	5	5	T	MTR	0.02			X	X	
20	M	4	4	T	MTR	1.50	X	X			
20	F	4	4	T	Private						
20	F	4	4	T	Private			X			
20	F	5	4	T	MTR	0.50	X	X			
20	F	1	5	T	MTR	1.00	X		X		
20	M	4	3	T	MTR	2.00	X	X			
20	F	3	3	T	Public Bus	2.50					
20		5	4	T	MTR	1.50	X	X			
20	F	4	5	T	MTR	0.50		X			Wan Chai
20	F	5	5	T	Public Bus	2.00			X		Wan Chai
20	F	5	5	T	Public Bus						
20	F	4	2	T	Public Bus	4.00	X		X		
20	F	5	5	T	MTR	2.00		X			Hung Hom
20	F	4	5	T	MTR	2.00	X	X			
20	M	3	2	T	Public Bus						
20	F	5	3	T	Public Bus	5.00					
20	F	3	4	T	MTR						
20	F	4	4	F	Public Bus	4.00	X		X		
20	F	4	4	T	Public Bus	2.00					
20	F	4	4	T	MTR	0.75		X	X		
20	M	4	2	F	MTR	2.00	X	X			
20	M	4	4	T	Public Bus	1.00		X			Wan Chai
20	F	5	3	T	Public Bus	1.50			X	X	
20	F	3	2	F	MTR	0.75			X	X	
20		4	4	T	MTR	1.00			X		Hong Kong
20	M	5	5	T	Public Bus	1.50		X	X		
20		5	4	T	MTR	0.67				X	Cross-Harbor Tunnel
20	M	3	2	T	Public Bus	1.00				X	Kowloon
20	F	5	5	T	MTR	1.00		X	X		
21	F	5	2	T	Public bus	0.50			X	X	
21	M	5	4	T	MTR	3.00	X	X			
21	F	4	4	T	Public bus	1.50	X	X			
21	F	4	5	T	Public bus	1.00	X	X			
21	F	5	5	T	Public Bus	2.00		X		X	
21	M	3	4	F	MTR						

21	M	5	5	F	MTR	0.75	X	X			
21	F	5	4	T	MTR	1.50		X	X		
21	M	4	4	T	Public Bus	1.00					Wan Chai
21	M	4	5	T	MTR	6.00					MTR bus
21	M	3	5	T	Public Bus	5.00		X	X		
21	M	5	3	T	Public Bus	0.50			X		Admiralty
21	F	5	5	F	MTR	1.00	X		X		
21	F	5	5	T	MTR	0.50					
21	F	4	4	T	Public Bus	3.00	X		X		
21	F	3	4	F	MTR	0.75	X	X			
21	M	4	5	T	MTR	1.00					Tseun Wan, Jordan
21	M	3	2	T	Public Bus	3.00					
21	M	3	3	T	MTR	0.25	X	X			
21	M	2	1	F	Private						
21	M	2	5	T	MTR	0.25	X	X			
21	F	1	2	T	Public Bus						
21	M	3	4	F	Private	0.75					
21	M	3	4	F	MTR						
21	F	4	5	T	Public Bus	0.25		X		X	
21	F	5	5	T	MTR						
21	F	5	5	T	Public Bus	0.75					
21	M	5	4	T	MTR						
21	F	5	4	T	Public Bus	2.00	X	X			
21	F	4	3	F	Public Bus						
21	F	4	5	T	MTR	everyday	X		X		
21		5	5	T	Public Bus	6.00	X		X		
21	M	3	2	T	Public Bus	2.50	X	X			
21	M	4	2	T	Public Bus	4.00		X	X		
21		3	5	T	Public Bus	3.00	X	X			
21		5	5	T	Public Bus	6.00	X		X		
21	F	5	4	T	Public Bus	0.50	X	X			
21	M	5	5	T	MTR	1hr	MK X	CWB	C	TST	Wan Chai
21	F	4	2	T	Public Bus						
21	F	3	3	T	Public Bus						
22	F	5	4	T	MTR	3.00	X	X			
22	M	4	5	T	MTR	8.00	X	X			
22	M	5	4	T	MTR	2.00	X	X			
22	F	5	5	T	Public bus	4.00	X	X			
22	M	2	4	T	MTR	0.25	X		X		
22	F	5	5	F	MTR	1.50	X				Tsuen Wan
22	M	5	5	T	MTR	3.00	X				Tai koo
22	M	5	5	T	Private	0.50					
22	F	4	4	T	Private	6.00					
22	F	5	5	T	MTR	1.00	X			X	
22	M	5	3	T	MTR	0.25		X	X		
22	F	4	4	T	MTR	3.00	X	X			
22	F	4	5	T	MTR	I don't live here					I don't know
22	F	4	2	T	MTR	0.50	X				Tai Koo
22	M	4	4	T	MTR	3.00		X			Hung Hom
22	M	5	5	T	Public Bus	1.00	X	X			

22	M	4	3	T	Public Bus	8.00	X	X			
22	F	4	4	T	MTR	1.50	X	X			
22	F	3	4	T	MTR	2.50	X	X			
22	F	4	4	T	Public Bus	1.00		X		X	
22	M	4	4	T	MTR	1.00					
22		5	4	F	MTR	2.00	X			X	
22	M	5	5	T	Public Bus	1.00	X	X			
22	F	3	1	T	Private Vehicle	0.50					
22	M	4	3	T	MTR	0.80		X		X	
23	F	5	5	T	MTR	3.00	X				Admiralty
23	M	5	2	T	MTR	4.00					
23	F	5	5	T	MTR	1.00	X		X		
23	M	5	5	T	Public bus	0.50	X	X			
23	F	5	5	T	Public bus	2.00		X		X	
23	M	5	4	T	MTR	0.50	X				Kowloon Tong
23		4	4	T	MTR	1.00	X			X	
23		4	4	T	Public Bus	8.00		X	X		
23	M	5	5	T	MTR	3.00	X	X			
23	M	3	3	T	MTR	4.00		X	X		
23	F	3	4	T	Public Bus	0.25		X	X		
23	F	5	2	T	Public Bus	1.00					
23	F	3	4	T	MTR	3.00	X				Prince Edward
23	F	5	3	F	Private	4.00			X		Prince Edward
23	F	3	4	T	MTR	2.00					Centre
23	M	3	3	F	MTR	10.00		X	X		
23	F	4	3	T	Public Bus						
23	F	4	5	T	MTR	1.00					
23	F	3	4	F	MTR						
23	M	4	2	T	Public Bus						
23	M	5	2	F	Public Bus	0.75		X			Admiralty
23	M	5	3	T	MTR	4.00	X	X			
23	M	5	5	F	Public Bus	2.00				X	Hung Hom Tunnel
23	M	4	3	T	MTR	2.00					
24	M	4	3	T	MTR	2.00	X	X			
24	M	3	2	T	MTR	1.50	X	X		X	
24	F	4	4	T	MTR	1.00					
24	F	4	3	T	MTR	3.00	X		X		
24	F	5	5	T	MTR	0.50	X			X	
24	F	4	1	F	MTR	8.00	X				Admiralty
24	F	5	5	T	Public Bus	1.00	X	X			
24	M	5	5	T	MTR	0.75		X		X	
24	F	5	3	T	Private	0.50					
24	M	5	3	T	MTR	1.00	X	X			
24	F	5	4	T	MTR	1.00		X	X		
24	F	1	2	T	MTR						
24	F	1	2	T	MTR						
24	F	4	5	T	MTR	0.25	X	X			
24	F	3	3	T	MTR	5.00		X		X	

24	M	4	2	F	MTR	0.75				X	Sheung Wan
24	F	3	4	F	Private	0.75					
24	F	2	4	T	Public Bus						
24	F	4	5	T	MTR						
24	F	4	5	F	Private						
24	F	4	5	T	MTR						
24	F	5	5	T	Public Bus	3.00	X	X			
24	F	3	3	T	Public Bus	1.00	X	X			
24	F	4	4	T	MTR						
24	F	4	4	T	MTR						
24	F	4	2	T	MTR	0.50					
24	M	3	3	T	MTR	4.00					Hung Hom, Kowloon
24	M	3	3	T	Public Bus	2.00	X	X			
24	M	5	5	T	MTR	3.00	X	X			
24	F	5	3	T	MTR	0.50					Wan Chai
24	M	4	4	T	Private Vehicle	8.00		X			
24	M	4	4	T	MTR	1.00	X			X	
24	M	2	1	F	Private Vehicle	2.00					Tunnel, Bus Stop
25	M	4	5	T	MTR	4.00					
25	M	5	5	T	MTR	1.00	X	X			
25		4	5	T	MTR	8.00		X			Admiralty
25	M	4	2	T	MTR	2.00	X			X	
25		3	3	T	Public bus	8.00			X		Kowloon
25	F	5	4	T	MTR	4.00	X	X			
25	M	4	2	T	MTR	3.00	X		X		
25	M	5	5	T	Public Bus	8.00	X				
25	F	4	3	T	MTR						
25	M	2	3	T	MTR	3.00	X			X	
25	M	4	4	T	Public Bus	1.00					Sheung Wan, Wong Tai Sin
25	F	4	3	T	Public Bus						
25	M	4	5	F	Public Bus	2.00					
25	M	4	4	T	MTR	0.25	X				Admiralty
25	M	3	4	F	Public Bus						
25	F	4	3	T	MTR	0.50	X			X	
25	M	2	3	T	Public Bus	1.00		X			Yuen Long
25	F	4	4	T	MTR						
25	F	4	4	T	MTR						
25	F	3	5	T	MTR	0.25	X		X		
25	M	5	5	T	MTR						
25	F	4	3	F	MTR						
25	M	4	5	F	MTR						
25	M	2	1	T	MTR	0.75					
25	M	4	1	T	Public Bus	6.00		X			Admiralty
25	F	2	2	T	MTR	1.00	X	X			
25	F	4	4	T	Public Bus	8.00					
26	M	3	2	T	MTR	1.00					
26	M	3	4	T	MTR	2.00	X			X	
26	M	4	4	T	MTR	0.75	X				Admiralty

26	M	3	3	T	MTR						
26	M	5	5	F	Public Bus	0.75	X	X			
26	F	5	5	T	Public Bus	1.00		X		X	
26	M	4	3	F	MTR	1.00				X	North Point
26	M	4	5	T	MTR	3.00		X		X	
26	M	2	4	T	Public Bus	0.25		X	X		
26	F	4	4	T	MTR	10.00					
26	M	4	5	T	Public Bus	2.00	X	X			
26	F	5	5	T	Public Bus	0.25			X		Hung Hom Tunnel
26	M	4	2	T	MTR	0.50	X	X			
27	M	4	3	T	MTR	2.00	X	X			
27	F	4	3	T	MTR	1.00	X	X			
27	M	4	4	T	Public bus	0.10				X	Wan Chai
27	M	5	5	T	Public Bus	0.25					
27	F	2	2	F	MTR	0.50	X				Wan Chai
27	F	2	2	F	MTR	0.50	X				Wan Chai
27	F	4	1	T	Public Bus	2.00	X	X			
27	F	3	2	T	MTR						
27	M	3	4	F	Public Bus	8.00					
27	M	3	3	F	MTR	1.00				X	Kowloon
27	F	2	2	T	MTR, Public Bus	1.00					None
27	M	4	4	T	Public Bus	1.00	X	X			
27	M	4	5	T	MTR						
27	M	4	5	T	MTR						
27	M	4	4	T	Public Bus	1.00		X		X	
27	M	5	1	F	Private Vehicle	0.25					
27	F	4	2	F	MTR						
27	M	4	3	T	MTR	4.00		X			Admiralty
28	M	5	5	T	MTR	3.00	X		X		
28	F	4	4	T	MTR	0.50	X	X			
28	F	4	4	T	Public bus	8.00	X	X			
28	M	4	3	T	MTR	0.50	X		X		
28	M	4	5	T	MTR	3.00	X		X		
28	M	2	2	T	Public Bus	10.00					
28	F	4	5	T	MTR						
28	F	4	3	T	Private	1.00					Airport, Bus stop
28	M	5	1	T	MTR, Public Bus	2.00					Beijing, Shanghai
28	M	5	3	F	MTR	1.00	X	X			
28	M	1	1	T	MTR	1.00					
28	M	4	5	T	MTR						
28	M	5	5	T	Private Vehicle	0.25			X		Central Cross Harbour Tunnel
28	M	3	2	T	Public Bus	0.25					
28	M	3	2	T	MTR	0.50			X	X	
28		2	5	T	Public Bus	1.00				X	
28	M	5	2	T	MTR						
28	M	5	5	T	Private Vehicle	0.25			X		Cross Harbour

											Tunnel
28	M	3	3	T	MTR	0.50	X	X			
28	M	5	4	T	MTR	8.00	X	X			
29	M	3	5	T	Public Bus						
29	M	2	2	F	MTR	0.75			X		Kowloon
29	F	4	4	T	MTR	8.00	X			X	
30	F	5	5	F	MTR	2.00		X			Tsuen Wan
30	F	4	5	T	MTR	1.50	X			X	
30	F	4	4	F	MTR	4.00		X		X	
30		5	5	T	MTR	1.00	X				
30	F	4	5	T	Public Bus	5.00		X		X	
30	M	2	5	T	MTR	1.00	X		X		
30	F	4	3	F	Private						
30	F	3	2								
30	M	5	3	T	Public Bus						
30	M	2	3	T	MTR	1.00		X			Quarry Bay
30	M	2	2	F	Private Vehicle						
30	M	3	1	T	MTR	0.50		X		X	
30	M	3	3	T	Public Bus	4.00			X		Admiralty
30	M	4	4	T	MTR						
30	F	4	5	T	MTR	3.00	X	X			
31	F	4	2	T	MTR	4.00	X				
31	F	5	3	T	MTR	1.00	X	X			
31	F	5	4	T	Public Bus	Everyday	X	X			Sham Shui Po
31	F	5	5	T	Public Bus	4.00		X	X		
31	F	4	3	T	MTR	4.00	X		X		
31	M	3	2	F	Public Bus	0.50	X	X			
31	F	4	4	T	MTR						
31	F	4	2	T	MTR	4.00	X	X			
31	M	3	3	T	MTR	4.00	X				Tsuen Wan
31	F	4	4	T	MTR	0.50					
32	M	5	5	T	Public Bus	0.50					
32	M	4	5	T	Public Bus	4.00					
32	M	4	4	F	MTR						
32	M	2	2	T	MTR	1.00			X	X	
33	F	2	2	T	MTR	0.50			X		
33	M	5	3	F	Private	1.00		X	X		
33	M	5	4	T	MTR	3.00	X	X			
33	M	4	2	F	Public Bus						
33	M	2	4	F	Public Bus	1.00		X	X		
33	M	5	5	F	MTR	8.00	X	X			
33	M	2	1	T	MTR	1.00		X	X		
34	M	5	5	T	MTR						
34	M	5	5	T	MTR	0.25					
34	F	3	4	T	MTR	1.00					
35	M	5	4	T	MTR	1.00	X		X		
35	M	5	1	T	Public bus	8.00	X	X			
35	M	4	5	T	MTR	2.00		X		X	
35	F	4	5	T	Public Bus	0.50	X	X			
35	M	5	5	F	Private	1.00	X			X	

35	F	5	5	T	Public Bus	2.50	X				
35	F	4	3	F	MTR	0.50	X				
35	M	5	4	F	Public Bus	0.75	X	X			
35	M	1	4	F	MTR	0.75	X			X	
35	M	4	2	T	MTR	2.00		X	X		
36	F	2	3	T	MTR	0.50					Sham Shui Po
36	F	4	4	T	Public Bus	2.00		X	X		
36	F	5	5	T	MTR	3.00					Buses, private car
37	F	5	4	T	MTR	0.75		X	X		
38	M	3	4	T	MTR	4.00			X		
38	M	1	1	T	MTR	1.00	X	X			
38	M	1	1	T	MTR, Public Bus	1hr	X	X			
39	M	4	2	T	Public bus	2.00					
40	F	5	3	T	MTR	3.00	X	X			
40	M	2	4	T	Public bus	1.00		X			Wan Chai
40	F	3	5	T	Public bus	1.00					Bus, MTR
40	M	3	1	T	MTR	0.25		X	X		
40	M	5	5	T	MTR	8.00				X	
40	F	4	4	T	MTR	1.00		X	X		
40	F	5	4	T	Public Bus	1.00					
40	M	2	2	F	MTR	0.50		X			
40	M	3	4	F	MTR	0.75		X			North Point
41	F	5	2	T	MTR	0.25	X				Admiralty
42		4	5	T	MTR	2.00	X	X			
42	F	4	5	T	Public Bus	8.00					Bus
42	F	4	3	T	MTR	0.50		X	X		
43	M	3	5		MTR						
43	M	2	3	T	MTR	3.00		X			
44		1	1	T	Public bus	4.00			X		Wan Chai
44		1	5	T	Public bus	3.00		X	X		
44	M	4	4	T	Public Bus	1.00					Bus and Taxi
44	M	4	4	T	Public Bus	1hr					Bus, Taxi
45	M	5	5	T	Private	0.75	X	X			
45	M	3	2	T	Public Bus	2.00					Bus Stations
45	M	4	1	T	Private Vehicle	0.75					Beijing and Shanghai
45	M	1	1	F	Private Vehicle	2.50		X	X		
45	M	4	1	T	Private Vehicle	50min					Beijing, Shanghai
46	F	5	3	T	MTR	4.00					Kowloon, N.T.
47	F	5	3	T	MTR	2.00	X		X		
47	M	5	4	T	MTR	0.75	X	X			
47	M	5	4	T	MTR	0.75	X	X			
49	M	5	5	F	Public bus	0.50	X	X			
50	M	5	5	T	Ferry	1.00		X		X	
50	M	5	4	T	MTR	0.50					
50	M	3	5	T	Public Bus	1.50	X	X			
50	F	5	5	T	Public Bus	1.00	X	X			

