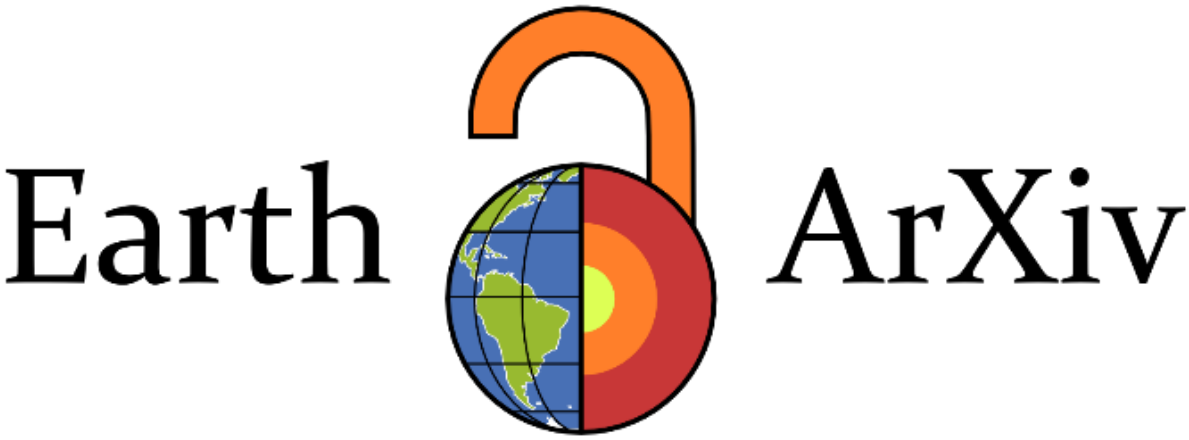

Correlation Between Commuting Behavior and Air Pollution

Raphael Yang*
Palos Verdes Peninsula High School
Palos Verdes, United States of America
dkyang0817@gmail.com

Abstract – One of the biggest causes of air pollution in a city is the use of gasoline engined vehicles, such as cars, buses, and motorcycles, which is used every day as a commuting mode for citizens. Commuting behaviors of people can be categorized into two big factors, public transportation and private transportation. The research invested on whether or not higher usage rate of public transportation affected the air pollution level, through comparison between three cities, New York City, London, and Jakarta. It was found that the cities with higher utility of public transportation and a lower use of private vehicles had substantially less pollutant density than cities with excessive amounts of private vehicle use, concluding that public transportation has significant influence in the pollution level of a city.

Introduction

Increase in the risk of heart disease, lung cancer and asthma attacks and interference with the growth and work of the lungs. These are some of the dangers that can be caused by air pollution pollutants, and more specifically, particulate matter. Particulate Matter is a microscopic pollutant caused mainly through the utility of gasoline-engined vehicles, which could cause a list of harmful infections when mixed with the air in high density. Especially to homeless or to people living areas near traffic roads, the level of particulate matter can cause serious fatal infections as they might directly inhale the substance.

Everyday commuting behavior of citizens, whether it's going to work or riding their children to school, the usage of private vehicles through such a process is a main source of air pollution and creation of particulate matter. Consequently, public transportation, which has the capability to transport large amounts of people with much less use of gasoline compared to private motor vehicles, is a possible way to prevent an increase in particulate matter density. As a response, a question can be suggested: Can higher use of public transportation result in decrease in air pollution level within the city?

Through comparison between New York, London, and Jakarta with different usage rates of public transportation and level of pollution, I tend to find the correspondence between public transportation and air pollution, and confirm whether commuting behavior with the use of public transportation could or could not prevent particulate matter density from rising.

*This work was done under the mentorship of Aviral Marwal from University of Cambridge(am2839@cam.ac.uk).

Literature review

One of the major causes of air pollution, one the most concerning topic today, is daily commuting behavior of citizens. In fact, according to the Environmental Protection Agency, gasoline engined vehicles may be responsible for as much as 95% of all carbon monoxide emission levels [1].

Cities with high use of gasoline engined vehicles and low use of gasoline vehicles show critical amounts of differences. For example, Detroit, being called a motor city, marks 113 in the Air quality Index, when in comparison, Budapest, which contains a higher population, only showed 2 in the Air quality index.

Emission of gasses from vehicles forms a minute matter called particulate matter (PM), and inhalation of these microparticles can cause long term effects of coronary heart diseases, which can possibly lead to severe conditions. These damages are more critical towards the elderly, pregnant people, and developing children. A major problem is, although higher income people show to have more direct damages due to the pollutants. In the San Francisco Bay area, a higher percentage of colored people have double the rate of pollution related childhood Asthma compared to predominantly white neighborhoods[2].

