Air Quality Perception of Commuters in Delhi

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Air Quality Perception of Commuters in Delhi

Dissertation

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By

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Under the Guidance of

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I would like to dedicate this thesis to my loving parents ...

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled **"Air Quality Perception of Commuters in Delhi"** submitted by **Kapil Kumar Meena** bearing the **Enrollment No: 19524005**, in the partial fulfilment of the requirements for the award of degree of Master of Technology in Civil Engineering with specialization in Transportation Engineering, submitted to the Department of Civil Engineering, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out under the supervision of **Dr. Amit Agarwal** Department of Civil Engineering, IIT Roorkee. The matter embodied in this dissertation has not been submitted for the award of any other degree.

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" Talent wins games, but teamwork and intelligence win championships."

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Kapil Kumar Meena

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List of Abbreviations

$PM_{2.5}$	Particulate matter less than 2.5 micrometer
PM_{10}	Particulate matter less than 10 micrometer
NO_2	Nitrogen Dioxide
CO	Carbon Monoxide
CPCB	Central pollution control board
NAMP	National air quality monitoring program
WHO	World health organization
MOE	Margin of error
AQI	Air quality index
NCR	National capital region
MNL	Multinomial logit

Abstract

Air pollution has a significant impact on health but is often invisible to the naked eye. The rise in air pollution has affected not only human health but also short-term and long-term behaviours. This study aims to explore the commuters perception of how they perceive air quality information and the change in their travel choices to reduce air pollution exposure if air pollution information is provided. To comprehend the objectives, Delhi is selected as the study area. After delineating it on the basis of annual and hourly ambient air quality levels. Two types of survey (n = 643) were conducted (a) Online (b) Offline, Online survey was conducted in whole Delhi and NCR, while an offline survey conducted in south Delhi where the exposure is high as according to CPCB data. The study findings show that only half of the respondents are aware of the air quality index but did not understand it. Commuters' preference to air pollution exposure in their travel is the least, and lack of any information intervention is the main reason for it. With the availability of information, commuters prefer close transport modes (car, bus, and metro) during severe air quality levels. This finding shows the importance of real-time information in commuters decision-making, and due to the unavailability of any information concerning air pollution exposure, the commuters cannot make any decisions that can reduce their exposure during travel

Keywords: On-road, Air Pollution, Exposure, Travel Behaviour, Transport Emission

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Chapter 1

Introduction

1.1 Background

With rapid urbanisation and expanding industrial and transport sectors, air pollution has become more than just an environmental issue in the last two decades. In 2016, according to World Health Organisation (WHO), 91% of people lived in the area where WHO air quality limits directions did not meet (WHO, 2020; HEI, 2019). Air pollution has become a significant threat to human health and is now one of the world's leading cause of deaths (Manisalidis et al., 2020). In the whole world, 4.2 million deaths occur every year due to ambient air pollution (WHO, 2020). The main proportion of these deaths occur in India, where air pollution has alone contributed to 1.7 million deaths in 2019, which is 18% of total deaths in the country (Pandey et al., 2021). Due to the increase in air pollution, the risk factor for health is also increasing, leading to short-term and long-term diseases (HEI, 2019). Air pollution can cause respiratory/ cardiovascular, lung cancer, stroke, heart disease, chronic bronchitis, asthma attacks, etc., (Balali-Mood et al., 2016; Kumar, 2015). Air pollution not only has a negative impact on health, but it also reduces people's life expectancy. Air pollution reduces a person's average lifetime by 20 months over the world, and in India, the figure is significantly greater, with 5.2 years lost in life expectancy (Greenstone and Fan, 2020). In 2020, India was the third most pollutant country in the world, with an annual average $PM_{2.5}$ concentration of 51.29 $\mu g/m^3$ (IQAir, 2020). For the duration between the year 2011-16, India had 14 cities out of 15 with having the worst $PM_{2.5}$ (Goel and Guttikunda, 2015). Delhi is the world's most polluted capital city, with an annual average $PM_{2.5}$ concentration of 143

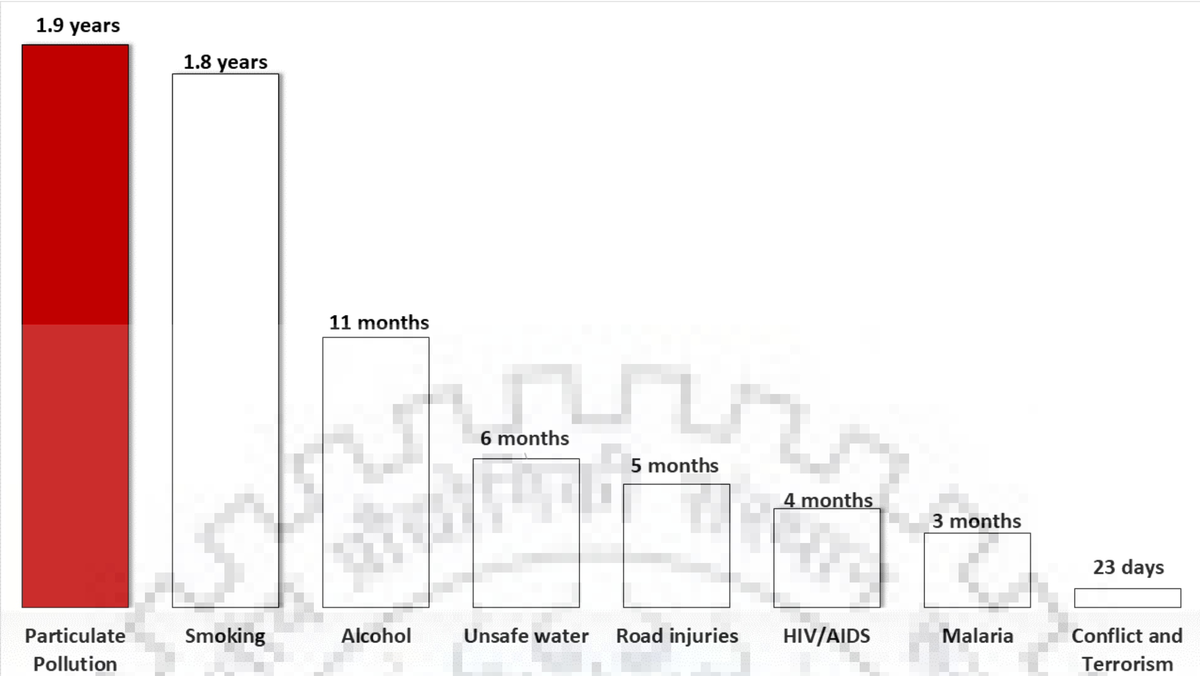


Figure 1.1: Average life expectancy lost per person. Source: Greenstone and Fan (2020)

$\mu g/m^3$ and the 6th most polluted city in the world (IQAir, 2020). Moreover, the ambient $PM_{2.5}$ concentration exceeded the national air quality standard by more than 300% in Delhi several times (Maji et al., 2020). Air pollution is not only a risk to health but

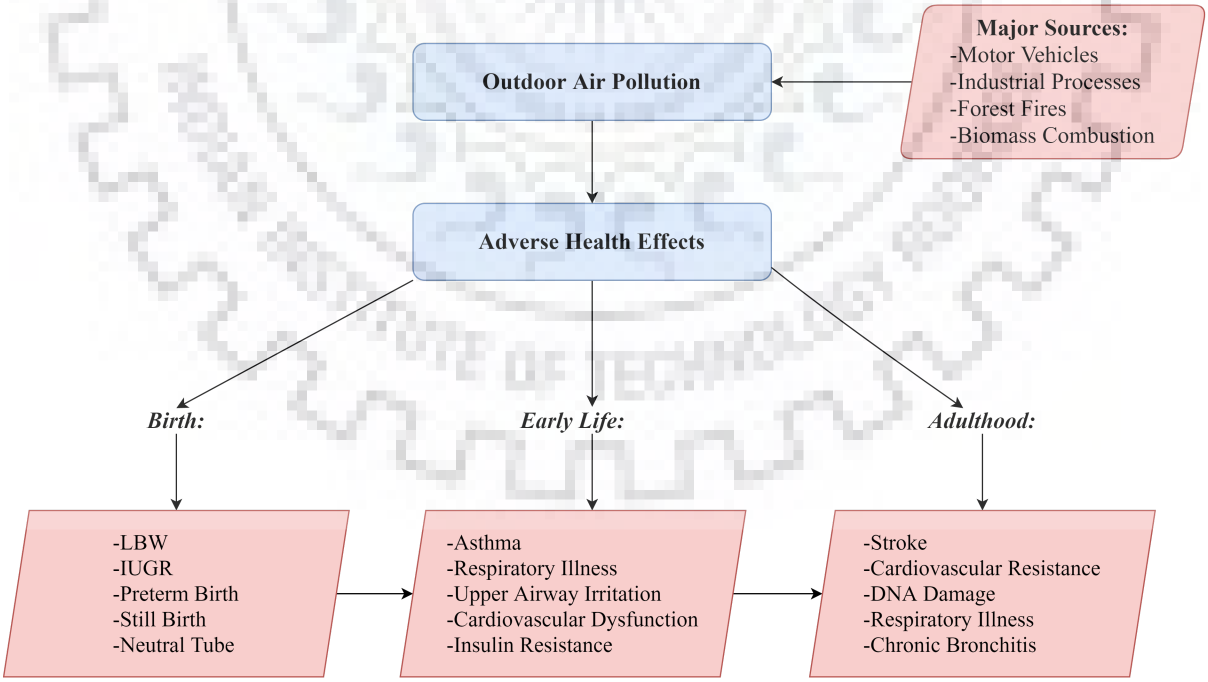


Figure 1.2: Sources and effect of air pollution.

also a developmental drag. By causing sickness and unexpected passing, air pollution diminishes the quality of life.

With rising levels of air pollution, not only are more people affected, but the time of their exposure is also increasing. Among all activities, travel is one of the activity where commuters are most exposed to air pollution in daily life (International Energy Agency, 2016; Singh et al., 2021). On average, 8% of time spent in transport is responsible for 32.7% of exposure (Dons et al., 2019). The dedicated infrastructure for cyclists can contribute to reduce in the overall emissions (Agarwal et al., 2020) but, it is likely to elevate the exposure to air pollution for cyclists (Agarwal and Kaddoura, 2019). To avoid exposure to higher air pollution, commuters take preventive measures to change their behaviour. In the past, it is found that commuters take actions such as adjusting travel choices, avoiding trips and decreasing outdoor activities (Li and Kamargianni, 2017; Cui et al., 2019; Qiu et al., 2020).

To know how commuters make changes in their choices, it is important to gather the perception of commuters towards air pollution. In Australia, it is found that higher educated people or those who live in the major cities are more likely to recognise air pollution as a major concern for their health damages irrespective of their travel mode (Badland and Duncan, 2009). A similar study has been done in California, and the findings show that people who are more concerned about air quality check it more frequently. People with asthma were found to check air quality more likely when working and exercising in the open air (Veloz et al., 2020). However, as per the author's knowledge, there is no study available for Indian context, which shows the perception of commuters towards air quality.

In a city like Delhi, where air pollution is severe, commuters should inevitably take preventive measures. However, there is very little clarity on the perception of travellers' in Delhi. Therefore, this research aims to learn about daily commuters' attitudes toward air pollution in Delhi. First, this study investigates commuters' perceptions of air pollution and whether they understand the air pollution exposure, whether they change their travel choices to reduce their exposure to air pollution. Afterwards, their stated choices are analyzed through choice modelling when air quality information is provided to them.

1.2 Current scenario in India

In India, to monitor and control the level of air pollution, an organization is established under the air pollution act 1974 named CPCB (central pollution control board). This organization has taken many steps to improve air quality and to prevent, regulate, or reduce air pollution in the country Still, India remains one of the most polluted country(WHO 2018). CPCB runs across the country projects of surrounding air quality, mainly in urban areas, observing known as National Ambient Monitoring Program (NAMP). As of June 2020, available data, there are 793 monitoring stations in the country nationwide covering 344 cities (Goel and Guttikunda, 2015). While In Delhi, monitoring has been done by many organizations as shown in Tab. 1.1 and Other private companies have installed many monitors and show it on the dashboard, but this data is not public. Examples are Atmos and Prana Air.

Table 1.1: Current monitoring station in Delhi

type of station	monitoring station
AAQMS (manual)	10
CAAQM (continuous)	11
DPCC	6
SAFAR	8
total	35

Source: https://app.cpcbccr.com/ccr/; Goel and Guttikunda (2015)

System of Air Quality and Weather Forecasting and Research (SAFAR) is a collaborative program between the Indian Institute of Tropical Meteorology (IITM, Pune) and Government of India that were started in 2010[1]. The program currently runs in four cities viz. Delhi, Mumbai, Ahmedabad, and Pune, where eight air quality-monitoring stations are installed in each city. SAFAR also has a smartphone application, and it gives real-time Air Quality Index (AQI) of these four cities and forecasts AQI of the next two days (Pant et al., 2018). Furthermore, under NAMP major three vital components, i.e., Particulate Matter(PM_{10}), sulfur dioxide (SO_2), and Nitrogen dioxide (NO_2), while the rest of the country having a lack of monitoring systems due to which delay in real-time

[1] http://safar.tropmet.res.in

updates and transmission of data to users.

1.3 Need of study

With swift motorisation, dense urban activities and dependency on the motorised transport, vehicular emissions is rapidly becoming the major source of air pollution in urban area (Zavattero et al., 1998; Demirel et al., 2008) which is imposing a huge burden on the health (HEI, 2019). Exposure to air pollution can affect the human health, leading to respiratory and cardiovascular diseases, eyes, nose irritation, skin diseases, and cancer (Balali-Mood et al., 2016). Given its impact, air pollution is recognised today as a significant threat to human health. Fig. 1.1 shows the share of annual deaths due to outdoor air pollution through out the world. This proportion was highest in India with a 17.5%, it depicts the level of significance of air pollution contribution in India. Air pollution is more severe in the urban places due to dense activities, urbanisation

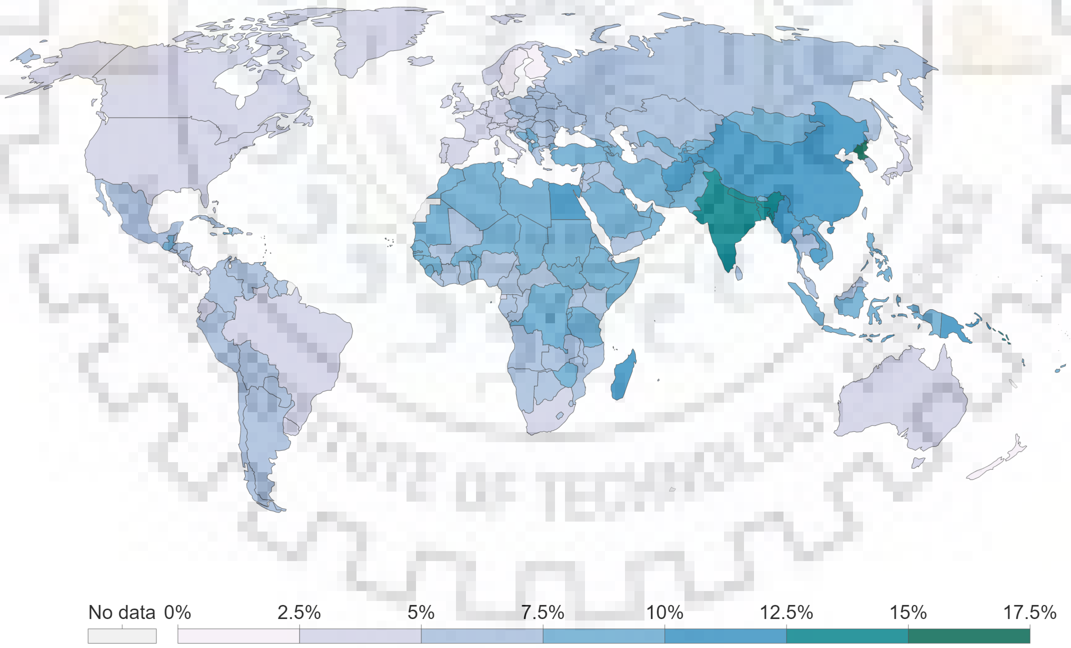


Figure 1.3: Share of deaths from Outdoor air pollution in year 2017. Source: (Ritchie and Roser, 2017)

and increased motorised transport. Owing to higher levels of emissions, more people are exposed to poor air quality and to reduce the exposure there is alter in behavioural impacts as discussed in Sec. 1.1. The change in behavioural aspects is due to awareness of the impact of air pollution on human health. This is forcing individuals to change their choices to reduce exposure to air pollution. This emphasises the requirement of policies and strategies that can help people in reducing their exposure to air pollution. These polices should be implemented globally and nationally and then practised at regional and local levels (Caplin et al., 2019). To implement these policies there is need of integrated air quality monitoring network that can provide air quality information at local level (Brauer et al., 2019). Monitoring air quality is significant for the policymakers that can accordingly frame policies and strategies to curb air pollution and for the environment experts to understand the impact of policy changes. In order to control the air quality, various monitoring mechanisms are used. The monitoring of air quality plays a vital role in disseminating information on air quality to the general public as well as in implementing the strategies to control the local air quality levels. But there there is a substantial gap in the availability of data on air pollution due to the lack of real-time air quality monitoring stations in India. Governments are making efforts to extend their monitoring network and provide people with real-time air quality information. Various communication strategies such as government/ private websites, mobile apps, and radio/ FM are used to provide air quality data. An added advantage of such information is that an individual can react to different levels of air pollution. For instance, during high pollution days, residents reduce their outdoors activities, adjust their departure time to various activities, reduce active-mobility and stay-at-home, etc. (Welch et al., 2005; Saberian et al., 2017; Siqi et al., 2016). Real-time and forecast information assist residents to alert in advance and initiate actions that curb down their exposure to the air pollution. The focus of this dissertation is to provide a perception of commuters towards the air quality and the changes in their travel behaviour when information is available to them.

1.4 Problem description

Multiple studies have been conducted on how various weather phenomena like rain, snow, and warm weather affect an individual's travel choices. A similar kind of effect is being observed due to the rising pollution level in many metropolitan cities across several developing nations around the world.

This dissertation investigates the effects of air pollution on individual choices, via the intercept survey done for an appropriate sample size following the demographic characteristics of the Delhi population. For collecting commuters preferences, perceptions, and travel and socioeconomic characteristics, a survey instrument has been designed in form of a questionnaire. The survey has been carried out through online and offline mode. For online mode, the survey has been carried out through whole Delhi & NCR while for an offline survey, it's been conducted in highest exposure level zone, i.e. Nehru Nagar which come under south Delhi. A descriptive analysis is carried out using tableau software after the survey's conduction, and then choice modelling is used to analyzed the impact of air pollution on travel behaviour.

1.5 Objectives of study

To find out solutions for the problem described above in Sec. 1.4 section, the following objectives of the study are formulated:

1. To investigates the commuters' perceptions of air pollution.
2. To evaluate the travel behavior under the influence of air pollution.
3. To develop a model for estimating the change in the behavior of commuters with the provision of air pollution levels.

1.6 Organisation of report

This seminar report is organised in to following below six chapters:

Chapter 1 provides a general overview to the topic.

Chapter 2 talks about various previous studies done on the research topic.

Chapter 3 explains the methodology for the achieving the aim.

Chapter 4 shows the data collection carried out through online & offline and descriptive analysis.

Chapter 5 shows the choice modelling through Multinomial logistic regression.

Chapter 6 shows the conclusion and future work direction.

Chapter 7 shows the carried out research publication.

Chapter 2

Literature Review

We expand on the past studies done over the impact of air pollution on travel behaviour that how people perceive the pollution, how people affecting due to it and most of the studies define the impact of these perceptions over various specific types of travel patterns. Basically, Literature review divided into following categories.

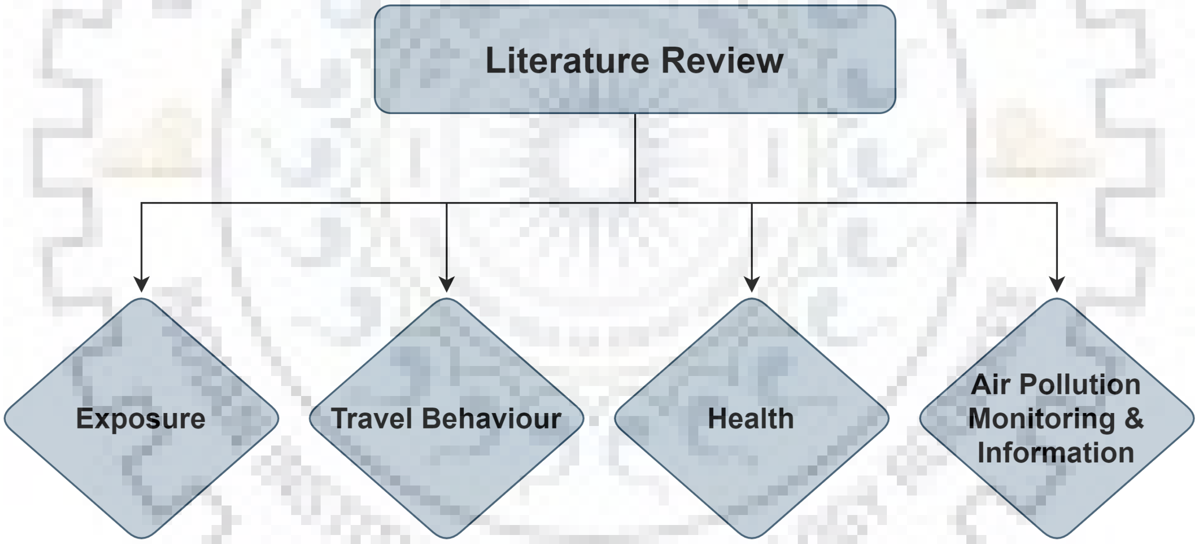


Figure 2.1: Literature review flowchart.

2.1 Health

Air pollution is one of the world's leading cause of deaths and have profound impact on human health. Air pollution can cause from various sources, such as vehicular exhaust emissions, pollution from industries, commercial activities, brick kiln, thermal plants, road dust, waste/agricultural waste burning, indoor air-pollution, etc. (Balali-Mood et al., 2016). Respiratory illness is one of the most common diseases caused by exposure to air pollution and there is a sharp increase in cases of respiratory illness in Mumbai due to air pollution (Kumar, 2015). In addition to respiratory and cardiovascular diseases, eyes/ nose irritation, skin diseases, etc., air pollution also affects pregnant women, infants, students, etc. (Ballester and Iniguez, 2011; Chen et al., 2018). The student are the most vulnerable group of people affected by exposure to air pollution. A study conducted on 26 school children suffering from asthma for 1035 days shows that traffic-related pollutants (VOCs, NO_x, PM_{10}, etc.) can lead to adverse health effects in asthmatic children (Delfino, 2002).

Künzli et al. (2000) provide an assessment of various health outcomes (e.g., long-term mortality, respiratory/ cardiovascular patients, bronchitis, asthma attacks, etc.) for three countries in Europe. The dynamic health impact assessment is proved to be a better exposure assessment technique in which mobility of the population is considered rather than assuming always at-home scenarios (Dhondt et al., 2012). To reduce the health risks due to air pollution, people are doing activities so that they get less exposed to air pollution. A study conducted in Beijing to understand the coping behaviour against health risks of haze pollution and it was found that people prefer to wear mask and purchases air purifier rather than using electric vehicle (Xu et al., 2020). In addition to emphasize the negative effects of air pollution on health, some other studies attempt to evaluate the health benefits by using active mode of transport or by reducing the air pollution exposure (WHO, 2017). For instance, Agarwal (2020) quantifies the health benefits of increased number of cycling trips and longer cycling duration. Similarly, providing a bus rapid transit system along a major traffic corridor in Indore, India can reduce the emissions by 11% and mortality risk by 1.1% (Mahendra and Rajagopalan, 2015).