50	F	5	5	T	MTR						Bus and private vehicles
50		4	4	T	Public Bus	2.00	X				
50	F	5	5	T	Public Bus	1.00	X	X			
50	M	3	5	T	Public Bus	1.50	X	X			
50	F	5	5	T	MTR						
50	M	5	3	T	MTR	0.50	X	X			
51	F	5	5	T	MTR	1.00		X	X		
53	F	5	5	T	MTR	2.00	X			X	
53	M	5	5	T	Public bus	0.50					Hung Hom Tunnel
53		5	3	T	MTR	0.25	X	X			
53	M	4	4	T	Public Bus	2.00	X			X	
53	M	4	4	T	Public Bus	2.00	X			X	
55	M	4	5	T	MTR	2.00					Wan Chai, Cheung Sha Wan
55		3	1	T	Public Bus	3.00		X	X		
56	M	5	5	T	Ferry	0.50		X	X		
57	M	2	2	T	MTR	1.25	X	X			
57		5	5	T	MTR	1.50	X				Admiralty
57	M	5	5	T	Public Bus						
58	M	3	1	T	MTR	1.00		X			Wan Chai - Gloucester Rd
60	F	3	3	F	MTR	3.00		X		X	
60	M	5	5	T	Public bus	0.50		X	X		
60	F	3	4	T	Public Bus						
60	M	5	5	T	Walking	2.00					
60	M	5	4	F	Public Bus	2.00					Cross Harbor Tunnel, Nathan Road
60	M	5	3	T	Public Bus	1.00	X	X			
60	F	4	4	T	Public Bus	0.50	X				Chun Mun
60	F	4	4	T	Public Bus	0.50	X				Chu Mun
61	M	5	5	T	Public Bus	0.50	X	X			
62	M	1	1	T	Public Bus						
62	M	5	5	F	walking	0.75	X	X			
63	F	4	2	T	MTR	1.00		X	X		
63	M	3	3	F	Public bus	2.00		X	X		
64	M	4	4	T	Public bus	1.00	X	X			
64	M	3	4	T	Public Bus	1.00	X	X			
65	F	5	4	T	MTR	1.00			X		Wan Chai
65		5	5	T	MTR	3.00		X	X		
65	M	4	4	T	MTR			X		X	
65		5	5	T	Public bus	2.00				X	Airport
66	M	5	5	T	MTR			X		X	
67	M	3	4	F	MTR	1.00	X	X			
69	M	4	3	T	Private	0.50		X			Yau Ma Ti
69		2	2	F	MTR	0.50					
72	M	4	4	T	MTR	1.00	X	X			
72	M	5	5	T	MTR	2.00	X	X			

73	F	3	2	T	MTR						
74	M	1	3	T	MTR	2.00	X		X		
76	M	5	5	T	Ferry			X	X		
77	F	1	2	T	MTR	5.00	X			X	
80	F	5	5	T	Public bus	1.00	X	X			
80	F	5	4	T	Public Bus	1.00	X	X			
N*	M	4	3	T	MTR	3.00		X	X		
N*	F	4	4	T	MTR	1.50					
N*	F	4	4	T	Public bus	0.50					
N*	M	4	3	T	MTR	4.00	X				
N*	F	5	5	T	Public bus	2.00	X	X			
N*	F	5	4	T	Public bus	6.00	X	X			
N*		4	4	T	MTR	3.00					Bus Station
N*		4	4	T	Private	1.50	X	X			
N*		5	5	F	Public bus	8.00					
N*	F	2	5	F	MTR	2.00					
N*		5	5	T	MTR				X		Kowloon
N*		5	5	T	Public bus						Bus, MTR
N*		3	4	T	MTR	2.00				X	
N*	F	3	3	T	MTR	3.00				X	
N*	M	2	2	T	Public Bus	0.50	X	X			
N*	M	4	5	T	Private	4.00					
N*	F	4	3	T	Public Bus	1.00			X		Wan Chai
N*	M	5	5	T	MTR	2.00		X	X		
N*	F	5	3	T	MTR	1.00			X		Kowloon
N*	F	2	5	F	Private Vehicle	1.00					
N*	F	4	2	T	Public Bus	5.00					Shatin, Lo Wu
N*		4	5	T	MTR	2.00		X		X	
N*		4	5	T	MTR	1-2hr	X	X			
N*	F	4	3	T	MTR	3.00	X		X		
N*	F	2	5	F		2.00					

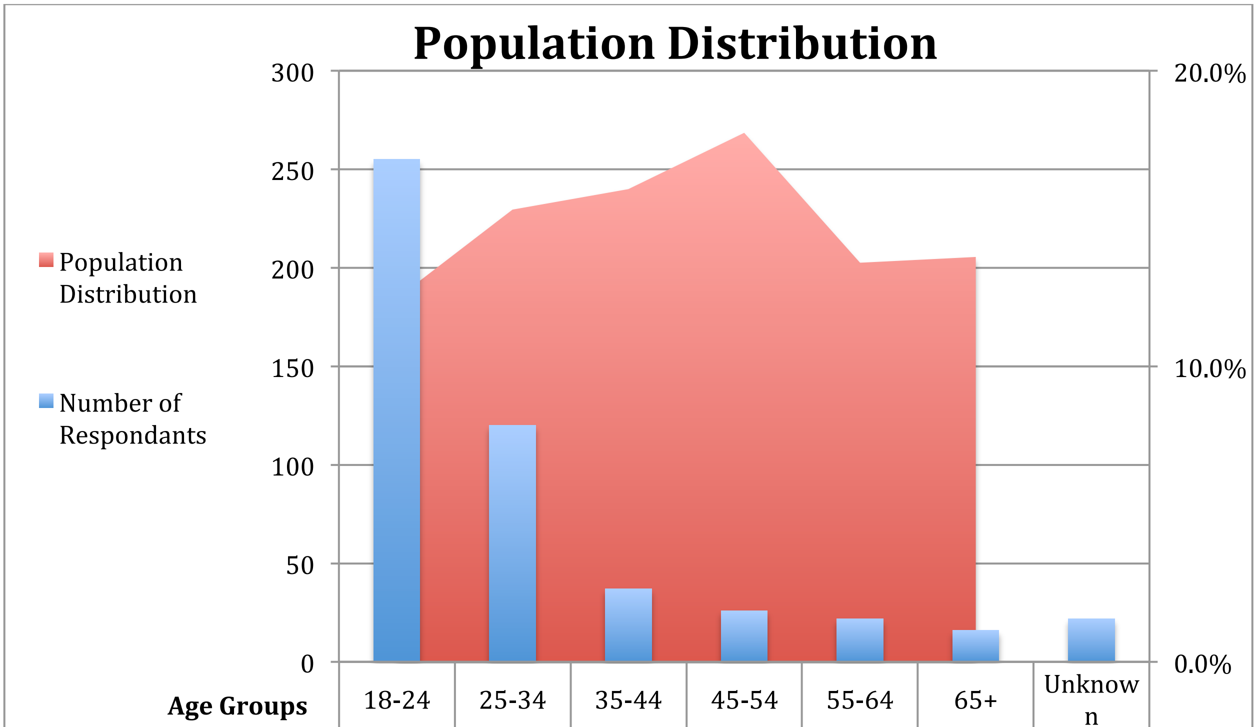
Note: N* = unknown

E.1. Combined data responses for survey responses

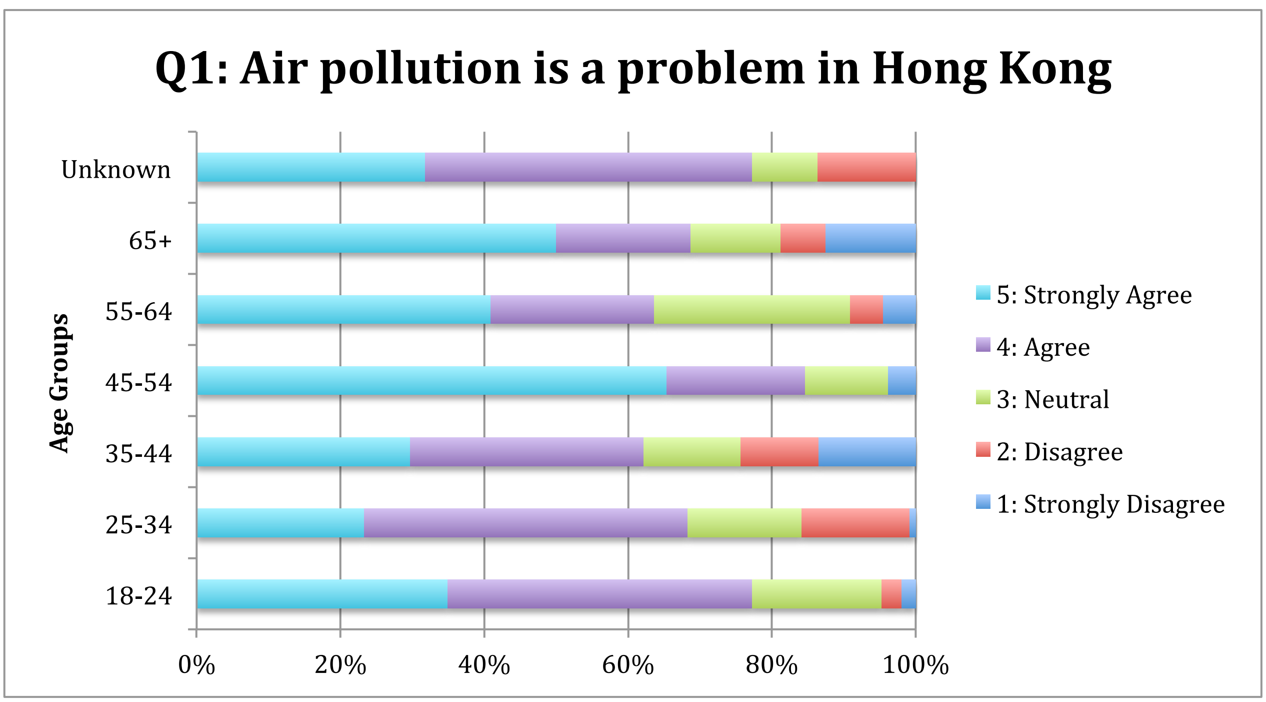
Age	Number of Respondents	Population Distribution	Population	Weight	Q. 1	Q. 2	Q.3 (True)	Q. 3 (False)	Q. 4 (MTR)	Q. 4 (Bus)	Q. 4 (Car)	Commute time
18-24	255	12.3%	12.3	0.048	4.1	3.8	219	36	150	85	5	2.12
25-34	120	15.3%	15.3	0.128	3.8	3.5	95	24	75	35	4	2.39
35-44	37	16.0%	16	0.432	3.5	3.5	30	6	21	14	0	2.01
45-54	26	17.9%	17.9	0.688	4.4	3.9	24	2	11	10	3	1.32
55-64	22	13.5%	13.5	0.614	3.9	3.6	18	4	6	13	0	1.32
65+	16	13.7%	13.7	0.856	3.9	3.9	14	2	11	3	0	1.67
Unknown	22				4.0	4.1	19	3	10	8	1	2.58

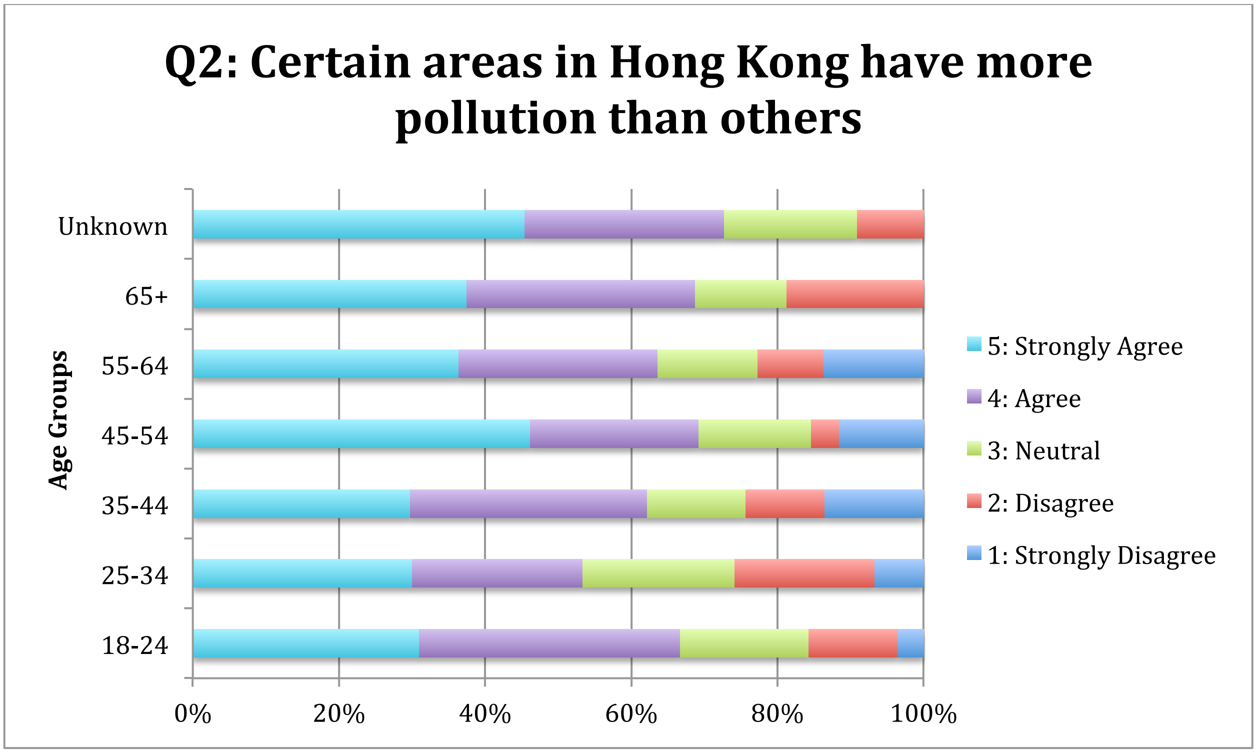
Age	Mong Kok	Causeway Bay	Central	TST	Other
18-24	119	115	42	40	194
25-34	43	39	21	18	119
35-44	13	19	10	4	28
45-54	15	13	3	4	17
55-64	9	13	5	1	16
65+	7	10	4	4	7
Unknown	6	7	4	3	24

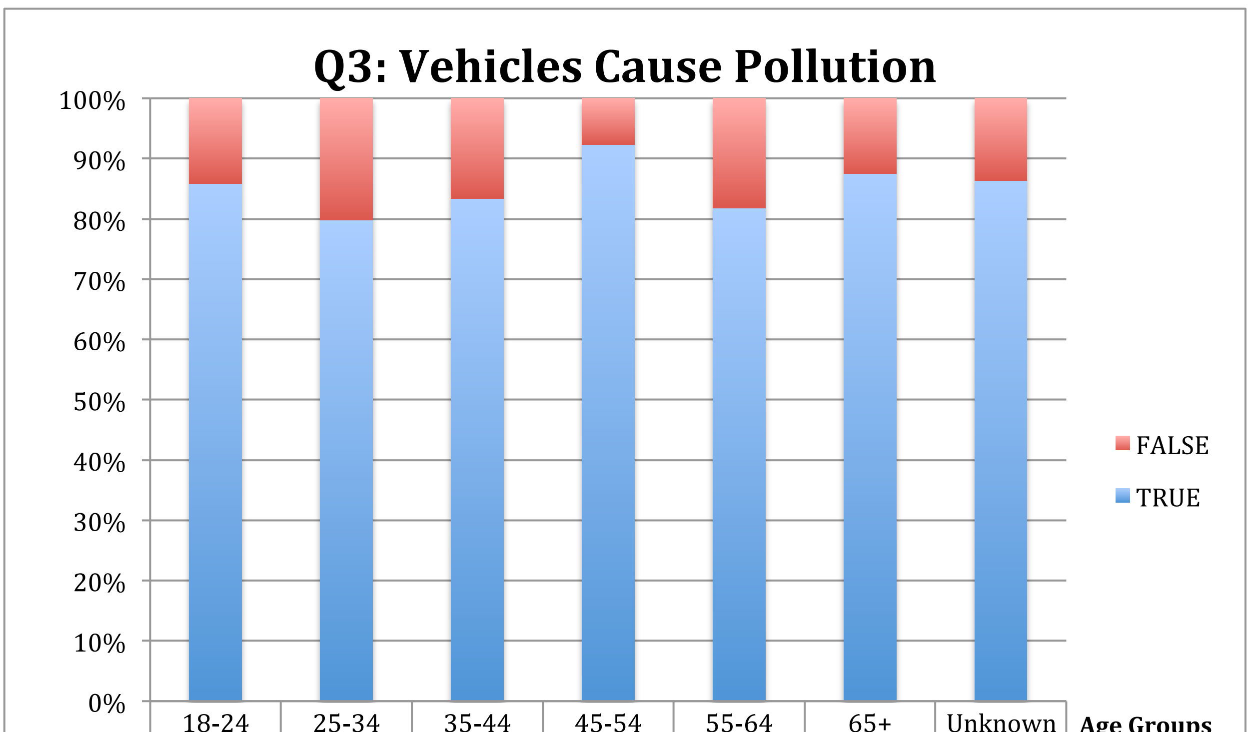
Appendix F. Charts from surveys responses



