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Changes in Air Quality Across the Adelaide CBD

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Please note that throughout the investigation, high scores on the Air Quality Index (AQI) are considered negative, meaning higher air pollution; and low scores on the Air Quality Index (AQI) are considered positive, meaning lower levels of air pollution.

Background Information

Earth's atmosphere holds various properties essential for all organisms' life processes. This atmosphere, which contains the air surrounding us, has been drastically impacted due to humans' universal footprint. This footprint has intensified over the years due to increased industrial processes and a rising world population with greater needs *(Zhang et al., 2023).* These changes have ultimately taken a toll on the environment in various ways, such as greater global warming rates, rapid climate change, rising sea levels, and negative air quality. The latter (air quality) is a particularly concerning variable, which has experienced significant change in recent years. Thus, through **citizen science** - a scientific research was conducted by us to measure - the effect of air quality in different aspects.

What is Air Quality and Its Importance?:

Air Quality essentially refers to the degree to which the air (a.k.a. atmosphere) is suitable for the healthy survival of different living organisms. Air quality is important as the standards/conditions of the air that humans breathe impacts their health, environment, and quality of life *(Education Victoria, 2021).* Air Quality is directly related to the term Air Pollution, defined as the contamination of air as a result of atmospheric pollutants. Lack of Air Quality is known to cause significant health problems including heart disease, lung disease, cancer, and other major health problems. In fact, within the past year in the United States of America, there have been over 100,000 premature deaths as a result of deteriorating air quality *(United States Environmental Protection Agency, 2023)*. The average air quality index score within the United States is 39.9 AQI. If this damage is caused at these levels then it is evident that at a higher air pollution score, the damage would be far greater - proving the need for urgent action in this subject *(Environment Protection, 2016).*

Various cities have recently experienced major dilemmas regarding lack of air quality due to diverse reasons. Fortunately, Adelaide and Australia as a whole have extremely low air quality index scores (Average is 9 AQI) in comparison to the rest of the world *(Government of South Australia, n.d.).*

Even though Adelaide (on a global scale) has relatively better air quality, some areas still contain poor of air quality and the Adelaide CBD is definitively one of those locations. Although it does not house industrial processes, it is inflicted by increased traffic (foot and vehicle), lack of vegetation, and unsuitable infrastructure.

Figure 1: *The figure shows the air pollution generated from various industrial processes. Generated by IQ AIR:* https://www.iqair.com/newsroom/does-air-pollution-cause-climate-change.

Composition of the Earth's Atmosphere (Air):

The Earth's atmosphere is a layer of gas and floating solids held extremely high above the Earth's surface through gravitational pull. The atmosphere allows for human survival by holding moisture (in the form of clouds), gases, and other tiny particles. The earth's atmosphere consists of various gases necessary for survival. These gases include 78% Nitrogen, 21% Oxygen (essential for human breathing), 0.1% Argon, and 0.035% Carbon Dioxide *(Why Air Quality is Important, 2024).*

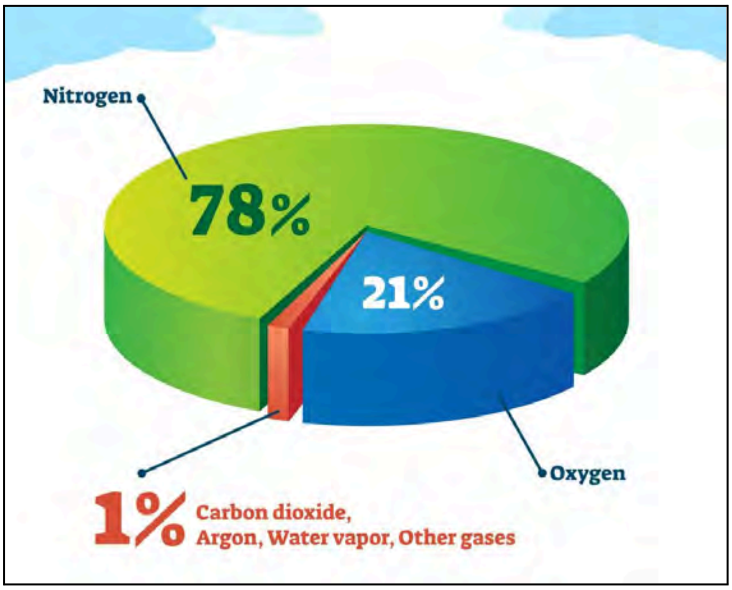


Figure 2: *The diagram shows the composition of the Earth's atmosphere. Generated by AEE:* https://www.australianenvironmentaleducation.com.au/education-resources/earths-atmosphere/.

Nitrogen is the most abundant gas in the atmosphere and exists since the first forms of life originated, about 3.8 billion years ago. The Nitrogen in the air undergoes a natural cycle with the soil bacteria and plant-based Nitrogen quantities.

Carbon Dioxide and Oxygen are both necessities, with the latter an obvious reason due to their essential nature in allowing for human and many organisms' respiratory function. The former is also important when in **small quantities,** as it maintains the higher average global temperatures through the greenhouse gas effect. Without carbon dioxide, average global temperatures would be -18ºC, which proves significantly difficult for human survival. Thus, a balance in amounts of oxygen and carbon dioxide is important, and to **some extent** naturally occurring through complementary actions of photosynthesis in plants and human respiration *(Air Quality - DCCEEW, 2024).*

The atmosphere also includes a layered gas named ozone, which shields the Earth's surface from dangerous ultraviolet radiation emmited by the Sun. There are two different ozone layer types; stratospheric and tropospheric. The stratospheric ozone layer is naturally occurring and is important for UV light protection. The tropospheric layer is artificially created through chemical reactions in human emissions. This layer contains greenhouse gases and is an air pollutant that harms human health, crop production, and ecosystems. The chemicals within the layer are nitrogen dioxide, carbon monoxide, and methane which are often present in industrial facilities, car exhaust, gasoline vapour, and other sources.

How is Air Quality Measured?:

The Air Quality is measured using a distinguished measuring index known as the Air Quality Index (AQI). The Air Quality Index measures 5 major pollutants in the air *(Environment Protection Authority, 2019):*

1. Ground level ozone
2. Carbon monoxide
3. Sulphur dioxide
4. Nitrogen dioxide
5. Airborne particles, or aerosols

These different pollutants and their presence determine the air quality within each region, as they hold distinct and large-scale organism and environmental health effects:

- **Ground Level Ozone:** Ground-level ozone is a significant component of air pollution and is contributed by vehicle and industrial facilities' pollutant reactions in the presence of sunlight. It is a harmful pollutant that can cause respiratory issues, aggravate asthma, and cause smog formation *(All About Weather, 2024).*

- **Carbon Monoxide:** Carbon monoxide (CO) is a colourless and odourless gas that is produced as a result of incomplete combustion of fossil fuels such as natural gas and wood. It can be particularly dangerous in enclosed or poorly ventilated spaces, as it can interfere with the body's ability to transport oxygen *(National Environment Protection, 2020).*

- **Sulphur Dioxide:** Sulfur dioxide (SO_2) is a gas produced by the burning of sulphur-containing fossil fuels, such as coal and oil. Sulphur Dioxide is prone to react with the atmosphere to form fine particles and pose health risks when inhaled. Exposure to sulphur dioxide can lead to respiratory issues and worsen existing conditions like asthma *(World Health Organisation, 2022a).*

- **Nitrogen Dioxide:** Nitrogen dioxide (NO_2) is a reddish-brown gas that forms when nitrogen oxides react with the air. It is primarily emitted from vehicles, power plants, and industrial processes. Nitrogen dioxide can irritate the lungs and lower respiratory infection resistance *(NSW Government, n.d.).*

- **Airborne Particles (Aerosols):** Airborne particles or aerosols are tiny solid or liquid particles suspended in the air. These particles can come from various sources such as vehicle emissions, construction activities, wildfires, and industrial processes. Depending on their size and composition, airborne particles can penetrate deep into the lungs and cause respiratory health effects *(All About Weather, 2024).*

Finding Curiosity and Preliminary Planning for the Investigation

As environmental enthusiasts, we chose to study changes in air quality across the Adelaide Central Business District (CBD) due to its significant impact on public health and environmental sustainability *(Environment Protection Authority South Australia, 2019)*. The CBD is a densely populated area with high levels of human activity and vehicular traffic. As a result, it is prone to various sources of air pollution, including emissions from vehicles, construction activities, and heating systems. Monitoring changes in air quality within the CBD can provide valuable insights into the effectiveness of existing pollution control measures and help identify areas for improvement.

One of the primary factors driving our passion for studying spatial patterns in air quality across the CBD is the environmental impact that lack of air quality can have. Air Quality is known to have a profound impact on climate change by releasing greenhouse gases (in the form of particulate matter) which alter atmospheric composition. Ultimately, these changes can harm ecosystems, damage vegetation, and contaminate water bodies *(Ai, Zhang and Zhou, 2023)*.

After our initial interest in the varying levels of air quality across the globe, whilst researching areas most affected by air pollution, we came across the country of our origin, India. Here we recognised that the air quality was extremely substandard. India's capital city, New Delhi, in particular, has an average daily air quality score of 441 AQI (Air Quality Index) which is extremely bad in comparison to the average level of 9 AQI in Adelaide. When further studying this data, we were intrigued to discover more about the factors that were affecting such air quality levels and the relationship between citizen action and the relative amounts of air pollution.

Figure 3: *The image shows the extremely high levels of air pollution in India. Generated by BBC: https://www.bbc.com/news/world-asia-india-58405479.*

To answer our questions, we decided that it is best to conduct a study on this topic. Although cities like New Delhi in India would allow us to obtain greater values and hence widely accepted results, we thought that we could organise a similar study within Adelaide. By organising such a citizen science investigation, we believed that we could recognise locations within the CBD with inferior air quality levels and places with strong air quality levels *(National Weather Service, n.d.)*. We would then analyse the characteristics of areas with high levels of air quality and then suggest those characteristics to be applied to low air quality scoring sites. The findings or principles of such characteristics could serve as the basis for helping to reduce the terrible air quality in locations such as New Delhi *(United Nations Environment Programme).*

For this research, we brainstormed the following questions:

1. Where in the CBD is air quality good, and where is it bad?
2. What are the reasons for the air quality in certain areas to be good or bad?
3. Does air quality relate to the amount of green spaces or traffic levels?
4. What effects can air quality have on human behaviour?
5. Have any Adelaide CBD citizens experienced such struggles with air quality which has caused changes in behaviour?
6. Is the Adelaide CBD air quality fairly good due to commuter choices? Do people make purposeful decisions to do good for the environment?

Ultimately, after careful analysis of the questions mentioned above, we decided that we could condense those into **three main aims** for the investigation:

1. **Identifying spatial changes in air quality.**
2. **Analysing the reasons behind changes in air quality, and where it is considered 'good' or 'bad'.**
3. **To discover commuter characteristics, demographics, behaviour, and perceptions.**

Aim 1 is mainly reliant on quantitative data, as it uses air quality index scores and measures the locations with good and bad air quality levels in the CBD.

Aim 2 recognises the data received in Aim 1 and quantitatively finds common trends and patterns that cause the given results. This allows us to compare the effect of different characteristics on the air quality level in a certain area. To find such trends, we will use the FSC Environmental Quality Survey Scoring Method. This survey is essentially a form in which a location is assessed on various environment-impacting qualities.

Aim 3 uses qualitative data, as it is based on interviewing citizens in the CBD and getting their opinions on issues related to air quality. This focuses on understanding what citizens believe could be done to improve air quality and the initiatives they may be currently taking to assist in lessening air pollution in the CBD.

As a part of the investigation role dedication, it was decided that both Samarbir and Darshbir would complete each section together, including the report writing and data collection processing.

Data Collection Understandings:

The data was collected on the 22nd of November 2023, between the times of 11:00 am and 2:10 pm in the Adelaide CBD. Surveys and air quality data were collected to measure and compare air quality around the CBD and its effect on citizens.