2.2 Exposure

The past studies on air pollution exposure show that exposure level is different for different transport modes. For instance, an analysis of personal exposure by Jyoti Maji et al. (2020) is conducted in Delhi in six different transport modes. The result shows that auto rickshaws and walking leads to the highest level of exposure. Given the heterogeneity in the exposure to individuals with different health conditions, travel behaviour, travel mode, socio-economic status, many studies quantify the level of exposure to air pollution at individual levels or smaller group levels (Liang et al., 2019). Those who were less educated, younger, overweight, low to middle household income, home and office without ventilation and did not have private vehicles are more prone to air pollution exposure.

For instance, Agarwal and Kaddoura (2019) maps the on-road air pollution exposure to the home-locations and demonstrate that slum-users are most affected. Similarly, cyclists is most affected due to air pollution exposure. The study comparing on-roadway mode and in-cabin mode shows that the concentrations of $PM_{2.5}$ for on-roadway mode (average) is 76.0 $\mu g/m^3$ whereas for in cabin modes (average) it is 53.5 $\mu g/m^3$ (Wu et al., 2013).

2.3 Travel behaviour

Among various travel behavior dimensions, mode choice is one of the most focused one in the studies and mainly it is related to change from non-motorized to motorized or vice versa. Cycling is found to most elastic towards the change in pollution levels. There have been studies that show that people avoid cycling when pollution levels are high because adverse effects of air pollution on cyclist's health are widely believed to hinder cycling and also worsen their cycling experience. There various studies in China that shows decrease in cycling and walking during bad pollution. Study conducted in Taiyuan, China of same individuals in two seasons (Summer and Winter) shows that biking, bike sharing and walking were not preferred when pollution levels were high i.e. winter season (Li, 2019). Travelers switched to cars, taxis, buses and electric bikes and moderate pollution doesn't have any significant impact on mode choice behavior. Another study conducted in Beijing on 307 cyclists considering different levels of air quality concentration of PM 2.5 on separate days (Zhao et al., 2018b). It was found that males of 30-year age having low income are those who travel short distances are more persistent in cycling in polluted weather. Usage of cycles for commuting trips has a lesser probability of being replaced by other means of transportation that non-commuting trips such as shopping. Other study from Sydney, Australia found that people are more likely to avoid cycling wherever an air quality alert is issued. The reduction in cycling was found out to be in-between 14% to 35% and cycling for leisure trips see more downfall than on work trips (Saberian et al., 2017). Similar type of study was done in Salt Lake and Davis counties, Utah to and it was found that air quality alert systems had reduced the traffic over a 10-year period and air quality alerts have some effectiveness for reducing traffic in the center city (Tribby et al., 2013).

Li (2019) shows in his study that in bad air quality people are less likely to walk and weakly more likely to bike. Results of study shows that bad air quality people prefer subway and cars during bad air quality and one people less is making trip from each household. Similar to bad air, smog can also affect mode preference and urge travelers to use cars (Zhao et al., 2018a). Bad air quality can also affect route choice behavior and Studies have shown that it can decrease commuter exposure (Li et al., 2016).

2.4 Air monitoring & information

Pant et al. (2018) which focused on upgrade in data quality and data access and the use of hybrid monitoring networks. In the studied en-lighted on early warning systems and air quality forecasting. These suggestions can lead to the path followed by China in decreasing their air pollution. One of the studies shows how ambient air quality in China has changed in the last four decades. Their results showed that there is a downward trend in PM10 annual average concentration from 2000-2018. This was due to the new ambient air quality standard issued in China in 2012 and outcome showed that the PM10 average concentration is 22.7% lower than 2013, and for Beijing, their PM2.5 fall from 89.5 $\mu g/m^3$ to 58 $\mu g/m^3$ in 2017 (Zhang and Batterman, 2013). Due to reform in the air pollution policy of China in 2012 and the introduction of real-time information through mobile apps, there was a lot of change in the behaviors of people. It was found that there was a reduction in outdoor activities, and people were traveling and migrating when air quality was bad. Another similar study done by Liu et al. (2017) upon the effect of air pollution on mode of travel before and after the china launched a disclosure of nation-wide real-time air quality monitoring program. The study find out the result prior to reform that air pollution exposure make people less likely to walk and more likely to bicycle. Take bus, take car, take subway, and take other transport modes and air pollution found that decrease in both the number and share of household members in each household who took at least 1 trip that hour. But In Contrast, in year 2014, after the reform program, Air pollution exposure make people more likely to walk and take a taxi, and less likely to bicycle, take bus, take care, take subway, and take other transport modes ; and air pollution increase in number of members in household who took at least 1 trip that hour. Due to reform in the air pollution policy of China in 2012 and the introduction of real-time information through mobile apps, there was a lot of change in the behaviors of people. It was found that there was a reduction in outdoor activities, and people were traveling and migrating when air quality was bad.They also found that the city was losing talented people and residents were staying indoors during weekends to avoid air exposure (Cui et al., 2019).

There is also of similar type of study that shows how travel-related exposure to air pollution based on travel diary sets. They used structural equation modeling to find the relationship between the built environment and travel behavior associated with individual exposure controlling his/her socio-economic status.The researchers observed differences between the exposures of PM 2.5 and CO on daily basis in relation to ones lifestyle, living condition, occupation etc. The people owning the residences were observed to have lesser exposures than those renting and residing. High income people had less exposures compared their counterparts, also the married couples had lesser level of exposures as compared to the unmarried group (Guo et al., 2020).

This can be depicted from above studies that how real time information changes travel behavior and similar type of study done by D. and Kohli (2019) in USA how air pollution information through a smartphone app can affect health of people. They learnt that 69% of people have found the application helpful in providing health benefits against air pollution and 59% of people availed the app in order to learn the impact of air pollution on health. In addition to that, there is absolutely no harm in using air conditioning with air filters inside the perimeter of their home. Survey suggested that over 70% of respondent's like to check the application at least once in week and there are 18% respondent's who check it daily.

Similar kind Study of study done in Barwick et al. (2019) in which after getting the real-time information behavior of people is changed, within a year air purifier purchases were more than double, people started going avoided many outside trips which are consumer trips and prefer less to go where AQI is high and there was the decline in cardio-respiratory diseases to 7% reduction in premature deaths. Based on the study, it was found that the real pollution-monitoring program has led to a cascade of changes such as increased pollution access and awareness, short- and long-term trip avoidance behavior, as well as muted pollution-health relationship.

Chapter 3

Methodology

3.1 Introduction

The methodology used for achieving the dissertation's desired objectives are dealt with in this chapter, and the flow chart depicting the process is shown in Fig. 3.1

3.2 Study area and methodology

Delhi, India's capital city and the biggest megacity of South Asia, is situated at 28.7041° N, 77.1025° E. Delhi has a population of over 11 million while NCR has over 26 million (India, accessed 2021).

Rapid population widening into intensive development of infrastructure has led to increased energy demand in the domestic, transport, and industrial sectors, leading to increased particulate matter emissions from the air. In Delhi, vehicular pollution singly contributes about 72% of the total air pollution exposure (Sindhwani and Goyal, 2014).

3.2.1 Site selection

Air quality monitoring in Delhi is carried out by a network of air quality monitoring stations located throughout the city. There are 38 monitoring stations that are monitored by several organizations, including the Central Pollution Control Board (CPCB), Delhi Pollution Control Committee (DPCC), and System of Air Quality and Weather Forecasting and Research (SAFAR) of the Indian Institute of Tropical Meteorology (IITM), Pune. A few other private companies also have installed different monitors across the city, however, this data is not in the public domain.

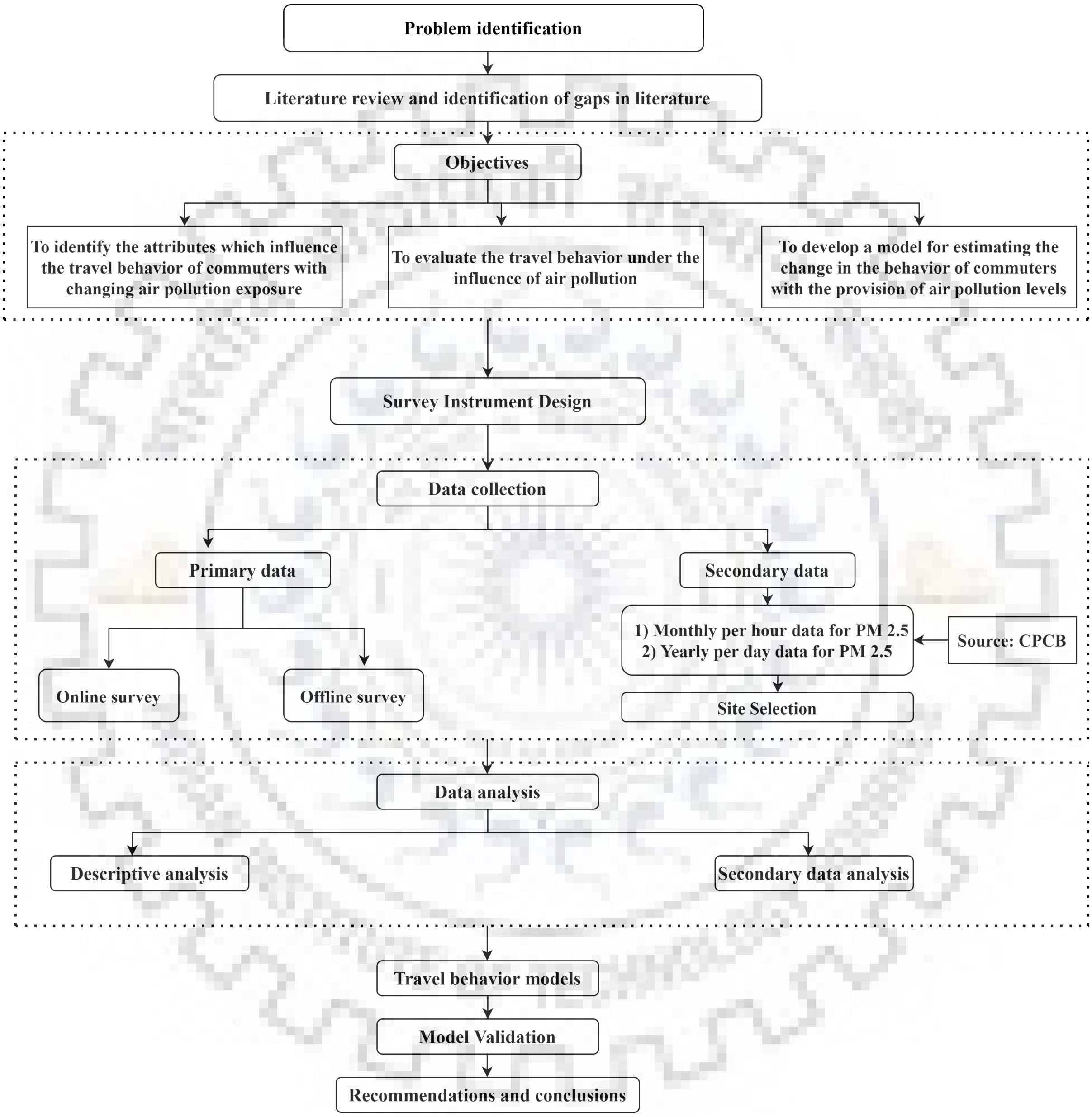


Figure 3.1: Methodology

The CPCB furnishes real-time air quality data in its online dashboard from all the continuous monitors.[1] This website also contains past data of air pollution that is available in 15 and 30 minutes bin size. Apart from this, data is also present in one, four, eight and twenty-four-hour time bins. This portal provides concentration data of all kinds of air pollutants ($PM_{2.5}$ and PM_{10}, Carbon monoxide(CO) and Nitrogen dioxide (NO_2), etc.) for respective time bins. The data can be extracted in the form of Comma Separated Value (CSV), Portable Document File (PDF) and word file. To select a survey selection site, hourly and day-wise data was downloaded in the form of a CSV file (see Sec. 3.2.2 and 3.2.3).

For this particular study, $PM_{2.5}$ was taken into account due to its prevalence and extensive health risk that is associated with long-term health effects. The retrieved data is analyzed in two parts for the selection of study site:

1. hourly ambient air quality level for January 2020, and
2. annual ambient air quality level from February 2019 to January 2020.

3.2.2 Hourly ambient air quality level for January 2020

The hourly $PM_{2.5}$ data of all the 38 monitoring stations were downloaded for the month of January 2020. In the past, it has been observed that the concentration of pollution is highest during Jan in Delhi (Tiwari et al., 2018). However, the $PM_{2.5}$ data for weekends are excluded from this to avoid biasedness because the concentration levels are very different on weekends as compared to weekdays, and from the perspective of daily commuters' exposure, weekdays are more critical.

With the hourly $PM_{2.5}$ data, a box plot is formed for all the 38 monitoring stations (See Fig. 3.2). The box plot is formed to see the variability of $PM_{2.5}$ concentration levels at all the monitoring stations. From Fig. 3.2, it can be depicted that Nehru Nagar, which is marked by red colour, has the highest value of the median (174.75 $\mu g/m^3$), whereas for the Lodhi road is lowest (97.21 $\mu g/m^3$).

Aside from that, the Inter-Quartile Range (IQR) for Nehru Nagar is the highest (149.5

[1] https://app.cpcbccr.com/AQI_India/

$\mu g/m^3$), indicating that with a high median, the variation in $PM_{2.5}$ concentrations is also the highest in Nehru Nagar.

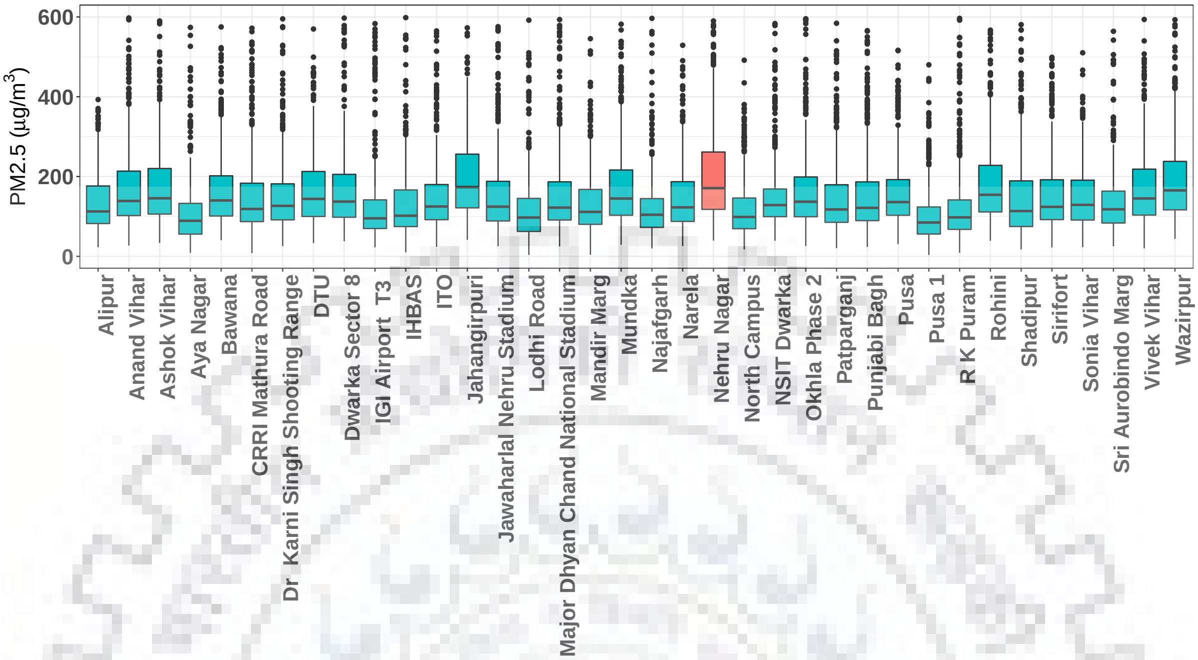


Figure 3.2: Hourly $PM_{2.5}$ analysis (January 2020)

3.2.3 Yearly per day basis data from February 2019 - January 2020

From the above discussion in Sec. 3.2.2, it is concluded that Nehru Nagar is likely to be a critical location for this study in January. However, the same may not be true for rest of the months as concentrations level varies with season. To find the monitoring station with the highest concentrations level each day, $PM_{2.5}$ data is downloaded for February 2019-January 2020 for 38 monitoring stations.

Table 3.1: Severity of yearly air pollution in Nehru Nagar

$PM_{2.5}(\mu g/m^3)$	> 50	> 100	> 200	> 300	> 400	> 500	> 600 or above
Frequency	260	154	64	30	11	4	1

For all the stations, the frequency of $PM_{2.5}$ concentrations exceeding the 50, 100, 200, 300, 400, 500 and 600 $\mu g/m^3$ for each day is counted. The resulting frequency table is shown in Tab. 3.1. After analyzing all of the stations, Nehru Nagar has 64 days with $PM_{2.5} > 200$ $\mu g/m^3$ and 30 days with $PM_{2.5} > 300$ $\mu g/m^3$ (See Tab. 3.1). This indicates that the air quality in Nehru Nagar is bad/ very bad for a significant number of days in a year. Thus, the Nehru Nagar area is selected for this study. The survey locations are shown in Fig. 3.3.

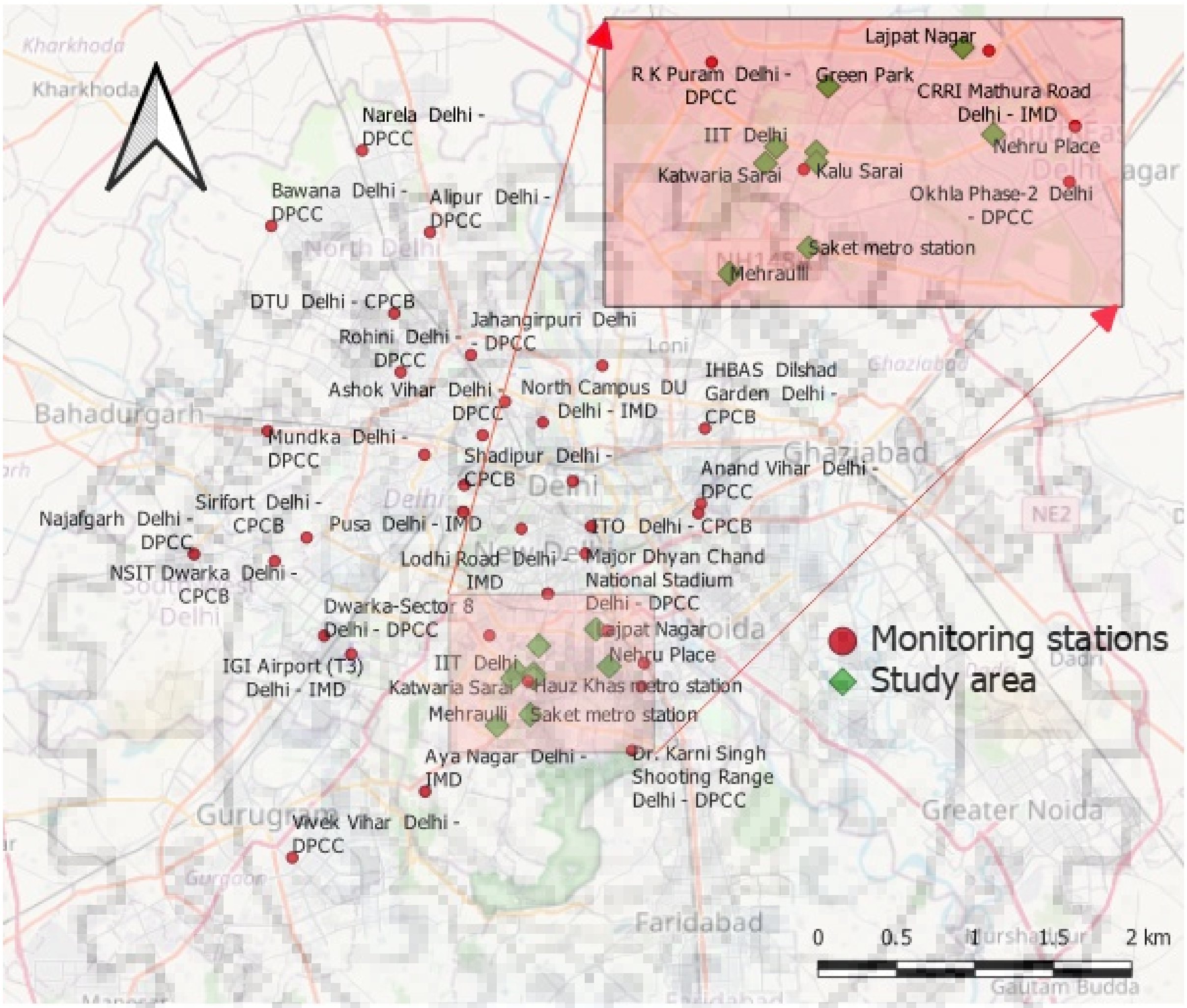


Figure 3.3: Monitoring stations and study area in Delhi

3.2.4 Design of survey instrument

This section includes a detailed methodology of how the objectives accomplished. To achieve the objectives questionnaire designed to capture the impact of air pollution on travel behaviour. This questionnaire is divided into six parts:

1. Information seeking and engagement
2. Trip information
3. Impact of air pollution exposure

4. Prevention/ self-protective action

5. Willingness to change/ adapt

6. Socioeconomic characteristics

The survey has been carried out using TSaaS (Travel Survey as a Service). TSaaS facilitates mobile/web-based self-completion or personal interview type surveys (Vardhan et al., 2020). The primary data is collected using face-to-face questionnaires surveys from 10th December 2020 to 11th January 2021 using the open-source data collection platform[2] in Delhi at multiple locations, as shown in Fig. 3.3. The output is saved in a JSON (JavaScript Object Notation) format on a secure server, which facilitated zero time for data entry. The source code of the project is hosted at GitHub[3]

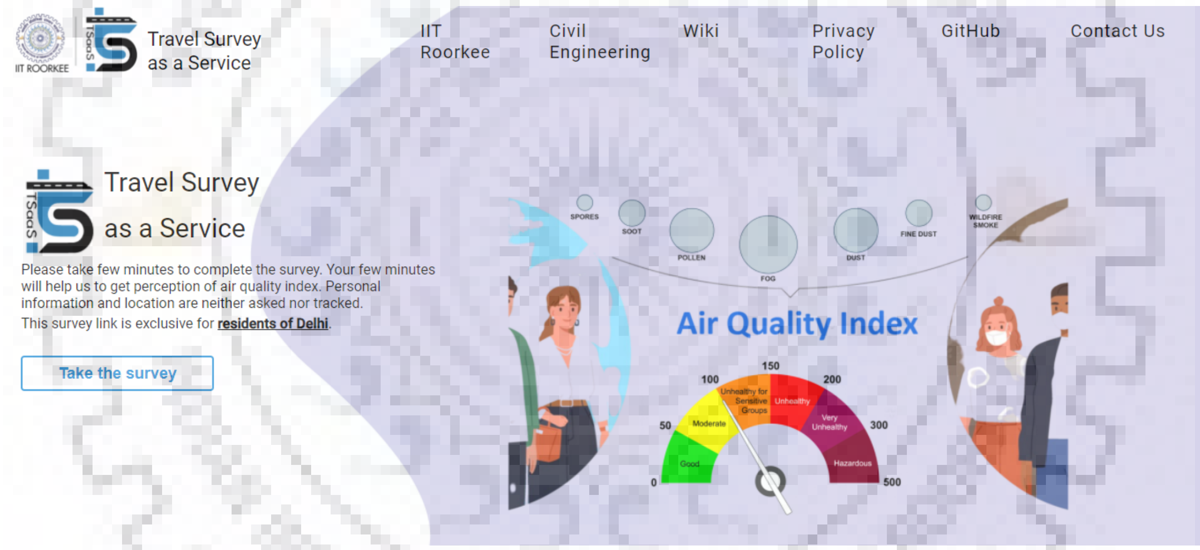


Figure 3.4: TSaaS (Travel Survey as a Survey).