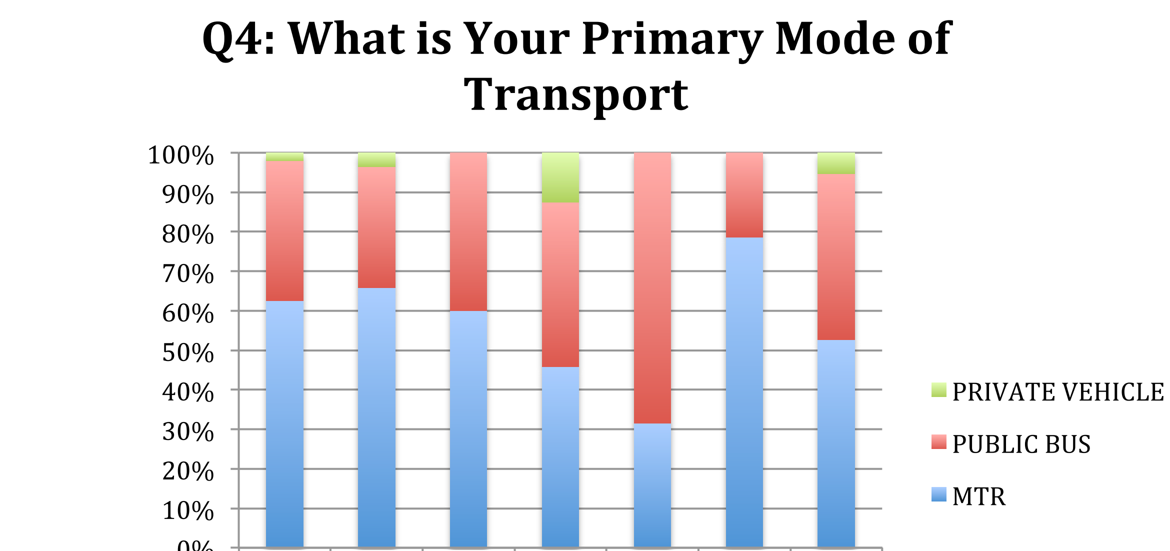
Age Groups	18-24	25-34	35-44	45-54	55-64	65+	Unknown
Population Distribution	12.3%	15.3%	16.0%	17.9%	13.5%	13.7%	
Number of Respondants	255	120	37	26	22	16	22



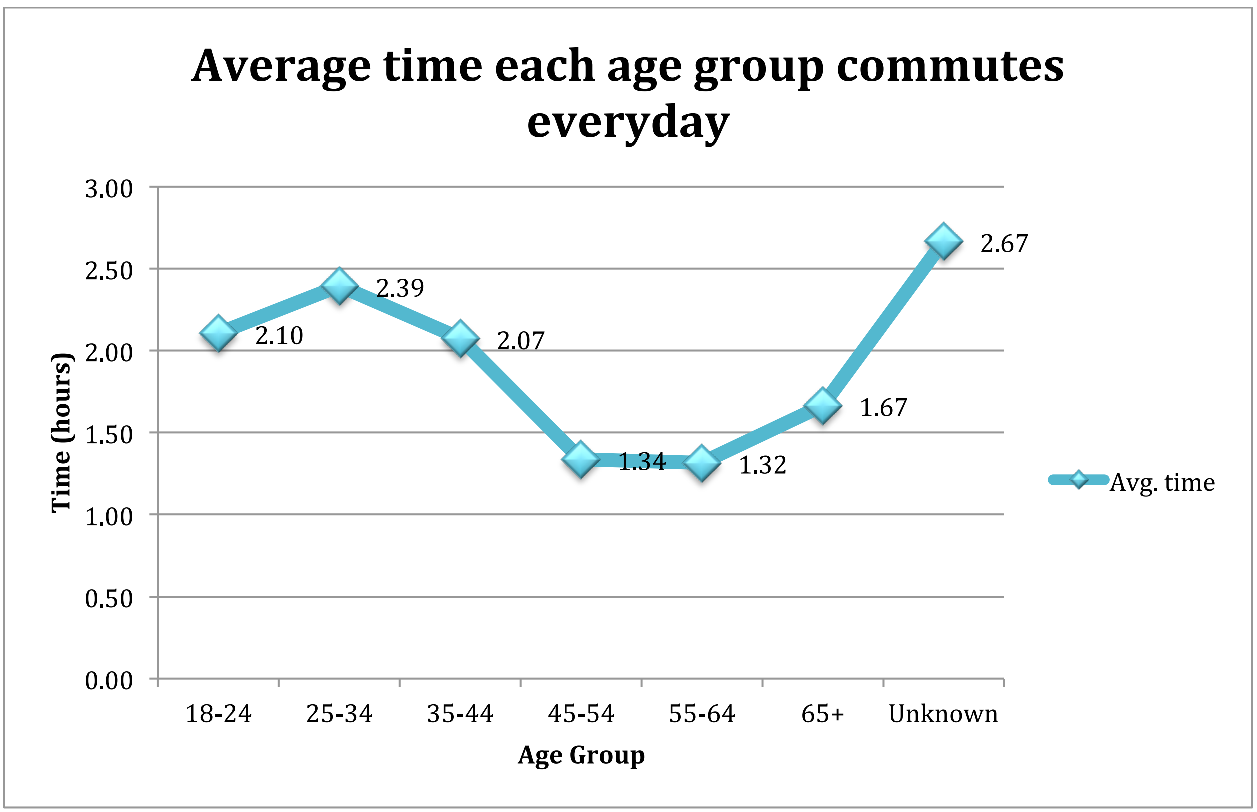




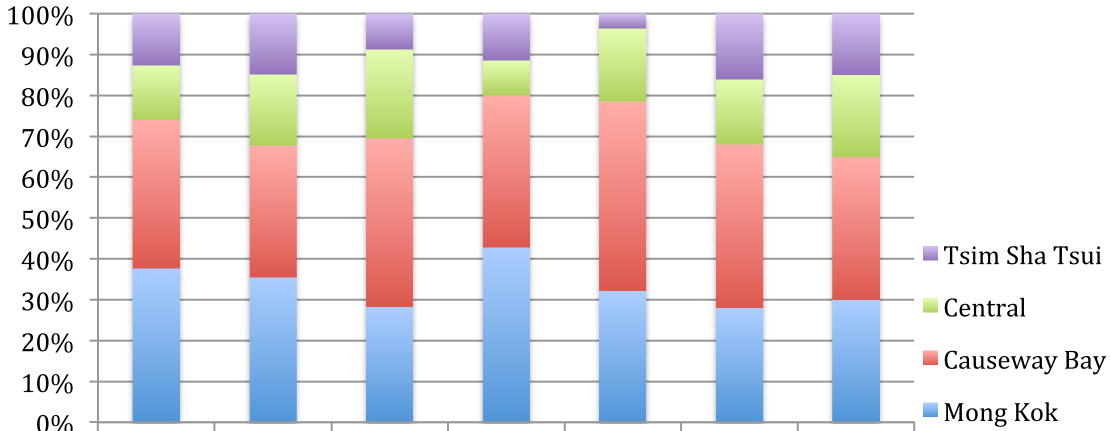
	18-24	25-34	35-44	45-54	55-64	65+	Unknown
FALSE	36	24	6	2	4	2	3
TRUE	219	95	30	24	18	14	19



Age Groups	18-24	25-34	35-44	45-54	55-64	65+	Unknown
PRIVATE VEHICLE	5	4	0	3	0	0	1
PUBLIC BUS	85	35	14	10	13	3	8
MTR	150	75	21	11	6	11	10



Q6: List two areas that have high congestion



Age Groups	18-24	25-34	35-44	45-54	55-64	65+	Unknown
Tsim Sha Tsui	40	18	4	4	1	4	3
Central	42	21	10	3	5	4	4
Causeway Bay	115	39	19	13	13	10	7
Mong Kok	119	43	13	15	9	7	6

Appendix G. January 2014 AQHI Data and Graphs

Note: CWB = Causeway Bay, Cen. = Central, MK = Mong Kok

G.1. Data Tables

Date	Hour	CWB	Cen.	MK
1/1	0:00	10	8	9
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	2:00	10	7	9
	3:00	9	6	8
	4:00	9	5	8
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	5:00	6	6	6
	6:00	6	6	6
	7:00	6	6	5
	8:00	6	6	6
	9:00	6	7	5
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	11:00	7	8	5
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	18:00	8	9	7
	19:00	8	10	7
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1/23	0:00	8	8	7
	1:00	8	7	7
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	8:00	5	5	5
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1/25	0:00	5	5	4
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1/26	0:00	5	5	4
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1/30	0:00	8	5	6
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	21:00	8	8	8
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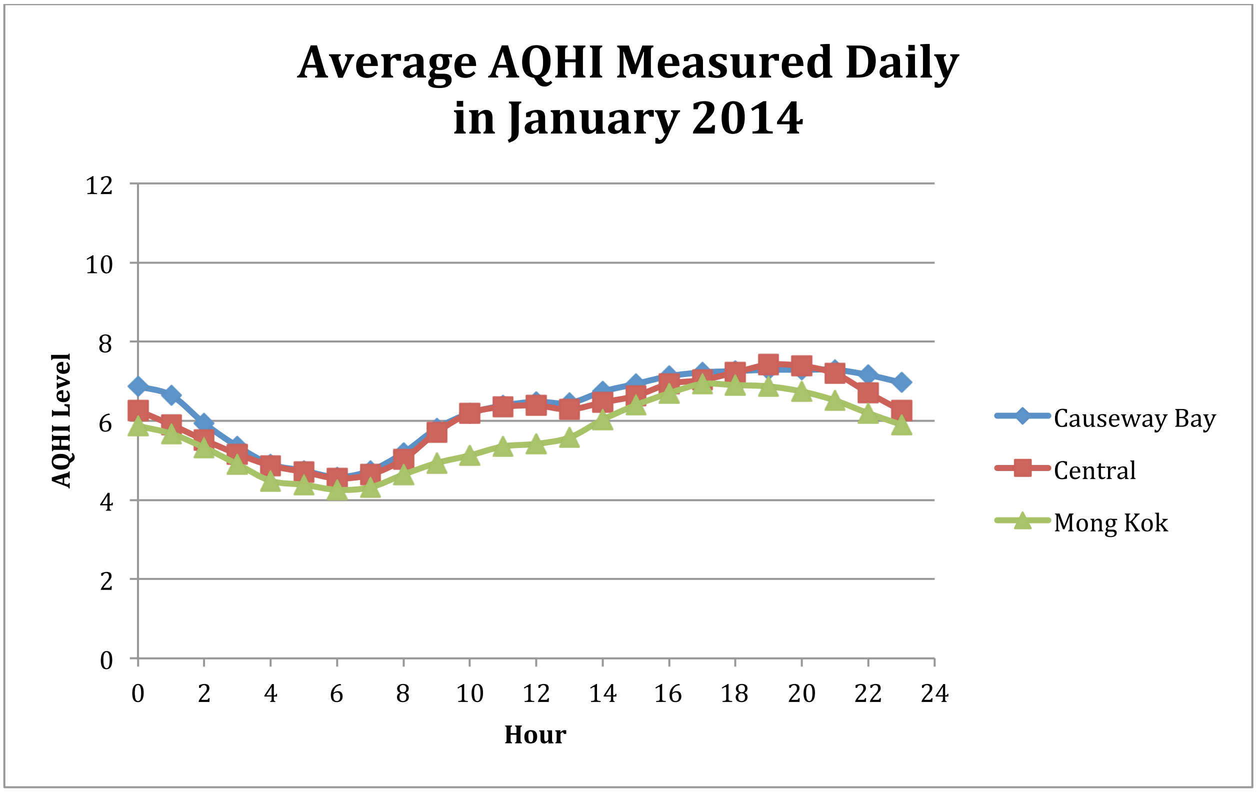
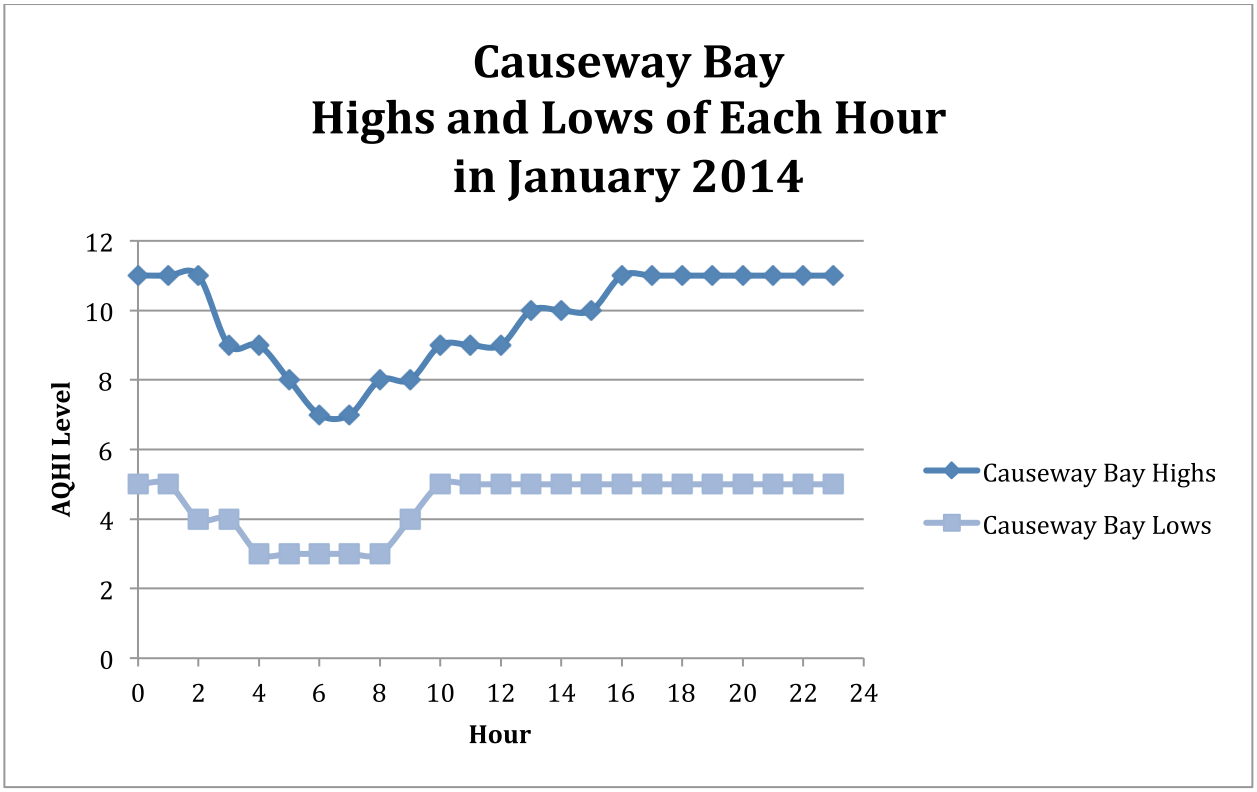
	17:00	6	6	6
	18:00	6	6	6
	19:00	7	5	6
	20:00	6	5	6
	21:00	6	5	5
	22:00	5	5	6
	23:00	6	5	6