Air Quality Data Collection

The air quality was measured using a Pocket Lab instrument along a transect line drawn systematically across the CBD to capture air quality measurements around traffic intersections, green spaces and urban areas *(PocketLab, 2023).* PocketLab Air calculates the AQI based on the U.S. EPA scale of 0 to 500 *(PocketLab, 2023).*

Data Collection Platform

The data platform EpiCollect will be used to record all data. EpiCollect is an online data-recording platform that was suggested to us by our teacher. The platform allowed us to construct our form in which we could fill in relevant data. EpiCollect was an efficient platform for this use, as it can create graphs based on data relationships, improving the efficiency of the investigation. The form we constructed contained the following categories: Location, General Area Description, Categorisation of Land Use, Air Quality Score, Picture of Location, Traffic Count Over Two Minutes, Total FSC Score — Buildings, Total FSC Score - Traffic, Total FSC Score - Open Space, Total FSC Score - General Quality, and FSC Total Environmental Quality Score. Hence, it would automatically be able to compare the relationship between different quantities and aims.

Surveys and Questionnaires

Surveying people for their thoughts allowed for qualitative research on the effects and observations of air quality around the CBD. Data of people believing there was good or bad air quality in the city formed quantitative data. These surveys were done randomly along the CBD with pre-set questions that included the people's age and postcode, along with their method of travel to the CBD. Two open-ended questions were also asked to record qualitative data.

Photographic Evidence

Photographic evidence of air quality and areas along the transect line were taken to discuss areas with different air quality indexes. This evidence can also be used along with the environmental quality score to see if there are any trends or outliers that occur when measuring air quality.

Overall, the different methods used at each location helped in representing data visually and in finding trends and anomalies. However, in the methods of data collection, some biases could have led to inaccurate results. For example, generally, people over the age of 50 were more cooperative in providing accurate answers and time to the questions. This may have influenced the data that was received, as the data would have been biased towards the opinions of older people. Questionnaires were also only asked to people around Rundle Mall, which could impact the qualitative data recorded from the results.

The results gathered by conducting surveys and collecting data along a transect line across the CBD would then be mapped out and put in graphs to visualise and compare the data.

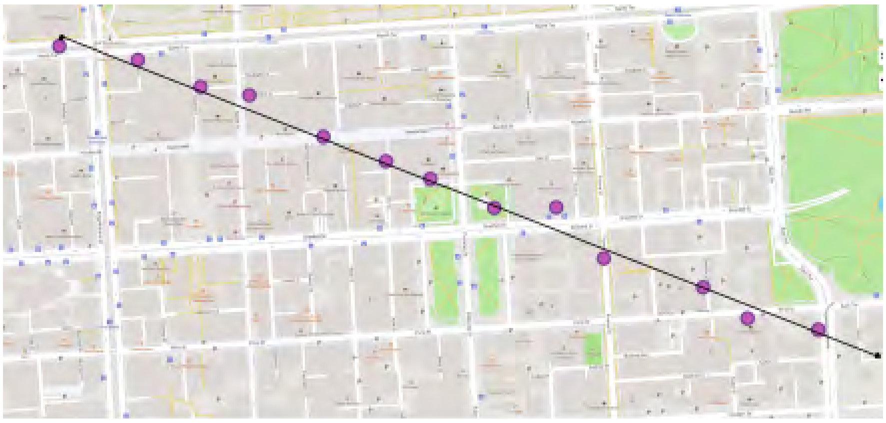


Figure 4 - Points on transect line (Each point is 100m from each other)

Outline of Each Aim:

Aim 1:

For Aim 1, the necessary steps were to set up different locations (randomly allocated) for measurement of Air Quality. We decided to use traditional data measurement methods of using a 'transect line', which is essentially a diagonal (straight) line that cuts through a certain location. The transect line, we planned, started from the corner of King William Road and North Terrace (facing the Parliament House) to the corner of Hutt Street and Pirie Street. Along this line, we decided to measure the Air Quality of 13 different points. Each point would be at 100-metre intervals. At each point, the air quality of the location would be measured using a PocketLAB scientific data measurement system.

Aim 2:

The purpose of Aim 2 was to analyse the factors affecting air quality (perceived from the data in Aim 1). Previously we recognised that open space, greenery, and traffic may be possible factors impacting air quality measurements. Hence, we searched online for measurement platforms for all of those qualities. Ultimately, we found the FSC (Field Studies Council) Environmental Quality Index Grading

Form. This scale ultimately presented a final Environmental Quality Index, which was based on various sections, including; Buildings Score, Traffic Score, Open Space/Gardens, and General Quality. All of these aspects gain a score out of 20, which is added up to create the total Environmental Quality Index (EQI) which is measured out of 80. These scores were mentioned in the same locations as the Transect Line in Aim 1. Ultimately, the various scores could then be compared to the Air Quality Index within that area. This would allow us to understand the relationship between different characteristics of EQI and their impact on air quality in the surrounding area.

Aim 3:

Aim 3 is determined to find the characteristics and behaviour of citizens travelling in the CBD. Fundamentally, Aim 3 is focused on understanding human patterns of behaviour and the connections they hold with the Air Quality Index within the CBD. This allows us to understand whether Adelaide (as a whole) has positive air quality levels due to natural reasons or human-based choices/factors, and also to create demographics of the relevant data comparisons. To resolve this aim, we believe that we could survey CBD commuters through the following questions (which would provide us with the most relevant information/data):

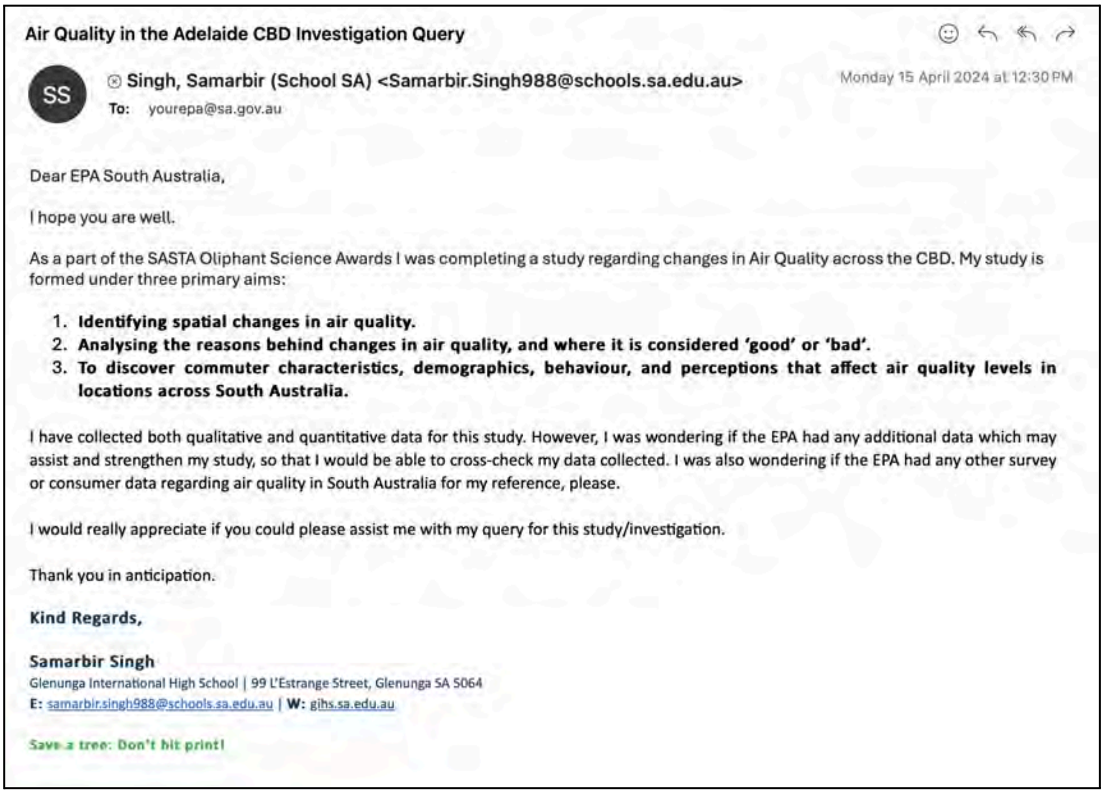
- What is your postcode?
- What is your age bracket? (below 20, 20-30, 30-40, 40-50, 50-60, 60-70)
- How many days of the week do you travel to the CBD?
- What is your means of travel to CBD?
- What would allow you to catch public transport/what restrains you from catching public transport?
- Open-ended question: How would you react if Adelaide City became a car-free zone?

Importance of Citizen Science in the Given Investigation

Citizen Science is essential within the given investigation as it allows for the investigation of a principle that is key to human survival - air quality. The principles of the investigation would ultimately allow for a key social and environmental benefit to both humans and supporting long-term human life.

Establishing Connections with Field Professionals

To improve the quality of the citizen science investigation and gain additional insight into the accuracy of the data collected, as well as the real-world applications of the results, we contacted the South Australian Environment Protection Authority (EPA).



Air Quality in the Adelaide CBD Investigation Query

Singh, Samarbir (School SA) <Samarbir.Singh988@schools.sa.edu.au>
To: yourepa@sa.gov.au
Monday 15 April 2024 at 12:30 PM

Dear EPA South Australia,

I hope you are well.

As a part of the SASTA Oliphant Science Awards I was completing a study regarding changes in Air Quality across the CBD. My study is formed under three primary aims:

1. **Identifying spatial changes in air quality.**
2. **Analysing the reasons behind changes in air quality, and where it is considered 'good' or 'bad'.**
3. **To discover commuter characteristics, demographics, behaviour, and perceptions that affect air quality levels in locations across South Australia.**

I have collected both qualitative and quantitative data for this study. However, I was wondering if the EPA had any additional data which may assist and strengthen my study, so that I would be able to cross-check my data collected. I was also wondering if the EPA had any other survey or consumer data regarding air quality in South Australia for my reference, please.

I would really appreciate if you could please assist me with my query for this study/investigation.

Thank you in anticipation.

Kind Regards,

Samarbir Singh
Glenunga International High School | 99 L'Estrange Street, Glenunga SA 5064
E: samarbir.singh988@schools.sa.edu.au | W: gihs.sa.edu.au

Save a tree: Don't hit print!

Figure 5: *The image shows the initial email sent to the South Australian EPA regarding the request for access to data, to confirm the validity of the experiment.*

The initial email was sent in the request of supporting air quality data to cross-check the validity of the experiment to another primary, reliable source. The email was responded to by renowned Senior Scientific (Air Quality) Officer, Dr Mohammad Iqbal, from the Science and Systems - Environmental Science department of the EPA.

Dr Iqbal provided us with resource links to current air quality monitoring locations data and calculation processes within South Australia. They also provided long-term, progressive air quality data that allowed for comparison to current data achieved, over time. Additionally, Dr Iqbal provided information regarding the onsets of air pollution within regional South Australia, which is carried into the CBD, "Major sources of air pollution in Adelaide include industries, motor vehicles, and wood heaters. We also have emissions from large industries in Port Pirie (smelter) and Whyalla (steelworks)."

Air Quality in the Adelaide CBD Investigation Query

IM Iqbal, Mohammad (EPA) <Mohammad.Iqbal@sa.gov.au> Thursday 18 April 2024 at 4:29 PM

To: Singh, Samarbir (School SA)

OFFICIAL

Dear Samarbir,

Thanks for your email and great to hear from you.

EPA monitors air quality at different locations of Metropolitan Adelaide. We have a monitoring station in CBD as well.

EPA air quality monitoring locations in SA: Air quality monitoring | EPA. You can find the current air quality categories and how they are calculated on the same page.

Major sources of air pollution in Adelaide includes industries, motor vehicles, and wood heaters. We also have emissions from large industries in Port Pirie (smelter) and Whyalla (steelworks).

To learn more about air quality and relevant documents please check: Air quality | EPA.

You can also find long term air quality data from our monitoring stations here: Environment Protection Authority (EPA) - Organisations - data.sa.gov.au.