To achieving an adequate sample size (N), a different strategy has been carried out for both type of survey viz. (a) Online (b) Offline

Online survey: The online survey has been carried out from 14 October 2020 to 9 December 2020 through Delhi, and National Capital Region(NCR) area via floating a link through (a) Social media webpages (b) e-mails to public and private companies in Delhi (c) personal messages to persons working and residing in the Delhi NCR (National

[2]https://tsaas.iitr.ac.in/aqips/siteDelhi
[3]https://github.com/teg-iitr/tsaas-frontend/

Capital Region) (d) radio jockey (e) Delhi NCR based NGO's (f) Delhi NCR based college Institute. Several posters and logo also made to encourage the commuters for participation in the survey which are attached in Appendix D.

After 56 days of conducting the survey, final sample size from the online survey achieved is **N=325**. After removing the incomplete and inappropriate responses, **N=297** responses were finalized for the further analysis in study.

Offline survey: Due to COVID - 19 situation, the offline survey started late. The offline survey has been started from 10 December 2020 to 11 January 2021. The total number of respondents was **N=365**. After removing the incomplete and inappropriate responses, **N=346** responses were finalized for further analysis in the study. The ease in data completion on TSaaS resulted in about 5% unusable responses. This survey was conducted in a particular area to know commuters' perception of air pollution, which has been analysed in Sec. 3.2.2 section. Nehru Nagar comes under south Delhi, and it contains three sub-division. Random sampling was done to avoid the biasedness in the survey. The survey was conducted in the respondent's preferred language, either Hindi or English, to effectively communicate the scenarios. An intercept based survey is conducted at places where a high concentration of individuals completing various trips are expected.

The potential locations will be identified based on the type of place like whether it is a workplace, school, leisure place, etc. Every kind of mix is included in all selected areas—for instance, service class, self-employed, rich, poor, middle-income, businessman. The respondents for the survey were recruited based on the type of trips they have done, their age group, and the intercept was made on a random basis. While conducting the survey, it's been kept in mind that respondents should only be the residents of south Delhi.

Chapter 4

Data Collection & Analysis

4.1 Introduction

This chapter presents a detailed analysis of data collected from the Online & Offline survey. The descriptive analysis of the collected data is also offered in this chapter.

4.2 Sample size

The sample size was calculated using the Cochran formula i.e.

$$n = N * \frac{X}{X + N - 1} \tag{4.1}$$

$$\text{Where, } X = Z_{a/2}^2 * \frac{p * (1 - p)}{MOE} \tag{4.2}$$

n = sample size

Z = Z value corresponding to 90% confidence level and $\alpha = 0.05$

Margin of Error (MoE) = 5%

N = total population size of south Delhi = 2731929

The minimum sample size required is **271** samples, and the data collected from the offline survey is **346**, which is higher than needed. Reason of using Cochran formula is considered especially appropriate in situations with large populations

4.3 Online survey analysis

4.3.1 Socioeconomic characteristics

Socioeconomic Characteristic has been to carry out the demographic information about the area of study. Among all the respondents who took part in the survey, 63% were male while, 36% were female. In contrast, the age-wise demographic shows that the study is a mix of all age groups, Tab. 4.1 shows that the 55% is of below 25 age. If further see the results, the interesting thing is that 32% has done post graduation.

Table 4.1: Socioeconomic Characteristics

	Options	Number of Respondents	Percentage
Gender	Female	108	36.12%
	Male	188	62.88%
	Other	3	1.00%
Age	below 18	31	10.44%
	18-25	132	44.44%
	25-40	95	31.99%
	40-60	32	10.77%
	above 60	7	2.36%
Educational Qualification	primary	9	3.04%
	secondary	21	7.09%
	senior secondary	31	10.47%
	graduation	126	42.57%
	post graduation	96	32.43%
	professional courses	13	4.39%
Marital Status	single	187	64.71%
	married	86	29.76%
	divorced/widowed	5	1.73%
	prefer not to mention	11	3.81%
Average monthly income	nil	52	17.99%
	<10000	34	11.76%
	10000-30000	48	16.61%
	30000-50000	63	21.80%
	50000-80000	42	14.53%
	80000-100000	23	7.96%
	>100000	27	9.34%

From this section of socioeconomic, it is found that in online survey, young/ student show more inclination as compared to married commuters or 40+ Age.

4.3.2 Information seeking & engagement

This section deals with the knowledge of air quality level/ index and commuters engagement towards air pollution to knowing these several questions has been asked. Firstly, the pre-existing health issue question was asked to see the perception of those commuters facing air pollution with health and found that 15% are having a pre-existing health issue. As the area of concern is the country capital city, 73% commuter said air pollution is a significant issue in their area.

The further questions have been asked about the engagement of air quality level/ index and found that 67% commuters are aware of air quality index/ level that information is exist but they don't understand it means. That means there is a lack of information gap. After illustration from images and CPCB AQI ranges, commuters find that they consider "Poor (201 - 300)" is a bad air quality range. Those who understand the AQI they check through mobile app once in a week.

4.3.3 Trip information

This section deals with the commuters trip information; in these questions, have been asked about their trips. Firstly, questions have been asked about no of trips per day, and the result showed that 60% trips are below 2 per day and the maximum is Office/ work/ business - (Primary trips). The travel mode highest used for the primary trip is metro, having a modal share of 21%.

Due to COVID - 19 commuters are travelling less for secondary trips (social leisure, shopping, gym), which can be seen from the Tab. 4.3. If they are travelling, preferring an inner mode of travel, for instance, metro, car and bus. The travel model share for secondary trips is 52%. So, it can be shown that commuter's preferring the inner mode of travel for secondary trips.

Further, questions have been asked related to change in choices due to bad air quality. In primary trips, 30% are changing the travel route while 26% said no effect on their travel choices. Further, questions have been asked related to change in choices due to bad air quality. In primary trips, 30% are changing the travel route while 26% said no effect

Table 4.2: Information seeking & engagement

	Options	Number of Respondents	Percentage
Existing health issue	yes	49	15.46%
	no	257	81.07%
	I don't know	11	3.47%
Major problem	yes	233	73.73%
	no	73	23.10%
	I don't know	10	3.16%
Adverse health effects	yes	271	86.03%
	no	29	9.21%
	I don't know	15	4.76%
AQI Understanding	Aware but do not understand	214	67.22%
	Aware but do not understand	74	23.42%
	Not aware	28	8.86%
AQI consider bad	Good(0-50)	3	0.95%
	Satisfactory(51-100)	10	3.16%
	Moderate(101-200)	53	16.77%
	Poor(201-300)	130	41.14%
	Very poor(301-400)	52	16.46%
	Severe(401-500)	59	18.67%
	I don't know	9	2.85%
Source of AQI	Website	69	21.97%
	Mobile app	86	27.39%
	Newspaper	64	20.38%
	Radio (FM)	16	5.10%
	Other	23	7.32%
	I don't look at air quality index/ level	43	13.69%
	I didn't know about existence of such information	13	4.14%
Frequency of AQI	Daily	53	16.98%
	2 - 4 times per week	74	23.71%
	Once a week	78	25.00%
	Once a month	56	17.94%
	I don't look at air quality index/ level	51	16.34%

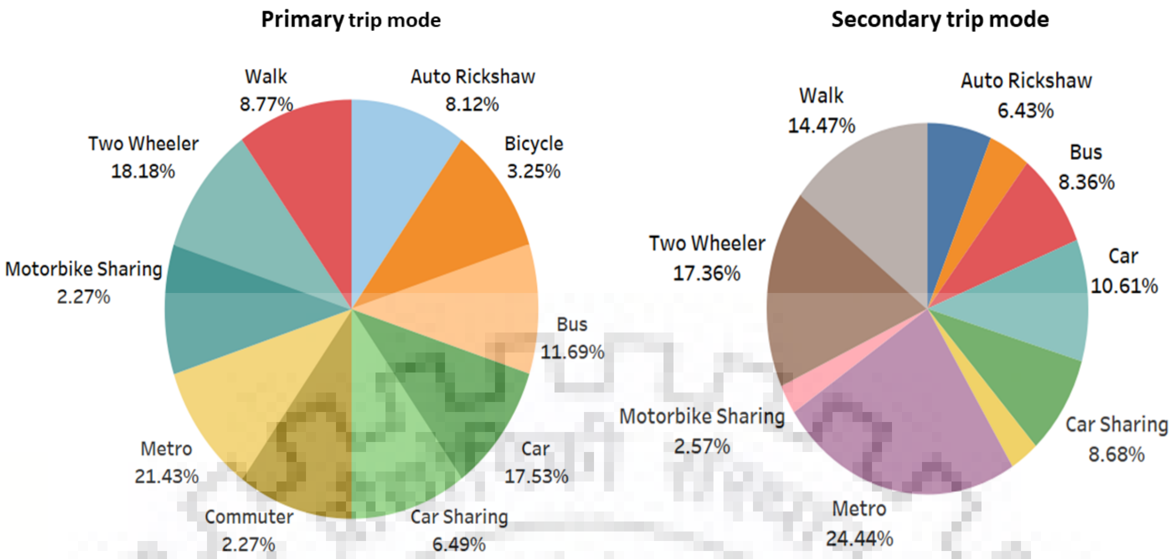


Figure 4.1: Trip information in offline survey

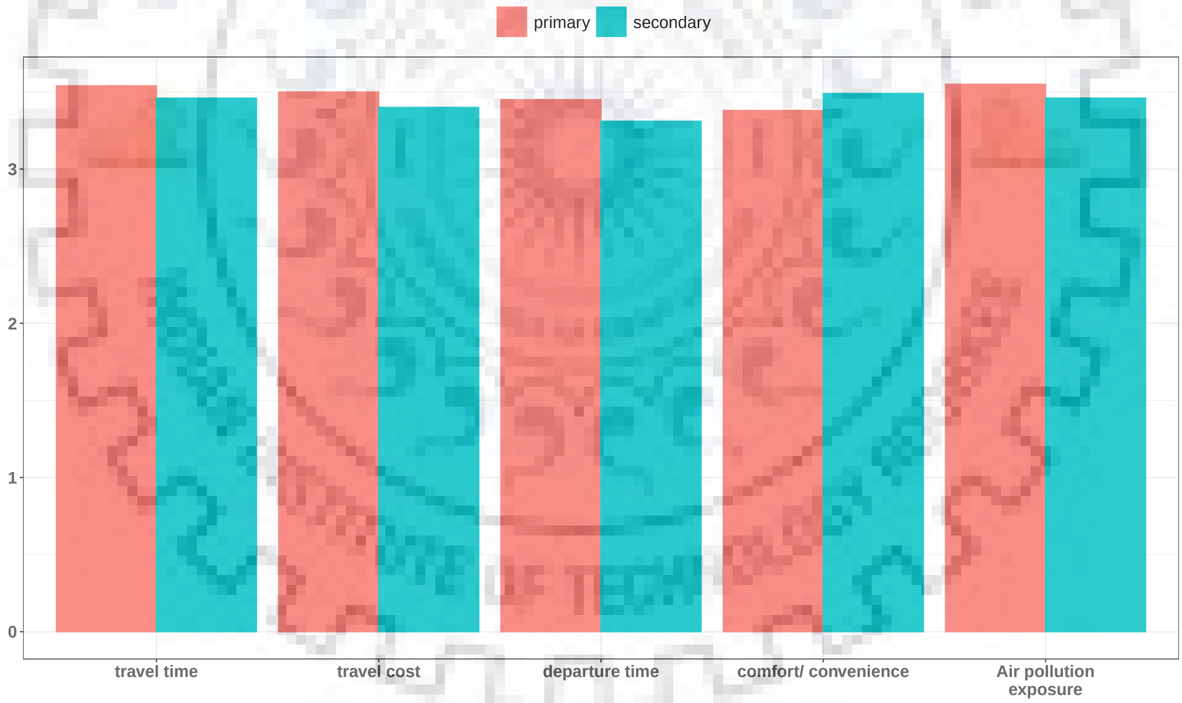


Figure 4.2: Level of preferences

on their travel choices. To know in more about choices, rating questions of a scale of 5 have been asked to have the variable of travel time, travel cost, departure time and air pollution exposure. In Primary trips, travel time and air pollution exposure are the highest levels of preference. While in secondary trips, comfort/ conveniences are the

Table 4.3: Trip information

	Options	Number of Respondents	Percentage
Trip per day	up to 2	186	59.62%
	3 - 4	67	21.47%
	5 or more	24	7.69%
	I do not travel	35	11.22%
Purpose of trip	School/ college/ university - (Primary trip)	99	31.83%
	Office/ work/ business - (Primary trip)	129	41.48%
	Shopping - (Secondary trip)	21	6.75%
	Gym/ sports - (Secondary trip)	19	6.11%
	Social/ leisure - (Secondary trip)	16	5.14%
	Other	27	8.68%
Average trip length (primary)	up to 2 km	37	11.94%
	2 - 5 km	57	18.39%
	5 - 10 km	93	30.00%
	10 - 25 km	79	25.48%
	More than 25 km	30	9.68%
	I do not travel	14	4.52%
Average trip length (secondary)	up to 2 km	78	25.08%
	2 - 5 km	67	21.54%
	5 - 10 km	64	20.58%
	10 - 25 km	59	18.97%
	More than 25 km	32	10.29%
	I do not travel	11	3.54%
Change in primary trip choice	Change of departure time	33	10.71%
	Change of travel mode	91	29.55%
	Change of travel route	44	14.29%
	Not travelling but working/ studying from home	38	12.34%
	Not travelling and not working/ studying from home	21	6.82%
	No effect	81	26.30%
Change in secondary trip choice	Change of departure time	58	19.02%
	Change of travel mode	69	22.62%
	Change of travel route	25	8.20%
	No effect	79	25.50%
	Not traveling at all	74	24.26%
Avoid traveling	Good (0-50)	16	5.19%
	Satisfactory (51-100)	29	9.42%
	Moderate (101-200)	39	12.66%
	Poor (201-300)	103	33.44%
	Very poor (301-400)	29	22.40%
	Severe (401-500)	35	11.36%
	Not traveling at all	17	5.52%

highest preference, as shown in Fig. 4.2.

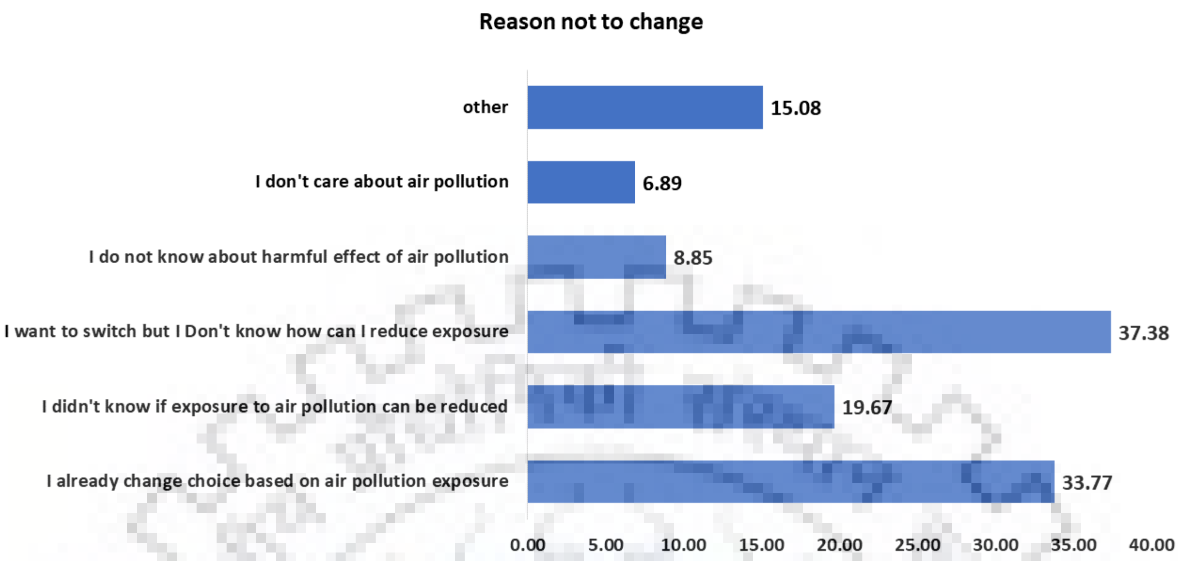


Figure 4.3: Reason not to change

Last, the question has been asked about the reason for not changing the choices, and the result shows in Fig. 4.3 that 37% want to switch.

4.3.4 Impact of air pollution exposure

This section deals with the level of air pollution exposure around their home/ residence and workplace as shown in Tab. 4.4 The result shows that 45% commuters living in a poor to severe AQI range. On the other hand, 48% commuters work in a poor to severe AQI range. In terms of an individual's health impact, maximum commuter's 55% faces irritation to eyes/ nose/ throat and 48% commuter's doing less outdoor activities.

Moreover, for family health impact 37% said "sometimes" their family affected by air pollution while 19% said "rarely" they affected from air pollution. The impact on health during or after the travel also been asked and the irritation in eyes/ nose/ throat is the maximum concern commuter's feels. An important finding from this section is that sensitive group, i.e. infant (lower age children) and older age, in this 53% infant are affected due to air pollution.

Table 4.4: Impact of air pollution exposure

	Options	Number of Respondents	Percentage
AQI at residence	Good (0-50)	24	7.87%
	Satisfactory (51-100)	48	15.74%
	Moderate (101-200)	93	30.49%
	Poor (201-300)	82	26.89%
	Very poor (301-400)	46	15.08%
	Severe (401-500)	12	3.93%
AQI at workplace or school	Good (0-50)	18	5.96%
	Satisfactory (51-100)	39	12.91%
	Moderate (101-200)	93	30.79%
	Poor (201-300)	99	32.78%
	Very poor (301-400)	42	13.91%
	Severe (401-500)	11	3.64%
Impact of air pollution	Skin problems	101	33.22
	Wanting to move to other less polluted places	102	33.55
	Breathlessness having more difficulty in breathing	103	33.88
	Doing less outdoor activities	147	48.36
	Poor visibility	94	30.92
	Worrying about the living environment for children	82	26.97
	Doing more to look after my skin	81	26.64
	Asthma Incidences	44	14.47
	Wanting to move to other less polluted places	102	33.55
	Not affected at all	24	7.89
	Body allergies	63	20.72
	Irritation to eyes/ nose/ throat	167	54.93
Family health effect	Always	47	15.46%
	Often	56	18.42%
	Sometimes	113	37.17%
	Rarely	57	18.75%
	Never	31	10.20%
Impact on health during travel	Eye Irritation	189	61.97
	Runny nose	86	28.20
	Sneezing	114	37.38
	Reduced lung functioning	46	15.08
	Other	23	7.54
	None	38	12.46
Sensitive group effect	Yes, infant	160	53.33
	Yes, older people	62	20.67
	None	113	37.67

4.3.5 Prevention/ self-protective action

This section deal with self-protective action taken by commuter's to protect themselves from air pollution. An essential finding of this part is that 50% commuter's started wearing a mask after COVID - 19 that means concern about self prevention is significantly less as shown in Tab. 4.5. On the other hand, 25% are using air-filter to protect themselves from air pollution.

Table 4.5: Prevention/ self-protective action

	Options	Number of Respondents	Percentage
Use of mask	I don't use mask	12	3.99%
	I started using mask since inception of COVID - 19	150	49.83%
	I used mask before COVID - 19	100	33.22%
	I will use mask after COVID - 19	39	12.96%
Use of air-filter/ air-purifier	Yes	74	24.67%
	No, but plan to buy	120	40.00%
	No, no plan to buy	106	35.33%
Miss school/ college	Yes	147	49.32%
	No	151	50.67%
Miss physical outdoor exercise	Yes	170	56.29%
	No	72	23.84%
	I don't do outdoor exercise	60	19.87%

Regarding the missing school due to bad air quality, half commuters said yes half said no. similarly, 56% said they avoided walking during bad air quality.

4.3.6 Willingness to change/ adapt

This section deals with the willingness to change, which means if real-time information will be provided to commuters, how they would change their preferences and what type of information they want. In next, at what AQI range which mode of travel they will prefer for primary and secondary trips. The result shows in Tab. 4.6 that multiple choices differentiate by travel time and exposure (like google maps) type information commuters would like to prefer.

Moreover, if the information provided to commuters 69% avoid walk or cycling during

Table 4.6: Willingness to change/ adapt

	Options	Number of Respondents	Percentage
Type of information would you like	Air quality index (AQI) or level only	80	26.85%
	Air pollution exposure for each travel mode	76	25.50%
	Multiple choices differentiate by travel time and exposure (like google maps)	122	40.94%
	Other	6	2.01%
	None	14	4.70%
Would you avoid walking and cycling	Yes	205	69.26%
	No	60	20.27%
	I don't know	31	10.47%

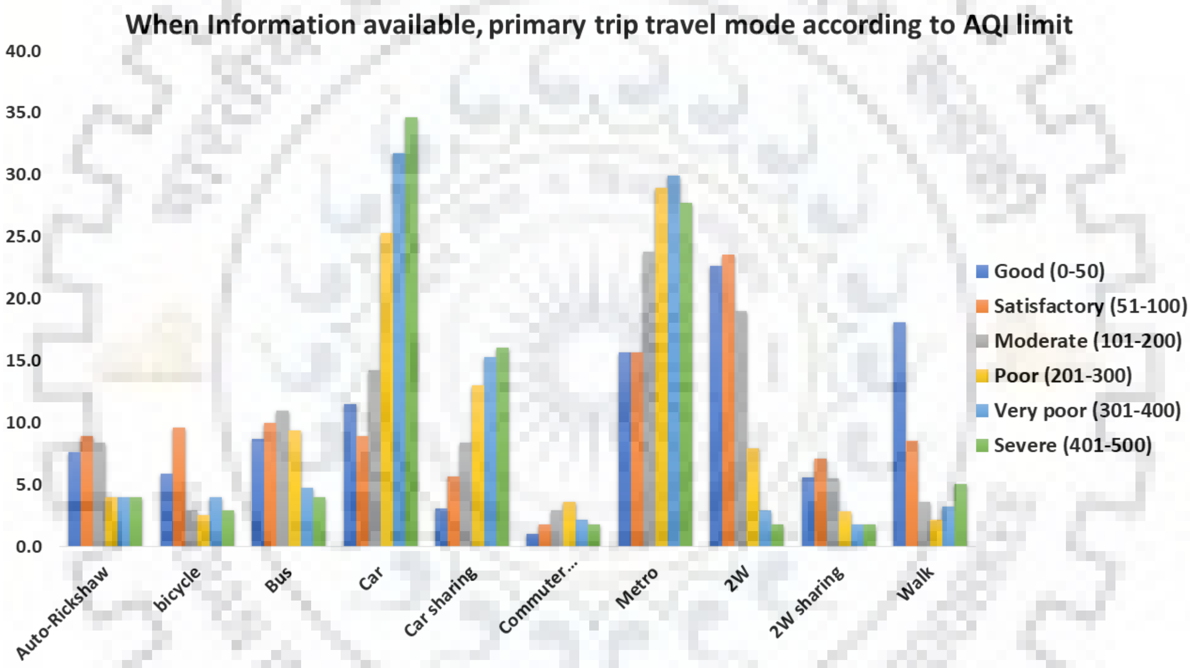


Figure 4.4: When information available primary trip travel mode

bad air quality. To know in more about choices, rating questions of a scale of 5 have been asked to have the variable of travel time, travel cost, departure time and air pollution exposure. In Primary trips, travel time will be the highest levels of preference. While in secondary trips, air pollution exposure will be the highest preference, as shown in Fig. 4.2.

For primary trips, if air quality is "good", commuters' preferences are walking, while in "severe" air quality preference would be the car.

For secondary trips, if air quality is "good", commuters' preferences is walk while in "severe" air quality preference would be the car.