G.2. Combined Data Table

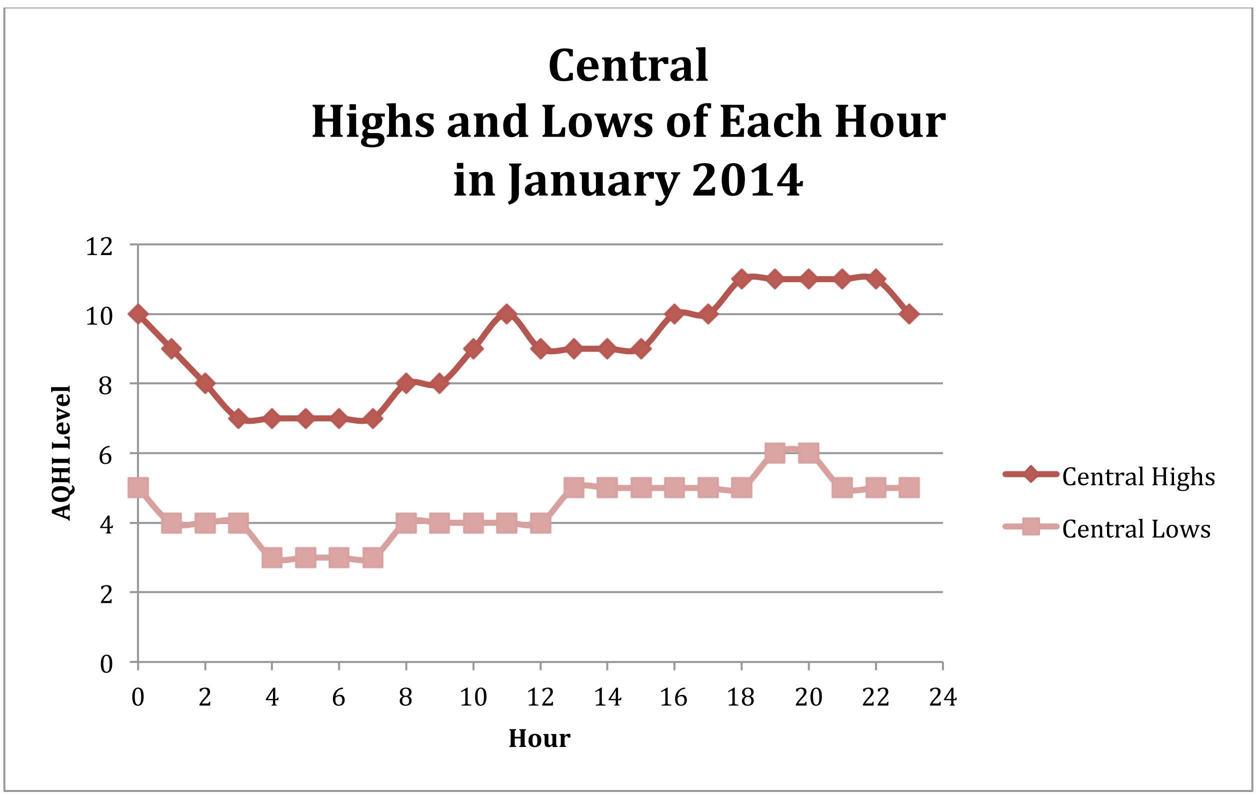
	Hourly Averages			Month Hourly Highs			Monthly Hourly Lows		
Hour	**CWB**	**Cen.**	**MK**	**CWB**	**Cen.**	**MK**	**CWB**	**Cen.**	**MK**
0:00	6.87	6.26	5.87	11	10	10	5	5	4
1:00	6.65	5.90	5.68	11	9	9	5	4	3
2:00	5.94	5.52	5.32	11	8	9	4	4	3
3:00	5.35	5.16	4.90	9	7	8	4	4	3
4:00	4.90	4.87	4.48	9	7	8	3	3	2
5:00	4.74	4.71	4.39	8	7	7	3	3	2
6:00	4.58	4.55	4.26	7	7	7	3	3	2
7:00	4.74	4.65	4.32	7	7	7	3	3	2
8:00	5.19	5.03	4.65	8	8	7	3	4	3
9:00	5.81	5.71	4.94	8	8	8	4	4	3
10:00	6.19	6.19	5.13	9	9	8	5	4	3
11:00	6.39	6.35	5.35	9	10	8	5	4	3
12:00	6.48	6.39	5.42	9	9	8	5	4	3
13:00	6.45	6.29	5.58	10	9	8	5	5	4
14:00	6.74	6.47	6.03	10	9	8	5	5	4
15:00	6.94	6.63	6.40	10	9	9	5	5	4
16:00	7.13	6.94	6.70	11	10	9	5	5	4
17:00	7.23	7.03	6.93	11	10	10	5	5	4
18:00	7.26	7.23	6.90	11	11	11	5	5	4
19:00	7.29	7.42	6.87	11	11	11	5	6	4
20:00	7.29	7.39	6.74	11	11	11	5	6	4
21:00	7.29	7.19	6.52	11	11	11	5	5	4
22:00	7.16	6.71	6.19	11	11	10	5	5	4
23:00	6.97	6.26	5.90	11	10	10	5	5	4

G.3. Graphs

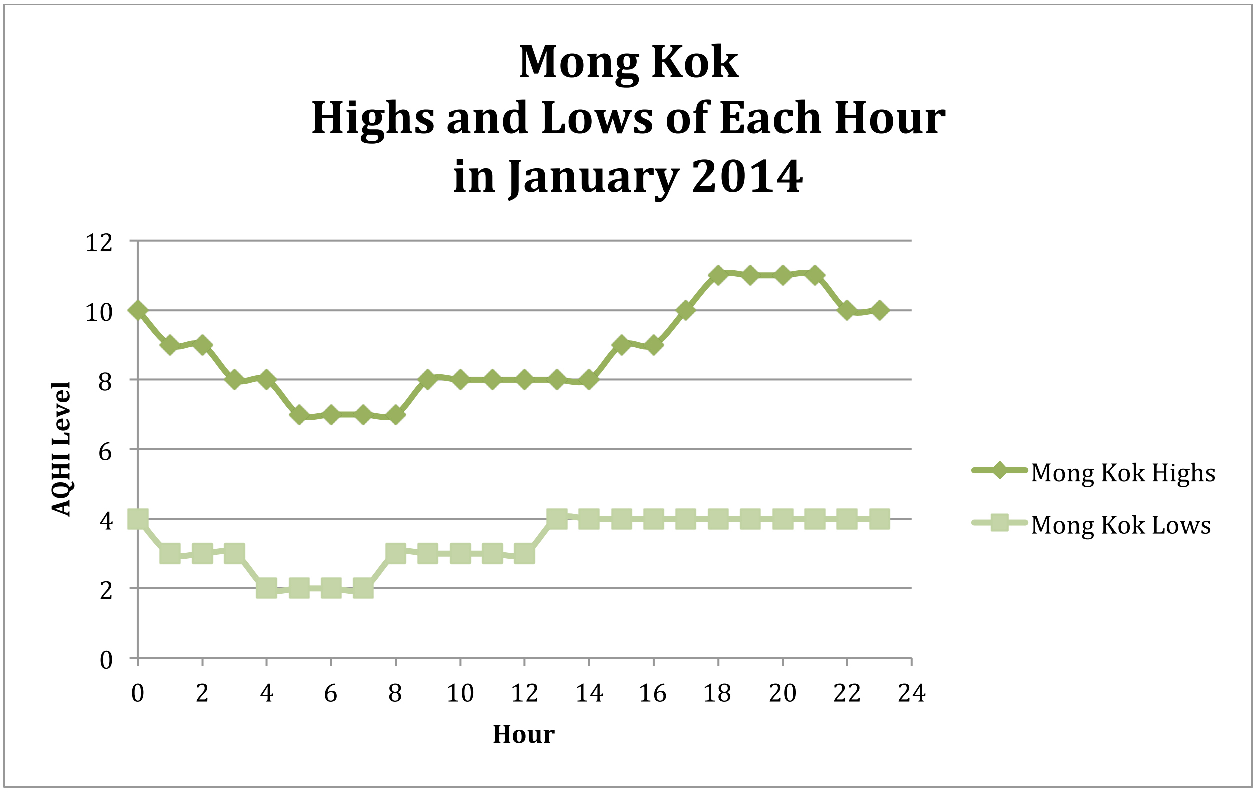

Average AQHI Measured Daily in January 2014
12
10
8
6
4
2
0
AQHI Level
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour
Causeway Bay
Central
Mong Kok



Causeway Bay
Highs and Lows of Each Hour
in January 2014
AQHI Level
Hour
0
2
4
6
8
10
12
14
16
18
20
22
24
Causeway Bay Highs
Causeway Bay Lows



Central
Highs and Lows of Each Hour
in January 2014
AQHI Level
Hour
0
2
4
6
8
10
12
14
16
18
20
22
24
Central Highs
Central Lows


Mong Kok
Highs and Lows of Each Hour
in January 2014
AQHI Level
Hour
0
2
4
6
8
10
12
0
2
4
6
8
10
12
14
16
18
20
22
24
Mong Kok Highs
Mong Kok Lows

Appendix H. Traffic Data Count

H.1. Central Data taken on Connaught Road Central (January 10, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:27	87	24	54	13	48.87640449	13.48314607	30.33707865	7.303370787
8:37	150	40	58	15	57.03422053	15.20912548	22.05323194	5.703422053
8:47	245	28	90	12	65.33333333	7.466666667	24	3.2
8:57	165	27	101	18	53.05466238	8.681672026	32.47588424	5.78778135
9:07	217	54	119	22	52.66990291	13.10679612	28.88349515	5.339805825
9:17	170	60	103	14	48.99135447	17.29106628	29.68299712	4.034582133
9:27	180	148	135	13	37.81512605	31.09243697	28.36134454	2.731092437
9:37	172	65	111	12	47.77777778	18.05555556	30.83333333	3.333333333
9:47	185	57	142	9	47.07379135	14.50381679	36.13231552	2.290076336
12:37	115	57	90	7	42.75092937	21.18959108	33.45724907	2.602230483
12:47	138	51	103	8	46	17	34.33333333	2.666666667
12:57	117	64	85	8	42.70072993	23.35766423	31.02189781	2.919708029
13:07	110	53	110	8	39.14590747	18.86120996	39.14590747	2.846975089
13:17	103	84	100	8	34.91525424	28.47457627	33.89830508	2.711864407
13:27	138	81	92	6	43.53312303	25.55205047	29.02208202	1.892744479
13:37	137	54	85	10	47.9020979	18.88111888	29.72027972	3.496503497
13:47	126	73	89	5	43.00341297	24.91467577	30.37542662	1.706484642
17:10	137	41	68	17	52.09125475	15.58935361	25.85551331	6.463878327
17:20	157	25	60	11	62.05533597	9.881422925	23.71541502	4.347826087
17:30	175	27	63	13	62.94964029	9.712230216	22.6618705	4.676258993
17:40	168	24	67	20	60.21505376	8.602150538	24.01433692	7.168458781
17:50	178	20	70	19	62.02090592	6.968641115	24.3902439	6.620209059
18:00	162	24	78	8	59.55882353	8.823529412	28.67647059	2.941176471
18:10	188	25	49	16	67.62589928	8.992805755	17.62589928	5.755395683
18:20	177	22	55	12	66.54135338	8.270676692	20.67669173	4.511278195
18:30	142	24	59	18	58.43621399	9.87654321	24.27983539	7.407407407
18:40	145	7	58	13	65.02242152	3.139013453	26.00896861	5.829596413
18:50	169	14	71	18	62.13235294	5.147058824	26.10294118	6.617647059

Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
1	1	0	7.692307692
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
6	6	0	42.85714286
1	1	0	7.692307692
0	0	0	0
0	0	0	0
5	4	1	71.42857143

3	3	0	37.5
6	4	2	75
6	5	1	75
9	5	4	112.5
4	2	2	66.66666667
6	2	4	60
1		1	20
11	6	5	64.70588235
9	6	3	81.81818182
8	5	3	61.53846154
11	7	4	55
13	8	5	68.42105263
5	5	0	62.5
8	6	2	50
3	2	1	25
9	9	0	50
5	4	1	38.46153846
8	6	2	44.44444444

	Private Vehicle Count	**Commercial Vehicle Count**	**Taxi**	**Total Buses**	**% Private**	**% Commercial**	**% Taxi**	**% Bus**
Total	4353	1273	2365	353	52.16922339	15.25647172	28.34372004	4.230584851
AVG					52.75811727	14.71873551	28.13365529	4.389491929

	Total Empty	**Total Big Bus Empty (<20%)**	**Total Light Bus Empty (<20%)**	**% Empty**
Total	138	97	41	39.09348442
AVG				39.2199761

H.2. Mong Kok Data taken from Argyle Street (January 7, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:35	90	30	79	76	32.72727273	10.90909091	28.72727273	27.63636364
8:45	63	32	65	74	26.92307692	13.67521368	27.77777778	31.62393162
8:55	58	27	92	62	24.26778243	11.29707113	38.49372385	25.94142259
9:05	62	43	96	64	23.39622642	16.22641509	36.22641509	24.1509434
9:15	60	46	103	87	20.27027027	15.54054054	34.7972973	29.39189189
9:25	60	36	84	75	23.52941176	14.11764706	32.94117647	29.41176471
9:35	84	19	79	71	33.20158103	7.509881423	31.22529644	28.06324111
9:45	86	32	83	75	31.15942029	11.5942029	30.07246377	27.17391304
9:55	90	35	67	58	36	14	26.8	23.2
12:30	63	12	74	48	31.97969543	6.091370558	37.56345178	24.36548223
12:40	79	22	83	54	33.19327731	9.243697479	34.87394958	22.68907563
12:50	61	18	64	37	33.88888889	10	35.55555556	20.55555556
1:00	76	20	97	57	30.4	8	38.8	22.8
1:10	81	19	44	63	39.13043478	9.178743961	21.25603865	30.43478261
1:20	61	21	64	47	31.60621762	10.88082902	33.16062176	24.35233161
1:30	73	30	71	68	30.16528926	12.39669421	29.33884298	28.09917355
1:40	98	19	82	78	35.37906137	6.859205776	29.60288809	28.15884477
1:50	63	21	52	49	34.05405405	11.35135135	28.10810811	26.48648649
5:10	95	14	63	74	38.61788618	5.691056911	25.6097561	30.08130081
5:20	105	16	53	60	44.87179487	6.837606838	22.64957265	25.64102564
5:30	78	10	59	58	38.04878049	4.87804878	28.7804878	28.29268293
5:40	79	12	50	55	40.30612245	6.12244898	25.51020408	28.06122449
5:50	72	13	61	86	31.03448276	5.603448276	26.29310345	37.06896552
6:00	82	8	35	51	46.59090909	4.545454545	19.88636364	28.97727273
6:10	110	4	57	74	44.89795918	1.632653061	23.26530612	30.20408163
6:20	103	5	45	83	43.6440678	2.118644068	19.06779661	35.16949153

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Total Empty
8:35	27	6	21	35.52631579
8:45	36	8	28	48.64864865
8:55	36	15	21	58.06451613
9:05	41	16	25	64.0625
9:15	27	9	18	31.03448276
9:25	42	14	28	56
9:35	33	14	19	46.47887324
9:45	24	10	14	32
9:55	35	14	21	60.34482759
12:30	17	7	10	35.41666667
12:40	22	11	11	40.74074074
12:50	12	6	6	32.43243243
1:00	14	4	10	24.56140351
1:10	10	1	9	15.87301587
1:20	11	2	9	23.40425532

1:30	16	4	12	23.52941176
1:40	30	8	22	38.46153846
1:50	12	5	7	24.48979592
5:10	26	7	19	35.13513514
5:20	19	6	13	31.66666667
5:30	22	2	20	37.93103448
5:40	26	8	18	47.27272727
5:50	35	11	24	40.69767442
6:00	16	5	11	31.37254902
6:10	24	4	20	32.43243243
6:20	38	8	30	45.78313253

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	2032	564	1802	1684	33.41006248	9.273265373	29.62841171	27.68826044
AVG					33.81861398	9.088512175	29.47628732	27.61658653

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	651	205	446	38.65795724
AVG				38.20618372

H.3. Causeway Bay Data taken from Hennessy Road (January 6, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
13:42	15	19	34	37	14.28571429	18.0952381	32.38095238	35.23809524
13:52	20	10	20	25	26.66666667	13.33333333	26.66666667	33.33333333
14:02	9	19	26	27	11.11111111	23.45679012	32.09876543	33.33333333
14:12	26	7	26	33	28.26086957	7.608695652	28.26086957	35.86956522
14:22	28	12	42	36	23.72881356	10.16949153	35.59322034	30.50847458
14:32	25	11	44	38	21.18644068	9.322033898	37.28813559	32.20338983
14:42	25	7	35	32	25.25252525	7.070707071	35.35353535	32.32323232
14:52	16	14	39	21	17.77777778	15.55555556	43.33333333	23.33333333
17:00	28	14	30	53	22.4	11.2	24	42.4
17:10	38	16	33	41	29.6875	12.5	25.78125	32.03125
17:20	26	2	33	42	25.24271845	1.941747573	32.03883495	40.77669903
17:30	31	10	32	42	26.95652174	8.695652174	27.82608696	36.52173913
17:40	32	9	28	39	29.62962963	8.333333333	25.92592593	36.11111111
17:50	26	6	25	45	25.49019608	5.882352941	24.50980392	44.11764706
18:00	30	10	32	41	26.54867257	8.849557522	28.31858407	36.28318584
18:10	28	10	24	27	31.46067416	11.23595506	26.96629213	30.33707865
18:20	26	6	25	43	26	6	25	43
18:30	31	10	32	46	26.05042017	8.403361345	26.8907563	38.65546218
18:40	31	2	31	45	28.44036697	1.834862385	28.44036697	41.28440367
18:50	31	2	33	30	32.29166667	2.083333333	34.375	31.25

Time Block	Total Empty	% Empty
13:42	23	62.16216216
13:52	19	76
14:02	18	66.66666667
14:12	22	66.66666667
14:22	29	80.55555556
14:32	21	55.26315789
14:42	18	56.25
14:52	15	71.42857143
17:00	30	56.60377358
17:10	17	41.46341463
17:20	17	40.47619048
17:30	22	52.38095238
17:40	17	43.58974359
17:50	17	37.77777778
18:00	20	48.7804878
18:10	15	55.55555556
18:20	19	44.18604651
18:30	17	36.95652174
18:40	20	44.44444444
18:50	13	43.33333333

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	522	196	624	743	25.03597122	9.400479616	29.92805755	35.63549161
AVG					24.92341427	9.578600046	30.052419	35.44556669

	Total Empty	% Empty
Total	389	52.35531629
AVG		54.02705111

H.4. Sham Shui Po Data taken from the footbridge on Yen Chow Street (January 13, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
9:10	28	24	20	18	31.11111111	26.66666667	22.22222222	20
9:20	30	26	13	13	36.58536585	31.70731707	15.85365854	15.85365854
9:30	42	20	13	23	42.85714286	20.40816327	13.26530612	23.46938776
9:40	28	15	26	11	35	18.75	32.5	13.75
9:50	36	11	16	13	47.36842105	14.47368421	21.05263158	17.10526316
10:00	35	16	16	20	40.22988506	18.3908046	18.3908046	22.98850575
10:10	37	18	22	17	39.36170213	19.14893617	23.40425532	18.08510638
10:20	25	13	15	10	39.68253968	20.63492063	23.80952381	15.87301587
16:57	46	26	14	21	42.99065421	24.29906542	13.08411215	19.62616822
17:07	69	19	24	19	52.67175573	14.50381679	18.32061069	14.50381679
17:17	56	23	23	13	48.69565217	20	20	11.30434783
17:27	49	13	24	25	44.14414414	11.71171171	21.62162162	22.52252252
17:37	60	13	23	17	53.09734513	11.50442478	20.3539823	15.04424779
17:47	82	16	17	14	63.56589147	12.40310078	13.17829457	10.85271318