Best regards
Dr Mohammad Iqbal CAQP
Senior Scientific Officer (Air Quality)
Science & Systems | Environmental Science
Environment Protection Authority
P (08) 8204 2068 | M 0469 802 444
211 Victoria Square, Adelaide 5000

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Figure 6: *The image shows the correspondence from Dr Mohammed Iqbal - an esteemed professional, as per the initial email that we sent.*

After utilising the informative data that Dr Iqbal provided, we used the information to confirm the experimentation's validity and improve the investigation's data analysis aspects. Ergo, we utilised the analysis to conform various ideations and conclusions in the application of the results of the study. During the research phase of the application of results, we came across renowned approaches that the New South Wales government were taking to improve air quality and establish consistency for future air quality scores. Hence, we took the opportunity to ask Dr Iqbal about the presence of any local South Australian initiatives, similar to that of NSW.

Re: Air Quality in the Adelaide CBD Investigation Query

SS Singh, Samarbir (School SA) <Samarbir.Singh988@schools.sa.edu.au> — Saturday 20 April 2024 at 10:55 AM
To: Iqbal, Mohammad (EPA)

Good Morning Dr Iqbal,

Thank you so much for your email, it has helped my research and data checks, significantly.

As per the project I am conducting, it is my aim to construct relationships between my data and future changes that can be constructed to answer relevant issues.

My data suggests that the Air Quality in Adelaide is good, which is consistent across not only South Australia but the whole country as well. However, it is important for air quality to be maintained and hence I was wondering if there are any future SA government agendas which are set to keep the air quality constant.

For example, New South Wales are completing an initiative which ensures the development of an open green space – a factor which is known to impact air quality – in a 10-minute walking radius of each urban housing near city areas. The system also ensures an increase in the size of public spaces by 10%, as of newly constructed spaces in 2024, which corroborates with the initiative to achieve a 40% tree canopy coverage in the Greater Sydney region by 2030. These factors/initiatives are in place to ensure long-term stability of air quality as the demand for industrial processes and population increases, which are prone to causing a natural decline in air quality conditions.

Thus, I was wondering if you were able to provide me with any links regarding such agendas for South Australia, please.

Thank you so much for all of your help, and patience.

Kind Regards,

Samarbir Singh
Glenunga International High School | 99 L'Estrange Street, Glenunga SA 5064
E: samarbir.singh988@schools.sa.edu.au | W: gihs.sa.edu.au

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Figure 7: *The image shows the response email sent to Dr Mohammed Iqbal, in which evidence of government action (future in improving and ensuring that air quality remains at a strong level was requested.*

Dr Mohammad Iqbal - in response to the email - provided links to the state and federal policy, as well as a record of future and current project planning. These links assisted the study as they provided evidence of government policy - discussed in the application of results and future uses of the study.

RE: Air Quality in the Adelaide CBD Investigation Query

IM Iqbal, Mohammad (EPA) <Mohammad.Iqbal@sa.gov.au> — Monday 22 April 2024 at 3:01 PM
To: Singh, Samarbir (School SA)

OFFICIAL

Dear Samarbir,

Thanks for your reply. We have this policy in place to regulate air pollution in SA: https://www.legislation.sa.gov.au/lz?path=%2FC%2FPOL%2FENVIRONMENT%20PROTECTION%20(AIR%20QUALITY)%20POLICY%202016.

There is federal legislation in place as well: https://www.legislation.gov.au/F2007B01142/latest/downloads

For greening, you may find some information here: https://www.greenadelaide.sa.gov.au/projects

Best regards

Dr Mohammad Iqbal CAQP
Senior Scientific Officer (Air Quality)
Science & Systems | Environmental Science
Environment Protection Authority
P (08) 8204 2068 | M 0469 802 444
211 Victoria Square, Adelaide 5000

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Figure 8: *The image shows the final evidence of correspondence between Dr Mohammed Iqbal, in which we were provided links of government action (future and current) in improving and ensuring that air quality remains at a strong level.*

Commencing 'Changes in Air Quality' Investigation

Introduction of Investigation:

Situated in Australia, Adelaide is regarded as the 12^{th} Most Liveable City in the World, as deduced by the Economists' 2023 rankings *(Green Adelaide, 2022)*. Although a quiet city, Adelaide is known for its cleanliness, even in the CBD. However, like all locations, traffic, pedestrian exposure, and increased factory emissions have led to changes in Air Quality *(Living Adelaide, 2017*). Hence, this study aimed to measure different aspects of livability that are connected to changes in Air Quality, within the Adelaide CBD. This citizen science investigation was accurately completed through the lens of three aims.

Aims of Investigation:

- **Aim 1:** Identifying spatial changes in air quality.
- **Aim 2:** Analysing the reasons behind changes in air quality, and where it is considered 'good' or 'bad'.
- **Aim 3:** To discover commuter characteristics, demographics, behaviour, and perceptions.

Hypothesis:

- **Aim 1:** Air Quality will decline in closed-off regions with limited air circulation, and it will strive near green spaces.
- **Aim 2:** Air Quality will be most impacted by the FSC Traffic Score and the FSC Greenery scores. These will determine whether a region has high or low levels of air quality.
- **Aim 3:** Citizens would recognise a common trend of negative air quality around the CBD. People residing closer to the city would have a higher chance of using public transportation systems.

Methodology of Each Aim:

Aim 1 and Aim 2:

1. Go to the allocated sample point and observe the area (5-metre radius from the point).

2. Use the air quality measuring device to measure the air quality of the area and record the value.

3. Photograph the nearby environment.

4. Note down the environmental air quality score, by providing the location with a score for each attribute of the FSC Scale; Buildings Score, Traffic Score, Open Space/Gardens, and General Quality.

5. Add these scores together to find the FSC Environmental Quality Index, and record this value.

6. Ensure that all data is recorded on the EpiCollect platform.

7. Repeat steps for all 13 other locations.

Aim 3:

1. Explore the city and interview strangers.
2. Ask the interviewee the following questions:
    - What is your postcode?
    - What is your age bracket? (below 20, 20-30, 30-40, 40-50, 50-60, 60-70)
    - How many days of the week do you travel to the CBD?
    - What is your means of travel to CBD?
    - What would allow you to catch public transport/what restrains you from catching public transport?
    - Open-ended question: How would you react if Adelaide City became a car-free zone?
3. Record answers in a Google Form.

Risk Assessment:

As with all investigations, certain risks or ethics are connected with different experimental procedures and thus need to be considered. Ergo, the experiment proved to hold a risk within Aim 1 and Aim 2, in which the transect line intersects a busy main road. This presents as a risk, because if data was collected whilst on the main road, there is a high chance of an accident. Thus, to prevent this risk, the transect line would have to be manipulated on the data recording day which the data recorders will have to measure to the side of the transect line, to avoid main roads. This perhaps limits the investigation's strength as it does not measure a diverse range of points (hence, excluding main road data collection).

Secondly, there would be a risk of environmental hazards in the event of inclement weather or uneven surfaces when recording air quality measurements. This risk could be mitigated by wearing appropriate footwear and avoiding a data collection day in which extreme weather conditions are predicted.

Thirdly, within Aim 3 certain personal safety risks are present, including approaching strangers whom the interviewer knows little about. This risk could be somewhat prevented by ensuring that one clearly identifies oneself, provides a project outline, and uses a polite/respectful tone or approach. It is also good practice to provide the interviewee with the option to decline the interview.

Results

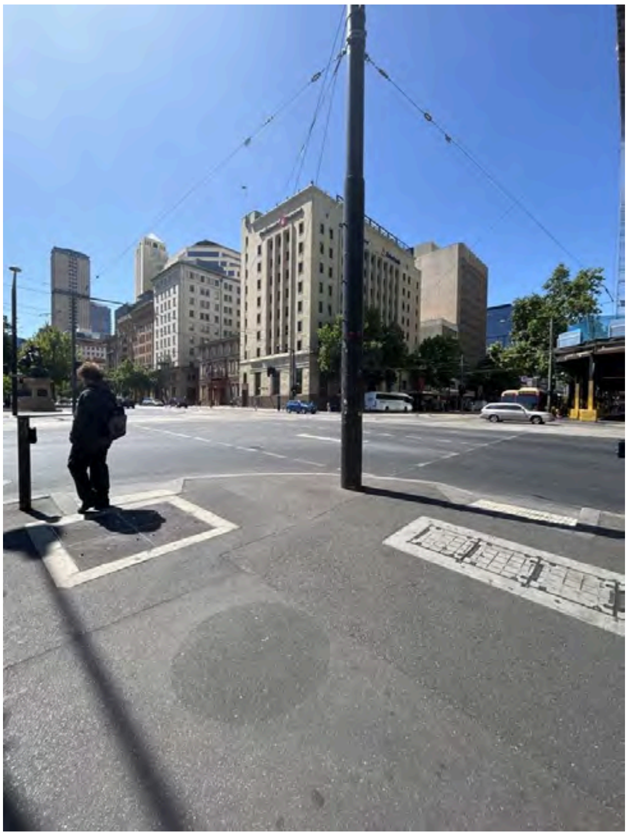
Raw Quantitative Data:

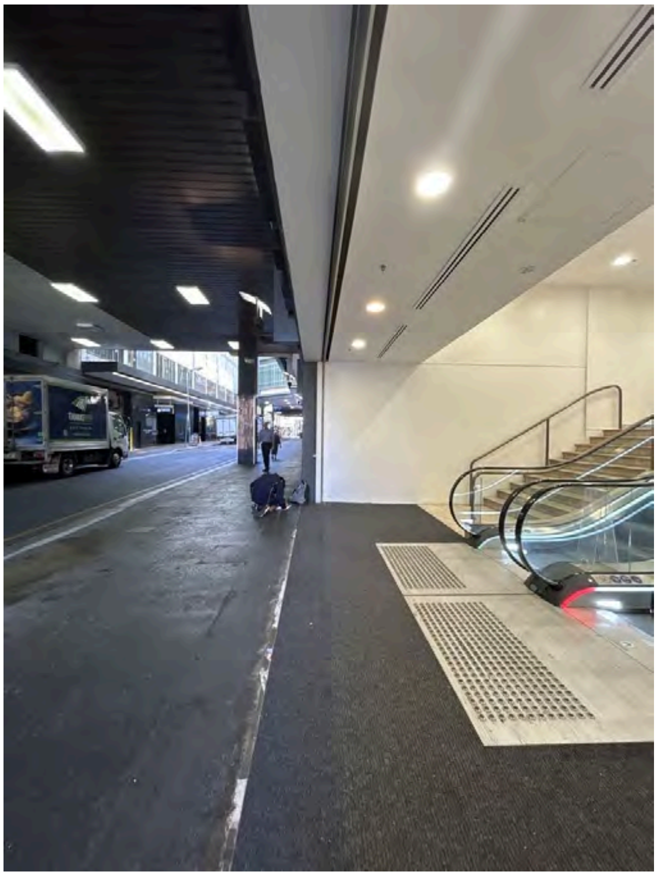
Title	Air Quality Index Score	Total Score - Buildings (FSC)	Total Score - Traffic (FSC)	Total Score - Open Space (FSC)	Total Score - General Quality (FSC)	Total FSC Environmental Score
Point 1	**15**	7	3	2	8	**20**
Point 2	**10**	4	6	7	2	**19**
Point 3	**9**	7	8	8	7	**30**
Point 4	**4**	8	11	8	2	**29**
Point 5	**5**	12	14	14	10	**50**
Point 6	**15**	3	3	1	2	**9**
Point 7	**5**	10	15	17	17	**59**
Point 8	**5**	7	16	16	18	**57**
Point 9	**12**	3	4	5	3	**15**
Point 10	**3**	16	15	16	17	**64**
Point 11	**4**	12	14	15	11	**52**
Point 12	**4**	16	13	13	15	**57**
Point 13	**4**	8	14	16	9	**47**