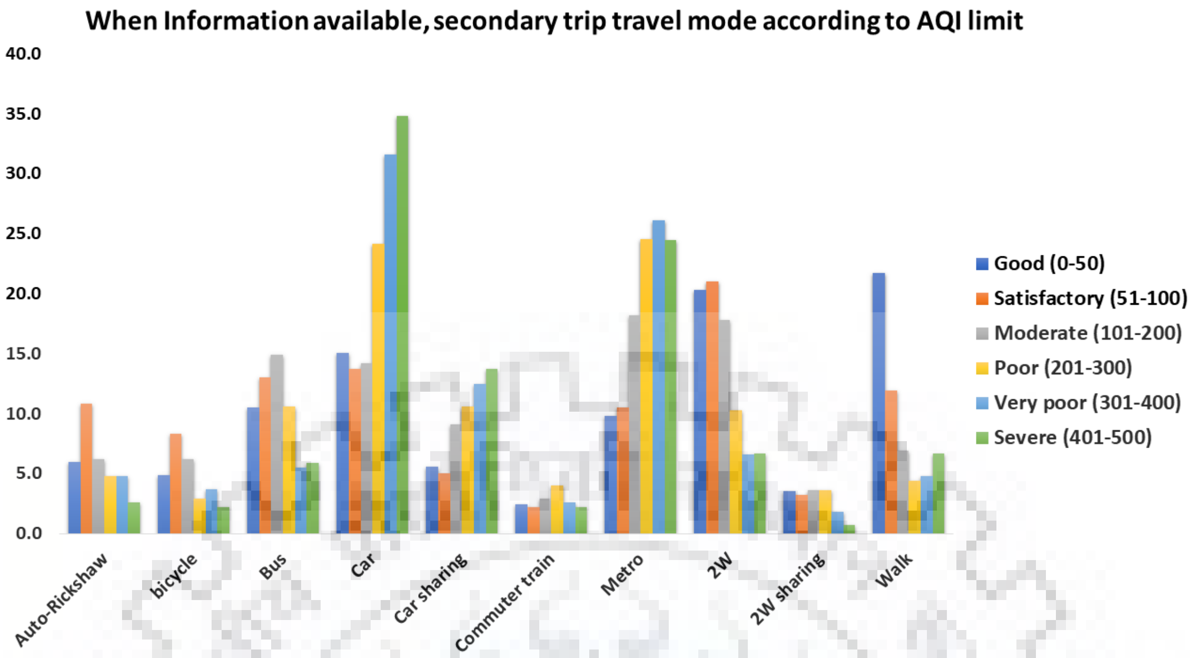


Figure 4.5: When information available secondary trip travel mode

4.4 Offline survey analysis

4.4.1 O - D matrix

During the survey, respondents were asked about their trip origin and destination to know the travel characteristics. The commuter's district was asked in the questionnaire as the trip origin and destination. For faster response, a drop-down option was given to respondents to choose their origin and destination districts. For the respondents that were working or living in Delhi NCR, a drop-down option of "Rest of NCR" was given to them, and for respondents living outside Delhi NCR, an option of "other areas" was for them. The origin-destination (OD) matrix, as shown in Tab. 4.7, exhibits the number of inter-zonal and intra-zonal trips. Hauz Khas, Mehrauli and Saket are areas in South Delhi, where the responses were taken from individuals. The matrix shows the highest number of trips for intra-zonal trips of Saket, and the least number of intrazonal trips for Mehrauli. For inter-zonal trips, the highest number of trips occurred between Hauz Khas and South East Delhi, while the least was found for Mehrauli and Shahdra. The flow of commuters from one zone to another is useful to determine the primary travel patterns, levels of air pollution exposure in the traveling zones and thus, to emphasize the need to

Table 4.7: O - D matrix

Origin / Destination		Hauz Khas	Mehrauli	Saket	Total
North Delhi		7	5	8	20
North East Delhi		4	3	3	10
North West Delhi		4	7	8	19
New Delhi		3	8	4	15
Central Delhi		7	4	4	15
South Delhi	Hauz khas	**23**	**9**	**11**	43
	Mehrauli	**9**	**10**	**6**	25
	Saket	**13**	**13**	**28**	54
South East Delhi		18	14	12	44
South West Delhi		7	5	9	21
East Delhi		7	2	6	15
West Delhi		9	3	8	20
Shahdara		3	2	4	9
Other		5	3	6	14
Rest NCR		8	3	11	22
Total		127	91	128	346

information dissemination of air pollution to the commuters.

4.4.2 Socioeconomic characteristics

For the socioeconomic characteristics of respondents, such as gender, age, qualifications, and income, the demographics are shown in Tab. 4.8. Out of 346 respondents, 69% were male, and 31.2% were female. The age-wise demographics show that the respondents were a mix of all age groups, with the highest number of respondents from the age group of 25 to 40 year. This also reflects in the statistics of the marital status of respondents as there were 55.2% were married.

4.4.3 Information seeking & engagement

The information seeking and engagement section of the questionnaire consisted of questions about pre-existing health issues and awareness about AQI levels, users perception of the various ranges of AQI, information sources, and frequency of checking AQI levels. Then, for the commuters who were not aware of or did not understand AQI levels, an illustrative example with images was shown to distinguish it.[1]

[1] Please refer to https://tsaas.iitr.ac.in/aqips for a demo survey.

Table 4.8: Demographic attributes in offline survey

	options	respondent count	percentage
Gender	female	108	31.21%
	male	238	68.78%
Age	below 18	2	0.57%
	18-25	70	20.23%
	25-40	160	46.24%
	40-60	106	30.63%
	above 60	8	2.19%
Educational qualification	primary	9	2.60%
	secondary	16	4.62%
	senior secondary	41	11.84%
	graduation	183	52.89%
	post graduation	65	18.78%
	professional courses	32	9.24%
Marital Status	single	142	41.04%
	married	191	55.20%
	divorced/widowed	13	3.75%
Average monthly income	nil	46	13.29%
	< 10000	36	10.40%
	10000-30000	61	17.63%
	30000-50000	115	33.23%
	50000-80000	52	15.02%
	80000-100000	17	4.91%
	> 100000	19	5.49%

Results show that only 27% of respondents are aware of the AQI information and understand it. Almost half of the commuters are aware of the AQI levels and know that there is some platform, where this information exists but did not understand it really. The Tab. 4.9 demonstrates that there is a lack of information gap/ awareness among commuters.

In order to understand the perception of the commuters about air quality, a few images distinguished by AQI levels were shown.

It is found that more than 60% of commuters consider "moderate' or 'poor' as a bad air quality range. As shown in Tab. 3.1, more than 40% of days in a year are having air quality worse than 'moderate'. This further highlights that they are aware of bad air quality and still traveling.

Table 4.9: Commuters perception of AQI in offline survey

	options	respondent count	percentage
Existing health issue	yes	54	14.75%
	no	283	77.32%
	I don't know	29	7.92%
AQI Understanding	aware understand	93	26.87%
	aware but do not understand	170	49.13%
	not aware	83	23.98%
AQI consider bad	good (0-50)	0	0.00%
	satisfactory (51-100)	4	1.15%
	moderate (101-200)	103	29.76%
	poor (201-300)	113	32.65%
	very poor (301-400)	49	14.16%
	severe (401-500)	70	20.23%
	I don't know	7	2.02%
Source of AQI	website	76	20.77%
	mobile app	58	15.85%
	newspaper	39	10.66%
	radio (FM)	7	1.91%
	other	31	8.47%
	I don't look at air quality index/ level	114	31.15%
	I didn't know about existence of such information	41	11.20%
Frequency of checking AQI	daily	70	19.18%
	2 - 4 times per week	95	26.03%
	once a week	43	11.78%
	once a month	3	0.82%
	I don't look at air quality index/ level	154	42.19%

4.4.4 Trip information

The commuters perception towards travel characteristics as travel time, travel cost, departure time, comfort, and air pollution exposure during trips was collected in the form of rating from lowest preference (1) to highest preference (5). The trips were examined concerning the number of trips and modal share for both primary and secondary trip. The related profile is shown in Fig. 4.6. The results show that 73% of trips are less frequent than twice a day, and the maximum number of respondents performed the trip for Office/ work/ business purpose - (Primary trips). To comprehend the perception of commuters' about air quality, the question has been asked that at which AQI level, commuters start changing their travel choices, 68% of respondents avoid traveling at very poor or severe air quality. Together with Tab. 4.9, it can be observed that even though the users consider the AQI levels up to 300 bad, they won't stop traveling.

Table 4.10: Trip information in offline survey

	Options	Number of Respondents	Percentage
Trip per day	up to 2	269	73.50%
	3 - 4	44	12.02%
	5 or more	26	7.10%
	I do not travel	27	7.38%
Purpose of trip	School/ college/ university - (Primary trip)	36	9.86%
	Office/ work/ business - (Primary trip)	238	65.21%
	Shopping - (Secondary trip)	29	7.95%
	Gym/ sports - (Secondary trip)	20	5.48%
	Social/ leisure - (Secondary trip)	26	7.12%
	Other	16	4.38%
Average trip length (primary)	up to 2 km	41	11.20%
	2 - 5 km	54	14.75%
	5 - 10 km	101	27.60%
	10 - 25 km	126	34.43%
	More than 25 km	37	10.11%
	I do not travel	7	1.91%
Average trip length (secondary)	up to 2 km	107	29.23%
	2 - 5 km	84	22.95%
	5 - 10 km	119	32.51%
	10 - 25 km	46	12.57%
	More than 25 km	5	1.37%
	I do not travel	5	1.37%
Avoid traveling	Good (0-50)	4	1.09%
	Satisfactory (51-100)	3	0.82%
	Moderate (101-200)	13	3.55%
	Poor (201-300)	91	24.86%
	Very poor (301-400)	120	32.79%
	Severe (401-500)	128	34.97%
	Not traveling at all	7	1.91%

Further, from Fig. 4.6, it can be observed that the highest modal share for a primary trip is for the metro, with a share of 28% (i.e., least exposed to air pollution). The share of a most exposed user group (i.e., walk, bicycle, motorized two-wheeler, auto-rickshaws) is about 38%.

From the analysis, it is found that 60% of commuters prefer closed mode of transport. This can be due to more comfort in long distance trips, use of own car, etc.

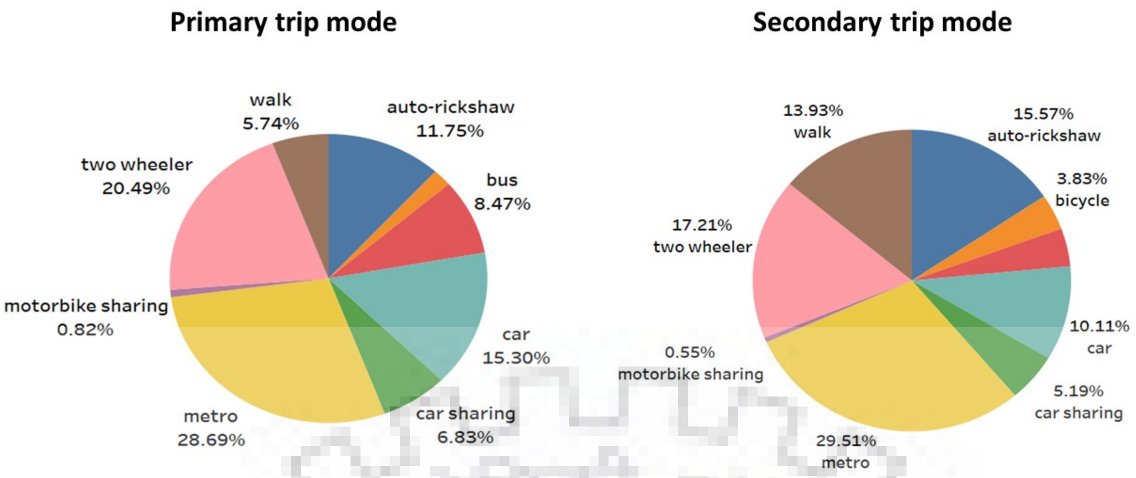


Figure 4.6: Modal share for primary and secondary trips

As the primary data was collected in December 2020, in the time of the COVID-19 pandemic, the commuters were found to be traveling less for secondary trips (i.e., social leisure, shopping, gym, etc.) Thombre and Agarwal, 2020. This might have some impact on the results shown in Tab. 4.10. The travel model share for secondary trips is highest in the metro, which is 30%, and the share of the most exposed user group is 35%.

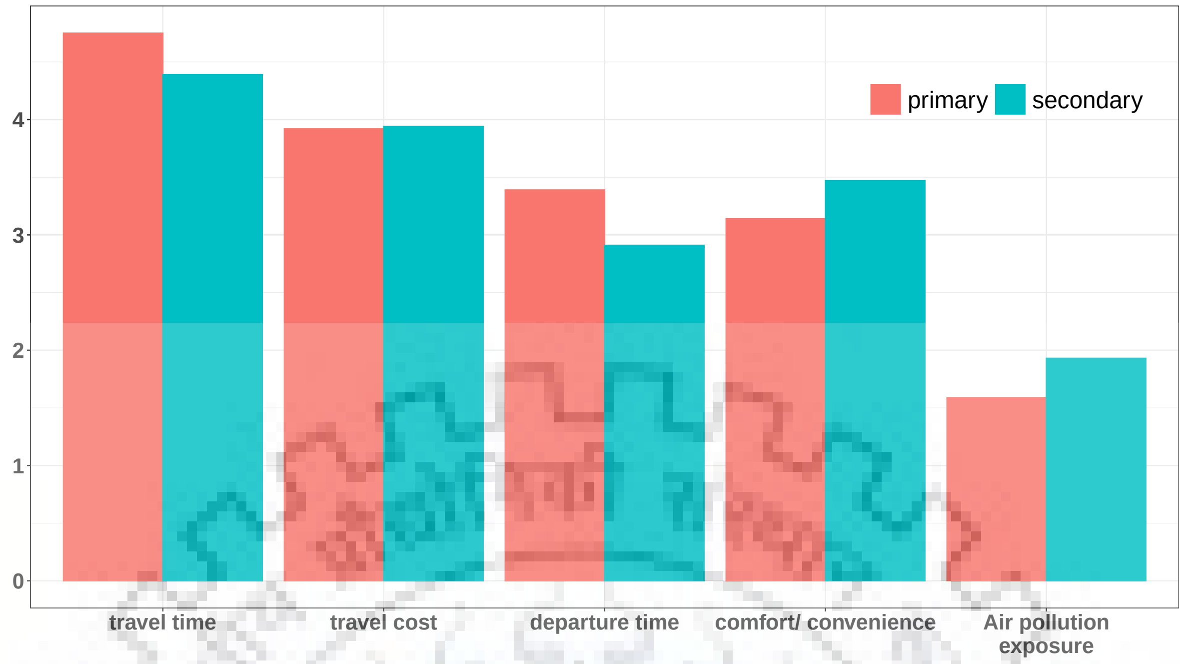
The respondents were asked about their current level of preferences for various components of travel. The results are shown in Fig. 4.7a. As expected, travel time is preferred most for primary and secondary trips. The preference for air pollution exposure is low compared to other components, and it is least for primary trips (1.59).

4.4.5 Impact of air pollution exposure

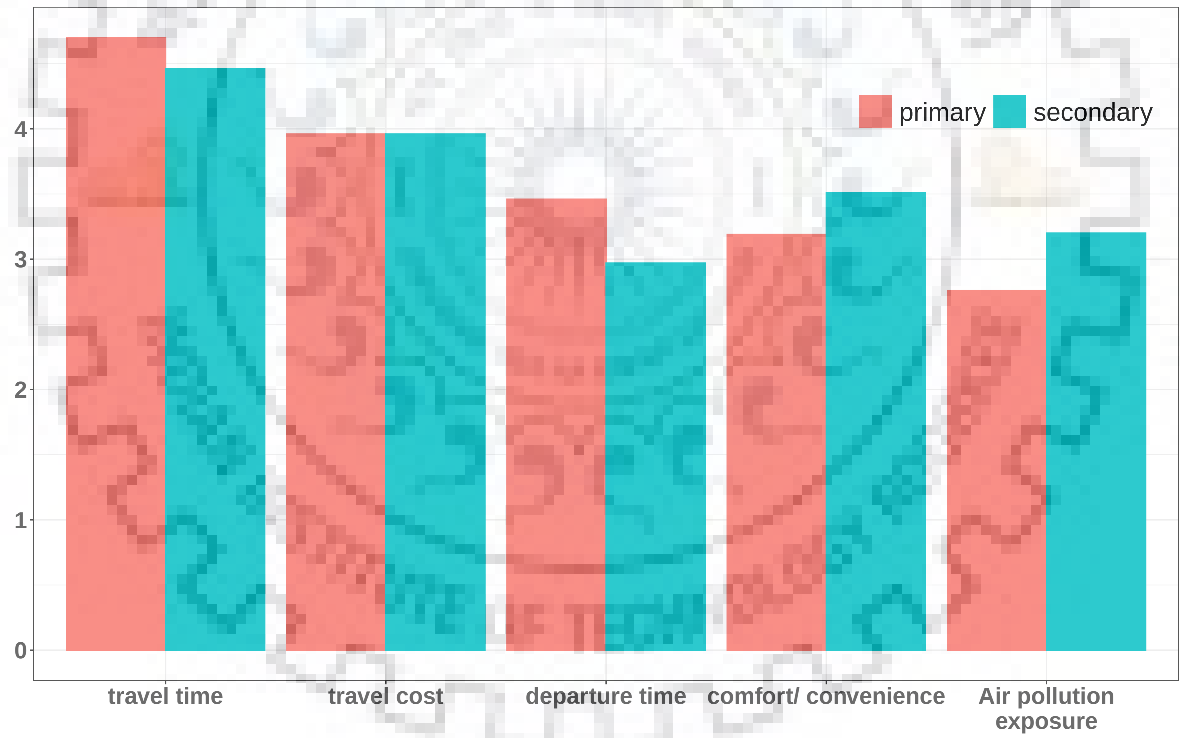
This section deals with the level of air pollution exposure around their home/ residence and workplace and its impact on commuters' health, as shown in Tab. 4.11 and Fig. 4.8. The result shows that 44% commuters living in a poor AQI range and 14% living in a severe AQI range show that air pollution is the most significant hazard to human health.

On the other hand, 44% commuters work in a poor AQI range, and 12% in the severe range. In terms of an individual's health impact, maximum commuter's 55% faces irritation to eyes/ nose/ throat and 48% commuter's doing less outdoor activities.

Moreover, for family health impact 43% said "sometimes" their family affected by air pollution while 19% said "rarely" they affected from air pollution. The impact on



(a) Commuters current level of preferences



(b) Commuters level of preferences if information intervention is available

Figure 4.7: Commuters level of preferences for primary and secondary trips

health during or after the travel also been asked and the irritation in eyes/ nose/ throat is the maximum concern commuter's feels. An important finding from this section is that sensitive group, i.e. infant (lower age children) and older age, in this 44% older age are

Table 4.11: Exposure effect on human health

	options	respondent count	percentage
AQI at residence	good (0-50)	0	0.00%
	satisfactory (51-100)	8	2.19%
	moderate (101-200)	31	8.49%
	poor (201-300)	161	44.11%
	very poor (301-400)	115	31.51%
	severe (401-500)	50	13.70%
AQI at workplace or school	good (0-50)	0	0.00%
	satisfactory (51-100)	3	0.82%
	moderate (101-200)	54	14.79%
	poor (201-300)	164	44.93%
	very poor (301-400)	100	27.40%
	severe (401-500)	44	12.05%
Impact of air pollution	skin problems	76	22.03%
	wanting to move to other less polluted places	183	52.89%
	breathlessness having more difficulty in breathing	85	24.57%
	doing less outdoor activities	105	30.35%
	poor visibility	25	7.25%
	worrying about the living environment for children	101	29.28%
	doing more to look after my skin	78	22.54%
	asthma Incidences	28	8.12%
	wanting to move to other less polluted places	183	52.89%
	not affected at all	2	0.58%
	body allergies	51	14.78%
	irritation to eyes/ nose/ throat	265	76.81%
Family health effect	always	26	7.20%
	often	70	19.39%
	sometimes	156	43.21%
	rarely	68	18.84%
	never	41	11.36%

affected due to air pollution.

4.4.6 Prevention/ self - protective action

This section deal with self-protective action taken by commuter's to protect themselves from air pollution. An essential finding of this part is that 78% commuter's started

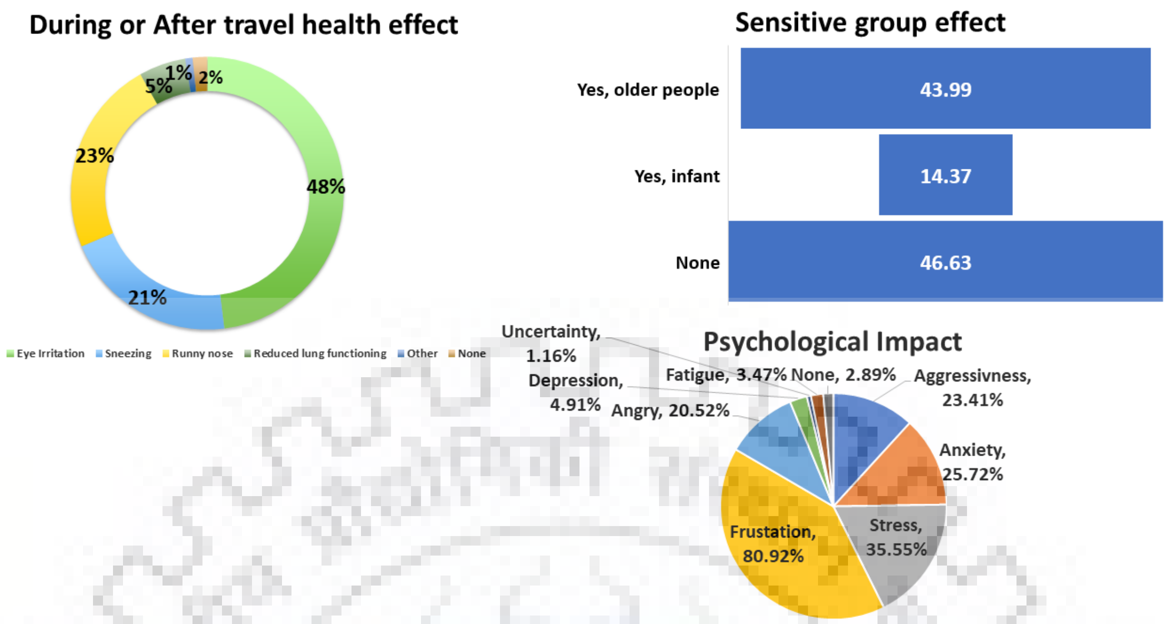


Figure 4.8: Effect on health

wearing a mask after COVID - 19 that means concern about self health prevention is significantly less as shown in Tab. 4.12. On the other hand, 15% are using air-filter to protect themselves from air pollution.

Table 4.12: Prevention/ self-protective action in offline survey

	options	respondent count	percentage
Use of mask	I don't use mask	2	0.55%
	I started using mask since inception of COVID-19	285	77.87%
	I used mask before COVID-19	76	20.77%
	I will use mask after COVID-19	3	0.82%
Use of air-filter/ air-purifier	yes	56	15.34%
	no, but plan to buy	172	47.12%
	no, no plan to buy	137	37.53%
Miss school/ college	Yes	127	34.79%
	No	238	65.21%
Miss physical outdoor exercise	yes	122	33.51%
	no	104	28.57%
	I don't do outdoor exercise	138	37.91%

Regarding the missing school due to bad air quality, 35% say yes. similarly, 34% said they avoided walking during bad air quality.