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
9:10	9	9	0	50
9:20	10	10	0	76.92307692
9:30	14	14	0	60.86956522
9:40	7	7		63.63636364
9:50	9	9	0	69.23076923
10:00	10	10	0	50
10:10	9	9	0	52.94117647
10:20	5	5	0	50
16:57	13	13	0	61.9047619
17:07	11	11	0	57.89473684
17:17	3	3	0	23.07692308
17:27	9	9	0	36
17:37	7	7	0	41.17647059
17:47	6	6	0	42.85714286

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	623	253	266	234	45.27616279	18.38662791	19.33139535	17.00581395
AVG					44.0972579	18.90018658	19.78978739	17.21276813

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	122	122	0	52.13675214
AVG				52.60792762

H.5. Sham Shui Po Data taken on Yen Chow Street (January 13, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
9:10	17	26	21	15	21.51898734	32.91139241	26.58227848	18.98734177
9:20	25	21	17	18	30.86419753	25.92592593	20.98765432	22.22222222
9:30	29	25	25	10	32.58426966	28.08988764	28.08988764	11.23595506
9:40	29	19	22	20	32.22222222	21.11111111	24.44444444	22.22222222
9:50	22	33	19	12	25.58139535	38.37209302	22.09302326	13.95348837
10:00	16	26	26	12	20	32.5	32.5	15
10:10	22	29	17	14	26.82926829	35.36585366	20.73170732	17.07317073
10:20	23	30	24	17	24.46808511	31.91489362	25.53191489	18.08510638
16:55	42	19	23	20	40.38461538	18.26923077	22.11538462	19.23076923
17:05	42	13	18	16	47.19101124	14.60674157	20.2247191	17.97752809
17:15	39	10	21	14	46.42857143	11.9047619	25	16.66666667
17:25	48	15	12	22	49.48453608	15.46391753	12.37113402	22.68041237
17:35	40	11	15	19	47.05882353	12.94117647	17.64705882	22.35294118
17:45	36	24	19	10	40.4494382	26.96629213	21.34831461	11.23595506
17:55	43	13	21	19	44.79166667	13.54166667	21.875	19.79166667

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
9:10	10	1	9	66.66666667
9:20	12	5	7	66.66666667
9:30	4	1	3	40
9:40	13	5	8	65
9:50	4	3	1	33.33333333
10:00	9	4	5	75
10:10	3	0	3	21.42857143
10:20	6	4	2	35.29411765
16:55	10	3	7	50
17:05	5	1	4	31.25
17:15	7	3	4	50
17:25	6	1	5	27.27272727
17:35	5	3	2	26.31578947
17:45	2	2		20
17:55	10	5	5	52.63157895

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	473	314	300	238	35.69811321	23.69811321	22.64150943	17.96226415
AVG					35.32380587	23.99232963	22.76950143	17.91436307

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	106	41	65	44.53781513
AVG				44.05729676

H.6. Cross-Harbour Tunnel Data taken from Kowloon side (January 14, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:25	145	39	17	51	57.53968254	15.47619048	6.746031746	20.23809524
8:35	212	56	12	52	63.85542169	16.86746988	3.614457831	15.6626506
8:45	190	62	22	58	57.22891566	18.6746988	6.626506024	17.46987952
8:55	241	80	19	53	61.32315522	20.3562341	4.834605598	13.48600509
9:05	204	63	6	35	66.23376623	20.45454545	1.948051948	11.36363636
9:15	39	13	7	14	53.42465753	17.80821918	9.589041096	19.17808219
9:25	150	67	17	47	53.38078292	23.84341637	6.049822064	16.72597865
9:35	118	67	21	49	46.2745098	26.2745098	8.235294118	19.21568627
9:45	204	110	15	57	52.84974093	28.49740933	3.886010363	14.76683938
17:00	210	43	29	54	62.5	12.79761905	8.630952381	16.07142857
17:10	237	61	55	60	57.38498789	14.76997579	13.31719128	14.52784504
17:20	280	32	52	54	66.98564593	7.655502392	12.44019139	12.91866029
17:30	252	47	51	51	62.84289277	11.72069825	12.71820449	12.71820449
17:40	302	49	55	44	67.11111111	10.88888889	12.22222222	9.777777778
17:50	250	46	43	46	64.93506494	11.94805195	11.16883117	11.94805195
18:00	207	35	70	38	59.14285714	10	20	10.85714286
18:10	260	34	42	42	68.78306878	8.994708995	11.11111111	11.11111111
18:20	277	25	38	38	73.28042328	6.613756614	10.05291005	10.05291005

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:25	7	4	3	13.7254902
8:35	16	7	9	30.76923077
8:45	15	6	9	25.86206897
8:55	11	6	5	20.75471698
9:05	6	3	3	17.14285714
9:15	2		2	14.28571429
9:25	15	7	8	31.91489362
9:35	15	9	6	30.6122449
9:45	10	8	2	17.54385965
17:00	38	32	6	70.37037037
17:10	33	21	12	55
17:20	35	28	7	64.81481481
17:30	30	27	3	58.82352941
17:40	24	18	6	54.54545455
17:50	26	19	7	56.52173913
18:00	15	9	6	39.47368421
18:10	26	15	11	61.9047619
18:20	21	17	4	55.26315789

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	3778	929	571	843	61.72194086	15.17725862	9.328541088	13.77225943
AVG					60.83759358	15.75788307	9.066190827	14.33833252

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	345	236	109	40.9252669
AVG				39.96269938

H.7. Cross-Harbour Tunnel Data taken from Hong Kong side (January 14, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:27	87	24	54	13	48.87640449	13.48314607	30.33707865	7.303370787
8:37	150	40	58	15	57.03422053	15.20912548	22.05323194	5.703422053
8:47	245	28	90	12	65.33333333	7.466666667	24	3.2
8:57	165	27	101	18	53.05466238	8.681672026	32.47588424	5.78778135
9:07	217	54	119	22	52.66990291	13.10679612	28.88349515	5.339805825
9:17	170	60	103	14	48.99135447	17.29106628	29.68299712	4.034582133
9:27	180	148	135	13	37.81512605	31.09243697	28.36134454	2.731092437
9:37	172	65	111	12	47.77777778	18.05555556	30.83333333	3.333333333
9:47	185	57	142	9	47.07379135	14.50381679	36.13231552	2.290076336
12:37	115	57	90	7	42.75092937	21.18959108	33.45724907	2.602230483
12:47	138	51	103	8	46	17	34.33333333	2.666666667
12:57	117	64	85	8	42.70072993	23.35766423	31.02189781	2.919708029
13:07	110	53	110	8	39.14590747	18.86120996	39.14590747	2.846975089
13:17	103	84	100	8	34.91525424	28.47457627	33.89830508	2.711864407
13:27	138	81	92	6	43.53312303	25.55205047	29.02208202	1.892744479
13:37	137	54	85	10	47.9020979	18.88111888	29.72027972	3.496503497
13:47	126	73	89	5	43.00341297	24.91467577	30.37542662	1.706484642
17:10	137	41	68	17	52.09125475	15.58935361	25.85551331	6.463878327
17:20	157	25	60	11	62.05533597	9.881422925	23.71541502	4.347826087
17:30	175	27	63	13	62.94964029	9.712230216	22.6618705	4.676258993
17:40	168	24	67	20	60.21505376	8.602150538	24.01433692	7.168458781
17:50	178	20	70	19	62.02090592	6.968641115	24.3902439	6.620209059
18:00	162	24	78	8	59.55882353	8.823529412	28.67647059	2.941176471
18:10	188	25	49	16	67.62589928	8.992805755	17.62589928	5.755395683
18:20	177	22	55	12	66.54135338	8.270676692	20.67669173	4.511278195
18:30	142	24	59	18	58.43621399	9.87654321	24.27983539	7.407407407
18:40	145	7	58	13	65.02242152	3.139013453	26.00896861	5.829596413
18:50	169	14	71	18	62.13235294	5.147058824	26.10294118	6.617647059

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:27	1	1	0	7.692307692
8:37	0	0	0	0
8:47	0	0	0	0
8:57	0	0	0	0
9:07	0	0	0	0
9:17	6	6	0	42.85714286
9:27	1	1	0	7.692307692
9:37	0	0	0	0
9:47	0	0	0	0
12:37	5	4	1	71.42857143
12:47	3	3	0	37.5

12:57	6	4	2	75
13:07	6	5	1	75
13:17	9	5	4	112.5
13:27	4	2	2	66.66666667
13:37	6	2	4	60
13:47	1		1	20
17:10	11	6	5	64.70588235
17:20	9	6	3	81.81818182
17:30	8	5	3	61.53846154
17:40	11	7	4	55
17:50	13	8	5	68.42105263
18:00	5	5	0	62.5
18:10	8	6	2	50
18:20	3	2	1	25
18:30	9	9	0	50
18:40	5	4	1	38.46153846
18:50	8	6	2	44.44444444

	Private Vehicle Count	**Commercial Vehicle Count**	**Taxi**	**Total Buses**	**% Private**	**% Commercial**	**% Taxi**	**% Bus**
Total	3778	929	571	843	61.72194086	15.17725862	9.328541088	13.77225943
AVG					60.83759358	15.75788307	9.066190827	14.33833252

	Total Empty	**Total Big Bus Empty (<20%)**	**Total Light Bus Empty (<20%)**	**% Empty**
Total	345	236	109	40.9252669
AVG				39.96269938

H.8. Tsim Sha Tsui Data taken on Salisbury Road (January 15, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
9:07	87	14	110	60	32.10332103	5.166051661	40.5904059	22.1402214
9:17	63	23	88	59	27.03862661	9.871244635	37.76824034	25.32188841
9:27	79	17	96	54	32.11382114	6.910569106	39.02439024	21.95121951
9:37	72	32	80	56	30	13.33333333	33.33333333	23.33333333
9:47	80	27	86	67	30.76923077	10.38461538	33.07692308	25.76923077
17:00	122	16	54	47	51.0460251	6.694560669	22.59414226	19.66527197
17:10	108	14	56	45	48.43049327	6.278026906	25.11210762	20.1793722
17:20	96	5	59	55	44.65116279	2.325581395	27.44186047	25.58139535
17:30	126	19	105	55	41.31147541	6.229508197	34.42622951	18.03278689
17:40	133	6	70	47	51.953125	2.34375	27.34375	18.359375
17:50	128	9	74	43	50.39370079	3.543307087	29.13385827	16.92913386
18:00	131	13	85	52	46.61921708	4.62633452	30.24911032	18.50533808
18:10	131	6	77	43	50.97276265	2.33463035	29.96108949	16.73151751
18:20	166	10	87	60	51.39318885	3.095975232	26.93498452	18.57585139

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
9:07	43	32	11	71.66666667
9:17	46	37	9	77.96610169
9:27	41	32	9	75.92592593
9:37	43	29	14	76.78571429
9:47	50	31	19	74.62686567
17:00	34	25	9	72.34042553
17:10	30	18	12	66.66666667
17:20	40	31	9	72.72727273
17:30	33	21	12	60
17:40	28	17	11	59.57446809
17:50	27	21	6	62.79069767
18:00	25	15	10	48.07692308
18:10	19	14	5	44.18604651
18:20	32	23	9	53.33333333

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	1522	211	1127	743	42.24257563	5.856230919	31.27948931	20.62170414
AVG					42.05686789	5.938392034	31.21360181	20.79113826

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	491	346	145	66.08344549
AVG				65.47622199

H.9. Eastern Harbour Tunnel Data taken from Kowloon side (January 16, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:45	234	42	53	29	65.36312849	11.73184358	14.80446927	8.100558659
8:55	271	57	67	34	63.17016317	13.28671329	15.61771562	7.925407925
9:05	292	63	93	29	61.21593291	13.20754717	19.49685535	6.07966457
9:15	298	70	56	21	66.96629213	15.73033708	12.58426966	4.719101124
9:25	280	76	79	12	62.63982103	17.00223714	17.67337808	2.684563758
9:35	241	86	102	9	55.02283105	19.6347032	23.28767123	2.054794521
9:45	232	61	84	16	59.03307888	15.5216285	21.3740458	4.071246819
17:00	185	35	40	17	66.78700361	12.63537906	14.44043321	6.137184116
17:10	238	37	47	11	71.47147147	11.11111111	14.11411411	3.303303303
17:20	181	38	34	17	67.03703704	14.07407407	12.59259259	6.296296296
17:30	240	34	45	27	69.36416185	9.826589595	13.00578035	7.803468208
17:40	266	35	56	25	69.63350785	9.162303665	14.65968586	6.544502618
17:50	290	37	58	17	72.13930348	9.2039801	14.4278607	4.228855721
18:00	294	26	67	16	72.9528536	6.451612903	16.62531017	3.970223325
18:10	280	21	58	21	73.68421053	5.526315789	15.26315789	5.526315789
18:20	334	21	58	20	77.13625866	4.849884527	13.39491917	4.618937644

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:45	6	6	0	20.68965517
8:55	9	9	0	26.47058824
9:05	13	11	2	44.82758621
9:15	5	4	1	23.80952381
9:25	5	5	0	41.66666667
9:35	4	3	1	44.44444444
9:45	7	5	2	43.75
17:00	10	10	0	58.82352941
17:10	6	5	1	54.54545455
17:20	4	2	2	23.52941176
17:30	6	4	2	22.22222222
17:40	12	10	2	48
17:50	9	8	1	52.94117647
18:00	13	10	3	81.25
18:10	10	9	1	47.61904762
18:20	14	9	5	70

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	4156	739	997	321	66.89200064	11.89441494	16.04699823	5.16658619
AVG					67.10106598	11.8097663	15.83514119	5.254026525

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	133	110	23	41.43302181
AVG				44.03683166

H.10. Eastern Harbour Tunnel Data taken from Hong Kong Island (January 16, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:27	87	24	54	13	48.87640449	13.48314607	30.33707865	7.303370787
8:37	150	40	58	15	57.03422053	15.20912548	22.05323194	5.703422053
8:47	245	28	90	12	65.33333333	7.466666667	24	3.2
8:57	165	27	101	18	53.05466238	8.681672026	32.47588424	5.78778135
9:07	217	54	119	22	52.66990291	13.10679612	28.88349515	5.339805825
9:17	170	60	103	14	48.99135447	17.29106628	29.68299712	4.034582133
9:27	180	148	135	13	37.81512605	31.09243697	28.36134454	2.731092437
9:37	172	65	111	12	47.77777778	18.05555556	30.83333333	3.333333333
9:47	185	57	142	9	47.07379135	14.50381679	36.13231552	2.290076336
12:37	115	57	90	7	42.75092937	21.18959108	33.45724907	2.602230483
12:47	138	51	103	8	46	17	34.33333333	2.666666667
12:57	117	64	85	8	42.70072993	23.35766423	31.02189781	2.919708029
13:07	110	53	110	8	39.14590747	18.86120996	39.14590747	2.846975089
13:17	103	84	100	8	34.91525424	28.47457627	33.89830508	2.711864407
13:27	138	81	92	6	43.53312303	25.55205047	29.02208202	1.892744479
13:37	137	54	85	10	47.9020979	18.88111888	29.72027972	3.496503497
13:47	126	73	89	5	43.00341297	24.91467577	30.37542662	1.706484642
17:10	137	41	68	17	52.09125475	15.58935361	25.85551331	6.463878327
17:20	157	25	60	11	62.05533597	9.881422925	23.71541502	4.347826087
17:30	175	27	63	13	62.94964029	9.712230216	22.6618705	4.676258993
17:40	168	24	67	20	60.21505376	8.602150538	24.01433692	7.168458781
17:50	178	20	70	19	62.02090592	6.968641115	24.3902439	6.620209059
18:00	162	24	78	8	59.55882353	8.823529412	28.67647059	2.941176471
18:10	188	25	49	16	67.62589928	8.992805755	17.62589928	5.755395683
18:20	177	22	55	12	66.54135338	8.270676692	20.67669173	4.511278195
18:30	142	24	59	18	58.43621399	9.87654321	24.27983539	7.407407407
18:40	145	7	58	13	65.02242152	3.139013453	26.00896861	5.829596413
18:50	169	14	71	18	62.13235294	5.147058824	26.10294118	6.617647059

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:27	1	1	0	7.692307692
8:37	0	0	0	0
8:47	0	0	0	0
8:57	0	0	0	0
9:07	0	0	0	0
9:17	6	6	0	42.85714286
9:27	1	1	0	7.692307692
9:37	0	0	0	0
9:47	0	0	0	0
12:37	5	4	1	71.42857143
12:47	3	3	0	37.5

12:57	6	4	2	75
13:07	6	5	1	75
13:17	9	5	4	112.5
13:27	4	2	2	66.66666667
13:37	6	2	4	60
13:47	1		1	20
17:10	11	6	5	64.70588235
17:20	9	6	3	81.81818182
17:30	8	5	3	61.53846154
17:40	11	7	4	55
17:50	13	8	5	68.42105263
18:00	5	5	0	62.5
18:10	8	6	2	50
18:20	3	2	1	25
18:30	9	9	0	50
18:40	5	4	1	38.46153846
18:50	8	6	2	44.44444444