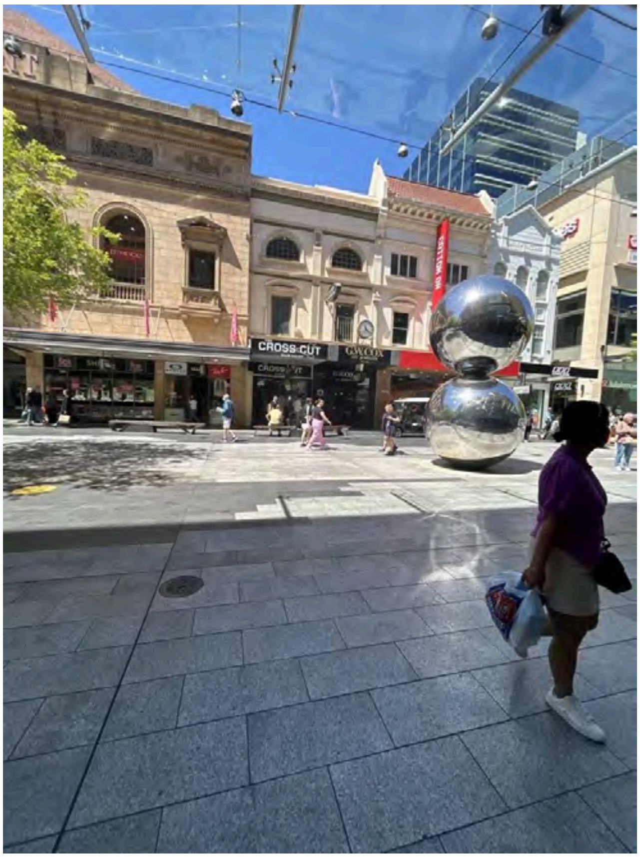
LINK TO ADDITIONAL EXPANDABLE RESULTS:

- EpiCollect Results Link: https://five.epicollect.net/project/geography-air-quality-cbd-data-collection
- Collated Google Sheet Spreadsheet Link: https://docs.google.com/spreadsheets/d/1eWeMiJZXB2dmepFbqtT2hv2XomLbDrw2fSyCDkRDZrA/edit?usp=sharing

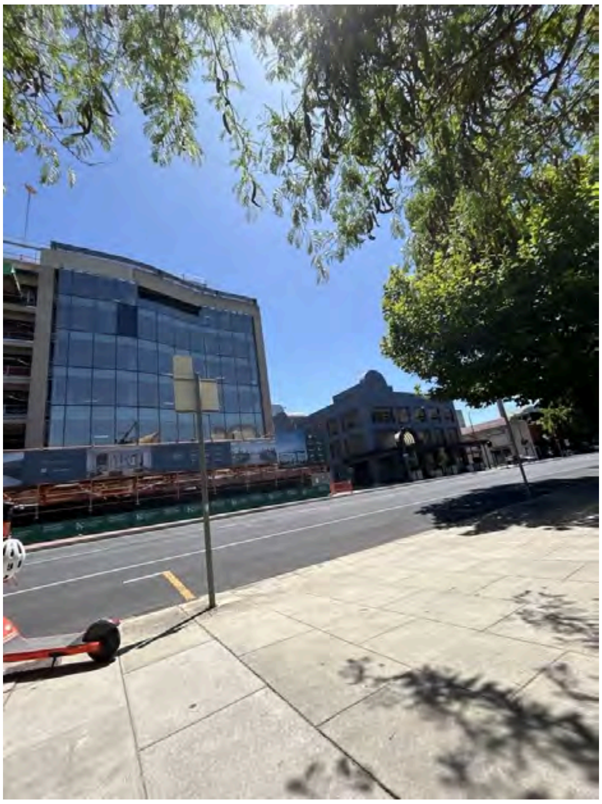
Raw Qualitative Data:

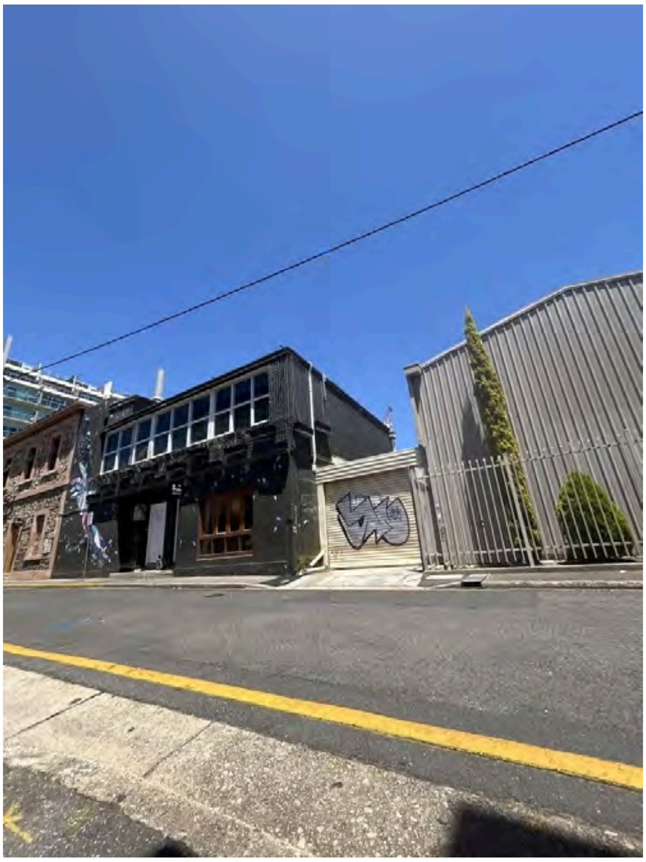
Title	General Area Description	Categorisation of Land-Use	Image of Relevant Point
Point 1	Extremely busy intersection with exposure to both pedestrian and vehicular traffic. Numerous commercialised buildings with a small green-space area in the corner. Strong access to outdoor light. A construction site, perpendicular to the photo site, possibly, suggests that fumes from this location may manipulate data.	Roadways	
Point 2	Alleyway alongside North Terrace - a busy road with lots of vehicular traffic. Thus, a large quantity of emissions from this road. It is a small-enclosed space with limited access to direct sunlight exposure. No nearby green space.	Roadways/Alleyways	

Point 3	Alleyway with entry into various shops such as Myer Centre, not many vehicles or pedestrian traffic, however, it is perpendicular to the North Terrace intersection which is quite busy. The area is also roofed, thus there is little to no access to outdoor lighting, meaning that the chances of any fumes remaining within the area are longer.	Roadways/Alleyways/ Business	
Point 4	An alleyway, situated as a two-minute walk away from central Rundle Mall. The alleyway has multiple large dump binds and excess construction equipment that has been deserted. There are numerous signs of vandalism in the form of graffiti. There is an exposure to outdoor lighting.	Alleyway/Roadway	

Point 5	Central Rundle Mall, with exposure to high amounts of pedestrian traffic, yet no vehicular traffic. Strong access to outdoor lighting, with few fully enclosed areas branching from the central area. Presence of patterned greenery along the mall/area.	Business/Recreational Location	
Point 6	An alleyway, connecting Rundle Mall to Grenfell Street. Lots of large dump bins. Good access to natural light, however lots of unnatural fumes in the form of cigarette smells. Quite windy, meaning that these smells are dispersed quickly. No visible green spaces.	Business/Alleyway	

Point 7	A side street perpendicular to a busy road. However, the street is facing a local green space/park. A high amount of access to direct sunlight. The green space holds a large number of trees, which may act as natural purifiers for air pollution.	Recreational Location	
Point 8	This city garden is situated alongside a busy intersection, thus it has high exposure to air pollution from traffic. Yet, this high amount of green space mitigates the air pollution to improve CBD Air Quality. Overall, there is great access to outdoor natural lighting, with limited visibility of other pollution forms.	Parklands/Recreational Location	

Point 9	Point is situated alongside Grenfell Street, a busy road with high pedestrian and vehicular traffic. However, there is a high number of trees on the sidewalks, which uplift the air quality. Additionally, there is a high exposure to natural sunlight.	Business/Roadways	
Point 10	Parallel to Frome Street, the area has a high number of natural trees and plants which would mitigate the effects of vehicular pollution. The location has high access to natural light and is highly maintained.	Roadways/Business	

Point 11	An alleyway that is perpendicular to Pirie Street, thus it is exposed to some level of fumes from vehicular traffic on the main road. There is a limited amount of green space, however, there is a large quantity of natural light. There is evidence of vandalism and smoke from cigarettes can be smelt within the air - resultantly, there is a high number of cigarettes on the floor.	Alleyway/Roadway	
Point 12	Pirie Street, which is a busy roadway, thus exposed to vehicular fumes. There is an extremely limited number of green spaces. There was a construction space close by, thus there may be greater fumes than normally predicted. There are large amounts of natural lighting.	Business/Roadways	

Point 13	Hutt Street is normally a busy road, however, it has quite a large number of trees and other greenery that purify the fumes from the busy roadways. Due to the VAILO 500, the roadway was blocked, thus there is a limited number of vehicles on the road - creating a better-than-normal air quality score.	Roadways/Business	

Processed Data:

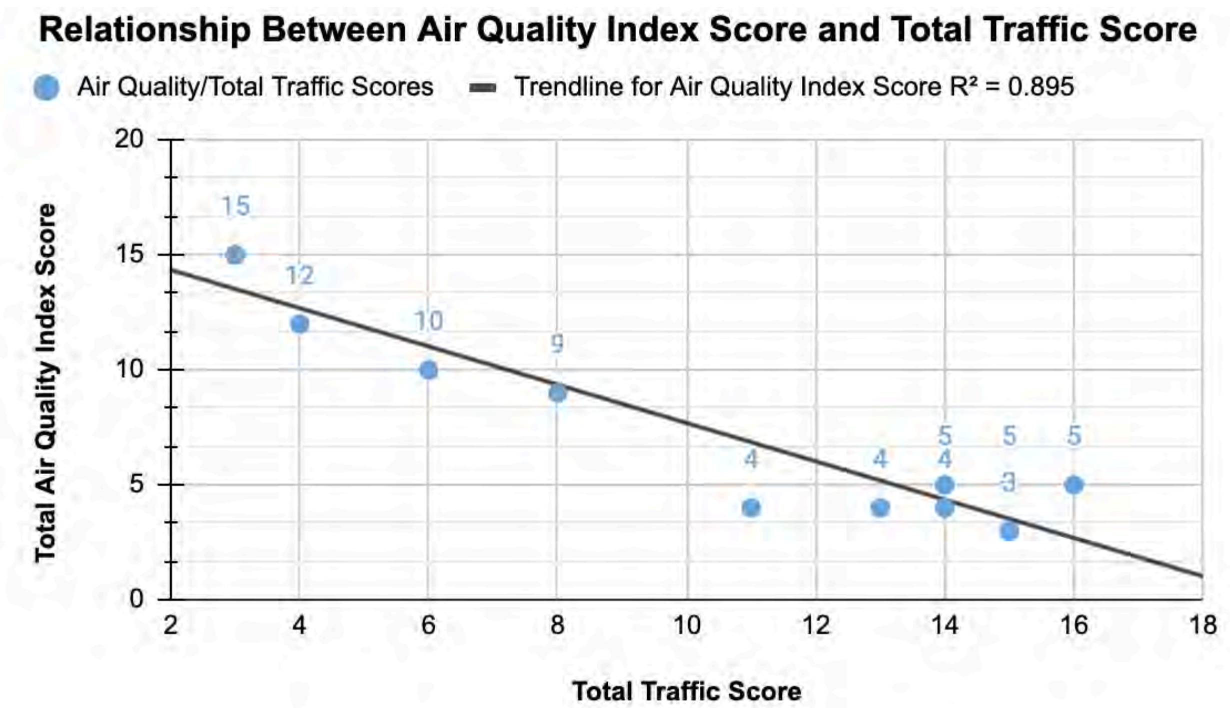


Figure 9: *Relationship between air quality and total traffic score.*

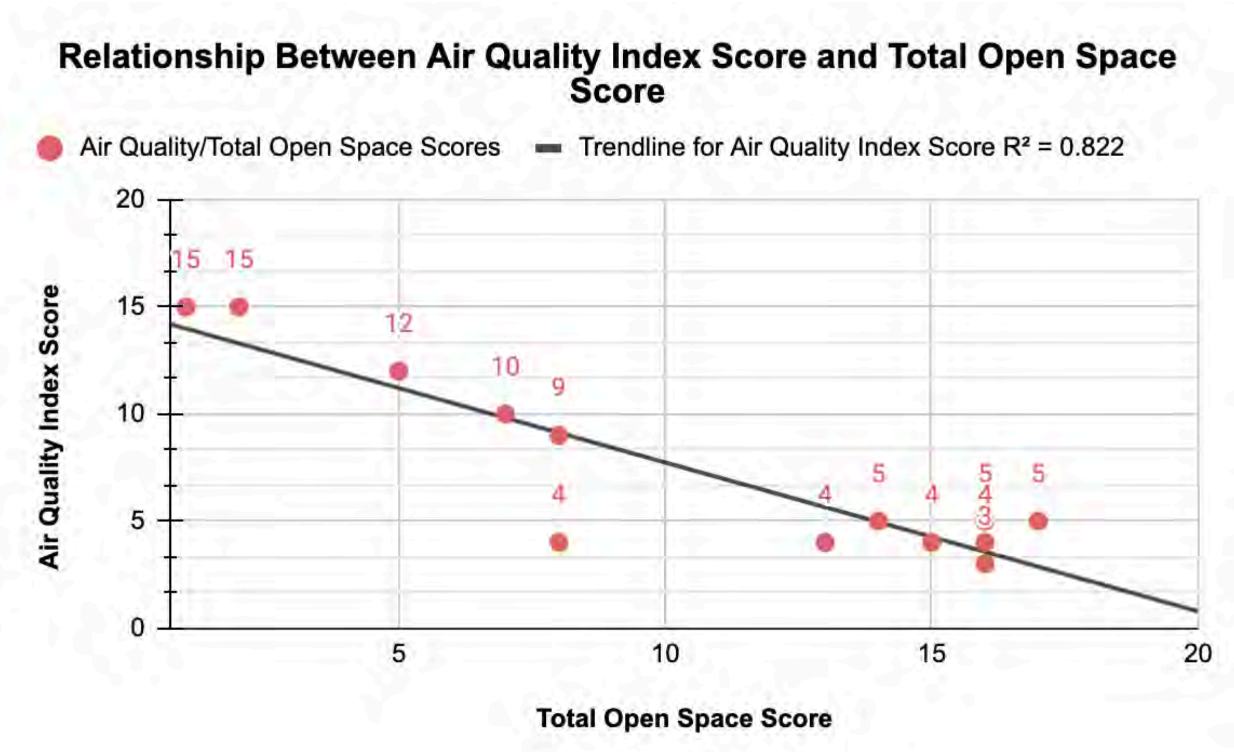


Figure 10: *Relationship Between Air Quality Index and Total Open Space Score.*

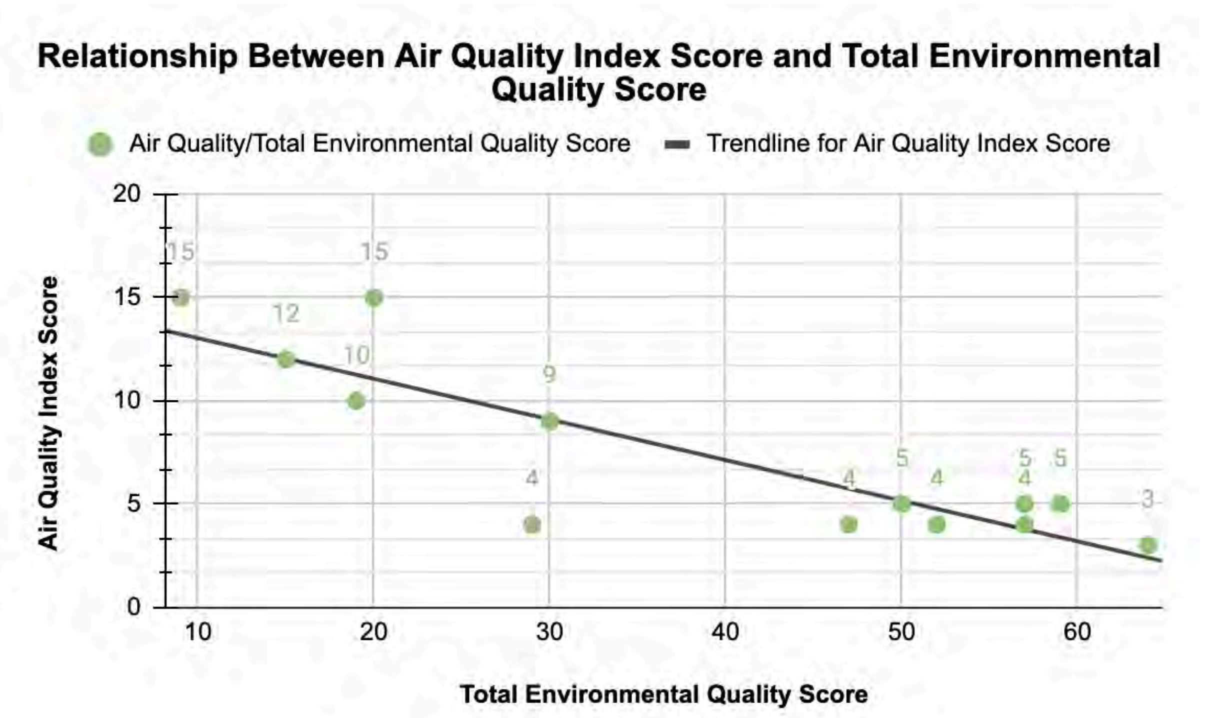
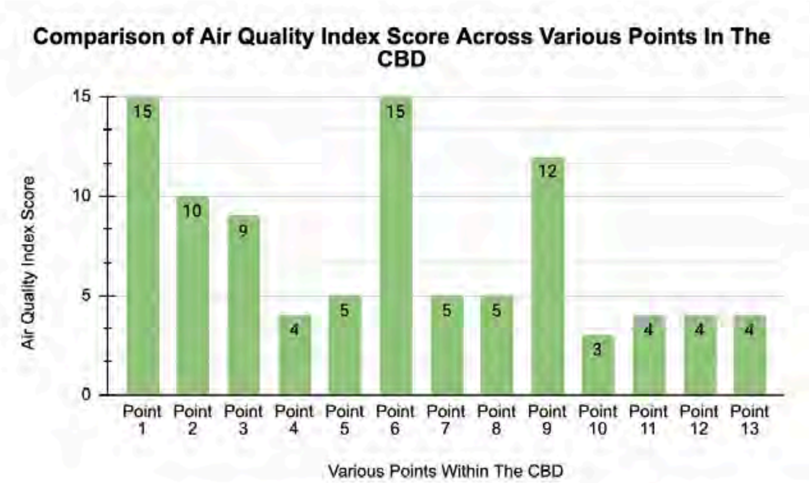
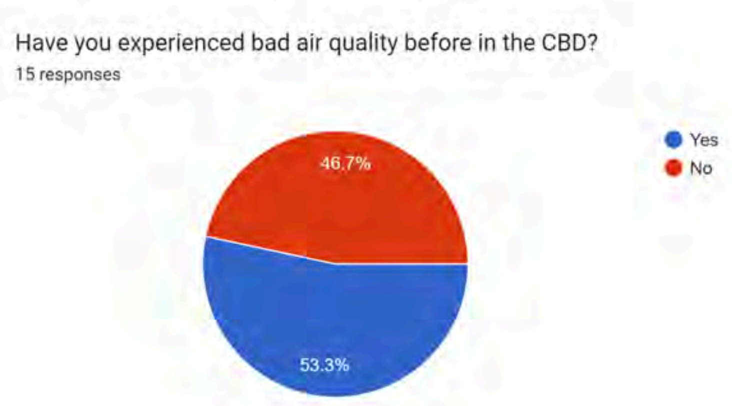


Figure 11: *Relationship Between Air Quality Index and Total Environmental Score*





Figures 12 and 13: Air quality across various points in the CBD through user recounts/interviews and quantitative data.

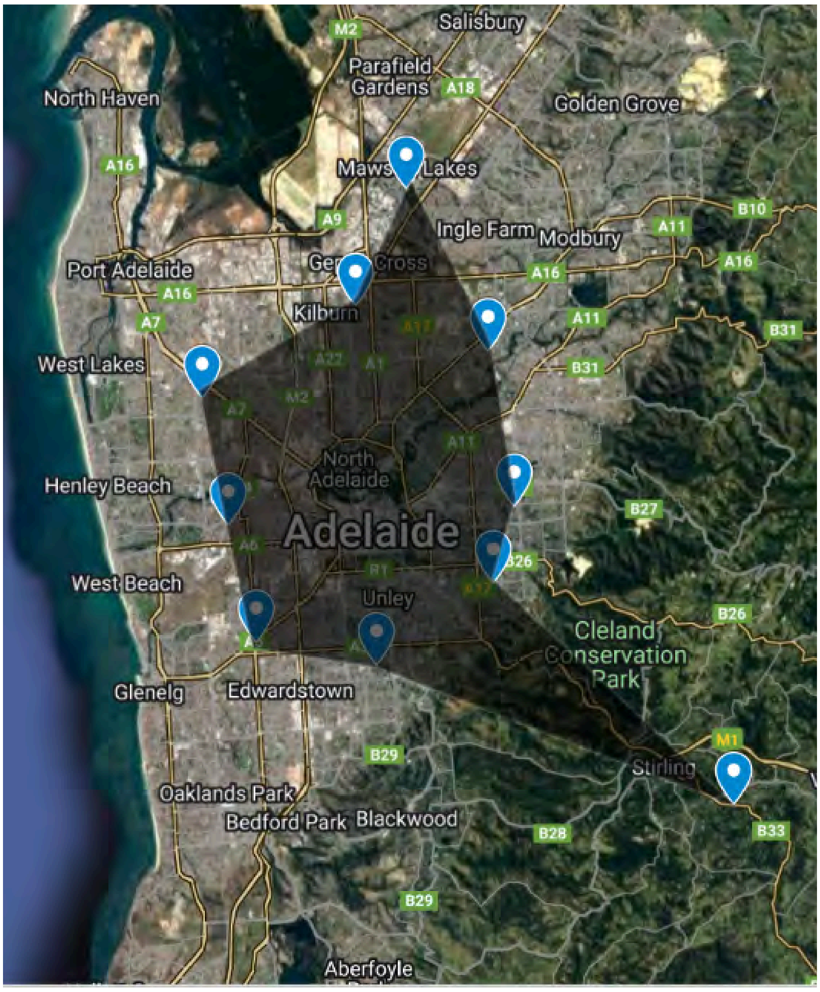


Figure 14: Location of citizen's postcodes that take the bus to the city.

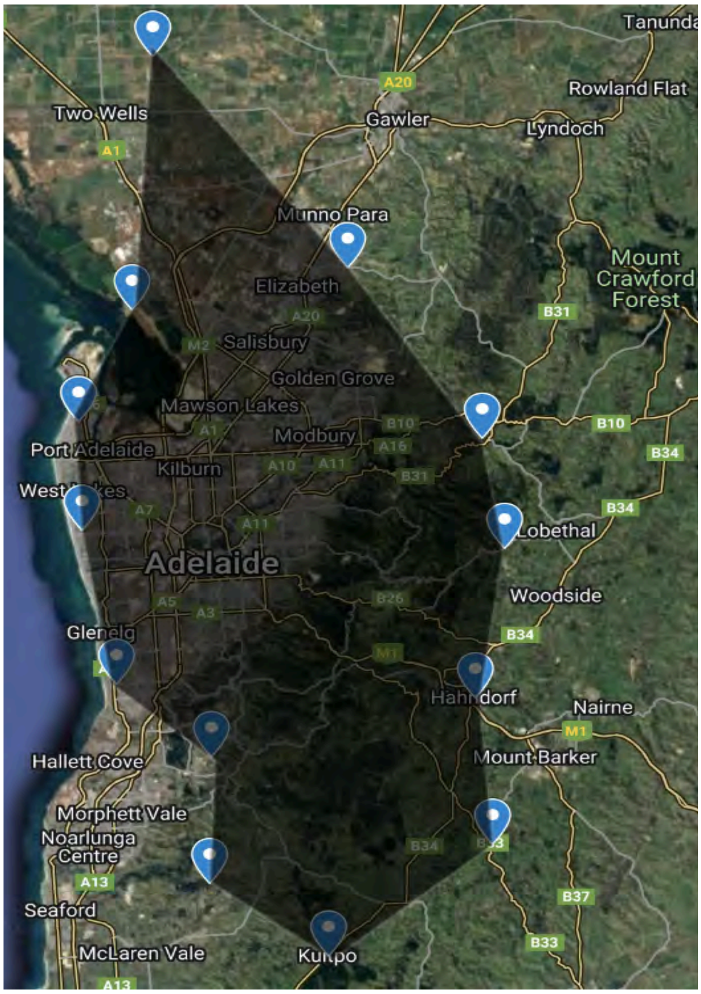


Figure 15: Location of citizen's postcodes that take the car to the city.