4.4.7 Willingness to change/ adapt

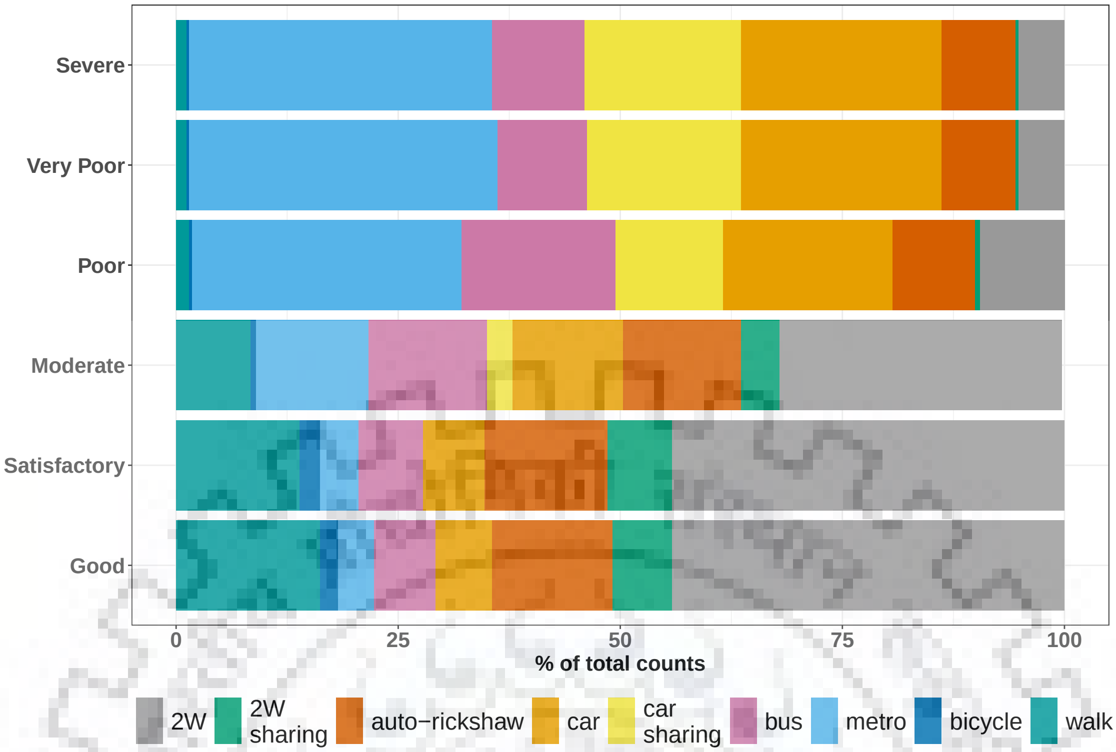
ome of the harmful impacts of air pollution can be reduced or avoided by changing the mode of transportation, travel route, departure time, etc. However, information about air pollution exposure should be provided to assist an individual traveller in making a decision. For this, questions are posed based on a hypothesis that considers whether such information is available to the commuters, what would be their choices and what kind of information they want? The result is shown in Tab. 4.13. Interestingly, most of the commuters (73.69%) would like to have information about multiple choices differentiate by travel time and exposure (like google maps) to alter their choices.

Table 4.13: Willingness of commuters for different type of information

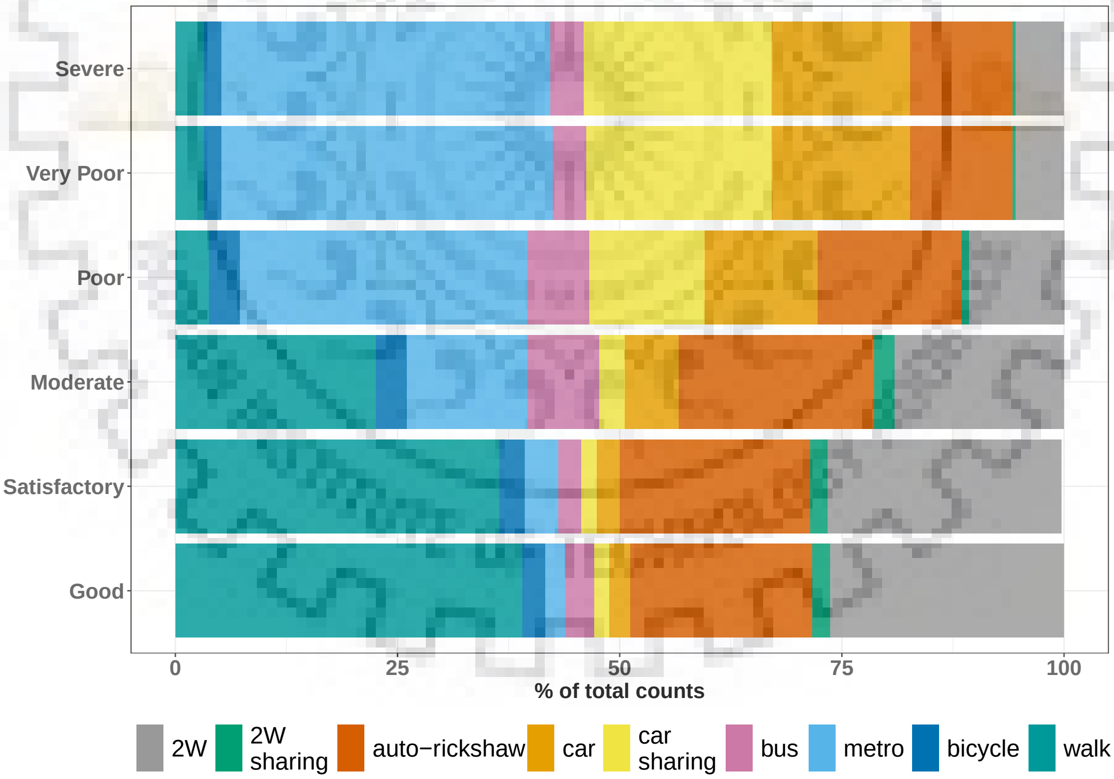
	options	respondent count	percentage
Type of information	air quality index (AQI) or level only	35	10.11%
	air pollution exposure for each travel mode	53	15.31%
	multiple choices differentiate by travel time and exposure (like google maps)	255	73.69%
	other	1	0.28%
	none	2	0.57%
avoid walking and cycling	yes	251	68.58%
	no	86	23.50%
	I don't know	29	7.92%

From Fig. 4.7b, it can be observed that the average level of preference for air pollution exposure after the provision of information is 2.76 for the primary trip and 3.20 for the secondary trip. Clearly, the preferences to air pollution exposure during primary and secondary trip increase significantly, if proper air quality information and alternative choices are available (see Fig. 4.7).

To know the importance of useful information for the commuters (e.g., alternative choices differentiated by travel mode, travel time, air pollution exposure, departure time,



(a) primary trip mode



(b) secondary trip mode

Figure 4.9: Mode choice preferences at different AQI if information is provided

etc.), a question has been asked for the primary and secondary trip. If air quality is severe (401-500) or very poor (301-400), for primary trips, metro, car, car-sharing, bus modes will be preferred by 34%, 23%, 18% and 10% of respondents, respectively (see Fig. 4.9a). The Sum of all these travel modes is 85%, which means that if air quality is bad, commuters prefer closed mode of transport. Similarly, for the secondary trip, if air quality is severe (401-500) or very poor (301-400), 78% of commuters would prefer closed mode of transport, where exposure to air pollution is lower compared to open transport modes (see Fig. 4.9b). This indicates that there is a potential for providing air quality information and alternative choices to reduce air pollution exposure. Since the commuters showed the willingness to change, it is most likely to reduce the harmful effects of air pollution on commuters.

Chapter 5

Model Results

5.1 Introduction

In this Chapter 5 modelling of data has been carried out to find the impact of air pollution exposure on travel choices. For modelling, data has been collected from the locations shown in Fig. 3.3.

5.2 Choice modeling

The reason behind modern approaches to travel demand modelling is to get the result of choice made by an individuals. Discrete choice modeling is widely used method in revealing user preferences for a given choice that uses the principle of utility maximization. This means that each individual will choose the alternative having the highest utility, which is based on attributes related to the alternative and the characteristics of decision-maker. For an alternative i and an individual q, the utility is a combination of a systematic element V_{iq} and a random component ϵ_{iq}, as shown in equation below (Louviere et al., 2000):

$$U_{iq} = V_{iq} + \epsilon_{iq} \tag{5.1}$$

Where,

U_{iq} is the utility of alternative i for individual q

V_{iq} is the systematic component of alternative i for individual q

ϵ_{iq} is the random error component associated with V_{iq}

V_{iq} is a combination of components exclusively associated with the attributes to the alternative (varying for the same individual across different alternatives), the decision-maker (constant for the same individual across different alternatives), and the interaction between attributes of the alternatives and characteristics of the decision maker. The systematic component V_{iq} also includes an alternative-specific constant for the given alternative i.

V_{iq} can be written in terms of its explanatory observed variables or attributes as follows:

$$V_{iq} = \beta_{1i}X_{1iq} + \beta_{2i}X_{2iq} + \ldots + \beta_{ki}X_{kiq} \tag{5.2}$$

Where,

$\beta_{1i}, \beta_{2i}, \ldots \beta_{ki}$ are the unknown parameters to be estimated, that are constant for the individual but may vary across alternatives.

$X_{1iq}, X_{2iq}, \ldots, X_{kiq}$ are the k independent variables including all attributes of alternative i for individual q: decision-maker and alternative related.

For a given utility, the alternative-specific constant (ASC) captures the effect of factors that are not part of the model. By adding this constant, the unobserved or remaining error term is bound to a mean zero.

The outcomes of model helps in:

1. Determining the decisions that must be made and the alternatives available to the individual.
2. Determining the variables that are likely to influence the choices of interest.
3. Creating a mathematical equation that describes the relationship between choice and the relevant variables.

Multinomial logit models (MNL): Multinomial logit models (MNL) are logit models with more than two dependent variables or unordered outcomes. The main assumptions followed in this model are the Independence from-Irrelevant Alternatives (IIA) and Independent and Identically Distributed (IID) variables. IIA states that choosing one alternative over the other does not depend or is not affected by the presence/absence of other alternatives (Louviere et al., 2000). IIA also means that for different alternatives, the random error terms ϵ_{iq} are independent and identically distributed.

$$P_{ij} = \frac{e^{V_{jq}}}{\sum_{j=1}^{j} e^{V_{jq}}} \tag{5.3}$$

Where,

P_{iq} is the probability of choosing alternative i by individual q

V_{iq} is the systematic component of the utility of alternative i for individual q

V_{jq} is the systematic component of the utility of alternative j for individual q

5.3 Model development

The stated preference data is been used to for the analysis. The data was reframed as required for analysis through Biogeme[1] software. Biogeme is a free open source software designed with special emphasis on discrete models, for the maximum probability estimates of the parametric models in general. As shown in Fig. 5.1 GUI of the software, it requires two type of data files (a) .mod file (b) .dat file. .mod file include the all the β variables and .dat file include survey data set. Out of the data collected through face to face questionnaire survey, three categories of attribute types are selected for estimation that affect the travel choice due to air pollution exposure such as socio-demographic factors, trip factors, and air pollution exposure factor, as shown in Fig. 5.2. The data was extracted into two data set types i.e, primary trip and secondary trip. Multinomial logit choice modelling was used for the analysis of the results. The code was written for both the trip modes which used for the analysis in which travel mode choice "car" slot kept fixed and the rest six i.e., walk, car sharing, bus, metro, 2W, auto rickshaw choice are kept as dependent variable for the primary and secondary trip. The step wise method of analysis was followed for the development of significant mathematically equation, insignificant parameter are excluded at every step.

Abbreviation In Tab. 5.1 is used in to depicts in the shortened form of a equation and results, these abbreviation are same in both kind of data set i.e, primary and secondary

[1] https://transp-or.epfl.ch/pythonbiogeme/home.html

Figure 5.1: Biogeme GUI.

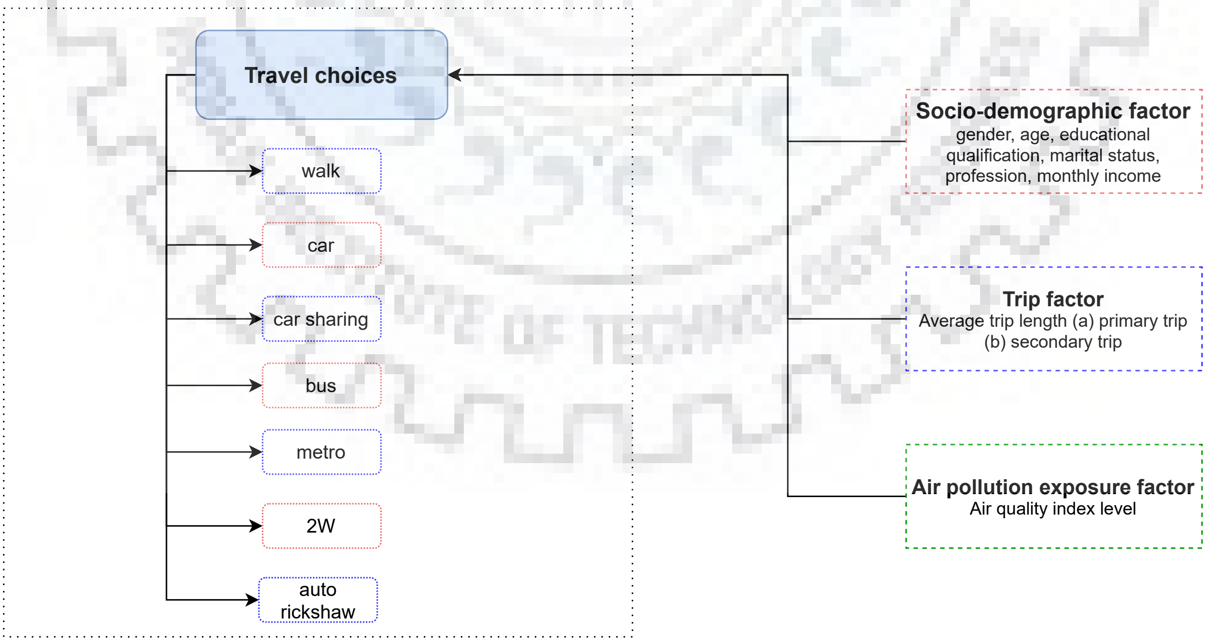


Figure 5.2: Model framework.

trip.

Table 5.1: Definition of variables used in model estimation

Average trip length	D1	up to 2km
	D2	2 - 5km
	D3	5 - 10km
	D4	10 - 25km
	D5	more than 25km
Age	A1	below 18
	A2	18 - 25
	A3	25 - 40
	A4	40 - 60
	A5	above 60
Gender	Male	gender
	Female1	
Educational qualification	EQ1	primary
	EQ2	secondary
	EQ3	senior secondary
	EQ4	graduation
	EQ5	post graduation
	EQ6	professional education
Monthly income	MI1	<10000
	MI2	10000 - 30000
	MI3	30000 - 50000
	MI4	50000 - 80000
	MI5	80000 - 100000
	MI6	<100000
Marrital status	MS1	single
	MS2	married
	MS3	divorced
	PF1	student

	PF2	job seeker
	PF3	private employee
	PF4	government employee
	PF5	business/ self consultant
	PF6	ngo
	PF7	retired
	PF8	driver
	PF9	house wife
	PF10	other
AQI level	Good	Good
	Satisfactory	Satisfactory
	Moderate	Moderate
	Poor	Poor
	Very Poor	Very Poor
	Severe	Severe

5.4 Primary trip

For the primary trips(education, office), factors that influence travel mode due to the impact of air pollution exposure are analyzed through MNL model. The alternatives in dependent variable are travel mode choices i.e. walk, car, car-sharing, bus, metro, 2W, auto-rickshaw. While the independent variables are socio-demographic, average trip length for primary and air pollution levels (AQI) is taken. When many insignificant variables are found, each insignificant variable which are outside the confidence interval is removed step by step. Eq. (5.4) shows the initial primary trip utility equation which carried out all the variable is shown in Sec. 5.4. The reason behind removing these variables is to make the model stable in the decided confidence interval. After many iterations, the final results and utility equation are carried out at p $\leq$ 0.001.

$U(1,2,3,4,5,6,7) = \alpha(1,2,3,4,5,6,7) + \beta_{female} \times female + \beta_{age} \times age_{<18} + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{married} \times MS_{married} + \beta_{student} \times pf_{student} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta_{graduation} \times eq_{graduation} + \beta_{postgraduation} \times eq_{postgraduation} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi_{80000-100000} +$

$$\beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \quad (5.4)$$

Table 5.2: Summary for primary trip model

model	multinomial logit
number of estimated parameters	216
number of observations	2208
number of individuals:	2208
null log-likelihood	-4296.57
cte log-likelihood	-4111.256
init log-likelihood	-4296.57
final log-likelihood	-2351.685
likelihood ratio test	3889.769
rho-square	0.453
adjusted rho-square	0.402

From the Tab. A.1, all the parameters were included, and the results has been shown, as we can see there were lot of insignificant variables with high P-Values. So these variables has to be removed to make the make the model statistically significant. Either it has to be iterated to get the good significant values by excluding the parameters from the model or the model developed in a way which makes it statistically significant by removing or adding certain attributes. As we can see in the above model the Frequency attribute has high p-vales when compared to other attributes so another model was developed by excluding frequency from the model to check whether it was statistically significant or insignificant.

$U(walk) = \alpha(walk) + \beta_{age} \times age_{25-40} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{ngo} \times pf_{ngo} +$

$$\beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate \quad (5.5)$$

$$U(car) = \alpha(car) + \beta_{female} \times female + \beta_{age} \times age_{<18} + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{married} \times MS_{married} + \beta_{student} \times pf_{student} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta_{graduation} \times eq_{graduation} + \beta_{postgraduation} \times eq_{postgraduation} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi_{80000-100000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \quad (5.6)$$

$$U(car - sharing) = \alpha(car - sharing) + \beta_{female} \times female + \beta_{age} \times age_{<18} + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{single} \times MS_{single} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{business} \times pf_{business} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{secondary} \times eq_{secondary} + \beta_{postgraduation} \times eq_{postgraduation} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{80000-100000} \times mi_{80000-100000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate \quad (5.7)$$

$$U(bus) = \alpha(bus) + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{housewife} \times pf_{housewife} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \quad (5.8)$$

$$U(metro) = \alpha(metro) + \beta_{age} \times age_{<18} + \beta_{2-5km} \times D_{<2-5km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{secondary} \times eq_{secondary} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} \quad (5.9)$$

$U(2W) = \alpha(2W) + \beta_{female} \times female + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{student} \times pf_{student} + \beta_{retired} \times pf_{retired} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi80000 - 100000+$

$$\beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \quad (5.10)$$

$U(auto - rickshaw) = \alpha(auto - rickshaw) + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta_{graduation} \times eq_{graduation} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi_{80000-100000}+$

$$\beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate \quad (5.11)$$

Table 5.3: Summary for primary trip model after iterations

model	multinomial logit
number of estimated parameters	122
number of observations	2208
number of individuals	2208
null log-likelihood	-4296.57
cte log-likelihood	-4111.256
init log-likelihood	-4296.57
final log-likelihood	-2448.811
likelihood ratio test	3695.518
rho-square	0.43
adjusted rho-square	0.43

From the Tab. A.2 the model, it can be seen this model is statistically significant and has good p-values.

Statistical Inferences To make the MNL model stable, the variable having p value above than 0.01 were removed. Total 216 parameters are estimated initially and after doing iteration 30 times again and again 122 parameters are left which are statistically significant. For Eq. (5.5) walk as a mode for primary trip, it can be observed that people from age group 25-40 years prefers it less compared to car. For lower distances, walk is highly favourable mode by the commuters. Keeping all other parameters constant, the people earning 10000-30000 INR per month are indicating higher preference for walk compared to car. Walk is highly preferable in good air quality level. For Eq. (5.7) car-sharing, it can be seen that people below 18 year age prefer it less as compared to car, while age group of 25-40 years prefer car-sharing. For lower distance, car-sharing is less favourable mode by the commuters. keeping all other parameters constant, the people earning less than 10000 INR are avoiding car-sharing. car-sharing is avoided at good air quality level. For Eq. (5.8) bus, it can be seen that people above 25 year prefer. For higher distance, bus is highly favourable mode by the commuters. less earning people below 30000 INR prefer bus. When air quality is good, bus is avoidable. For Eq. (5.9) metro, it can be seen that people below 18 year age prefer it less as compared to car. For higher distance more than 10km, metro is highly favourable mode by the commuters. Every bin of monthly income prefer metro. Air quality level doesn't impact over metro. In Eq. (5.10) 2W mode of transport is prefer at short distance of travel. When air quality is good, 2W is prefer. less earning people prefer highly 2W. In Eq. (5.11) highly income people avoid auto-rickshaw. For shorter distance, auto-rickshaw is highly favourable mode by the commuters. . In good air quality, auto-rickshaw is prefer.

5.5 Secondary trip

For the secondary trips(shopping, social leisure), factors that influence travel mode due to the impact of air pollution exposure are analyzed through an MNL model. This dependent variable is travel choices, i.e. walk, car, car-sharing, bus, metro, 2W, auto-rickshaw, etc. While the independent variables are socio-demographic, average trip length for primary and air pollution AQI levels is taken. When many insignificant variables are found, each insignificant variable is removed step by step. Eq. (5.12) shows the Initial secondary trip utility equation which carried out all the variable is shown in Sec. 5.5. The reason behind removing these variables is to make the model stable and under the confidence interval. After many iterations, the final results are carried out at $p \leq 0.001$.

$$U(1,2,3,4,5,6,7) = \alpha(1,2,3,4,5,6,7) + \beta_{female} \times female + \beta_{age} \times age_{<18} + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{married} \times MS_{married} + \beta_{student} \times pf_{student} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta_{graduation} \times eq_{graduation} + \beta_{postgraduation} \times eq_{postgraduation} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi_{80000-100000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \quad (5.12)$$

Table 5.4: Summary for secondary trip model

model	multinomial logit
number of estimated parameters	216
number of observations	2182
number of individuals	2182
null log-likelihood	-4245.976
cte log-likelihood	-4053.312
init log-likelihood	-4245.976
final log-likelihood	-2612.748
likelihood ratio test:	3266.457
rho-square:	0.385
adjusted rho-square	0.334

From the Tab. B.1, all the parameters were included, and the results has been shown, as we can see there were lot of insignificant variables with high P-Values. So these variables has to be removed to make the make the model statistically significant. Either it has to be iterated to get the good significant values by excluding the parameters from the model or the model developed in a way which makes it statistically significant by removing or adding certain attributes. As we can see in the above model the Frequency attribute has high p-vales when compared to other attributes so another model was developed by excluding frequency from the model to check whether it was statistically significant or insignificant.