	Private Vehicle Count	**Commercial Vehicle Count**	**Taxi**	**Total Buses**	**% Private**	**% Commercial**	**% Taxi**	**% Bus**
Total	4353	1273	2365	353	52.16922339	15.25647172	28.34372004	4.230584851
AVG					52.75811727	14.71873551	28.13365529	4.389491929

	Total Empty	**Total Big Bus Empty (<20%)**	**Total Light Bus Empty (<20%)**	**% Empty**
Total	138	97	41	39.09348442
AVG				39.2199761

H.11. Western Harbour Tunnel Data taken from Kowloon side on (January 20, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:15	305	35	91	106	56.79702048	6.517690875	16.94599628	19.73929236
8:25	270	38	117	98	51.62523901	7.265774379	22.3709369	18.73804971
8:35	277	63	106	82	52.46212121	11.93181818	20.07575758	15.53030303
8:45	300	54	131	74	53.66726297	9.660107335	23.43470483	13.23792487
8:55	266	50	135	49	53.2	10	27	9.8
9:05	229	64	134	46	48.41437632	13.53065539	28.32980973	9.725158562
9:15	243	88	122	38	49.49083503	17.92260692	24.84725051	7.739307536
9:25	251	69	122	32	52.9535865	14.55696203	25.73839662	6.751054852
9:35	287	87	106	43	54.87571702	16.63479924	20.26768642	8.221797323
9:45	210	53	91	24	55.55555556	14.02116402	24.07407407	6.349206349
17:10	172	18	64	31	60.35087719	6.315789474	22.45614035	10.87719298
17:20	156	8	60	53	56.31768953	2.888086643	21.66064982	19.13357401
17:30	175	9	56	31	64.57564576	3.32103321	20.66420664	11.43911439
17:40	155	9	67	42	56.77655678	3.296703297	24.54212454	15.38461538
17:50	210	15	50	38	67.09265176	4.792332268	15.97444089	12.14057508
18:00	177	11	59	37	62.32394366	3.873239437	20.77464789	13.02816901

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:15	0	0	0	0
8:25	0	0	0	0
8:35	0	0	0	0
8:45	0	0	0	0
8:55	0	0	0	0
9:05	0	0	0	0
9:15	0	0	0	0
9:25	0	0	0	0
9:35	0	0	0	0
9:45	0	0	0	0
17:10	3	0	3	9.677419355
17:20	1	0	1	1.886792453
17:30	0	0	0	0
17:40	0	0	0	0
17:50	0	0	0	0
18:00	0	0	0	0

	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	3683	671	1511	824	55.06054717	10.03139483	22.58932576	12.31873225
AVG					56.02994242	9.158047668	22.44730144	12.36470847

	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	4	0	4	0.485436893
AVG				0.722763238

H.12. Western Harbour Tunnel Data taken from Hong Kong side (January 20, 2014)

Time Block	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
8:25	240	18	65	56	63.32453826	4.749340369	17.15039578	14.77572559
8:35	225	22	69	43	62.67409471	6.128133705	19.22005571	11.97771588
8:45	214	28	65	36	62.39067055	8.163265306	18.95043732	10.49562682
8:55	207	28	64	43	60.52631579	8.187134503	18.71345029	12.57309942
9:05	207	23	51	39	64.6875	7.1875	15.9375	12.1875
9:15	197	22	71	44	58.98203593	6.586826347	21.25748503	13.17365269
9:25	182	33	72	34	56.69781931	10.28037383	22.42990654	10.59190031
17:00	171	34	66	36	55.70032573	11.07491857	21.49837134	11.72638436
17:10-17:16	247	68	46	21	64.65968586	17.80104712	12.04188482	5.497382199

Time Block	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
8:25	10	9	1	17.85714286
8:35	10	10	0	23.25581395
8:45	6	6	0	16.66666667
8:55	14	14	1	32.55813953
9:05	8	8	0	20.51282051
9:15	14	13	1	31.81818182
9:25	13	13	1	38.23529412
17:00	1	0	1	2.777777778
17:10-17:16	0	0	0	0

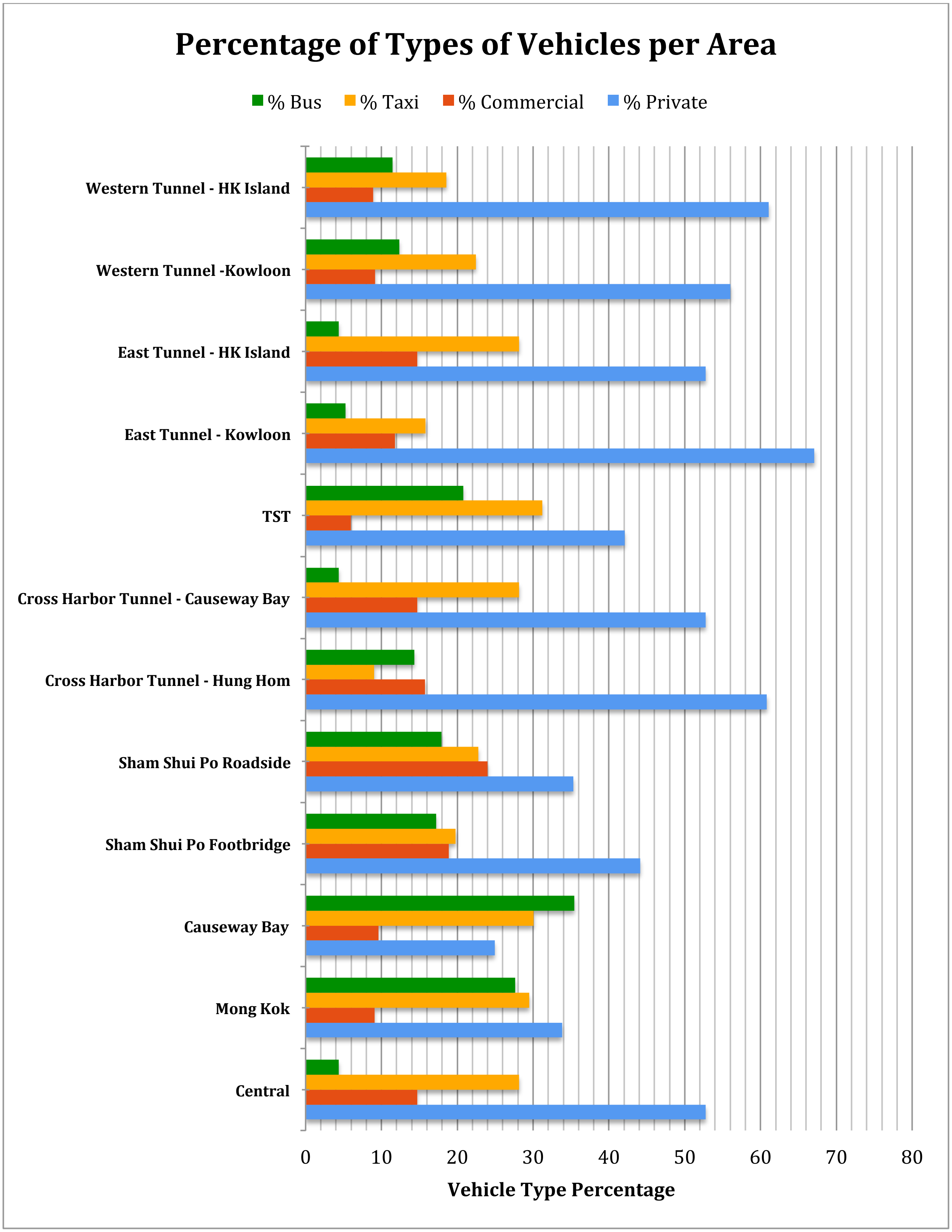
	Private Vehicle Count	Commercial Vehicle Count	Taxi	Total Buses	% Private	% Commercial	% Taxi	% Bus
Total	1890	276	569	352	61.2244898	8.940719145	18.43213476	11.4026563
AVG					61.07144291	8.906504417	18.57772076	11.44433192

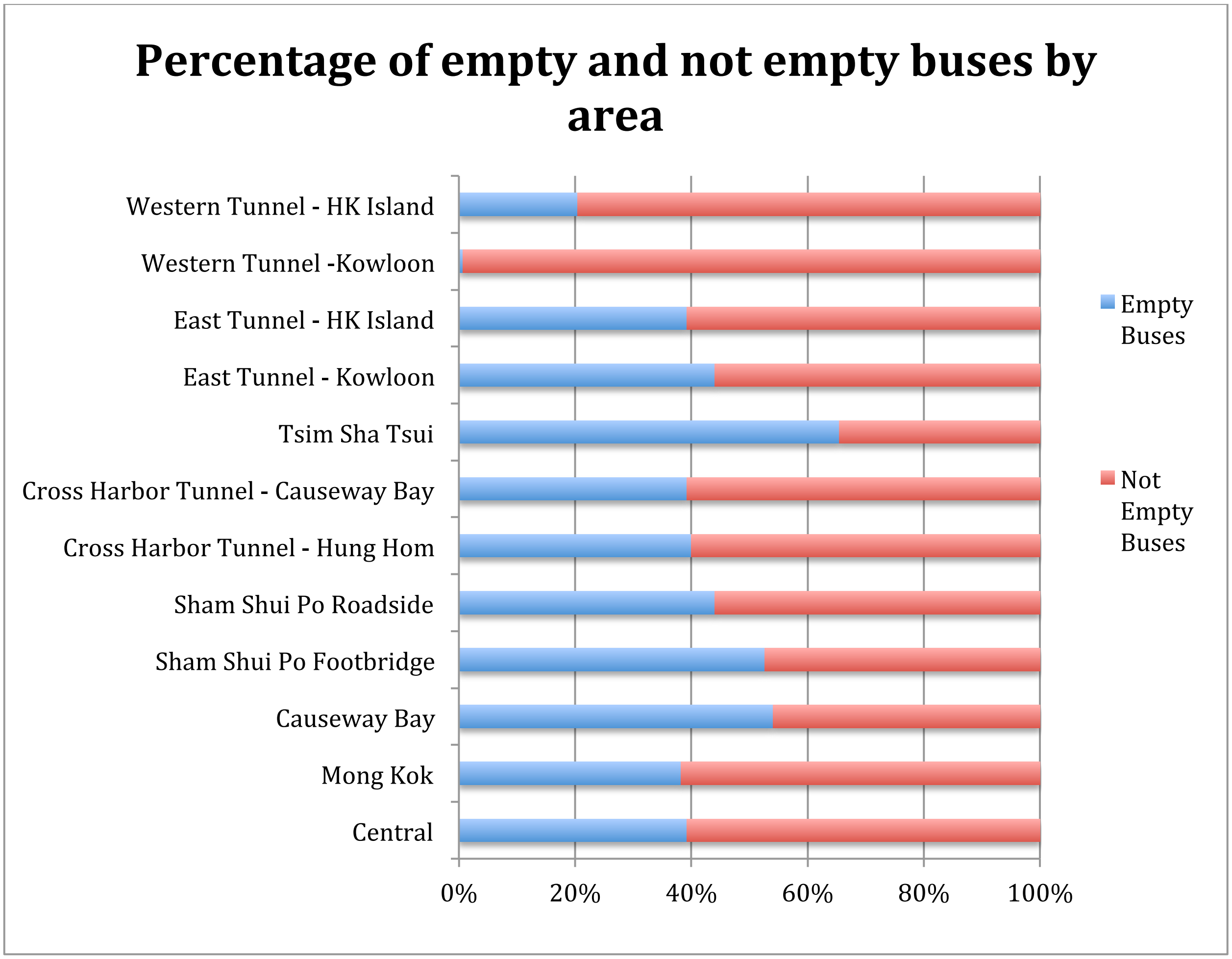
	Total Empty	Total Big Bus Empty (<20%)	Total Light Bus Empty (<20%)	% Empty
Total	76	73	5	21.59090909
AVG				20.40909303

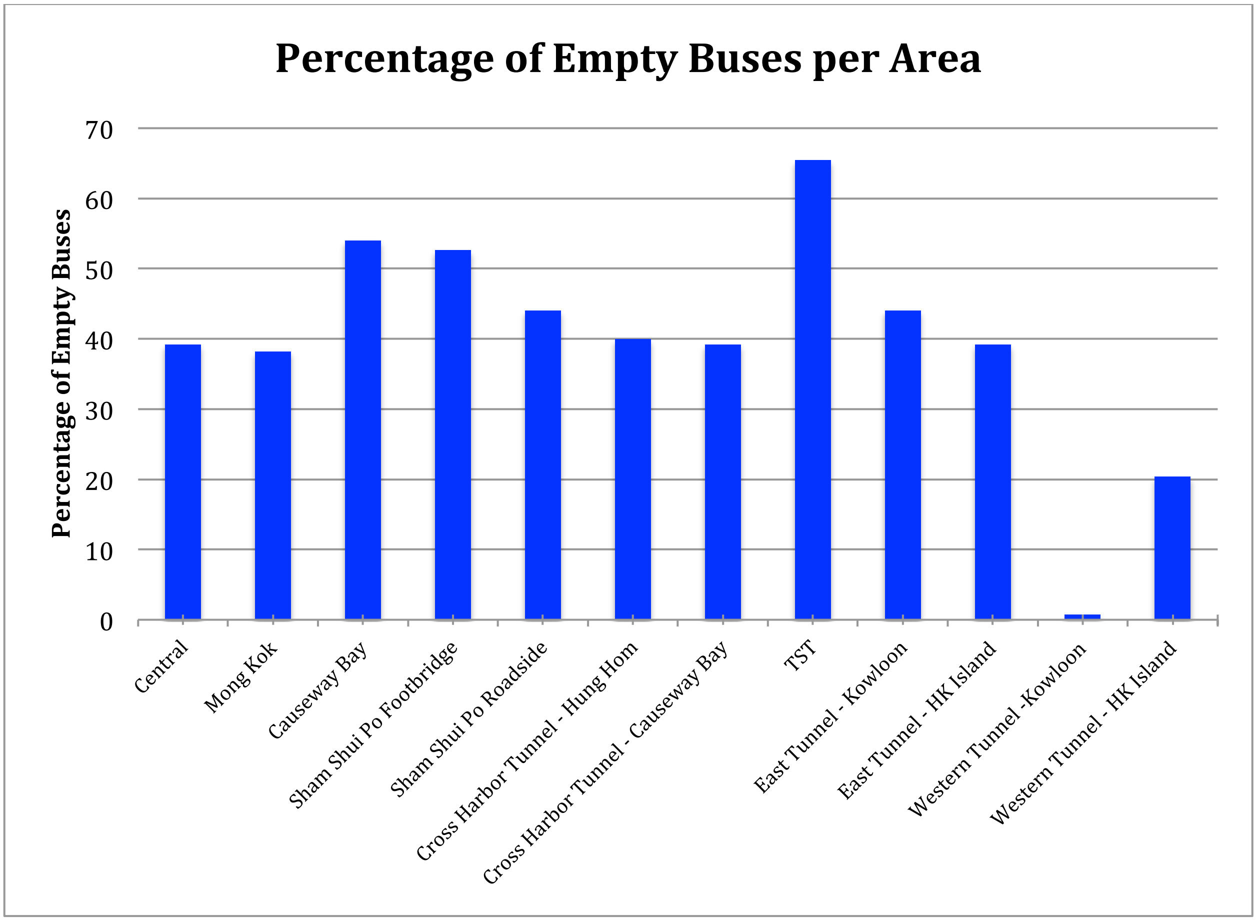
H.13. Overall Vehicle Percentages for Each Specified Area

Area	% Private	% Commercial	% Taxi	% Bus	% Empty
Central	52.75811727	14.71873551	28.13365529	4.389491929	39.2199761
Mong Kok	33.81861398	9.088512175	29.47628732	27.61658653	38.20618372
Causeway Bay	24.92341427	9.578600046	30.052419	35.44556669	54.02705111
Sham Shui Po Footbridge	44.0972579	18.90018658	19.78978739	17.21276813	52.60792762
Sham Shui Po Roadside	35.32380587	23.99232963	22.76950143	17.91436307	44.05729676
Cross Harbour Tunnel - Hung Hom	60.83759358	15.75788307	9.066190827	14.33833252	39.96269938
Cross Harbour Tunnel - Causeway Bay	52.75811727	14.71873551	28.13365529	4.389491929	39.2199761
TST	42.05686789	5.938392034	31.21360181	20.79113826	65.47622199
Eastern Tunnel - Kowloon	67.10106598	11.8097663	15.83514119	5.254026525	44.03683166
Eastern Tunnel - HK Island	52.75811727	14.71873551	28.13365529	4.389491929	39.2199761
Western Tunnel - Kowloon	56.02994242	9.158047668	22.44730144	12.36470847	0.722763238
Western Tunnel - HK Island	61.07144291	8.906504417	18.57772076	11.44433192	20.40909303

H.14. Vehicle and Empty/Not Empty Bus Comparison Charts




Percentage of empty and not empty buses by area
Western Tunnel - HK Island
Western Tunnel -Kowloon
East Tunnel - HK Island
East Tunnel - Kowloon
Tsim Sha Tsui
Cross Harbor Tunnel - Causeway Bay
Cross Harbor Tunnel - Hung Hom
Sham Shui Po Roadside
Sham Shui Po Footbridge
Causeway Bay
Mong Kok
Central
0%
20%
40%
60%
80%
100%
Empty Buses
Not Empty Buses


Percentage of Empty Buses per Area
Percentage of Empty Buses
70
60
50
40
30
20
10
0
Central
Mong Kok
Causeway Bay
Sham Shui Po Footbridge
Sham Shui Po Roadside
Cross Harbor Tunnel - Hung Hom
Cross Harbor Tunnel - Causeway Bay
TST
East Tunnel - Kowloon
East Tunnel - HK Island
Western Tunnel -Kowloon
Western Tunnel - HK Island

Appendix I. Observational walks

Observations listed in order witnessed during research walks around areas during designated time periods.