Data and Graphical Analysis

Aim 1: Identifying spatial changes in air quality

The graphs and data present various conclusions that can be interpreted by interpolating the given qualitative and quantitative results. For instance, the spatial changes in air quality can be depicted in *Graph 2* where indications of air quality are measured from light purple (low air quality score) to dark purple (high air quality score) - the lower the air quality score, the better the air quality within the region. It can be seen that areas near traffic intersections and less open areas are darker coloured. For example, the air quality score that was taken near the Adelaide City Rundle Mall Myer Center *(Point 3)* was considerably higher than most other locations, as it was situated, in an alleyway (with greater closed-off areas and hence reduced air circulation). The open space score suggests that enclosed areas - with limited air circulation - have negative air quality scores. For locations such as commonly used roads, the air quality can be <u>assumed</u> to be unsatisfactory, however, due to the greater open space, these regions in most cases are known to hold greater Air Quality Scores than alleyways. This is particularly evident when comparing Point 10 (alongside Frome Street/Road) and Point 2. Although Point 10 encounters greater traffic congestion, it holds improved air quality due to its open space, in comparison to the closed-off environment of Point 2. Yet, there are outliers to the pattern of roads holding greater air quality scores than alleyways such as Point 1 (intersection facing the Parliament House). Point 1 experiences extremely high traffic (throughout the day) and hence is home to lots of carbon emissions, which the Pocket Lab (data collection device) pick up.

Point 10 (Frome Street) can be identified as a model location to remove the increased carbon emissions within such areas due to the increased vegetation alongside the footpaths and roads. This vegetation allows the location to prompt considerably better Air Quality Scores *(US EPA, 2014)*. This prompts the conclusion that the introduction of vegetation to heavily used roads results in improved air quality results.

Another spatial pattern identified in air quality was through the data at Point 8 (a recreational park) which had a relatively low air quality score due to its limited traffic score. Location 8, had a large and green area with extremely limited traffic (Traffic Count: 0, Traffic Score: 16/20) which is the likely reason for the low air quality score at this point. For the most part, all the collected data followed this trend, making a direct correlation between the traffic score and the Air Quality Index Score. This relationship is also supported by Graph 3 where there is a very solid connection between the air quality score and recorded traffic scores (as the total traffic score increases, the total air quality index decreases). This is shown by the strong R^2 value of 0.895 where the closer the value is to 1, the stronger the correlation between the 2 variables. Therefore, it is clear that there is a strong correlation between air quality and total traffic score. Graph 4 also demonstrates a strong correlation between the air quality index score and the total open space score with an R^2 value of 0.822, displaying that the locations with more open space tend to have better air quality.

These spatial patterns can be summarised through the data in Graph 5 which compares the Total Environment Score (according to the FSC scale) to the Air Quality Score. The relationship between these quantities can be considered as strong - interpreted through the R^2 value of 0.812. Ultimately, it can be concluded that the higher the environmental score of an environment, the greater the air quality within the location.

Aim 2: Analysing the reasons behind changes in air quality, and where it is considered 'good' or 'bad'

From the aforementioned data, it is clear that adequate air quality is likely to be found in open spaces and green spaces, whilst negative air quality is most often found in large roads near major intersections (with no green spaces and open spaces). This disparity can be attributed to several influential factors. For example, areas with open spaces tend to allow stronger air circulation than closed spaces (Zhang and Batterman, 2013). Research by the Science of Total Environment suggests that regions with ample open spaces experience improved airflow or movement, which ensures that pollutants are dispersed effectively. The natural ventilation mechanism - essentially - is less effective in confined or congested areas.

Thus, alleyways, which are closed-off dark areas, accumulate more dust, particulate matter and other pollutants. The primary reason for this is the limited air circulation in alleyways, which leads to stagnant air and a buildup of harmful substances. Unlike open spaces, alleyways are less likely to be regularly cleaned and maintained, exacerbating the accumulation of pollutants. Thus, the limited air circulation within alleyways results in higher dust and particulate matter particle concentrations within those areas. Furthermore, alleyways are also typically known to contain concentrated sources of pollutants such as vehicle exhaust, garbage bins, and industrial activities - which is particularly evident in locations such as Point 2, where the presence of these pollutants is more pronounced *(World Health Organisation, 2022b).*

Ultimately, areas with poor air quality are typically characterised by high traffic density and a lack of green spaces. these areas suffer from high concentrations of pollutants due to vehicle emissions. The presence of major roads or intersections - with high traffic density - near such locations exacerbates the issue. From a chemical perspective, it is clear that near high-use roads, there is a strong presence of Nitrogen Dioxide (NO_2) and Carbon Monoxide (CO). These pollutants are primarily released from vehicle exhausts. Nitrogen Dioxide and Carbon Monoxide are of significant concern as they carry significant health impacts which may cause health damage to any pedestrians or users within the location. The absence of grain spaces within these areas results in fewer natural filters to absorb pollutants, leading to substandard air quality. A study by Ecological Indicators suggested this further by highlighting the negative impact of high traffic volumes on air quality (*IQAir, 2024).*

Green spaces prove to hold greater air quality due to the higher vegetation amounts. Natural vegetation acts as a filter to absorb pollutants and mask unpleasant smells. This process involves plants taking in carbon dioxide and other harmful substances, which are then used in photosynthesis to ultimately release oxygen to the environment. This - another form of a natural filtration system - reduces pollutant concentrations in the atmosphere, leading to reduced air pollution (Ai, Zhang and Zhou, 2023).

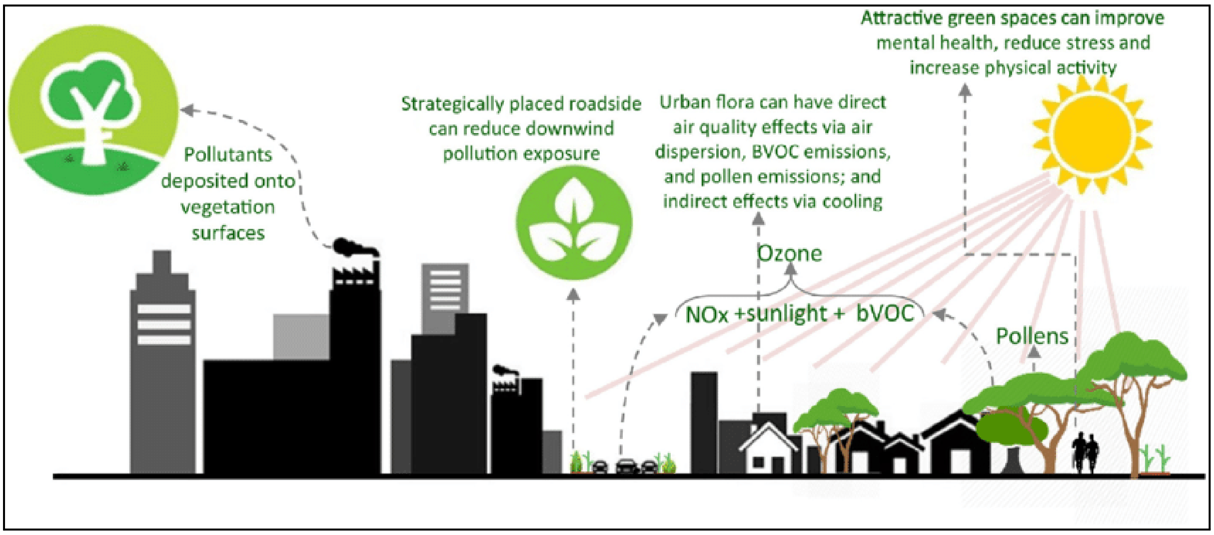


Figure 16: *The schematic diagram displays the benefits of vegetation in improving air quality. Generated by Global Centre for Clean Air Research (GCARE) University of Surrey:* *https://www.researchgate.net/figure/Schematic-diagram-showing-the-air-quality-benefits-and-downsides-of-green-infrastructure_fig1_336116251*

Other factors that impact air quality include sunlight. This is primarily due to the greater presence of ground-level ozone, which is made more efficiently in sunny or hot weather, due to the greater number of reactions that occur creating harmful ozone in the atmosphere. Thus, in the hotter seasons, ozone often reaches dangerous levels in cities or nearby rural areas. Another environmental factor that affects air quality is humidity, which plays an opposing role to sunlight. Humidity decreases ozone pollution as - particularly in the afternoon - moisture-holding clouds block the sunlight, causing ozone production, whilst the moisture from storm clouds also destroys the ozone that may have formed from earlier stages in the day.

It is also evident that heat waves lead to poor air quality, as extreme heat and stagnant air in a heat wave cause an increase in particulate pollution. Other by-products of heat waves such as drought conditions may also occur in a heat wave, resulting in dry soils. Drought conditions also cause an increase in the likelihood of forest fires. The consequent forest fires would add carbon monoxide and particle pollution to the atmosphere, reducing air quality. From this, it can be understood that weather conditions also play a significant role in air quality levels.

Litter and physical pollution also play significant roles in air quality, as when the physical pieces degrade, they are released as microparticles or chemicals into the atmosphere. These are often unnatural chemicals, hence causing numerous environmental problems. For example, cigarette remains often contain toxic chemicals such as arsenic or formaldehyde. These chemicals can typically be evaporated into the atmosphere, causing human harm and an overall increase in air pollution.

When discussing the removal of litter outside the urban context of the given city (Adelaide), the burning of litter in rural areas causes significant pollution. Scientific estimations infer that 40% of the world's litter is frequently burned in the open air, releasing toxic emissions. From a human health perspective, these chemicals are capable of causing respiratory issues and other health dilemmas.

The chemicals regularly detected or those that contribute to air quality readings include Ground-level ozone, Carbon monoxide, Sulphur dioxide, Nitrogen dioxide, and Airborne particles, or aerosols. Ground-level ozone, Carbon monoxide, Nitrogen dioxide, and Airborne particles are all chemicals that, in an urban setting such as the Adelaide CBD, contribute to the air quality measurement. The aforementioned chemicals are almost always highly produced from vehicles, which through spatial understanding and knowledge is quite common in the CBD region. Ground-level ozone, as explained above, occurs through the presence of sunlight-based reactions. The only chemical that is lowly present or implausible in occurrence is Sulphur Dioxide, as it is only present through large-scale industrial plants, which are not present within the CBD.

Aim 3: To discover commuter characteristics, demographics, behaviour, and perceptions

The third aim of this study was to delve into the commuter characteristics, demographics, behaviours, and perceptions regarding air quality. The data collected through surveys reveals crucial insights into how commuters perceive and interact with their urban environment, particularly concerning air quality.

A common trend of answers from interviewees was that they experienced bad air quality within areas (in the CBD) with heavy industrialisation and lowly lit locations that were particularly known to have limited air circulation. Interviewees also commented that the alleyways held drastic air quality due to extensive smokers or increased construction work. Within such areas, smoke was a common product, which is a known sign of substandard air quality *(Victoria Education, 2017)*. These perspectives match up well with the data that was collected, as it shows that air quality does tend to be worse in alleyways.

In the process of understanding commuter characteristics, commuters' behaviour of transportation was also graphed per their postcode location and the relevant transportation method they took from that location, as seen in Graphs 8 and 9. The graphs provide valuable commuter demographics, as it can be identified that most locations closer to the city followed a bus transportation route - this area is represented through a ‘ring’ formation within the inner city. The ‘outer ring’ area - where most commuters reside outside the city - displays the citizens who prefer to travel by car, when travelling to the CBD. This spatial differentiation in transportation methods underscores the influence of proximity to the city centre on commuters' choices.