Table 5.5: Summary for secondary trip model after iterations

model	multinomial Logit
number of estimated parameters	117
number of observations	2182
number of individuals	2182
null log-likelihood	-4245.976
cte log-likelihood	-4053.312
init log-likelihood	-4245.976
final log-likelihood	-2709.098
likelihood ratio test:	3073.755
rho-square:	0.362
adjusted rho-square	0.334

$$U(walk) = \alpha(walk) + \beta_{female} \times female + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{married} \times MS_{married} + \beta_{student} \times pf_{student} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \tag{5.13}$$

$$U(car) = \alpha(car) + \beta_{female} \times female + \beta_{age} \times age_{<18} + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{married} \times MS_{married} + \beta_{student} \times pf_{student} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{pvt_emp} \times pf_{pvt_emp} + \beta_{govt_emp} \times pf_{govt_emp} + \beta_{business} \times pf_{business} + \beta_{ngo} \times pf_{ngo} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times pf_{driver} + \beta_{housewife} \times pf_{housewife} + \beta_{primary} \times eq_{primary} + \beta_{secondary} \times eq_{secondary} + \beta_{seniorsecondary} \times eq_{seniorsecondary} + \beta_{graduation} \times eq_{graduation} + \beta_{postgraduation} \times eq_{postgraduation} + \beta < 10,000 \times mi_{<10,000} + \beta_{10000-30000} \times mi_{10000-30000} + \beta_{30000-50000} \times mi_{30000-50000} + \beta_{50000-80000} \times mi_{50000-80000} + \beta_{80000-100000} \times mi_{80000-100000} + \beta_{good} \times good + \beta_{satisfactory} \times satisfactory + \beta_{moderate} \times moderate + \beta_{poor} \times poor \tag{5.14}$$

$$U(car - sharing) = \alpha(car - sharing) + \beta_{age} \times age_{18-25} + \beta_{age} \times age_{25-40} + \beta_{age} \times age_{40-60} + \beta_{<2km} \times D_{<2km} + \beta_{2-5km} \times D_{<2-5km} + \beta_{5-10km} \times D_{5-10km} + \beta_{10-25km} \times D_{10-25km} + \beta_{single} \times MS_{single} + \beta_{jobseeker} \times pf_{jobseeker} + \beta_{business} \times pf_{business} + \beta_{retired} \times pf_{retired} + \beta_{driver} \times$$

$pf_{driver}+\beta_{primary}\times eq_{primary}+\beta_{seniorsecondary}\times eq_{seniorsecondary}+\beta_{10000-30000}\times mi_{10000-30000}+$

$$\beta_{30000-50000}\times mi_{30000-50000}+\beta_{50000-80000}\times mi_{50000-80000} \quad (5.15)$$

$U(bus)=\alpha(bus)+\beta_{5-10km}\times D_{5-10km}+\beta_{10-25km}\times D_{10-25km}+\beta_{single}\times MS_{single}+\beta_{married}\times MS_{married}+\beta_{student}\times pf_{student}+\beta_{jobseeker}\times pf_{jobseeker}+\beta_{pvt_emp}\times pf_{pvt_emp}+\beta_{govt_emp}\times pf_{govt_emp}+\beta_{business}\times pf_{business}+\beta_{ngo}\times pf_{ngo}+\beta_{driver}\times pf_{driver}+\beta_{housewife}\times pf_{housewife}+\beta_{secondary}\times eq_{secondary}+\beta_{seniorsecondary}\times eq_{seniorsecondary}+\beta< 10,000\times mi_{<10,000}+\beta_{10000-30000}\times mi_{10000-30000}+\beta_{30000-50000}\times mi_{30000-50000}+\beta_{50000-80000}\times mi_{50000-80000}+\beta_{80000-100000}\times mi_{80000-100000}$

$$+\beta_{good}\times good+\beta_{satisfactory}\times satisfactory+\beta_{moderate}\times moderate+\beta_{poor}\times poor \quad (5.16)$$

$U(metro)=\alpha(metro)+\beta_{5-10km}\times D_{5-10km}+\beta_{10-25km}\times D_{10-25km}+\beta_{single}\times MS_{single}+\beta_{student}\times pf_{student}+\beta_{jobseeker}\times pf_{jobseeker}+\beta_{pvt_emp}\times pf_{pvt_emp}+\beta_{business}\times pf_{business}+\beta_{primary}\times eq_{primary}+\beta_{secondary}\times eq_{secondary}+\beta_{seniorsecondary}\times eq_{seniorsecondary}+\beta< 10,000\times mi_{<10,000}+\beta_{10000-30000}\times mi_{10000-30000}+\beta_{30000-50000}\times mi_{30000-50000}+\beta_{50000-80000}\times$

$$mi_{50000-80000}+\beta_{80000-100000}\times mi_{80000-100000} \quad (5.17)$$

$U(2W)=\alpha(2W)+\beta_{female}\times female+\beta_{<2km}\times D_{<2km}+\beta_{married}\times MS_{married}+\beta_{student}\times pf_{student}+\beta_{jobseeker}\times pf_{jobseeker}+\beta_{ngo}\times pf_{ngo}+\beta_{housewife}\times pf_{housewife}+\beta_{graduation}\times eq_{graduation}+\beta< 10,000\times mi_{<10,000}+\beta_{10000-30000}\times mi_{10000-30000}+\beta_{30000-50000}\times mi_{30000-50000}+\beta_{50000-80000}\times mi_{50000-80000}+\beta_{good}\times good+$

$$\beta_{satisfactory}\times satisfactory+\beta_{moderate}\times moderate+\beta_{poor}\times poor \quad (5.18)$$

$U(auto-rickshaw)=\alpha(auto-rickshaw)+\beta_{age}\times age_{18-25}+\beta_{age}\times age_{25-40}+\beta_{age}\times age_{40-60}+\beta_{<2km}\times D_{<2km}+\beta_{5-10km}\times D_{5-10km}+\beta_{married}\times MS_{married}+\beta_{student}\times pf_{student}+\beta_{jobseeker}\times pf_{jobseeker}+\beta_{business}\times pf_{business}+\beta_{driver}\times pf_{driver}+\beta_{housewife}\times pf_{housewife}+\beta_{primary}\times eq_{primary}+\beta_{seniorsecondary}\times eq_{seniorsecondary}+\beta_{postgraduation}\times eq_{postgraduation}+\beta< 10,000\times mi_{<10,000}+\beta_{10000-30000}\times mi_{10000-30000}+\beta_{30000-50000}\times mi_{30000-50000}+\beta_{50000-80000}\times mi_{50000-80000}+$

$$\beta_{good}\times good+\beta_{satisfactory}\times satisfactory+\beta_{moderate}\times moderate+\beta_{poor}\times poor \quad (5.19)$$

From the Tab. B.2 the model, it can be seen this model is statistically significant and has good p-values.

Statistical Inferences To make the MNL model stable, the variable having p value above than 0.01 were removed. Total 216 parameters are estimated initially and after doing iteration 32 times again and again 117 parameters are left which are statistically significant. For Eq. (5.13) walk as a mode for secondary trip, it can be observed that people for every age group bin not prefer walk. For lower distances, walk is highly favourable mode by the commuters. Keeping all other parameters constant, the people earning 10000-30000 INR per month are indicating higher preference for walk compared to car. Walk is highly preferable in good air quality level. For Eq. (5.15) car-sharing, it can be seen that people above 18 year age prefer more as compared to car. For every distance bin, car-sharing is highly favourable mode by the commuters. keeping all other parameters constant, the people earning less than 10000 INR are avoiding car-sharing. Air quality level doesn't impact over car-sharing. For Eq. (5.16) bus, it can be seen that every age bin have no impact over it. For higher distance, bus is highly favourable mode by the commuters. less earning people prefer bus. Air quality level doesn't impact over bus. For Eq. (5.17) metro, it can be seen that every age bin have no impact over it. For higher distance, metro is highly favourable mode by the commuters. Every bin of monthly income prefer metro. Air quality level doesn't impact over metro. For Eq. (5.18) 2W mode of transport is prefer only at short distance of travel. When air quality is good, 2W is prefer. Every bin of monthly income prefer 2W. In Eq. (5.19) secondary trip, all kind of income people use auto-rickshaw. For shorter distance, auto-rickshaw is highly favourable mode by the commuters. . In poor air quality, auto-rickshaw is avoidable.

Chapter 6

Summary

6.1 Conculsion

Delhi, a Union Territory, is one of the world most polluted urban agglomerations. It has disastrous consequences for the health of residents, the city environment, and economic well-being. This thesis attempts to understand the perception of commuters towards air pollution exposure and to show the importance of real-time information in the decision making of commuters. Only 27% of the respondents are aware of the AQI and understand it. More than 60% of the respondents consider 'moderate' and 'poor' as bad air quality range. Along these lines, 68% of commuters avoid traveling at a very poor or severe level of air pollution. The share of most exposure user group (i.e., walk, bicycle, motorized two-wheeler, auto-rickshaws) is about 38% and 35% respectively for primary and secondary trips.

Commuters prefer to have information according to multiple choices differentiated by travel time and exposure to air pollution. This is in addition to air quality levels and air pollution exposure for travel mode. It is likely that with this information, commuters can alter their travel behaviour to reduce personal exposure to air pollution. This is demonstrated by an increased preference for air pollution exposure while making the decision about a primary or secondary trip. Also, it was found that more users are likely to use the closed mode of transport during severe or very poor air quality levels. The study shows that due to the unavailability of any information concerning air pollution exposure, the commuters can not make any decisions that can reduce their exposure during travel. This study suggests the authorities and policymakers provide or develop a real-time information system that can help commuters alter their choices.

6.2 Way forward

There is no doubt that air pollution significantly affects human short term and long term behaviour. Suitably, travellers are the most exposed group of peoples. Among all, the daily traveller's users are most susceptible and inhale the maximum amount of pollutants. This can hamper transport policies aimed at making the transport system more economical and environmentally sustainable. Following are the items that can be investigated further:

1. The Perception change according to the weather condition, in this study data has been taken into account of the winter month. To know the perception survey should also be carried out in different season.
2. In this study stated preference is carried, revealed preference survey should also be done to depict which travel mode should prefer at high air pollution exposure.
3. The further study should contain question-related to nudging, which helps in making transport policies.

Chapter 7

Publication

This dissertation is comprised of two papers. The details of the publications are listed below:

1. Singh, V., **K. K. Meena** and A. Agarwal (2021). "Travellers' exposure to air pollution: a systematic review and future directions" In **Urban Climate**. DOI: https://doi.org/10.1016/j.uclim.2021.100901
2. **Meena, K. K.**, V. Singh and A. Agarwal (2021)."Perception of Commuters Towards Air Quality in Delhi". ***CTRG-21*** (submitted). http://faculty.iitr.ac.in/~amitfce/pdfs/MeenaEtc2021AQIPerception.pdf

Appendix A

Primary Result

Table A.1: Initial result of primary trip

choice	name	value	std err	p-value
walk	ASC_1	-8.22	2.52	0
car	ASC_2	0	fixed	
car-sharing	ASC_3*	-1.48	7.8	0.29
bus	ASC_4	-8.75	5.71	0
metro	ASC_5*	1.49	1.78	0.26
2W	ASC_6	-5.3	2.03	0.01
auto-rickshaw	ASC_7	-6.85	9.85	0
walk	Gender	-0.771	0.355	0.04
car-sharing	A1*	-1.91	22.1	0.14
car	PF4	0	fixed	
car-sharing	PF4	-3.22	1.55	0
bus	PF4	-2.61	1.61	0.02
metro	PF4	-2.74	1.5	0
2W	PF4*	-1.42	1.65	0.31
auto-rickshaw	PF4	-5.09	12.5	0
walk	PF5	-2.9	1.75	0
car	PF5	0	fixed	
car-sharing	PF5	-5.46	1.52	0

bus	PF5	-11.3	6.09	0
bus	A1*	-1.36	41.2	0.33
metro	PF5	-4.26	1.47	0
2W	PF5*	-2.56	1.63	0.06
auto-rickshaw	PF5*	-1.17	9.16	0.33
walk	PF6	-4.87	1.94	0
car	PF6	0	fixed	
car-sharing	PF6	-3.56	1.54	0
bus	PF6	-3.87	1.62	0
metro	PF6	-3.7	1.5	0
2W	PF6*	-2.74	1.67	0.06
auto-rickshaw	PF6*	-0.363	9.17	0.78
metro	A1	-5.03	13.6	0
walk	PF7	-3.45	2.02	0.02
car	PF7	0	fixed	
car-sharing	PF7	-9.38	6.24	0
bus	PF7	-5.16	1.84	0
metro	PF7	-5.57	1.68	0
2W	PF7	-3.87	1.82	0.02
auto-rickshaw	PF7	-10.4	11.9	0
walk	PF8	4.13	14.2	0.03
car	PF8	0	fixed	
car-sharing	PF8	-4.5	18	0
2W	A1	5.82	7.65	0
bus	PF8*	-2.33	18.5	0.11
metro	PF8	-3.98	18	0
2W	PF8*	2.78	14.2	0.12
auto-rickshaw	PF8	8.65	16.8	0

walk	PF9	-3.52	1.9	0.01
car	PF9	0	fixed	
car-sharing	PF9	-3.89	1.68	0
bus	PF9	-4.1	1.75	0
metro	PF9	-3.15	1.6	0
2W	PF9	-10.7	6.01	0
auto-rickshaw	A1*	0.758	7.69	0.63
auto-rickshaw	PF9*	-1.45	9.19	0.3
walk	EQ1	6.88	25.8	0
car	EQ1	0	fixed	
car-sharing	EQ1	-2.82	184	0
bus	EQ1*	-0.853	87.5	0.46
metro	EQ1	-2.11	59.4	0.01
2W	EQ1	-2.97	28.9	0.02
auto-rickshaw	EQ1	4.17	25.7	0
walk	EQ2	6.18	3.53	0
car	EQ2	0	fixed	
walk	A2*	0.16	1.2	0.91
car-sharing	EQ2	3.69	3.49	0
bus	EQ2	3.04	3.51	0
metro	EQ2	3.33	3.47	0
2W	EQ2	4.12	3.48	0
auto-rickshaw	EQ2	5.7	3.51	0
walk	EQ3*	0.612	0.692	0.36
car	EQ3	0	fixed	
car-sharing	EQ3*	0.496	0.543	0.32
bus	EQ3	1.03	0.523	0.04
metro	EQ3*	0.734	0.484	0.11

car	A2	0	fixed	
2W	EQ3	1.17	0.505	0.01
auto-rickshaw	EQ3	1.79	0.702	0.01
walk	EQ4*	0.517	0.55	0.28
car	EQ4	0	fixed	
car-sharing	EQ4*	-0.0427	0.393	0.91
bus	EQ4*	-0.144	0.373	0.68
metro	EQ4*	0.537	0.349	0.08
2W	EQ4*	0.164	0.369	0.62
auto-rickshaw	EQ4	1.46	0.583	0.01
walk	EQ5*	-1.16	0.648	0.07
car-sharing	A2*	1.88	7.63	0.07
car	EQ5	0	fixed	
car-sharing	EQ5	-1.15	0.453	0.01
bus	EQ5	-0.84	0.417	0.03
metro	EQ5*	-0.244	0.377	0.47
2W	EQ5	-0.696	0.405	0.05
auto-rickshaw	EQ5*	-0.787	0.705	0.24
walk	MI1	2.11	0.841	0.02
car	MI1	0	fixed	
car-sharing	MI1	2.13	0.943	0.04
bus	MI1	5.94	3.39	0
bus	A2*	1.64	4.33	0.14
metro	MI1	2.41	0.727	0
2W	MI1	5.37	0.828	0
auto-rickshaw	MI1	7.88	3.61	0
walk	MI2	2.21	0.671	0
car	MI2	0	fixed	

car-sharing	MI2	4.07	0.799	0
bus	MI2	7.71	3.35	0
metro	MI2	4.63	0.57	0
2W	MI2	5.32	0.641	0
auto-rickshaw	MI2	8.12	3.58	0
metro	A2*	-1.62	0.893	0.07
walk	MI3*	1.22	0.621	0.06
car	MI3	0	fixed	
car-sharing	MI3	3.19	0.743	0
bus	MI3	7.22	3.34	0
metro	MI3	3.48	0.478	0
2W	MI3	4.73	0.546	0
auto-rickshaw	MI3	7.71	3.56	0
walk	MI4*	-0.277	0.651	0.69
car	MI4	0	fixed	
car-sharing	MI4	2.01	0.751	0.02
car	Gender	0	fixed	
2W	A2*	-1.06	1.02	0.31
bus	MI4	5.33	3.34	0
metro	MI4	2.46	0.466	0
2W	MI4	2.98	0.523	0
auto-rickshaw	MI4	5.07	3.55	0
walk	MI5*	0.0323	0.744	0.97
car	MI5	0	fixed	
car-sharing	MI5	-5.71	11.5	0
bus	MI5	2.93	3.41	0
metro	MI5*	-0.241	0.65	0.7
2W	MI5	1.55	0.558	0.01

auto-rickshaw	A2	-5.11	1.27	0
auto-rickshaw	MI5	-4.48	52.7	0
walk	Good	7.79	0.685	0
car	Good	0	fixed	
car-sharing	Good	-7.19	10.2	0
bus	Good	2.1	0.463	0
metro	Good*	0.0115	0.43	0.98
2W	Good	5.85	0.476	0
auto-rickshaw	Good	4.34	0.545	0
walk	Satisfactory	7.47	0.679	0
car	Satisfactory	0	fixed	
walk	A3*	-0.544	1.06	0.68
car-sharing	Satisfactory	-1.96	0.81	0.02
bus	Satisfactory	2.02	0.453	0
metro	Satisfactory*	-0.105	0.422	0.8
2W	Satisfactory	5.71	0.468	0
auto-rickshaw	Satisfactory	4.22	0.537	0
walk	Moderate	5.36	0.646	0
car	Moderate	0	fixed	
car-sharing	Moderate	-1.01	0.435	0.02
bus	Moderate	1.61	0.375	0
metro	Moderate*	-0.0209	0.327	0.95
car	A3	0	fixed	
2W	Moderate	4.11	0.414	0
auto-rickshaw	Moderate	2.87	0.491	0
walk	poor*	0.888	0.718	0.22
car	Poor	0	fixed	
car-sharing	Poor*	-0.201	0.315	0.52

bus	Poor	0.954	0.333	0
metro	Poor*	0.193	0.273	0.48
2W	Poor	1.32	0.4	0
auto-rickshaw	Poor*	0.869	0.48	0.06
walk	VP*	-0.0246	0.734	0.97
car-sharing	A3	1.96	7.61	0.03
car	VP	0	fixed	
car-sharing	VP*	-0.0719	0.291	0.8
bus	VP*	-0.0284	0.34	0.93
metro	VP*	-0.00734	0.259	0.98
2W	VP*	-0.025	0.426	0.95
auto-rickshaw	VP	-0.0294	0.496	0.95
bus	A3	2.44	4.3	0.02
metro	A3	-1.27	0.768	0.12
2W	A3	-0.699	0.89	0.46
auto-rickshaw	A3	-4.78	1.14	0
walk	A4	0.562	0.997	0.65
car-sharing	Gender	0.466	0.285	0.06
car	A4	0	fixed	
car-sharing	A4	2.4	7.61	0.01
bus	A4	3.32	4.29	0
metro	A4	-0.903	0.745	0.26
2W	A4	0.574	0.86	0.54
auto-rickshaw	A4	-3.06	1.1	0.01
walk	D1	8.52	0.992	0
car	D1	0	fixed	
car-sharing	D1	0.544	0.585	0.34
bus	D1	2.41	0.718	0

bus	Gender	-0.403	0.29	0.12
metro	D1	0.0529	0.54	0.92
2W	D1	4.27	0.593	0
auto-rickshaw	D1	4.07	0.658	0
walk	D2	3.55	0.932	0
car	D2	0	fixed	
car-sharing	D2	-0.889	0.471	0.03
bus	D2	1.79	0.568	0
metro	D2	-1.28	0.432	0
2W	D2	1.67	0.482	0
auto-rickshaw	D2	0.797	0.567	0.12
metro	Gender	-0.0611	0.25	0.79
walk	D3	3.32	0.888	0
car	D3	0	fixed	
car-sharing	D3	-0.179	0.422	0.62
bus	D3	1.84	0.53	0
metro	D3*	0.0929	0.372	0.78
2W	D3	1.51	0.429	0
auto-rickshaw	D3*	0.758	0.517	0.1
walk	D4	2.2	0.888	0.01
car	D4	0	fixed	
car-sharing	D4	-0.734	0.426	0.05
2w	Gender	-1.33	0.28	0
bus	D4	1.67	0.526	0
metro	D4*	0.46	0.365	0.15
2W	D4	0.959	0.419	0.01
auto-rickshaw	D4*	-0.0912	0.519	0.85
walk	MS1*	1.62	0.983	0.17

car	MS1	0	fixed	
car-sharing	MS1	2.27	0.753	0
bus	MS1*	1.26	0.633	0.08
metro	MS1	1.3	0.517	0.03
2W	MS1	1.44	0.574	0.03
auto-rickshaw	Gender*	0.386	0.332	0.24
auto-rickshaw	MS1*	0.0134	0.681	0.99
walk	MS2*	0.168	0.924	0.88
car	MS2	0	fixed	
car-sharing	MS2*	0.82	0.722	0.28
bus	MS2*	0.889	0.579	0.18
metro	MS2*	0.197	0.463	0.72
2W	MS2*	0.102	0.515	0.87
auto-rickshaw	MS2*	-0.426	0.615	0.54
walk	PF1	-3.17	1.87	0.01
car	PF1	0	fixed	
walk	A1	4.35	7.73	0.02
car-sharing	PF1	-3.35	1.63	0
bus	PF1*	-1.74	1.73	0.16
metro	PF1*	-1.76	1.58	0.07
2W	PF1	-4.12	1.76	0.01
auto-rickshaw	PF1*	0.393	9.19	0.77
walk	PF2	3.69	7.19	0
car	PF2	0	fixed	
car-sharing	PF2	2.39	7.13	0.02
bus	PF2	4.49	7.14	0
metro	PF2	3.74	7.11	0
car	A1	0	fixed	

2W	PF2	3.62	7.15	0.02
auto-rickshaw	PF2	5.76	11.5	0
walk	PF3	-2.13	1.73	0.03
car	PF3	0	fixed	
car-sharing	PF3	-3.93	1.49	0
bus	PF3	-2.9	1.56	0.01
metro	PF3	-3.56	1.46	0
2W	PF3*	-1.98	1.61	0.14
auto-rickshaw	PF3*	0.494	9.16	0.66
walk	PF4	-7	6.43	0