1. Causeway Bay

H.1.1. Walk 1

January 27th

1. **11:06** Walk begins from SOGO
2. Great George Rd
    - 2 lane street brought down to 1 lane due to commercial unloading
3. Great George and Paterson Intersection
    - Truck taking 40 full seconds attempting a turn from Paterson onto Great George due to heavy traffic flow.
4. After reaching Gloucester Rd, we walk back to SOGO in 2 minutes 25.89 seconds.
5. East Point onto Lockhart
    - 3 vans and 6 commercial trucks unloading into sidewalk, blocking pedestrian walkways
6. Lockhart Rd
    - Circling Trucks: Observed many commercial vehicles driving while watching parking areas. Assumed to be specifically looking for a spot to unload.
7. **11:15** Cannon St
    - High traffic flow and extensive unloading. Circling commercial vehicles apparent.
8. Jaffe Rd
    - Blocked Vehicles: Multiple vehicles blocked on Jaffe and Cannon for 53.55 seconds by a truck performing a 3 point turn perpendicular park on Jaffe
9. Upper Cannon St
    - Blocked Vehicles: Truck unloads in only lane and idles for 39.34 seconds
10. Cannon onto Gloucester Rd
    - Terrible Merge: Heavy traffic on Gloucester and traffic extends down Cannon due to length of wait of merging
11. Gloucester Rd
    - Very heavy, slow moving traffic flow of a mix of vehicles. Many bus stops without a dedicated bus lane resulting in hectic driving habits
12. Gloucester onto Percival
    - Heavy Traffic Merge: 1 lane of Gloucester that is heading back towards populated areas. This lane backs up so far that it affects a bus stops before it and affects other lanes
13. Lockhart Rd
    - Truck attempts to double park in a 3 lane rd where 1 is completely filled with parked vehicles and 1 is partially blocked with unloading vans. He attempts

via parallel parking where he continuously blocked the 3rd lane with his front resulting in completely blocked traffic temporarily that backs up across Percival. Take 50 seconds to park.

14. **11:31** Hennessey Rd
    - Vehicles double parked on 3 lane Hennessey causes buses to swerve dangerously to get to bus stops. Vehicle observed idle for 1 min 22 seconds and was idle before our arrival as well.
15. **11:35** Hennessey Bus stop via Footbridge
    - Buses attempting to pull over into a single stop. 4 buses already at stop with 5th attempting to pull over,. Back of 5th bus blocks middle lane, causing swerving vehicles. After 5th finally enters bus stop area, a 6th and 7th bus arrive blocking 2 of 3 lanes again. More buses arrive and all 3 lanes are blocked by this singular bus stop.
    - Time duration of buses and blocked lanes, 2 lanes blocked for 1 minute, 3 lanes blocked for 52 seconds, 2 lanes blocked for 30 seconds, 3 lanes blocked for 1 minute. Over the course of this 3 minutes 22 seconds, over 15 buses stopped at this bus stop.
16. Percival St
    - Low congestion but moderate vehicle flow. Low congestion attributed to lack of bus stops and commercial vehicles along street sides.
17. **11:40** Time's Square
    - Few commercial vehicles passing through area with none unloading. Organized, manned taxi stand in front of the square with 8 taxi spots, all full. 1 taxi used approximately every 45 seconds with no line of people waiting. Roads leading to square lined with taxis parked and lanes are filled about 90% with taxis incoming. 26 taxis (not included the 8 in formal spots) observed within one "view."
18. Pak Sha, Lan Fong, Hysan
    - Low congestion and low traffic flow, attributed to lack of vehicles as well as these streets being designed to be 1 driving lane with 1 parking lane. Few commercial vehicles and virtually no buses

H.1.2. Walk 2

January 27th

1. **1:25** Walk Begins at SOGO towards Great George St
    - Large flow from East Point onto Great George
2. Yee Wo St
    - Mainly filled with buses. Slight congestion due to conflicting buses.
3. **1:30** Pennington and Jardine Intersection
    - Low Congestion overall. Large traffic flow towards SOGO area from Irving to Pennington
4. Pennington St
    - Bus Stopping: Light bus stops unexpectedly and rapidly and blocks its lane. Not at a bus stop. Blocks lane for 19.63 seconds

5. Leighton Rd
    - Few double decker buses. 3 lanes overall, 1 blocked by commercial vehicles sitting/idling. No businesses in sight. 7 trucks idling directly outside St Paul's Nursery.
    - One truck idle for more than 5 minutes. Duration longer as he was idle before we arrived and after we left. 6 vehicles parked behind initial vehicle blocking 1 of 3 lanes that should be used for travel only.
6. Yee Wo St
    - Empty Buses: Buses passing through area lowly populated or completely empty. Examples include routes 72, 592, 5, 5B, 233, 603, 112.
7. **1:45** Sugar St
    - No observable congestion
8. Gloucester Rd
    - A truck attempts to parallel park in 2 lane portion of the road, 1 lane already used for parking. Blocks traffic for about 40 seconds. He then begins to unload his vehicle. No unloading signs very apparent in area.
    - Heavy congestion towards Kowloon on ground level. Highway level has virtually no congestion and very low traffic flow. Opposite direction has no congestion but moderate traffic flow.
9. Kingston Rd
    - Low traffic. No buses or commercial vehicles traveling.
10. **1:55** Cleaveland Rd
    - Low traffic flow. No buses and low commercial vehicle travel.
11. Gloucester Rd - Harborside
    - Very congested. No bus lane. Relatively even mix of all vehicle types. Street lined with bus stops without a bus lane, resulting in buses stopping abruptly and blocking vehicles behind it.
12. **1:57** Paterson St
    - No vehicle travel.
13. World Trade Centre
    - Vehicles attempting to pull into and out of World Trade Centre block inner most lane. Most notable it would greatly hurt a bus lane in the area.
14. Cannon St Merge with Gloucester
    - Cannon St, like many other streets lining Gloucester, had a very heavy flow attempting to merge into the congested traffic. This resulted in traffic backing up heavily down its roads towards the SOGO area.
15. Gloucester and Percival Merge
    - Heavy Traffic Merge: Still large flow going towards SoGo
16. Percival St
    - Relatively low congestion but very high traffic flow. Low congestion attributed to lack of pulling over and light control.
17. **2:01** Jaffe Rd
    - Large flow turning onto Percival

18. Lockhart Rd
    - Truck unloading: Due to 2 of 3 lanes already double parked and filled, truck stops in 3rd lane and unloads, blocking all traffic behind it. Blocks for 2 minutes 15 seconds.

2. Mong Kok

H.2.1. Walk 1

January 28th

1. **10:45** Walk Begins
2. Argyle Rd
    a. Very controlled by light system. Mostly commercial with even mix of other vehicle types.
3. Shanghai St

. Large cross flow across Argyle Rd. Interesting as it runs parallel to the high capacity Nathan Rd.

4. Portland St

. Taxi Stand: Large Taxi stand. 6 currently sitting in line with 4 of them idle. Taxi's blocking traffic flow trying to pull over into stand.

a. Only 1 drive-able lane. Many pulled over commercial vehicles. Very few actually loading/unloading. Mostly just sitting

5. **10:55** Changsha St

. Street fully parked. Not much traffic flow.

6. Nathan Rd

. 3 Lanes per side. 1st Lane filled with buses attempting to pull over. Very few other types of vehicles. Viewed 4 buses attempting to pull over to one bus stop within 5 seconds, slowing traffic significantly.

7. Dundas St

. Fully parked. Moderate traffic flow of mostly commercial. Multiple commercial vehicles possibly "circling" for a spot.

8. Portland St

. Large traffic flow. No light control. Many sitting vehicles.

9. Hamilton St

. 2 lanes. 1 blocked by a commercial vehicle. Unloads for 2 min 30 seconds.

10. Shanghai St

. Large traffic flow. No buses

11. **11:07** Nathan Rd

. Relatively low traffic flow. Mostly buses. Taxi drops off at bus stop blocking buses and causing dangerous swerving.

12. Sai Yeung Choi st South

. Only 1 drive-able lane. Large traffic congestion with commercial vehicles fighting for spots. Extreme double parking by vans.

a. 1 van double parks behind the others in a "narrow area" where only small cars can get by. Drops of a suit and leaves his vehicle for 3 min 25 seconds. Blocks a truck that can't make the corner for approximately 1 minute.

13. Soy St

. Very long stop light backing up Sai Yeung Choi St South. Large flow interfering with pedestrians in market.

14. Fa Yuen St

. Multiple empty large commercial vehicles. 8 red buses sitting.

15. Shan Tung St

. Many taxis and commercial vehicles. Dumpster in turn off lane. Many empty commercial vehicles on this road portion and on the other side of Argyle as well.

16. **11:25** Argyle Rd

. High vehicle traffic towards Nathan, mostly big buses, commercial vehicles, and taxis. Highly stop-and-go driving with 20 second idle periods. Believed main flow is coming from highway

17. Sai Yee St

. All lanes filled in both viewed directions. Mostly commercial, taxis, and private vehicles.

18. Fife St

. Many sitting commercial vehicles.

19. Sai Yeung Choi St

. Large traffic flow towards Argyle. Extensive double parking.

20. Mong Kok Rd

. Large mixed type vehicle flow; however, low congestion due to light control.

21. Walk Ends

H.2.2. Walk 2

January 28th

1. **17:35** Walk Begins
2. Nathan Rd
    - Extreme number of buses on road.
3. Argyle St
    - Heavy traffic flow, even mix of vehicle types
4. Portland Rd
    - Low flow. Double parking
5. Fife St
    - No problems noticeable.
6. **17:44** Shanghai St
    - Very backed up with mix of vehicles (lower commercial counts). Most parking filled with smaller commercial vehicles.
    - Abrupt Bus Stop: Multiple buses, both large and light, abruptly stop to let passengers off, causing dangerous situations and blocking traffic. 1 light bus tries to let passengers off, blocks lane, 2nd bus attempts to pass and blocks the other lane.

7. Shanghai - Argyle Intersection
    - Vehicles turning onto Argyle get stuck and cause Shanghai to back up. Argyle has a very large traffic flow, although it is controlled by light system.
8. Shanghai St- Opposite side of Argyle
    - Heavy Congestion. Triple parking. 1 moving lane. Light buses drop offs blocking lane with taxis blocking the light buses.
9. **17:47** Shan Tung St
    - High flow. Slow movement over the entire road. Emptying parking garage blocking lanes.
10. Shanghai St
    - Stop and go movement. Horns blaring.
11. Shanghai Soy Intersection
    - Double parking on right and single parking on left on Shanghai right before Soy, resulting in 2 moving lane. Soy backed up, thus backing turning lane of Shanghai, resulting in "straight" lane of Shanghai to be blocked.
12. Soy St
    - Almost completely non-moving.
13. Soy Portland Intersection
    - All vehicles from Soy merging into Portland, resulting in backup
14. Portland St
    - 3 lanes total, 2 used for parking, 1 moving. Taxis loading/unloading passengers in the 1 moving lane as they cannot move to the side. Apparent "Looping" of vehicles.
15. **17:55** Changsta St
    - No vehicle movement however heavily parked.
16. Portland St
    - 1 slow moving lane.
17. Dundas St
    - Similar traffic jam as Soy. No lights to control vehicles or crosswalks to control pedestrians.
18. Nathan Rd
    - Heavily populated by buses, slow movement but steady due to light control. Taxi pulls over into bus stop to load passenger and almost causes accident with buses forced to stop to wait.
19. **18:00** Sai Yeung Choi St South
    - Massive amounts of pedestrians due to markets. Commercial vehicles attempting to cut through them. No public transportation visible.
20. **18:06** Soy St
    - Extreme amount of pedestrians. Road should definitely be closed off to vehicles; however, it is not. Commercial vehicles continue to turn from Sai Yeung onto Soy. Multiple sitting/idle commercials.

21. Shan Tung St
    - Very highly congested with a mix of commercial, private, and taxis. Many vehicles coming from Nathan. Vans unloading on the sides.
22. Nelson St
    - Closed to vehicles; however, large cross flow of pedestrians across Sai Yeung.
23. Sai Yeung Choi - Argyle Intersection
    - Extreme vehicle traffic with awful merging. Crowded with people on all corners.
24. **18:14** Mong Kok Rd
    - Moderate number of vehicles. Large percentage turned down Nathan
25. Walk Ends

3. Central/Sheung Wan

H.3.1. Walk 1

February 10th

1. **9:06** Walk Begins Central MTR Exit A
2. Connaught Rd Central
    - Low commercial vehicles, moderate bus count, high private, high taxis. Bus's appear to be mostly empty. Low flow in Sheung wan to Admiralty direction, moderate flow Admiralty to Sheung Wan direction (many more buses in this direction)
    - **9:10** Congestion forms very rapidly near highway exit. Road splits into highway and urban areas. Highway flows nicely while urban is packed. Commercial unloading on urban split.
    - **9:14** Very backed up going up highway ramp in Sheung Wan direction. Low flow towards Admiralty. Large traffic flow going under highway.
3. 9:16 Des Voeux Rd Central
    - Moderate flow but well light controlled, resulting in large gaps in traffic. Numerous bus stops with many buses, but lights still controlling well.
4. Gilman St, Wing Wo St, Rumsey St
    - Low mixed flow
5. Man Wa Lane
    - Virtually no vehicles.
6. Connaught Rd Central
    - 4 lanes total, 1 parking. Lane going straight towards Admiralty backed up at lights
    - Double parking in one particular area as commercial vehicle attempts to avoid bus stop and other spots filled with other commercial vehicles. 24 hour no unloading sign clearly visible.
    - **9:25** Road splits again into 3 and 1. The "1 lane has largely blocked by commercial vehicles, leaving half a lane available. The other 3 have low congestion despite their high flow due to light control.
7. **9:26** Hillier St
    - Large outflow onto Des Voeux, mostly taxis and commercial vehicles, initially appears to just be a crossing to Connaught. 1 lane heavily parked.
8. Cleverly St
    - Moderate flow turning onto Des Voeux
9. **9:30** Morrison Rd
    - Moderate flow of larger vehicles turning onto Connaught (traffic normalized on Connaught)
10. **9:32** Des Voeux Rd Central
    - Reasonable flow on street. Large cross flow coming from opposite side of Morrison Rd
11. **9:35** Morrison Rd (south side)
    - Backed up traffic at light

12. **9:37** Bonham Strand
    - 2 lanes, 1 parked. Moderate flow. No buses in area.
13. Jervois St
    - 2 lanes, 1 parked (intentional parking lane). Low flow.
14. Queen's Rd Central
    - 3 lanes with low flow. Mix of commercial, taxis, and private
    - **9:40** Side parking begins in 1 lane.
    - Lok Fu Rd has low flow onto Queen's
15. Mercer St
    - Low flow
16. **9:45** Bonham Strand
    - Moderate flow heading towards Central.
17. **9:46** Hillier St
    - Large flow that is almost backed up into next intersection.
18. Wing Kok
    - Large slowing moving flow going straight. Many circling commercials and pedestrians.
    - Flow blocked by backed up Hillier traffic, no lights so at driver discretion when to let out.
19. **9:55** Des Voeux Rd Central
    - Low-moderate flow.
    - Hillier confirmed to just be crossing to Connaught.
20. Connaught Rd Central.
    - High traffic, low congestion due to lights. Many empty Buses
21. **9:57** Walk Ends

H.3.2. Walk 2

February 10th

1. **6:15** Walk Begins
2. Des Voeux Rd Central

a. Large bus flow in both directions. Reasonable passenger amounts. Extremely long lines waiting for certain bus routes. Dangerous driving by buses due to number of bus stops.

3. Jubilee St

. Low Flow

4. Connaught Rd Central

. Moderate flow towards Sheung Wan. Mixed types with mostly private.

a. Taxis attempting to pick up interfering with 3 of the 4 possible lanes.

5. Queen VIctoria St

. Large flow onto Des Voeux Rd Central

6. **6:20** Pottinger St

. 3 possible lanes, extensive double parking. Low flow.

a. Opposite side has moderate flow turning onto Des Voeux. 3 possible lanes, 1 parked.

7. Des Voeux Rd Central

. Bus line still very long with buses fighting each other for driving room. Bus 961 very full with lines.

8. **6:25** Queen's Rd Central (near D'Anguilar Intersection)

. 2 lanes (1 larger lane), 1 parked. Large flow but steady due to light control. Clear problem of pedestrians being picked up by non-public transportation. Appear to be cheouffers.

9. **6:30** Queen's onto Pottinger

. Pottinger backed up with private, commercial and taxis. Causes Queen's turning lane to be back up, which causes the straight lane to be congested as well.

10. Stanley St

. Low flow, some parking.

11. **6:32** Lan Kwai Fong area

. Moderate flows in surround area, high number of pedestrians. Mostly taxis and private

12. Wellington St

. Low flow, some parking

13. **6:36** Wyndham St

. Moderate flow, some congestion due to light onto Queen's.

14. Queen's onto Pedder St

. Large flow that backs up onto main road affecting other lanes. No light buses seen in area for some time.

15. **6:40** Ice House St Intersection

. Moderate flow from Ice House. 2 lanes total with most taking left onto Queen's

a. Opposite Queen's Rd has heavy flow going straight.

b. **6:44** Ice House across Queen's has moderate flow onto Des Veoux. Private Bus stops in middle of the street and blocks all traffic, causing traffic to back up into Queen's.