Ultimately, the commuter survey suggests a relationship between proximity to the city and the likelihood of using public transport. The survey found that the citizens, residing closer to the city, were more likely to take public transport - a method that is known to assist in reducing air quality in the environment. The reason for this is specifically due to simple efficiency, as while cars usually carry 1 or 2 passengers at a time, a bus can carry 50 or more, and a train in a large city may carry thousands, meaning more people are travelling in one system. Initially, this may emit more than a singular car, but when there are multiple passengers the energy output of singular public transport is less than the number of cars if all commuters were to travel individually. However, the data also shows that the further away people live from the city **(approximately further than 7 km from the city)**, the more likely they are to travel via car. This preference for car travel among those living in the outer ring contributes to increased emissions and potentially poorer air quality, particularly along major commuter routes.

Several factors influence commuters' decisions to use or avoid public transport. The most commonly cited reasons for the lack of public transport use included the additional time required, the need for a Metrocard and associated costs, and the accessibility of public transport services. These barriers highlight the practical challenges faced by commuters, suggesting areas of improvement within public transportation to encourage widespread use of public transportation.

The demographics of commuters also play a significant role in transportation behaviours and air quality perceptions. For instance, younger commuters and students are more likely to use public transport, due to financial constraints and travel conveniences within the city. In contrast, older commuters or those with higher incomes may prefer the convenience and comfort of private cars, despite the higher environmental impact.

As previously established, the geographic distribution of commuters further illustrates the environmental implications of transportation choices. Inner-city residents, who are more likely to use public transport, contribute less to air pollution per capita. In contrast, suburban and rural commuters, who predominantly use cars, have a larger per capita carbon footprint. This spatial dynamic is crucial for urban planners and policymakers aiming to reduce urban air pollution and promote sustainable transportation solutions.

Finally, the survey data also identified the specific locations at which commuters encountered negative air quality. From these locations, construction sites and major intersections were notable hotspots. These areas were characterised by high levels of smoke and exhaust gases, which significantly degrade air quality. Additionally, alleyways where people often smoke were repeatedly mentioned by interviewees as having particularly poor air quality. These locations not only gather pollutants easily, but also hold a greater risk of spreading diseases or causing health failures.

Application of Results

The results suggest a clear relationship between the amount of open green space and the air quality index, as well as the relationship between the total traffic score and the air quality index. Furthermore, it also shows an evident connection between the total environmental quality score and the air quality index. This data suggests that areas with greater open space, i.e. larger access to air ventilation, with lots of greenery, tend to yield better air quality levels. This is further backed by photo evidence which shows locations such as Frome Street/Road, which had greater open space and greenery, had lower air quality levels. As population levels increase, it can be deemed fairly impossible to control traffic amounts, however introducing greenery and more open space can significantly reduce air quality levels within such areas. Hence, we can withdraw this verified knowledge and apply it to different locations across the world.

Key Future Policies and Changes to Improve Air Quality:
The findings propose that open space and greater environmental quality in the form of greenery or natural plantations/vegetation increase the air quality within an environment. These aspects are coherently beneficial to absorb carbon dioxide and offset greenhouse gas emissions. They perform this through the natural cooling of the air and surfaces, improving air quality and supporting water management in urban areas.

Due to the improvement in air quality as a result of the greater greenery and open space, the effect of climate change can also be reduced. Past studies have shown that vegetation included in urban design withholds the benefit of collecting and storing carbon dioxide, which not only purifies the air but also - over time - limits climate change effects. A mature tree is capable of absorbing 150 kg of Carbon Dioxide every year. By planting 12 trees, the carbon emissions of an individual per year are equalled *(United States Environment Protection Agency, 2023).*

Such systems are being developed in surrounding parts of Australia, including New South Wales, which are establishing a framework that compulsories a green space within a 10-minute walking radius of each urban-based home. The system also ensures an increase in the size of public spaces by 10%, as of newly constructed spaces in 2024, which corroborates with the initiative to achieve a 40% tree canopy coverage in the Greater Sydney region by 2030. These changes will ensure not only environmental benefits, but it will establish long-term security for air quality improvements and a reduction of the emissions effect.

Additionally, although the data shows clear differences and reasoning for the importance of urban vegetation and greater open space to improve air quality levels, it can also be inferred that improving the given aspects will also allow for processes such as urban heat management as vegetation provides shade and cool, in addition to cleaning the air through evapotranspiration. Evapotranspiration at its peak is capable of reducing peak summer temperatures by 5ºC.

Locally, it can be determined that although South Australia does boast a relatively clean and pollutant-less environment - due to its limited population - however, certain aspects require improvement. These areas will allow Adelaide to continue to maintain a good air quality level in the future. For example, a recent study by the State and Local Governments of SA, funded by the government organisation; Green Adelaide, proved that in the suburban areas of Adelaide, there is only a 16.7% tree canopy coverage (*Green Adelaide, 2022)*. This is quite limited in comparison to NSW and Victoria. Regardless, of South Australia's lack of tree canopy coverage, the air quality is upheld due to the limited population, and thus, reduced emissions amounts.

Of the various future systems and programs that are being implemented for construction in the future, South Australia is a leader in the urban greenery industry, in which the state and local governments have planned to introduce greenery in the forms of private greening, green streetscaping, and urban parks. The latter is similar to the introduction of greater open spaces in New South Wales.

Figure 17: *The modelled outlook of the benefits and spaces created under the NSW Urban Parks Planning Committee. Generated by NSW UDLP: https://caportal.com.au/rms/m6/urban-design-and-landscape-plan*

As described in the data analysis of aim three, it can be identified that residents of South Australia follow responsible methods of travel, such that those travelling to the CBD within a 10-15 km radius aim to utilise public transport to limit individual carbon footprint. However, in international locations, such as India - a focal point of the given citizen science investigation - there is a distinct difference in the quality of public transport, and hence there is a decreased number of citizens travelling via public transportation. Furthermore, there is a limited organisation behind such public transport systems with a large quantity of services being provided, yet there is no quality public service. This impacts the amount of control withheld on the maintenance of public transportation systems, ergo, leading to a greater number of individuals using other modes of transport such as cars or motorcycles. Due to the larger number of individualised vehicles, there is a related rise in air pollution, reducing air quality levels.

To counter such issues, there should be greater government-led initiatives to improve public transportation services which will not only allow for greater air quality levels, but it will also reduce the total number of vehicles. Thus, there would be a lower requirement for large amounts of road space, meaning there is a greater incentive for the introduction of open green spaces as there is a space for such locations to be developed.

Other projects that are provided greater respect due to the data analysis and evidence of the report is the National Green Highways Mission, which is a project outlining the introduction of road-splitting and side-road green spaces, which purify the high amounts of air pollution from industrial and large vehicles.

Figure 18: *The modelled outlook of the National Green Highways Mission. Generated by Medium:* *https://medium.com/@NGHMIndia/how-a-green-highway-project-is-changing-lives-of-people-baf4a119e034*

Using motor-powered vehicles such as cars and buses is not the only method of commuting accessible to individuals, walking and biking are other transportation methods. However, lots of walking or biking trails are damaged or inaccessible, thus the government needs to invest in infrastructure that supports alternative modes of transportation, such as bike lanes and pedestrian pathways, which can encourage commuters to choose healthier and more sustainable options. Ensuring that these alternatives are safe, well-maintained, and connected to key destinations will make them more attractive to a broader range of individuals.

Lastly, construction sites were defined as target locations with increased air pollution, thus new government policies should include implementing stricter emission standards for construction equipment and machinery, as well as funding for dust control measures that can allow for air quality maintenance within these areas. In closed locations such as alleyways, air circulation could be improved through fans and ventilation systems, which could disperse pollutants. Regular cleaning and maintenance of these areas, along with restrictions on smoking and waste disposal, can also reduce the accumulation of harmful substances.

Overall, these results provide relevance for improvement in not only national Australian matters but also provide cause for action to locations internationally, such as India, which would benefit from the aforementioned programs to improve air quality levels and ensure appropriate health and safety standards for its citizens.

To achieve long-term improvements in air quality, cities need to adopt comprehensive and sustainable urban development strategies. This includes transitioning to cleaner energy sources, promoting energy-efficient buildings, and supporting the development of low-emission transportation networks. Government agencies, private sector stakeholders, and community organisations need to collaborate to implement these strategies effectively. As engaging the public in the planning process for an improved environment and air quality levels can drive collective action towards a sustainable urban environment.

The Effectiveness of Current Government-Based Policies:

At the status quo, electric vehicles are a major talking point in society due to their supposed impacts in improving the environmental air quality and helping in the achievement of sustainability. Governments have issued policies for these matters, including electric vehicle rebates, however, electric vehicles are too expensive for citizens to purchase and allow for the rise in air quality caused by vehicles. Electric vehicles are also not as effective as determined in the long term it has been proven that battery manufacturing is ineffective due to the strong chances of the battery failing in an average time period of 6–8 years. If the battery fails within this time period, it does not outweigh the emissions of production - and thus means that the electric vehicle holds the same environmental footprint as a non-electric vehicle. Thus, for these policies and the electric vehicle market to be successful in reducing urban air quality as well as improving sustainability, there is a requirement that the industrial making of the vehicles is improved so that there is an eventual net decline in emissions for each car.

Wider Societal Impacts:

Improving air quality holds various implications which extend beyond the primary motive of environmental benefits. Improved air quality has profound impacts on public health, reducing the chances of respiratory diseases, cardiovascular problems, and other pollution-related health issues. Having cleaner air contributes to overall better health outcomes, reducing healthcare costs and improving the quality of life. Furthermore, better air quality can enhance productivity, as healthier individuals are less likely to miss work due to illness. In urban areas, this can translate to significant economic benefits.

Moreover, urban greenery and open spaces provide recreational areas for individuals within the local community, which also promotes physical activity and well-being. These spaces can serve as community hubs, to allow social interactions between the residents. The aesthetic value of green spaces also enhances the attractiveness of cities, potentially boosting tourism and local economies. By investing in green infrastructure, cities can create more livable environments that attract and retain residents and businesses, contributing to sustained economic growth.

Impacts of Air Quality Beyond Urban Areas:

Air Quality plays an important role in not only urban settings but also within country fields such as ecosystems and agricultural productivity. Whilst, air quality within those areas is quite improved, in the future, air quality may significantly reduce, thus it is essential to understand the impacts of air pollution in those locations. Air pollutants such as nitrogen dioxide and ozone can often harm plant life, reducing photosynthesis and growth rates. This has direct implications for crop yields and food security. Furthermore, substandard air quality can damage crops, leading to reduced agricultural output and economic losses for farmers.

Additionally, healthy ecosystems rely on clean air for the well-being of various species, including pollinators like bees and butterflies, which are essential for pollinating crops and maintaining biodiversity. Pollutants can disrupt these ecosystems, leading to declines in biodiversity. By improving air quality, these vital ecosystems can be protected to ensure they continue to support agriculture, biodiversity, and overall environmental health.

Future Prospects for Key Cities - Adelaide, New Delhi, Beijing, New York, and London:

Adelaide, Australia; and New Delhi, India:

(As the issues of Adelaide and New Delhi were explored in depth above, under the Starting the Project and Finding Curiosity section, the future prospects are written in a shorter form).

In the future, Adelaide and New Delhi have differing challenges and opportunities for managing air quality. With its low population density and environmentally friendly policies, Adelaide can further improve its air quality through projects like more green spaces or better public transport *(Environment Protection Policy, 2016)*. These initiatives are quite feasible due to the small number of residents within the city. The ongoing efforts - which to some extent could be improved - to increase tree canopy coverage and promote sustainable urban development will also likely yield positive results, making Adelaide a model for other cities aiming to improve air quality.

In contrast, New Delhi faces more significant challenges due to its high population density, rapid urbanisation, and severe air pollution problems *(Zhang and Batterman, 2013)*. To address these issues, New Delhi needs comprehensive strategies that include stricter emission controls, better waste management, and significant improvements in public transportation infrastructure. By implementing green infrastructure projects, such as urban forests and green roofs, pollution and air quality can be improved.