*Insignificant variables

Table A.2: Primary trip result after iteration

choice	name	value	std err	p-value
walk	ASC_1	-9.23	0.714	0
car	ASC_2	0	fixed	
car-sharing	ASC_3	-3.67	7.04	0
bus	ASC_4	-11.8	7	0
metro	ASC_5	-1.49	0.403	0
2W	ASC_6	-6.87	0.539	0
auto-rickshaw	ASC_7	-8.34	5.5	0
car-sharing	A1	-3.03	19.7	0
metro	A1	-6.39	11.7	0
car	A1	0	fixed	
car	A2	0	fixed	
car-sharing	A2	2.9	7.04	0
bus	A2	3.22	5.34	0
2W	A2	-1.38	0.318	0

auto-rickshaw	A2	-2.73	0.665	0
walk	A3	-0.781	0.279	0.01
car	A3	0	fixed	
car-sharing	A3	2.76	7.03	0
bus	A3	3.65	5.33	0
2W	A3	-1.06	0.216	0
auto-rickshaw	A3	-2.98	0.649	0
auto-rickshaw	A3	-1.87	0.611	0.01
car	A4	0	fixed	
car-sharing	A4	2.95	7.03	0
bus	A4	4.27	5.33	0
walk	D1	7.11	0.614	0
car	D1	0	fixed	
car-sharing	D1	1.05	0.308	0
bus	D1	2.37	0.556	0
2W	D1	3.52	0.375	0
auto-rickshaw	D1	3.28	0.334	0
walk	D2	2.43	0.593	0
car	D2	0	fixed	
bus	D2	2.01	0.457	0
metro	D2	-1.06	0.227	0
2W	D2	1.31	0.319	0
walk	D3	2.07	0.565	0
car	D3	0	fixed	
bus	D3	1.78	0.432	0
2W	D3	0.983	0.277	0
walk	D4	1.26	0.586	0.02
car	D4	0	fixed	

bus	D4	2.05	0.437	0
metro	D4	0.727	0.154	0
2W	D4	0.849	0.279	0
walk	EQ1	9.82	8.93	0
car	EQ1	0	fixed	
2W	EQ1	-2.93	44.2	0
auto-rickshaw	EQ1	6.96	8.92	0
walk	EQ2	7.21	4.85	0
car	EQ2	0	fixed	
car-sharing	EQ2	4.81	4.86	0
bus	EQ2	3.8	4.86	0
metro	EQ2	3.95	4.84	0
2W	EQ2	4.96	4.84	0
auto-rickshaw	EQ2	6.47	4.85	0
car	EQ3	0	fixed	
bus	EQ3	0.799	0.265	0
2W	EQ3	0.733	0.223	0
auto-rickshaw	EQ3	1.18	0.408	0.01
car	EQ4	0	fixed	
auto-rickshaw	EQ4	1.32	0.328	0
car	EQ5	0	fixed	
car-sharing	EQ5	-0.74	0.255	0
car	Gender	0	fixed	
car-sharing	Gender	0.597	0.175	0
2W	Gender	-1.17	0.159	0
walk	Good	7.13	0.444	0
car	Good	0	fixed	
car-sharing	Good	-7.37	11.9	0

bus	Good	1.83	0.312	0
2W	Good	5.41	0.299	0
auto-rickshaw	Good	3.78	0.338	0
walk	MI1	2.04	0.397	0
car	MI1	0	fixed	
bus	MI1	6.59	4.52	0
metro	MI1	2.39	0.43	0
2W	MI1	5.41	0.53	0
auto-rickshaw	MI1	8.27	5.5	0
walk	MI2	2.65	0.471	0
car	MI2	0	fixed	
car-sharing	MI2	2.34	0.391	0
bus	MI2	8.42	4.52	0
metro	MI2	4.83	0.444	0
2W	MI2	5.82	0.551	0
auto-rickshaw	MI2	8.91	5.51	0
walk	MI3	1.56	0.418	0
car	MI3	0	fixed	
car-sharing	MI3	1.49	0.281	0
bus	MI3	7.95	4.51	0
metro	MI3	3.73	0.349	0
2W	MI3	5.18	0.461	0
auto-rickshaw	MI3	8.5	5.5	0
car	MI4	0	fixed	
bus	MI4	6.02	4.51	0
metro	MI4	2.63	0.345	0
2W	MI4	3.38	0.444	0
auto-rickshaw	MI4	5.89	5.5	0

car	MI5	0	fixed	
car-sharing	MI5	-7.41	12.1	0
bus	MI5	3.55	4.57	0
2W	MI5	1.7	0.502	0
auto-rickshaw	MI5	-4.07	54.2	0
walk	Moderate	4.9	0.428	0
car	Moderate	0	fixed	
car-sharing	Moderate	-0.813	0.33	0.01
bus	Moderate	1.49	0.243	0
2W	Moderate	3.85	0.267	0
auto-rickshaw	Moderate	2.47	0.313	0
walk	MS1	1.52	0.28	0
car	MS1	0	fixed	
car-sharing	MS1	1.25	0.238	0
metro	MS1	0.993	0.168	0
2W	MS1	1.28	0.203	0
walk	MS2	0	fixed	
walk	PF1	0	fixed	
2W	PF1	-1.34	0.3	0
car	PF2	0	fixed	
car	PF3	0	fixed	
car-sharing	PF3	-0.774	0.23	0
bus	PF3	-1.42	0.401	0
metro	PF3	-1.69	0.324	0
car	PF4	0	fixed	
bus	PF4	-1.42	0.479	0
metro	PF4	-1.03	0.381	0.01
auto-rickshaw	PF4	-6.92	12	0

walk	PF4	-6.14	12.2	0
car	PF5	0	fixed	
car-sharing	PF5	-2.19	0.349	0
bus	PF5	-11.2	14.2	0
metro	PF5	-2.03	0.349	0
auto-rickshaw	PF5	-0.908	0.316	0
walk	PF6	-1.86	0.799	0
car	PF6	0	fixed	
bus	PF6	-1.96	0.493	0
metro	PF6	-1.45	0.38	0
car	PF7	0	fixed	
car-sharing	PF7	-7.17	12.6	0
bus	PF7	-3.02	0.907	0
metro	PF7	-2.39	0.664	0
2W	PF7	-1.41	0.522	0.01
auto-rickshaw	PF7	-9.76	11.6	0
car	PF8	0	fixed	
car-sharing	PF8	-5.52	11.6	0
metro	PF8	-6.61	11.7	0
auto-rickshaw	PF8	3.08	0.603	0
car	PF9	0	fixed	
bus	PF9	-1.89	0.459	0
2W	PF9	-8.89	12.2	0
car	Poor	0	fixed	
bus	Poor	0.798	0.206	0
2W	Poor	1.04	0.268	0
walk	Satisfactory	7.09	0.439	0
car	Satisfactory	0	fixed	

bus	Satisfactory	2.02	0.303	0
2W	Satisfactory	5.55	0.292	0
auto-rickshaw	Satisfactory	3.96	0.33	0
car	VP	0	fixed	

Appendix B

Secondary Result

Table B.1: Initial result for secondary trip

choice	name	value	std err	p-value
walk	ASC_1	-9.68	2.81	0
car	ASC_2	0	fixed	
car-sharing	ASC_3	-8.15	7.06	0
bus	ASC_4	-9.63	5.59	0
metro	ASC_5*	-0.373	2.38	0.77
2W	ASC_6	-5.06	2.6	0
auto-rickshaw	ASC_7	-9.86	3.3	0
walk	Gender	-0.981	0.319	0
car-sharing	A1*	-1.28	431	0.33
car	PF4	0	fixed	
car-sharing	PF4	-5.03	2.06	0
bus	PF4	-4.43	2.37	0
metro	PF4	-4.17	2.01	0
2W	PF4	-3.31	2.12	0
auto-rickshaw	PF4*	-1.14	2.77	0.22
walk	PF5	-4	2.18	0
car	PF5	0	fixed	
car-sharing	PF5	-5.65	2.02	0

bus	PF5	-4.92	2.32	0
bus	A1*	-1.52	130	0.42
metro	PF5	-5.2	1.99	0
2W	PF5	-4.08	2.09	0
auto-rickshaw	PF5	-2.56	2.75	0
walk	PF6	-4.04	2.23	0
car	PF6	0	fixed	
car-sharing	PF6	-5.58	2.06	0
bus	PF6	-4.41	2.35	0
metro	PF6	-4.96	2.02	0
2W	PF6	-5.05	2.14	0
auto-rickshaw	PF6*	-1.8	2.77	0.06
metro	A1	-2.81	53.5	0.01
walk	PF7*	-3.15	2.36	0.07
car	PF7	0	fixed	
car-sharing	PF7	-9.57	8.65	0
bus	PF7*	-0.965	2.61	0.65
metro	PF7	-4.93	2.18	0
2W	PF7	-4.31	2.32	0.01
auto-rickshaw	PF7*	-1.99	2.96	0.27
walk	PF8	3.93	5.93	0.04
car	PF8	0	fixed	
car-sharing	PF8	-5.31	28.4	0
2W	A1	10	11.9	0
bus	PF8	7.2	6.09	0
metro	PF8	3.83	5.89	0
2W	PF8*	0.817	5.95	0.69
auto-rickshaw	PF8	7.11	6.15	0

walk	PF9	-7.13	2.35	0
car	PF9	0	fixed	
car-sharing	PF9	-4.49	2.12	0
bus	PF9	-5.45	2.57	0.01
metro	PF9	-5.28	2.11	0
2W	PF9	-11.9	7.81	0
auto-rickshaw	A1*	-8.54	22	0.29
auto-rickshaw	PF9*	-1.94	2.84	0.09
walk	EQ1	9.54	7.28	0
car	EQ1	0	fixed	
car-sharing	EQ1	-2.23	110	0.02
bus	EQ1*	-1.03	36.3	0.56
metro	EQ1	-4.43	72.1	0
2W	EQ1*	-1.13	136	0.54
auto-rickshaw	EQ1	8.51	7.29	0
walk	EQ2	2.16	1.02	0.03
car	EQ2	0	fixed	
walk	A2*	-0.429	1.02	0.68
car-sharing	EQ2*	-0.0323	0.924	0.97
bus	EQ2	-9.68	9.82	0
metro	EQ2	-4.49	1.37	0
2W	EQ2*	-0.293	0.978	0.78
auto-rickshaw	EQ2*	-0.803	1.01	0.4
walk	EQ3	3.01	0.703	0
car	EQ3	0	fixed	
car-sharing	EQ3	1.41	0.673	0.01
bus	EQ3	3.32	0.781	0
metro	EQ3	1.72	0.628	0

car	A2	0	fixed	
2W	EQ3	2.11	0.656	0
auto-rickshaw	EQ3	2.13	0.654	0
walk	EQ4*	0.517	0.478	0.23
car	EQ4	0	fixed	
car-sharing	EQ4*	0.11	0.431	0.78
bus	EQ4*	0.23	0.564	0.68
metro	EQ4*	0.00447	0.387	0.99
2W	EQ4*	-0.401	0.419	0.29
auto-rickshaw	EQ4*	0.18	0.417	0.63
walk	EQ5*	-0.553	0.518	0.22
car-sharing	A2	2.02	5.36	0.04
car	EQ5	0	fixed	
car-sharing	EQ5*	-0.627	0.469	0.14
bus	EQ5*	-0.0119	0.615	0.98
metro	EQ5*	-0.272	0.404	0.44
2W	EQ5*	-0.713	0.448	0.07
auto-rickshaw	EQ5	-1.02	0.458	0.01
walk	MI1	2.93	0.82	0
car	MI1	0	fixed	
car-sharing	MI1	1.77	0.787	0.02
bus	MI1	7.17	4.71	0
bus	A2*	0.452	1.59	0.78
metro	MI1	3.29	0.758	0
2W	MI1	3.93	0.86	0
auto-rickshaw	MI1	2.98	0.834	0
walk	MI2	3.48	0.657	0
car	MI2	0	fixed	

car-sharing	MI2	3.51	0.681	0
bus	MI2	9.87	4.64	0
metro	MI2	4.68	0.58	0
2W	MI2	5.1	0.671	0
auto-rickshaw	MI2	4.79	0.734	0
metro	A2*	-1.52	1.03	0.06
walk	MI3*	0.923	0.56	0.12
car	MI3	0	fixed	
car-sharing	MI3	2.92	0.594	0
bus	MI3	9.22	4.63	0
metro	MI3	3.61	0.456	0
2W	MI3	3.82	0.559	0
auto-rickshaw	MI3	3.53	0.641	0
walk	MI4*	0.837	0.531	0.13
car	MI4	0	fixed	
car-sharing	MI4	1.81	0.592	0
car	Gender	0	fixed	
2W	A2*	0.206	1.11	0.84
bus	MI4	7.25	4.63	0
metro	MI4	2.5	0.433	0
2W	MI4	2.71	0.539	0
auto-rickshaw	MI4	2.48	0.632	0
walk	MI5*	-0.899	0.615	0.14
car	MI5	0	fixed	
car-sharing	MI5*	0.267	0.758	0.7
bus	MI5	-5.34	137	0
metro	MI5	2	0.455	0
2W	MI5*	0.752	0.594	0.21

auto-rickshaw	A2*	1.55	1.38	0.18
auto-rickshaw	MI5*	-0.465	0.821	0.55
walk	Good	7.55	0.587	0
car	Good	0	fixed	
car-sharing	Good*	0.0363	0.599	0.95
bus	Good	2.33	0.617	0
metro	Good*	-0.694	0.529	0.21
2W	Good	5.06	0.513	0
auto-rickshaw	Good	3.74	0.487	0
walk	Satisfactory	7.41	0.584	0
car	Satisfactory	0	fixed	
walk	A3*	1.01	0.863	0.28
car-sharing	Satisfactory*	0.175	0.577	0.76
bus	Satisfactory	2.12	0.629	0
metro	Satisfactory*	-0.13	0.488	0.79
2W	Satisfactory	5.02	0.51	0
auto-rickshaw	Satisfactory	3.74	0.483	0
walk	Moderate	5.22	0.506	0
car	Moderate	0	fixed	
car-sharing	Moderate*	-0.637	0.461	0.17
bus	Moderate	2.33	0.48	0
metro	Moderate*	0.163	0.352	0.65
car	A3	0	fixed	
2W	Moderate	3.39	0.424	0
auto-rickshaw	Moderate	2.51	0.386	0
walk	poor	1.27	0.498	0.02
car	poor	0	fixed	
car-sharing	poor*	-0.169	0.309	0.58

bus	poor	1.14	0.442	0.01
metro	poor*	0.158	0.28	0.57
2W	poor	1.26	0.385	0
auto-rickshaw	poor	0.854	0.336	0.01
walk	VP*	0.0589	0.523	0.92
car-sharing	A3	3.41	5.34	0
car	VP	0	fixed	
car-sharing	VP*	0.0155	0.286	0.96
bus	VP*	0.029	0.48	0.95
metro	VP*	0.0262	0.268	0.92
2W	VP*	0.135	0.405	0.73
auto-rickshaw	VP*	0.0311	0.34	0.93
bus	A3*	1.67	1.4	0.26
metro	A3*	0.0093	0.89	0.99
2W	A3*	1.22	0.971	0.19
auto-rickshaw	A3	3.58	1.27	0
walk	A4*	1.47	0.822	0.11
car-sharing	Gender*	0.0359	0.291	0.9
car	A4	0	fixed	
car-sharing	A4	3.83	5.34	0
bus	A4*	2.21	1.34	0.13
metro	A4*	0.168	0.864	0.8
2W	A4*	1.59	0.942	0.09
auto-rickshaw	A4	3.75	1.24	0
walk	D1	10	1.35	0
car	D1	0	fixed	
car-sharing	D1	7.17	4.08	0
bus	D1	2.23	1.22	0.03

bus	Gender*	-0.366	0.365	0.29
metro	D1	2.13	0.854	0.01
2W	D1	5.17	0.994	0
auto-rickshaw	D1	6.4	1.09	0
walk	D2	8.1	1.35	0
car	D2	0	fixed	
car-sharing	D2	7.04	4.08	0
bus	D2	3.98	1.15	0
metro	D2	2.73	0.859	0
2W	D2	3.99	1	0
auto-rickshaw	D2	5.52	1.1	0
metro	Gender*	-0.0655	0.27	0.8
walk	D3	7.03	1.34	0
car	D3	0	fixed	
car-sharing	D3	6.77	4.08	0
bus	D3	4.29	1.13	0
metro	D3	3.57	0.843	0
2W	D3	3.7	0.986	0
auto-rickshaw	D3	5.63	1.09	0
walk	D4	4.41	1.46	0
car	D4	0	fixed	
car-sharing	D4	6.62	4.09	0
2w	Gender	-1.03	0.302	0
bus	D4	4.62	1.17	0
metro	D4	4.69	0.873	0
2W	D4	3.74	1.02	0
auto-rickshaw	D4	4.98	1.12	0
walk	MS1*	0.213	0.835	0.8

car	MS1	0	fixed	
car-sharing	MS1*	1.92	0.974	0.06
bus	MS1*	-0.993	0.807	0.21
metro	MS1*	0.608	0.697	0.38
2W	MS1*	0.387	0.783	0.61
auto-rickshaw	Gender*	-0.258	0.289	0.37
auto-rickshaw	MS1*	-0.306	0.745	0.68
walk	MS2*	-1.28	0.75	0.07
car	MS2	0	fixed	
car-sharing	MS2*	0.437	0.917	0.65
bus	MS2	-1.84	0.714	0
metro	MS2*	-0.279	0.606	0.63
2W	MS2*	-0.865	0.7	0.16
auto-rickshaw	MS2	-1.36	0.662	0.03
walk	PF1	-4.82	2.25	0
car	PF1	0	fixed	
walk	A1	9.75	11.9	0
car-sharing	PF1	-3.99	2.07	0
bus	PF1	-3.52	2.5	0.03
metro	PF1	-5.43	2.06	0
2W	PF1	-5.69	2.18	0
auto-rickshaw	PF1*	-1.05	2.8	0.29
walk	PF2	3.38	17.2	0.01
car	PF2	0	fixed	
car-sharing	PF2	3.4	17.2	0
bus	PF2	5.31	17.2	0
metro	PF2	3.58	17.1	0
car	A1	0	fixed	

2W	PF2	3.37	17.2	0.01
auto-rickshaw	PF2	6.72	17.3	0
walk	PF3	-3.06	2.17	0.01
car	PF3	0	fixed	
car-sharing	PF3	-4.52	2	0
bus	PF3	-4.38	2.3	0
metro	PF3	-4.58	1.98	0
2W	PF3	-3.57	2.08	0
auto-rickshaw	PF3*	-1.49	2.74	0.08
walk	PF4	-3.42	2.23	0.01

*Insignificant variables

Table B.2: Secondary trip result after iteration

choice	name	value	std err	p-value
walk	ASC_1	-8.24	0.657	0
car	ASC_2	0	fixed	
car-sharing	ASC_3	-11	8.55	0
bus	ASC_4	-6.84	6.3	0
metro	ASC_5	-2.45	0.373	0
2W	ASC_6	-3.43	0.404	0
auto-rickshaw	ASC_7	-6.2	0.849	0
car	A1	0	fixed	
car	A2	0	fixed	
car-sharing	A2	4.35	6.35	0
auto-rickshaw	A2	2.08	0.786	0
car	A3	0	fixed	
car-sharing	A3	4.42	6.35	0
auto-rickshaw	A3	2.84	0.768	0

car	A4	0	fixed	
car-sharing	A4	4.58	6.35	0
auto-rickshaw	A4	2.69	0.766	0
walk	D1	5.91	0.519	0
car	D1	0	fixed	
car-sharing	D1	5.85	5.77	0
2W	D1	1.65	0.224	0
auto-rickshaw	D1	1.51	0.219	0
walk	D2	3.51	0.492	0
car	D2	0	fixed	
car-sharing	D2	5.17	5.77	0
walk	D3	2.7	0.491	0
car	D3	0	fixed	
car-sharing	D3	5.08	5.77	0
bus	D3	0.74	0.276	0
metro	D3	1.1	0.181	0
auto-rickshaw	D3	0.46	0.175	0.01
car	D4	0	fixed	
car-sharing	D4	5	5.77	0
bus	D4	1.16	0.341	0
metro	D4	2.19	0.218	0
walk	EQ1	9.86	10	0
car	EQ1	0	fixed	
car-sharing	EQ1	-1.17	309	0.01
metro	EQ1	-2.51	53.7	0
auto-rickshaw	EQ1	8.83	10	0
walk	EQ2	3.04	0.417	0
car	EQ2	0	fixed	

bus	EQ2	-8.18	13.7	0
metro	EQ2	-2.71	0.816	0.01
walk	EQ3	2.32	0.451	0
car	EQ3	0	fixed	
car-sharing	EQ3	1.29	0.433	0
bus	EQ3	2.7	0.48	0
metro	EQ3	1.27	0.408	0
2W	EQ3	1.83	0.44	0
auto-rickshaw	EQ3	1.61	0.418	0
car	EQ4	0	fixed	
2W	EQ4	-0.473	0.159	0
car	EQ5	0	fixed	
auto-rickshaw	EQ5	-0.638	0.209	0
walk	Gender	-0.815	0.198	0
car	Gender	0	fixed	
2W	Gender	-0.971	0.177	0
walk	Good	7.72	0.395	0
car	Good	0	fixed	
bus	Good	2.7	0.444	0
2W	Good	5.24	0.319	0
auto-rickshaw	Good	3.92	0.297	0
walk	MI1	3.11	0.51	0
car	MI1	0	fixed	
bus	MI1	6.49	6.32	0
metro	MI1	2.05	0.479	0
2W	MI1	2.88	0.548	0
auto-rickshaw	MI1	2.4	0.47	0
walk	MI2	3.67	0.474	0

car	MI2	0	fixed	
car-sharing	MI2	1.99	0.386	0
bus	MI2	9.02	6.29	0
metro	MI2	3.76	0.479	0
2W	MI2	4.31	0.464	0
auto-rickshaw	MI2	4.19	0.533	0
walk	MI3	2	0.394	0
car	MI3	0	fixed	
car-sharing	MI3	2.13	0.311	0
bus	MI3	9.1	6.28	0
metro	MI3	3.63	0.398	0
2W	MI3	3.79	0.375	0
auto-rickshaw	MI3	3.91	0.461	0
walk	MI4	1.67	0.393	0
car	MI4	0	fixed	
car-sharing	MI4	0.895	0.326	0.01
bus	MI4	7.23	6.28	0
metro	MI4	2.48	0.387	0
2W	MI4	2.62	0.374	0
auto-rickshaw	MI4	2.84	0.457	0
car	MI5	0	fixed	
bus	MI5	-3.14	47.2	0
metro	MI5	1.88	0.401	0
walk	Moderate	5.15	0.341	0
car	Moderate	0	fixed	
bus	Moderate	2.37	0.317	0
2W	Moderate	3.3	0.26	0
auto-rickshaw	Moderate	2.45	0.226	0

car	MS1	0	fixed	
car-sharing	MS1	1.36	0.271	0
bus	MS1	-1.16	0.464	0.01
metro	MS1	0.675	0.232	0
walk	MS2	-1.3	0.27	0
car	MS2	0	fixed	
bus	MS2	-1.65	0.446	0
2W	MS2	-1.13	0.244	0
auto-rickshaw	MS2	-0.874	0.247	0
walk	PF1	-2.11	0.431	0
car	PF1	0	fixed	
bus	PF1	-1.88	0.907	0.01
metro	PF1	-1.52	0.411	0
2W	PF1	-2.01	0.496	0
walk	PF2	4.25	5.73	0
car	PF2	0	fixed	
car-sharing	PF2	5.85	5.72	0
bus	PF2	5.14	5.79	0
metro	PF2	5.88	5.72	0
2W	PF2	5.11	5.73	0
auto-rickshaw	PF2	6	5.72	0
car	PF3	0	fixed	
bus	PF3	-1.95	0.495	0
metro	PF3	-0.37	0.186	0.04
car	PF4	0	fixed	
bus	PF4	-1.84	0.65	0
car	PF5	0	fixed	
car-sharing	PF5	-0.906	0.245	0

bus	PF5	-2.04	0.535	0
metro	PF5	-0.716	0.226	0
car	PF6	0	fixed	
car-sharing	PF6	-1.56	0.596	0
2W	PF6	-0.827	0.35	0.02
auto-rickshaw	PF7	-0.652	0.21	0
car	PF7	0	fixed	
car-sharing	PF7	-6.1	14.3	0
car	PF8	0	fixed	
car-sharing	PF8	-5.31	14.4	0
bus	PF8	2.33	1.32	0.02
auto-rickshaw	PF8	1.68	0.507	0
walk	PF9	-3.57	0.579	0
car	PF9	0	fixed	
bus	PF9	-2.88	0.969	0.01
2W	PF9	-8.99	14.2	0
walk	Poor	1.19	0.363	0
car	Poor	0	fixed	
bus	Poor	1.08	0.306	0
2W	Poor	1.15	0.252	0
auto-rickshaw	Poor	0.805	0.207	0
walk	Satisfactory	7.3	0.38	0
car	Satisfactory	0	fixed	
bus	Satisfactory	2.19	0.454	0
2W	Satisfactory	4.91	0.301	0
auto-rickshaw	Satisfactory	3.63	0.278	0
car	VP	0	fixed	

Appendix C

Survey Format

Air Quality Perception Survey

You may have noticed that Air Pollution in Delhi is getting worse day by day. We are conducting this survey to determine how air pollution impacts changing the commuter's behavior in terms of air quality, travel cost and travel time. This survey will assist the commuters in reducing their air pollution exposure.
Please answer all questions in Sections A to F. This will take 3-5 minutes only.

A: Information Seeking and Engagement

Please select the District and Tehsil of your residence if you are a resident in Delhi. Else, select "Rest of NCR" and "Other areas".

Tehsil (Sub-division)

Do you have any pre-existing health issues (like asthma, bronchitis, lungs issues, etc.)?

◯ Yes ◯ No ◯ I don't know

Do you see air pollution as a major problem in your area of residence or office/ school/ college?

◯ Yes ◯ No ◯ I don't know

Do you know that air pollution can cause adverse health effects?

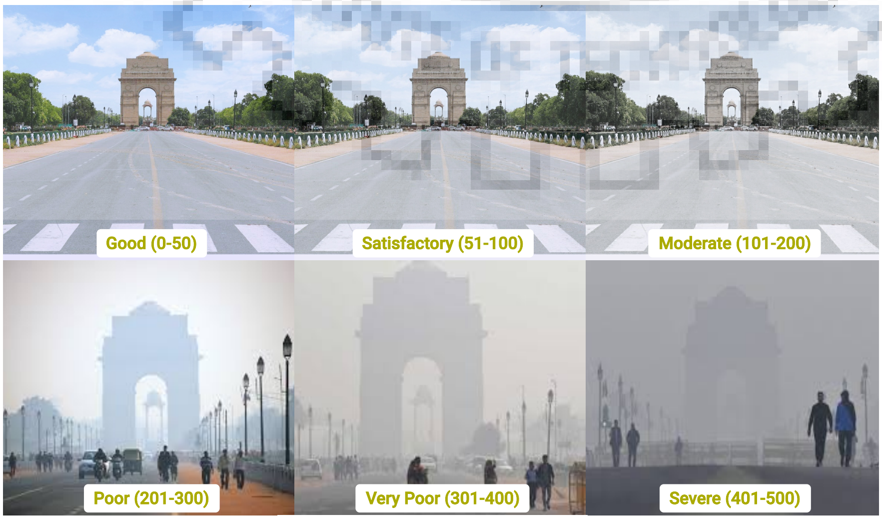
◯ Yes ◯ No ◯ I don't know

Are you aware of the Air Quality Index (AQI) or level and understand it?