16. Des Voeux Rd Central

    . Significant number of buses, very slow moving.

17. **6:46** Charter Rd

    . Very congested with mix vehicle type. 3 lanes total with 1 blocked by idle vehicles. Numerous bus stops but don't appear to be currently a problem, simply extreme vehicle counts.

    a. Charter Rd vehicles turning right onto Murray Rd

18. Connaught Rd Central

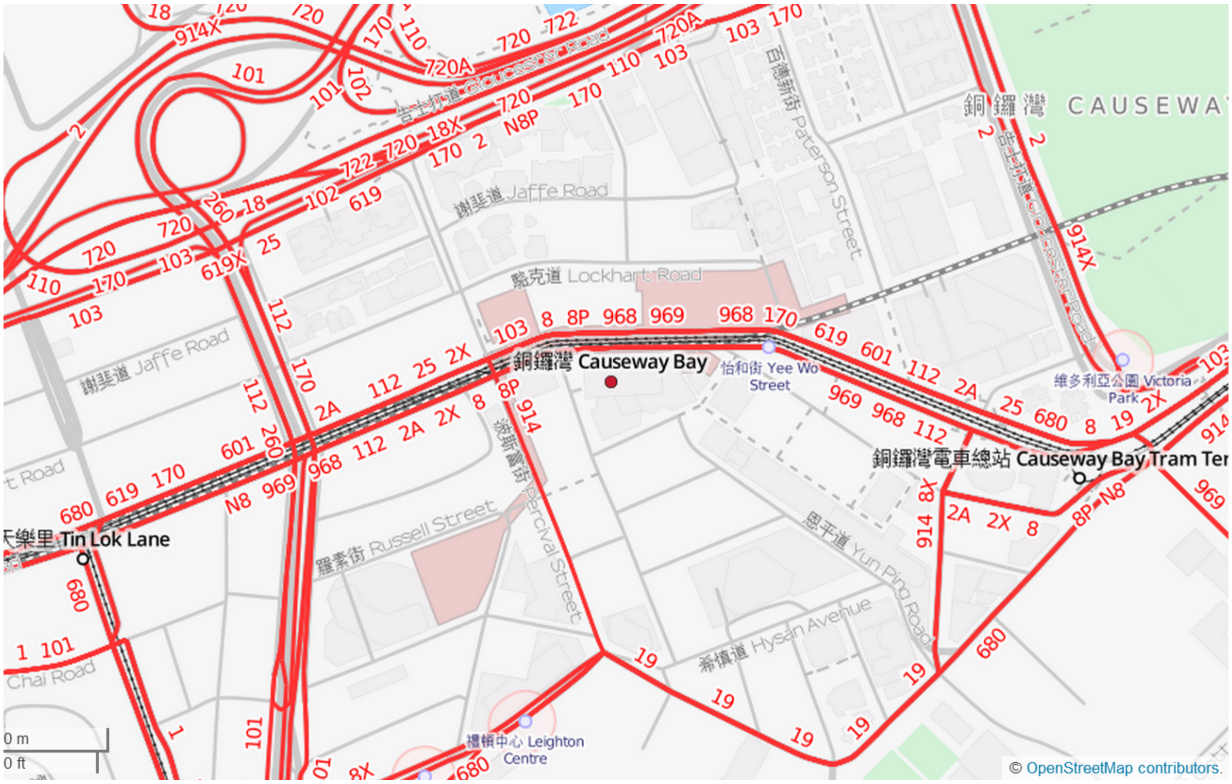
    . Heavy, congested vehicle flow going in both directions with mixed vehicle types.

Appendix J. Area Maps

The following maps illustrate each area of concentration with each bus routes' stop. Although there are bus stops on every street, only the main roads were labeled due to the high congestion in those areas.

J.1. Causeway Bay Area Map

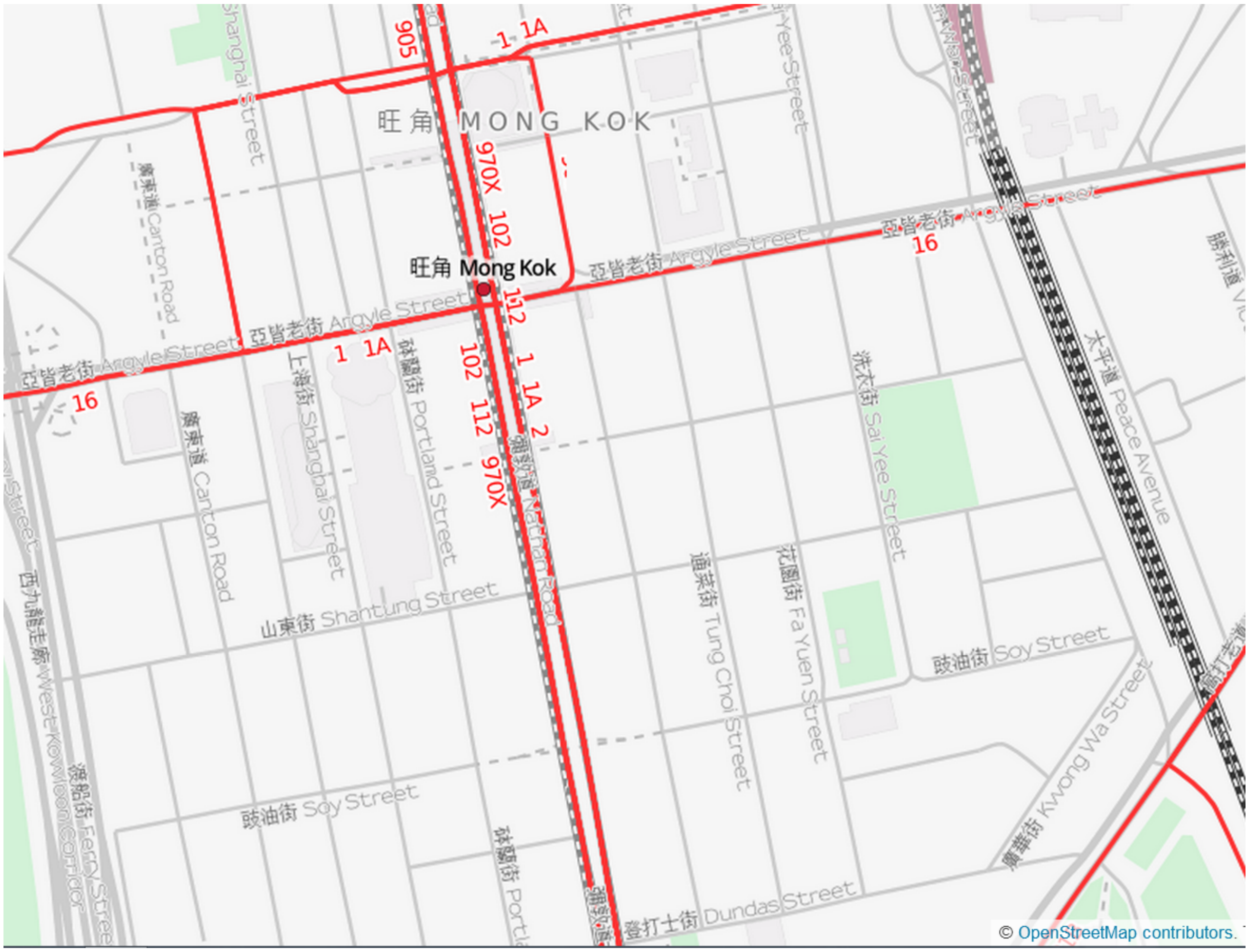
J.1.2. Causeway Bay Bus Route Map



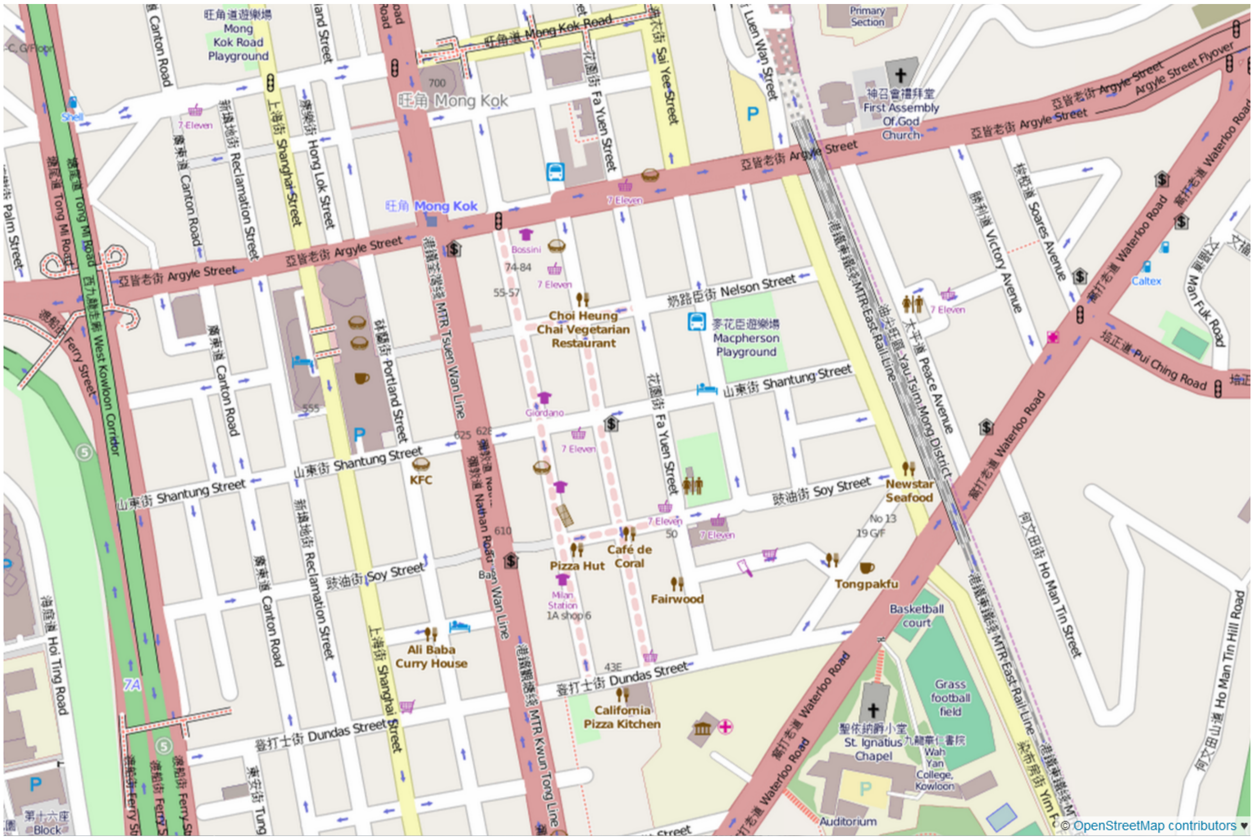
J.2. Central Area Map

J.2.1. Central Bus Route Map

J.3. Mong Kok Area Map



J.3.1. Mong Kok Bus Route Map



Appendix K. Transportation Policy Table

Method	Proposed in HK's acts?	Location of Reference	Why was it put in place?	Description	Positive impacts	Negative impacts	Application to Hong Kong
Low Emission Zones	Yes	London	To encourage polluting vehicles to go green	Covers most of Greater London. To drive within it without paying a daily charge, these vehicles must meet certain emission standards that limit the amount of particulate matter	1/3 of heavy vehicles are significantly cleaner than a year before. 96% of vehicles are compliant with emission standards compared to 70% in 2007.	Initially opposed by stake holders saying standards were different than forthcoming Euro 5 requirements and also stating additional cost to hauler.	Proposed in Clean Air Plan. Can be applied to high traffic areas (ex. MK, CWB, Central), drop off/pick up areas.
Vehicle Plate Restriction	No	Beijing	Reduce number of cars on road to reduce emission in prep for Beijing Olympics	If a license plate ended with an odd number, cannot drive on roads on even numbered days, and vice versa	Black carbon decreased 33% from 2007-2008, CO2 decreased 47%, and carbon-based microparticles decreased 78%. Almost 2 million vehicles were pulled off the roads.	Might not receive positive opinion from public	Can be applied to cross harbor tunnels. if a license plate ended with an odd number, cannot drive through Hung Hom tunnel on even numbered days, etc.
Area and time restriction on trucks	No	Beijing	Reduce number of cars on road to reduce emission in prep for Beijing Olympics	Trucks can only be driven inside the 6th ring road	decrease congestion on the roads, more open lanes for traffic flow	not flexible for businesses, shopkeepers	Applied everywhere where commercial trucks are the highest cause of congestion and road blocks
Limit use of government vehicles	No	Beijing	Reduce number of cars on road to reduce emission in prep for Beijing Olympics	70% of government vehicles were not allowed to be operated	decrease congestion on roads, reduce number of cars	government workers may not be happy	There are not too many government vehicles on the road, but can limit the use of government-contracted vehicles

Labeling high emission vehicles	No	Beijing	Reduce number of cars on road to reduce emission in prep for Beijing Olympics	Majority of the vehicles have yellow environmental labels (high emission) and were banned from the city	Significantly reduce the number of cars on the road	If people are still buying cars as a sign of luxury, will have the same number of cars on the road than enacted with this policy	Can be applied to high vehicle areas, similar to low emission zone. Cannot entirely ban high emission vehicles, can divert them to N.T.
Increasing fee for registering a private car	No	Singapore	To reduce new car ownership	Began in 1972, known as additional registration fees (ARF)	Reduces the number of private cars on the road	Didn't work out in the long term.	Currently have a 100% tax for every new private vehicle bought. Cars are a sign of wealth/luxury, hard to take down social image
Area Licensing Scheme	No	Singapore	Reduces traffic	Required a special license to travel to Central Business District	45% drop in traffic	More people began to work in CBD	Can be applied to high traffic centers like Central and Causeway Bay. However many roads connecting from one place to another, passes through these high traffic centers.
Vehicle Quota System	No	Singapore	Reduces number of new cars on road	Limited vehicle purchases to just 3% of expanded road systems	Reduced new cars by 41,000 from '90 to '93	Some cars will be denied application, therefore public will not approve	Can be applied if the application can cover different areas. For example, if a car has semi-high emission, then they are permitted to drive anywhere except South Kowloon and HK Island.

Off Peak Car Scheme	No	Singapore	Reduces driving usage	Lower car taxes and registration fees based on lower car usage	Tolls for using roads discourage drivers and thus reduce traffic and congestion	People preferred paying more for more car usage	Difficult because cars are a sign of luxury, and people will still pay the 100% tax to own one
Road Pricing Scheme	No	Singapore	Reduce traffic	System of tolls in the entryway of highest traffic areas. Drivers needed the correct change to obtain a ticket	Reduce traffic in some main roads and net a large sum of revenue for the city	Side routes were backed up	Can be applied to entrances of tunnels and congested highways
Electronic Road Pricing	No	Singapore	To decrease congestion and streamline process for public	Placing a device on the dashboard that reacts to sensors placed in high traffic areas. Passing through a checkpoint without a CashCard would incur a fine of $40 and driver info would be taken through license plate cameras.	Traffic decreased by 17%	Potentially very expensive to intitate; all drivers required to obtain in-vehicle unit	Tunnel toll plazas rely on manual payment methods In terms of use on general roadways, there are some roads with very heavy traffic that could be diverted to nearby routes
Semi-Public Bus System	No	Seoul	To improve public use of buses	Private firms still ran the buses, but government controlled routes, schedules, fares, and overall system design. Created 400 set bus routes with color-coded route types.	Every community had full access to the bus system. Added over 70 km of dedicated bus lanes. Alleviate the congestion. Buses run on compressed natural gas. Total passengers increased by 14%.	70% of passengers were dissatisfied. 60% of passengers said the changes were confusing.	Hong Kong bus system is inefficient and needs to be re-worked

Traffic Gravity Models	No	United States	To determine how to divide funds and for each city to access federal funding for transportation	Models are made to analyze traffic patterns, pinpoint areas that traffic is heaviest. Required by the Clean Air Act	More accurate depiction of traffic flow for use by road planners	Measuring equipment can be expensive, as can software	Can be used in conjunction with other tools to devise specific policy
Limited Traffic Zone	No	Rome	Reduce overall congestion and encouraging a shift from private to public transport	Covers roughly 5 km^2, concentration of gov buildings to reduce vehicle flow in this high traffic area. Uses automated access control system and a flat rate Road Pricing Scheme. Implements electronic gates and distribution of annual permits for authorized personnel (granted permission fee of charge).	Reduces pollution from private vehicles by restricting traffic flow and congestion	20% of vehicles enterring illegally.	Very high commercial traffic during peak hours in crowded areas of Hong Kong
Carbon Pollution Reduction Scheme	No	Australia	To control air pollution by transportation	cap-and-trade emissions trading scheme. to reduce greenhouse gas emissions	Reduces roadside air pollution caused by vehicles	Unable to be passed, due to criticism from all sides.	Many vehicles in Hong Kong are old and do not meet modern emission standards
Air Quality Management Areas	No	London	Defined by the 1995 Environment Act to centralize overall air pollution management by one authority organization	Requires local authorities to create an Air Quality Action Plan per AQMA. Areas include densely populated cities. Found that over 90% of AQMAs were	EU tightened emission standards.	Air quality has not responded to these sanctions, and pollution has increased in some large cities. Growing population of motor	Research shows that certain areas in Hong Kong have more air pollution than others

				caused by excessive road transportation emissions.		vehicles in Europe outweighs the advances in pollution reduction policy.	