New York, United States of America:

New York City is one of the largest and most densely populated cities in the United States. Within its recent history, the government has made significant strides in improving air quality over the past few decades. However, it still faces challenges related to vehicle emissions, industrial activities, and construction - which are partly associated with its high residential numbers. Yet, if the city's air quality trends are continued, they will hold implications for public health, the environment, and the economy *(Why is Air Quality Important, 2024).*

Firstly, vehicle emissions remain a major source of air pollution in New York City. Despite improvements in emission standards and the adoption of cleaner technologies, the high volume of traffic continues to contribute to elevated levels of Nitrogen Dioxide (NO_2) and Particulate Matter of size 2.5 (PM2.5). These pollutants are associated with respiratory and cardiovascular diseases which place vulnerable populations, including citizens with pre-existing illnesses, and the elderly, at even more risk *(Air Quality - DCCEEW, 2024).*

Secondly, industrial activities and construction projects contribute to air pollution. Emissions from factories, power plants, and construction sites release pollutants such as Silicon Dioxide (SO_2) and particulate matter into the air. Prolonged exposure to these pollutants can lead to adverse health effects described above.

Economically, poor air quality can impact New York City's attractiveness as a place to live and work. High levels of pollution can deter tourists and increase healthcare costs. Furthermore, the city's economy could suffer from reduced productivity due to the health impacts of air pollution on its workforce *(Primary Connections, 2024).*

In response to these challenges, New York City has currently implemented various measures to improve air quality. These include expanding public transportation, promoting cycling and walking, and investing in green infrastructure. The city has also introduced initiatives to reduce emissions from buildings, such as Local Law 97, which requires large buildings to meet strict greenhouse gas emission limits. Continued efforts to transition to renewable energy sources and improve energy efficiency are essential for sustaining these improvements in air quality.

Beijing, China:
Beijing, the capital city of China, has been notorious for its severe air pollution. However, in recent years, the city has made significant progress in improving air quality through stringent regulations and large-scale interventions. Despite these improvements, Beijing still faces challenges related to air pollution, primarily from industrial activities, vehicle emissions, and coal burning.

The health impacts of continued air quality trends in Beijing are substantial. High levels of Particulate Matter 2.5 and Particulate Matter 10 are a major concern. The chemicals present in the emissions in Beijing are known to cause chronic conditions such as bronchitis and lung cancer *(Education Victoria, 2021).* Environmental degradation due to air pollution is another critical issue. Acid rain, caused by SO_2 and Nitric Oxide emissions, can damage crops, forests, and water bodies. It also accelerates the deterioration of buildings and cultural heritage sites.

The economic implications of air pollution in Beijing are also significant. The costs associated with healthcare for pollution-related illnesses are considerable. Additionally, poor air quality can lead to decreased labour productivity, which is a major source of the country’s income. Thus, affecting the overall economic performance of the city. The tourism industry can also suffer, as visitors may be deterred by the city's reputation for poor air quality.

At the status quo, Beijing has implemented numerous measures to combat air pollution *(Nation Weather Dervice, n.d.)*. The city has introduced strict emission standards for vehicles, promoted the use of electric and hybrid vehicles, and expanded public transportation networks. Industrial emissions have been targeted through the closure of heavily polluting factories and the adoption of cleaner technologies. Additionally, efforts to reduce coal consumption and increase the use of natural gas and renewable energy sources have been made. Despite these efforts, continuous monitoring and enforcement are necessary to sustain and further improve air quality in the nation.

London, England:

The capital city of the United Kingdom (England), London has a long history of air pollution, dating back to the Industrial Revolution. Although air quality has improved since then, the city still faces challenges related to vehicle emissions, construction activities, and industrial pollution *(United Nations Environmental Programme, 2022).*

The health impacts of continued air quality trends in London are a major concern. The inhalation of air pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2) poses significant risks to respiratory and cardiovascular health. Poor air quality also exacerbates existing health inequalities and causes disproportionately in marginalised communities to worsen socioeconomic disparities in health outcomes *(Primary Connections, 2024)*.

Air pollution within the city can deter tourism and foreign investment, tarnishing London's reputation as a desirable destination for business and leisure. The degradation of natural environments due to poor air quality also damages urban development efforts, hindering the city's economic growth.

In response to these challenges, which can impact London in both the short and long term, the city implemented several measures to improve air quality. The introduction of the Ultra Low Emission Zone (ULEZ) aims to reduce vehicle emissions by imposing charges on vehicles producing emissions greater than the set limit. These zones are applied within various parts of the city to promote electric vehicle purchases. However, similar to all cities striving to improve air quality - more ambitious measures and stringent regulations are necessary to achieve significant improvement in air quality across the city.

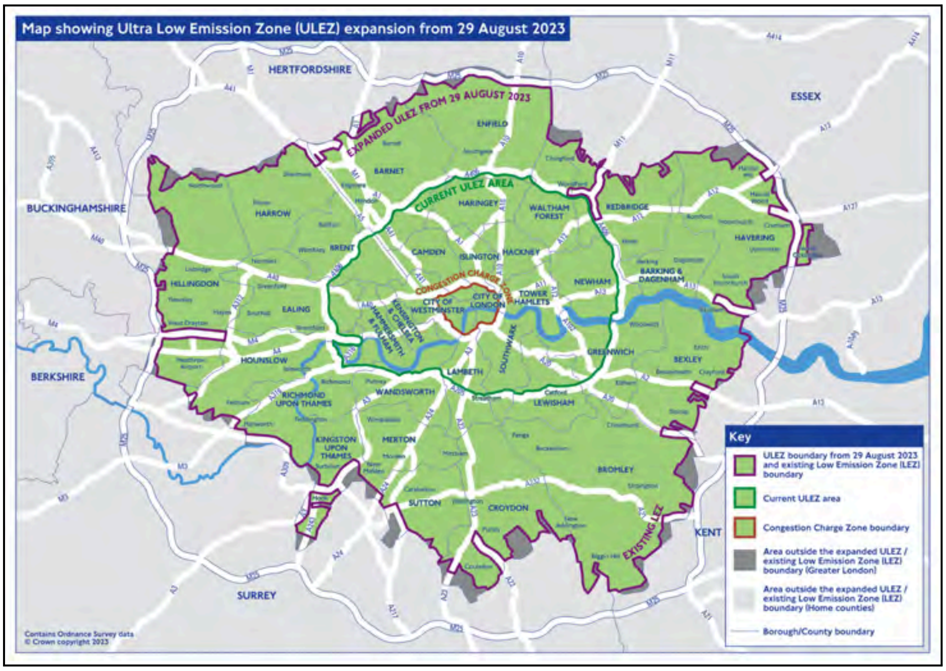


Figure 19: *The Ultra Low Emission Zone (ULEZ) vehicle map in England. Generated by Money Saving Expert:* https://www.moneysavingexpert.com/news/2023/08/ulez-august-expansion-how-to-avoid-charge/

Evaluation of Data

Investigation Errors:

Throughout the citizen science investigation, there was a presence of both systematic and random errors, which may have impacted data reliability and validity.

Within Aim 1, there is a clear systematic error present within the methodology of the air quality measurements at the transect locations occurring at different times of the day. This error is present as air quality can experience diurnal variations due to possible changes in traffic patterns, industrial activity, and meteorological conditions *(Queensland Government, 2017)*. As the data were not collected at the same time, the data would affect the conclusion as it would not wholly reflect spatial change in air quality, rather it would be subject to temporal variations. In the future, this error could be improved by ideally attempting to collect all data at the same time. However, if this is not possible, it should be attempted to the closest degree, i.e. by using more data collectors allowing for a wider range of data collection at the same time.

The citizen science investigation - particularly under the category of Aim 1 - was vulnerable to inconsistent environmental conditions. These conditions include wind speed and direction or temperature, which are factors known to have the capability of dispersing pollutants, leading to lower readings. The error would impact the conclusion, as the data would be prone to overestimation or underestimation of air quality levels. A future improvement of this error may be to record other factors such as wind speed, and to record data when this variable is constant in other locations.

Another random error within Aim 1 was the position of the PocketLAB data recorder, which was not able to be raised to a specific height in the air. This impacts the data, as air quality can vary at different heights due to the varying dispersion of pollutants. In some trials, the Pocket Lab was placed on the floor or held up high. This could have influenced the data collected as some denser particles could have been captured when the pocket lab was near the floor whilst up high, the particles would be significantly less dense. Thus, this error would impact the validity of the results. An improvement to the data quality would be to keep the position of the pocket lab consistent, or to measure the air quality twice; once whilst the Pocket Lab is on the floor and once when the Pocket Lab is held up.

Possible improvements:

In our surveys and questionnaires, there was a higher representation of older individuals (primarily above 50 years of age) than youths. This is likely to be due to the greater willingness and available time of older people, which could have impacted the outcomes. An improvement to this is to survey a more diverse range of ages equally to get the fairest answers (through using observation in analysing the approximate age of interview candidates before choosing the appropriate interview).

The environmental survey may have been subjective towards the likeability of the environment and its appeal to the eye, which can differ between people. Therefore, for the scores of the environmental data to be consistent and equitable, all the people in the group should complete the survey. The average of the scores should be recorded as the final FSC Environmental Score of the location. This would result in a less subjective and more generalised score of the environment.

Experimental Limitations:

A limitation that occurred during the data collection was that not all the points that were on the transect line could be accounted for. On the original transect line, 2 additional points were present, however, data could not be collected there due to the Adelaide VAILO 500 event. The Adelaide VAILO 500 is an annual motor racing event for Supercars held on the streets of the east end of Adelaide, due to this a lot of the routes/locations were restricted *(VAILO 500, 2023)*. Therefore, this limited the data and hence, impacted the results and trends of data.

Another investigation limitation was the presence of nearby construction works at the allocated point on the transect line. Although the air quality could still be measured, the value is only applicable for a short period of time as it denotes the air quality of the location whilst construction works were occurring. This means that it does not provide an accurate representation of the average air quality of that location. This could be improved in the future through collecting data at a later date when construction works are not occurring anymore.

Overall Data Reliability and Validity:

The data is proved to be at a strong level of reliability, which is displayed through the relationships between the data values, evident by the strength of the r^2 value. The r^2 throughout the experiment (in graphs) is above 0.080, hence the data is reliable. The investigation is also valid as the data was cross-checked with professional data accessed through the South Australian Environment Protection Authority.

Conclusions

In summary, the data collected from the investigation allowed for the identification of multiple important trends that successfully answered the aims of the citizen science investigation. It was found that air quality is significantly better in open green spaces, whilst air quality is worse near enclosed alleyways, due to the alleyways having limited air ventilation and higher concentrations of polluted air particles than open green spaces, leading to substandard air quality *(World Health Organisation, 2022)*. Furthermore, the investigation proved common commuter characteristics of transport in the CBD, with people living closer to the CBD more likely to take public transport whilst commuters living further than 7 km from the city were likely to travel by car *(National Environment Protection)*. This data confirms that distance and cost (associated with long-distance public transport) are reasons for citizens not to take public transportation methods - which would reduce carbon emissions and improve air quality *(NSW Government, n.d.)*. The study proved that the introduction of the various aforementioned factors in areas with low air quality is effective - and thus, proven to improve air quality levels. The data and understandings were found to be applicable to various worldwide nations to create a net improvement in environmental levels through sustainable and ethical practices for air quality management. Unfortunately, the investigation was accustomed to limitations, which could be improved in future repetition to increase the validity and reliability of the outcomes. Yet, through the citizen science investigation, the individual hypothesis for each aim was achieved:

- **Aim 1:** Air Quality will decline in closed-off regions with limited air circulation, and it will strive near green spaces.
- **Aim 2:** Air Quality will be most impacted by the FSC Traffic Score and the FSC Greenery scores. These will determine whether a region has high or low levels of air quality.
- **Aim 3:** Citizens would recognise a common trend of negative air quality around the CBD. People residing closer to the city would have a higher chance of using public transportation systems.

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