◯ Aware and understand it ◯ Aware but do not understand ◯ Not aware

---

Here is an example to distinguish the Air Quality Index (AQI). The AQI value is specified by the Central Pollution Control Board (CPCB), Delhi.



AIR QUALITY INDEX (AQI)	CATEGORY
0-50	Good
51-100	Satisfactory
101-200	Moderate
201-300	Poor

301-400	Very Poor
401-500	Severe

Which Air Quality Index (AQI) or level do you consider bad?

AQI perception

Which information source do you use for checking the Air Quality Index (AQI)/ level?

Source of AQI

How frequently do you look on Air Quality Index / level?

Frequency

B: Trip Information

How many trips do you make in a Day?

Trips per day

What is the purpose of the trip?

Purpose of trip

Which main mode of transport do you use for commuting the primary trip (work or education)?

Mode for primary trip

What is your average trip length for primary activities (to work or education)?

Average trip length

Please select the District and Tehsil of your primary trip (most usual) destination if you are a resident in Delhi. Else, select "Rest of NCR" and "Other areas".

Tehsil (Sub-division)

Which mode of transport do you use for commuting the Secondary Trip (to gym/ sport/ leisure/ social/ shopping)?

Mode for secondary trip

What is your average trip length for secondary activities (to gym/ sport/ leisure/ social/ shopping)?

Average trip length

How is air quality affecting your choices for primary (to work/ school/ college) trip?

Change in choice

How is air quality affecting your choices for secondary (to gym/ sport/ leisure/ social/ shopping) trip?

Change in choice

At which Air Quality Index (AQI) or level, would you start changing your travel choices?

Avoid traveling

Select the current level of preferences (1 as least and 5 as highest) for selecting " for your trip to primary activities (to work/ school/ college)?

Travel time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Travel cost	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Departure time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Comfort/ convenience	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Air pollution exposure	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

Select the current level of preferences (1 as least and 5 as highest) for selecting " for your trip to secondary activities (to gym/ sport/ leisure/ social/ shopping)?

Travel time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Travel cost	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Departure time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Comfort/ convenience	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Air pollution exposure	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

There are no effect of air pollution exposure on my travel choices because

- ☐ I already change my travel choice based on air pollution exposure
- ☐ I do not know about the harmful effect of air pollution.
- ☐ I want to switch but I don't know how can I reduce the exposure
- ☐ I didn't know if exposure to air pollution can be reduced
- ☐ I do not care about air pollution
- ☐ Other

C: Impact of Air Pollution Exposure

How would you rate air quality close to your residence/ home?

AQI at residence ▾

How would you rate air quality close to your office/ workplace/ school/ college?

AQI at workplace or school ▾

How air pollution is affecting you? Please select all applicable.

☐ Breathlessness/ difficulty in breathing ☐ Doing less outdoor activities ☐ Doing more to look after my skin

☐ Doing more to stay healthy ☐ Irritation to eyes/ nose/ throat ☐ Skin problems ☐ Body allergies

☐ Wanting to move to other less polluted places ☐ Asthma incidences ☐ Poor visibility

☐ Worrying about the living environment for children ☐ Not affected at all

In your view, has air pollution ever affected you or your family member or your friend's health?

○ Always ○ Often ○ Sometimes ○ Rarely ○ Never

After or during your travel, do you feel any of these? Please select all applicable.

☐ Sneezing ☐ Runny nose ☐ Eye irritation ☐ Reduced lung functioning ☐ Other ☐ None

Is any infant/ children/ older persons in your family is getting affected due to air pollution?

☐ Yes, infant ☐ Yes, older people ☐ None

Do you feel any of the following psychological impact due to air pollution?

☐ Aggressiveness ☐ Anxiety ☐ Stress ☐ Frustation ☐ Angry ☐ Depression ☐ Uncertainty

☐ Fatigue ☐ None

D: Prevention/ Self-protective action

Do you use mask to protect yourself from air pollution?

Use of mask ▾

Do you use air-filter/ air-purifier/ air-conditioner at home?

○ Yes ○ No, but plan to buy ○ No, no plan to buy

Does your child miss school/ college during high pollution days?

Yes No

Due to high air pollution, do you avoid/ skip physical outdoor exercise?

◯ Yes ◯ No ◯ I don't do outdoor exercise

E: Willingness to Change/ Adapt

Air pollution can have short-term and long-term adverse effect on your health. Some of these can be reduced or avoided by changing the travel mode, travel route, departure time, etc. To help in decision making of an individual traveler, information about the exposure of air pollution can be provided. Please answer the following questions considering if such information is available to you.

Image Source:
https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution

What type of information would you like to have?

◯ Air Quality Index (AQI) or level only ◯ Air pollution exposure for each travel mode

◯ Multiple choices differentiate by travel time and exposure to air pollution (like routes on Google Maps) ◯ Other

◯ None

Would you avoid walking and cycling in bad Air Quality?

◯ Yes ◯ No ◯ I dont know

Select the level of preferences (1 as least and 5 as highest) for your trip to primary activities (to work/ school/ college) if air quality information and alternatives are available?

Travel time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Travel cost	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Departure time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Comfort/ convenience	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Air pollution exposure	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

Select the current level of preferences (1 as least and 5 as highest) for your trip to secondary activities (to gym/ sport/ leisure/ social/ shopping) if air quality information and alternatives are available?

Travel time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Travel cost	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Departure time	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Comfort/ convenience	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5
Air pollution exposure	◯ None	◯ 1	◯ 2	◯ 3	◯ 4	◯ 5

Which travel mode would you choose for your trip to primary activities (to work/ school/ college)?

Good (0-50)	Travel mode
Satisfactory (51-100)	Travel mode
Moderate (101-200)	Travel mode
Poor (201-300)	Travel mode
Very poor (301-400)	Travel mode
Severe (401-500)	Travel mode

Which travel mode would you choose for your trip to secondary activities (to gym/ sport/ leisure/ social/ shopping)?

Good (0-50)	Travel mode
Satisfactory (51-100)	Travel mode
Moderate (101-200)	Travel mode
Poor (201-300)	Travel mode
Very poor (301-400)	Travel mode
Severe (401-500)	Travel mode

F: Socioeconomic Characteristics

Gender

Female Male Other

Age

Age category

Educational Qualification

Educational qualification

Marital Status

Marital status

Profession

Profession

No. of vehicles in household

Cars: 0

Two Wheeler: 0

Bicycle: 0

Average Monthly Income

Average monthly income (INR)

Any other crisp comment/ feedback?

comment *

SUBMIT

Appendix D

Survey Poster

For the better reach of survey counts, different posters have been shared which embedded with QR code. For the online survey, the poster has been shared through e-mail and social media while for offline survey posters have been given to south Delhi commuters.

Figure D.1: Posters used in the survey

Bibliography

Agarwal, A. (2020). *Quantifying health & economic benefits of bicycle superhighway: evidences from Patna*. WP# 35. URL http://faculty.iitr.ac.in/~amitfce/publications.html. Indian Institute of Technology Roorkee (cit. on p. 10).

Agarwal, A. and I. Kaddoura (2019). "On-road air pollution exposure to cyclists in an agent-based simulation framework". In: *Periodica Polytechnica Transportation Engineering* 48.2, pp. 117–125. DOI: 10.3311/PPtr.12661 (cit. on pp. 3, 11).

Agarwal, A., D. Ziemke, and K. Nagel (2020). "Bicycle superhighway: an environmentally sustainable policy for urban transport". In: *Transportation Research Part A: Policy and Practice* 137, pp. 519–540. DOI: 10.1016/j.tra.2019.06.015 (cit. on p. 3).

Badland, H. M. and M. J. Duncan (Nov. 2009). "Perceptions of air pollution during the work-related commute by adults in Queensland, Australia". In: *Atmospheric Environment* 43.36, pp. 5791–5795. DOI: 10.1016/j.atmosenv.2009.07.050 (cit. on p. 3).

Balali-Mood, M., A. Ghorani-Azam, and B. Riahi-Zanjani (2016). "Effects of air pollution on human health and practical measures for prevention in Iran". In: *Journal of Research in Medical Sciences* 21.1, p. 65. DOI: 10.4103/1735-1995.189646 (cit. on pp. 1, 5, 9).

Ballester, F. and C. Iniguez (2011). "Air pollution exposure during pregnancy and reproductive outcomes". In: *Air Pollution - New Developments*. DOI: 10.5772/16847 (cit. on p. 10).

Barwick, P. J., S. Li, L. Lin, and E. Zou (2019). *From fog to smog: The value of pollution information*. Tech. rep. Cornell University and NBER. DOI: 10.3386/w26541 (cit. on p. 14).

Brauer, M., S. K. Guttikunda, A. Nishad K, S. Dey, S. N. Tripathi, C. Weagle, and R. V. Martin (2019). "Examination of monitoring approaches for ambient air pollution: A case study for India". In: *Atmospheric Environment* 216, p. 116940. DOI: 10.1016/j.atmosenv.2019.116940 (cit. on p. 6).

Caplin, A., M. Ghandehari, C. Lim, P. Glimcher, and G. Thurston (2019). "Advancing environmental exposure assessment science to benefit society". In: *Nature Communications* 10.1. DOI: 10.1038/s41467-019-09155-4 (cit. on p. 6).

Chen, S., C. Guo, and X. Huang (2018). "Air pollution, student health, and school absences: Evidence from China". In: *Journal of Environmental Economics and Management* 92, pp. 465–497. DOI: 10.1016/j.jeem.2018.10.002 (cit. on p. 10).

Cui, C., Z. Wang, P. He, S. Yuan, B. Niu, P. Kang, and C. Kang (2019). "Escaping from pollution: the effect of air quality on inter-city population mobility in China". In: *Environmental Research Letters* 14.12, p. 124025. DOI: 10.1088/1748-9326/ab5039 (cit. on pp. 3, 13).

D., M. A. and A. Kohli (June 2019). "Can Apps Make Air Pollution Visible? Learning About Health Impacts Through Engagement with Air Quality Information". In:

Journal of Business Ethics 161.2, pp. 279–302. DOI: 10.1007/s10551-019-04215-7 (cit. on p. 13).

Delfino, R. J. (2002). *Evaluation of health effects of toxic air pollutants in a Southern California Community: A pilot study.* Tech. rep. California Air Resources Board. URL: https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/past/99-302a.pdf (cit. on p. 10).

Demirel, H., E. Sertel, S. Kaya, and D. Z. Seker (2008). "Exploring impacts of road transportation on environment: A spatial approach". In: *Desalination* 226.1–3, pp. 279–288. DOI: 10.1016/j.desal.2007.02.111 (cit. on p. 5).

Dhondt, S., C. Beckx, B. Degraeuwe, W. Lefebvre, B. Kochan, T. Bellemans, L. I. Panis, C. Macharis, and K. Putman (2012). "Health impact assessment of air pollution using a dynamic exposure profile: implications for exposure and health impact estimates". In: *Environmental Impact Assessment Review* 36, pp. 42–51. DOI: 10.1016/j.eiar.2012.03.004 (cit. on p. 10).

Dons, E., M. Laeremans, J. P. Orjuela, I. Avila-Palencia, A. de Nazelle, M. Nieuwenhuijsen, M. V. Poppel, G. Carrasco-Turigas, A. Standaert, P. D. Boever, T. Nawrot, and L. I. Panis (2019). "Transport most likely to cause air pollution peak exposures in everyday life: Evidence from over 2000 days of personal monitoring". In: *Atmospheric Environment* 213, pp. 424–432. DOI: 10.1016/j.atmosenv.2019.06.035 (cit. on p. 3).

Goel, R. and S. Guttikunda (2015). "Evolution of on-road vehicle exhaust emissions in Delhi". In: *Atmospheric Environment* 105, pp. 78–90. DOI: 10.1016/j.atmosenv.2015.01.045 (cit. on pp. 1, 4).

Greenstone, M. and C. Fan (2020). *Air Quality Life Index: Annual Update.* Tech. rep. The Energy Policy Institute at the University of Chicago (EPIC). URL: https://aqli.epic.uchicago.edu/wp-content/uploads/2020/07/AQLI_2020_Report_FinalGlobal-1.pdf (cit. on pp. 1, 2).

Guo, W., Y. Chai, and M. P. Kwan (2020). "Travel-related exposure to air pollution and its socio-environmental inequalities: Evidence from a week-long GPS-based travel diary dataset". In: *Spatiotemporal Analysis of Air Pollution and Its Application in Public Health.* Elsevier, pp. 293–309. DOI: 10.1016/b978-0-12-815822-7.00013-3 (cit. on p. 13).

HEI (2019). *State of global air/ 2019. Speical report., Boston, MA: Health Effects Institue.* Tech. rep. Health Effects Institue (cit. on pp. 1, 5).

India, C. of (accessed 2021). *GOI.* URL: https://www.censusindia.gov.in/2011-prov-results/data_files/delhi/3_PDFC-Paper-1-tables_60_81.pdf (cit. on p. 15).

International Energy Agency (2016). *Key CO_2 Emissions Trends.* URL http://www.iea.org/publications/freepublications/publication/KeyCO2EmissionsTrends.pdf (cit. on p. 3).

IQAir (2020). *World Air Quality Report.* URL: https://www.iqair.com/world-air-quality-report (cit. on pp. 1, 2).

Jyoti Maji, K, A. Namdeo, D. Hoban, M. Bell, P. Goodman, S. S. Nagendra, J. Barnes, L. D. Vito, E. Hayes, J. Longhurst, R. Kumar, N. Sharma, S. K. Kuppili, and D. Alshetty (2020). "Analysis of various transport modes to evaluate personal exposure to PM2.5 pollution in Delhi". In: *Atmospheric Pollution Research.* DOI: 10.1016/j.apr.2020.12.003 (cit. on p. 10).

Kumar, R. (2015). *Transport sector dynamics and its contribution to urban health burden in a rapidly growing metropolitan areas of India*. Tech. rep. National Environmental Engineering Research Institute. URL: https://theicct.org/sites/default/files/RKumar_0.pdf (cit. on pp. 1, 10).

Künzli, N., R. Kaiser, S. Medina, M. Studnicka, O. Chanel, P. Filliger, M. Herry, F. Horak, V. Puybonnieux-Texier, P. Quénel, J. Schneider, R. Seethaler, J.-C. Vergnaud, and H. Sommer (2000). "Public-health impact of outdoor and traffic-related air pollution: A European assessment". In: *The Lancet* 356.9232, pp. 795–801. DOI: 10.1016/s0140-6736(00)02653-2 (cit. on p. 10).

Li, D. (2019). "The effects of pollution on travel mode choice". MA thesis. Cornell University. DOI: 10.7298/HQWY-YQ85 (cit. on pp. 11, 12).

Li, H. C., P. T. Chiueh, S. P. Liu, and Y. Y. Huang (2016). "Assessment of different route choice on commuters' exposure to air pollution in Taipei, Taiwan". In: *Environmental Science and Pollution Research* 24.3, pp. 3163–3171. DOI: 10.1007/s11356-016-8000-7 (cit. on p. 12).

Li, W. and M. Kamargianni (2017). "Air pollution and seasonality effects on mode choice in China". In: *Transportation Research Record: Journal of the Transportation Research Board* 2634.1, pp. 101–109. DOI: 10.3141/2634-15 (cit. on p. 3).

Liang, L., P. Gong, N. Cong, Z. Li, Y. Zhao, and Y. Chen (2019). "Assessment of personal exposure to particulate air pollution: The first result of city health outlook (CHO) project". In: *Bmc Public Health* 19.1, p. 711. DOI: 10.1186/s12889-019-7022-8 (cit. on p. 11).

Liu, T., G. He, and A. Lau (2017). "Avoidance behavior against air pollution: Evidence from online search indices for anti-PM 2.5 masks and air filters in Chinese cities". In: *Environmental Economics and Policy Studies* 20.2, pp. 325–363. DOI: 10.1007/s10018-017-0196-3 (cit. on p. 12).

Louviere, J. J., D. A. Hensher, J. D. Swait, and W. Adamowicz (Sept. 2000). "Stated Choice Methods". In: DOI: 10.1017/cbo9780511753831. URL: https://doi.org/10.1017/cbo9780511753831 (cit. on pp. 44, 46).

Mahendra, A. and L. Rajagopalan (2015). "Evaluating health impacts from a bus rapid transit system implementation in India: Case study of Indore, Madhya Pradesh". In: *Transportation Research Record: Journal of the Transportation Research Board* 2531.1, pp. 121–128. DOI: 10.3141/2531-14 (cit. on p. 10).

Maji, K. J., A. Namdeo, D. Hoban, M. Bell, P. Goodman, S. M. S. Nagendra, J. Barnes, L. D. Vito, E. Hayes, J. Longhurst, R. Kumar, N. Sharma, S. K. Kuppili, and D. Alshetty (2020). "Analysis of various transport modes to evaluate personal exposure to $PM_{2.5}$ pollution in Delhi". In: *Atmospheric Pollution Research*. DOI: 10.1016/j.apr.2020.12.003 (cit. on p. 2).

Manisalidis, I., E. Stavropoulou, A. Stavropoulos, and E. Bezirtzoglou (2020). "Environmental and health impacts of air pollution: A review". In: *Frontiers in Public Health* 8. DOI: 10.3389/fpubh.2020.00014 (cit. on p. 1).

Pandey, A., M. Brauer, M. L. Cropper, and K. Balakrishnan (Jan. 2021). "Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019". In: *The Lancet Planetary Health* 5.1, e25–e38. DOI: 10.1016/s2542-5196(20)30298-9 (cit. on p. 1).

Pant, P., R. M. Lal, S. K. Guttikunda, A. G. Russell, A. S. Nagpure, and R. E. Ramaswami Peltier (Oct. 2018). "Monitoring particulate matter in India: recent trends and future outlook". In: *Air Quality, Atmosphere & Health* 12.1, pp. 45–58. DOI: 10.1007/s11869-018-0629-6 (cit. on pp. 4, 12).

Qiu, Q., Y. Wang, S. Qiao, R. Liu, Z. Bian, T. Yao, and T. S. Nguyen (2020). "Does air pollution affect consumer online purchasing behavior? The effect of environmental psychology and evidence from China". In: *Journal of Cleaner Production* 260, p. 120795. DOI: 10.1016/j.jclepro.2020.120795 (cit. on p. 3).

Ritchie, H. and M. Roser (2017). "Air Pollution". In: *Our World in Data*. URL https://ourworldindata.org/air-pollution (cit. on p. 5).

Saberian, S., A. Heyes, and N. Rivers (2017). "Alerts work! Air quality warnings and cycling". In: *Resource and Energy Economics* 49, pp. 165–185. DOI: 10.1016/j.reseneeco.2017.05.004 (cit. on pp. 6, 12).

Sindhwani, R. and P. Goyal (July 2014). "Assessment of traffic-generated gaseous and particulate matter emissions and trends over Delhi (2000–2010)". In: *Atmospheric Pollution Research* 5.3, pp. 438–446. DOI: 10.5094/apr.2014.051 (cit. on p. 15).

Singh, V., K. K. Meena, and A. Agarwal (2021). *Travellers' exposure to air pollution: a systematic review and future directions*. WP # 36. URL http://faculty.iitr.ac.in/~amitfce/publications.html. Indian Institute of Technology Roorkee (cit. on p. 3).

Siqi, Z., Z. Xiaonan, S. Zhida, and S. Cong (2016). "Influence of air pollution on urban residents' outdoor activity: Empirical study based on dining-out data from the Dianping website". In: *Journal of Tsinghua University(Science and Technology)* 56.1, 89, p. 89. DOI: 10.16511/j.cnki.qhdxxb.2016.23.018 (cit. on p. 6).

Thombre, A. and A. Agarwal (2020). *A paradigm shift in urban mobility: policy insights from travel before and after COVID-19 to seize the opportunity*. WP# 32. URL http://faculty.iitr.ac.in/~amitfce/publications.html. Indian Institute of Technology Roorkee (cit. on p. 37).

Tiwari, S., A. Thomas, P. Rao, D. M. Chate, V. K. Soni, S. Singh, S. D. Ghude, D. Singh, and P. K. Hopke (2018). "Pollution concentrations in Delhi India during winter 2015–16: A case study of an odd-even vehicle strategy". In: *Atmospheric Pollution Research* 9.6, pp. 1137–1145. DOI: 10.1016/j.apr.2018.04.008 (cit. on p. 17).

Tribby, C. P., H. J. Miller, Y. Song, and K. R. Smith (2013). "Do air quality alerts reduce traffic? An analysis of traffic data from the Salt Lake City metropolitan area, Utah, USA". In: *Transport Policy* 30, pp. 173–185. DOI: 10.1016/j.tranpol.2013.09.012 (cit. on p. 12).

Vardhan, H., I. Rai, N. Kathait, and A. Agarwal (2020). *Crowd-sourced web survey for household travel diaries*. WP# 30. http://faculty.iitr.ac.in/~amitfce/publications.html. Indian Institute of Technology Roorkee (cit. on p. 20).

Veloz, D., M. Gonzalez, P. Brown, H. Gharibi, and R. Cisneros (Apr. 2020). "Perceptions about air quality of individuals who work outdoors in the San Joaquin Valley, California". In: *Atmospheric Pollution Research* 11.4, pp. 825–830. DOI: 10.1016/j.apr.2020.01.010 (cit. on p. 3).

Welch, E., X. Gu, and L. Kramer (2005). "The effects of ozone action day public advisories on train ridership in Chicago". In: *Transportation Research Part D: Transport and Environment* 10.6, pp. 445–458. DOI: 10.1016/j.trd.2005.06.002 (cit. on p. 6).

WHO (2017). *Health economic assessment tools (HEAT) for walking and for cycling*. Tech. rep. World Health Organization. URL: https://www.euro.who.int/__data/assets/pdf_file/0010/352963/Heat.pdf (cit. on p. 10).

WHO (2020). *Ambient (outdoor) air pollution.* Tech. rep. World Health Organization. URL: https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health (cit. on p. 1).

Wu, D. L., M. Lin, C. Y. Chan, W. Z. Li, J. Tao, Y. P. Li, X. F. Sang, and C. W. Bu (2013). "Influences of commuting mode, air conditioning mode and meteorological parameters on fine particle ($PM_{2.5}$) exposure levels in traffic microenvironments". In: *Aerosol and Air Quality Research* 13.2, pp. 709–720. DOI: 10.4209/aaqr.2012.08.0212 (cit. on p. 11).

Xu, Z., J. Li, J. Shan, and W. Zhang (2020). "Extending the theory of planned behavior to understand residents' coping behaviors for reducing the health risks posed by haze pollution". In: *Environment, Development and Sustainability*. DOI: 10.1007/s10668-020-00666-5 (cit. on p. 10).

Zavattero, D. A., J. A. Ward, and C. K. Strong (1998). "Air quality effects of travel changes". In: *Transportation Research Record*. DOI: 10.3141/1641-11 (cit. on p. 5).

Zhang, K. and S. Batterman (2013). "Air pollution and health risks due to vehicle traffic". In: *Science of The Total Environment* 450-451, pp. 450–451. DOI: 10.1016/j.scitotenv.2013.01.074 (cit. on p. 12).

Zhao, J., L. Gladson, and K. Cromar (2018a). "A novel environmental justice indicator for managing local air pollution". In: *International journal of environmental Research and Public Health* 15.6, p. 1260. DOI: 10.3390/ijerph15061260 (cit. on p. 12).

Zhao, P., S. Li, P. Li, J. Liu, and K. Long (2018b). "How does air pollution influence cycling behaviour? Evidence from Beijing". In: *Transportation Research Part D: Transport and Environment* 63, pp. 826–838. ISSN: 1361-9209. DOI: 10.1016/j.trd.2018.07.015 (cit. on p. 11).

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