Some people may think that the emission amount of gasses dramatically increased over the years, but that is not exactly the case. Many technological advancements have delayed the rapid increase of such conditions. For example, in New York cities, which has one of the highest uses of gas engined vehicles, there has only been 15% of increase in CO2 emission levels between 1980 to 2019, due to the use of cleaner fuels in vehicles. In the 1970s, lead contents in gasoline used to be a critical problem to people's health, which not specifically is the case now, since the lead content sharply decreased ever since the 1980s[3].

Another important factor in the decrease of air pollution through vehicle transportation is the increase in the rate of public transportation. In fact the differences between cities with high use of public transportation shows a drastic difference in air pollution level. A public transport strike which occurred in Barcelona, Spain, caused a sudden rise in pollution level. Within the days where strikes occurred, it was shown that the amount of pollution increased ranging from 4% to 8%[4].

One of the greatest differences between the United States and Europe in the case of transportation is that only 50% of Europeans drive themselves when 85% of Americans drive. In other words, half of the population in Europes utilizes public transportation as their commuting behavior when only 15% of Americans use public transportations. The reason for such different types of transportation development is due to the historic backgrounds of the two areas. The US for instance, had major developments in their cities during the industrial revolution, where long distance travel through trains were available. So, the wealthier lived outside the city-center, which had high levels of air pollution due to the industrial factories. This urban structure in the United States causes

difficulties in the function of Public transportation. However, Europe on the other hand, had most of its cities built during the renaissance and even before, where no such transportation systems were available, so cities had to be built compacted and dense, leading to a higher use of public transportation[5].

The research points out the evident reduction in the overall pollution level of New York City with graphical evidence describing the change in levels of diverse pollutants starting between the years 2009 to 2014. The different pollutants, including NO, NO2, and $PM_{2.5}$, all showed dramatic decreases in their density over cubic meters[6].

Jakarta, the capital of Indonesia and the fourth most populated city in the world, is showing great levels of air pollution, marking the most polluted city in the whole world according to IQAir. Researchers have identified that more than 44% of the pollution in the city of Jakarta is caused due to transportation, where 31% of it is caused due to industry. The streets of Jakarta are filled with polluting, inefficient vehicles such as motorcycles, and lack in the usage of public transportation[7].

context

Today, one of the major grievances many cities have is the pollution level within their urban areas. By comparing New York, London, and Jakarta, I will investigate the air qualities of the three cities as well as their usage rate in public transportation to find the correlation between the two factors.

New York City, as many people know, is one of the most populated metropolis in the world, with a population of 8.5 million and population density of 11,313/km2, the city itself booms with everyday commuting behaviors, diversifying from private cars to public transportations such as buses and subways.

London shows similar phenomenons as New York City. London is also a very populated city, with a population density of 5598/km2, and a population of 8.9 million. The commuting behaviors are also a reflection of New York's with diverse transportation methods starting from private transportation to bicycles, subways, and the infamous double decker bus.

The third city, Jakarta, shows similar characteristics as London and New York in the population, having the heaviest density of 16,152/km2, with a total population of 10.56 million. However, its transportation usage, on the other hand, has a different aspect compared to the other cities, as it is heavily tilted towards private transportation, with an absolute majority commuting through motorcycle or motor cars.

Method: Comparative Analysis

New York

New York, being the most heavily dense city in the world, shows great amounts of riderships through gasoline engined vehicles. However, surprisingly, the air pollution levels of the entire city is remarkably low, the AQI of the city is constantly staying in the safe region, and even shows a steady downfall of the pollution level.

Between 2009 and 2014, nitrogen dioxide has declined by 21%, nitric oxide levels declined by 24%, and most importantly, the particulate matter (PM) within the air decreased significantly between the six years from 11.2μg/m^3 to 8μg/m^3 (Figure 1). All the gasses and molecules listed above are all compounds produced from gasoline engined vehicles. Then, how is it possible for New York City, with the most heavy population density, and high use of vehicle ridership to have such a dramatic decrease in the emission of gasses and air pollution level?

New York shows an interesting statistics with their use of car vehicles. Although New York shows high usage of gasoline engined vehicles, most of the usage of the vehicles includes public transportation such as subway or bus usage. In fact, within major cities in the United States, New York City shows an outstandingly low ownership of private vehicles of 45.6%. On the other hand, the usage of public transportation has been showing a steady rise; bus usage of NYC stayed comparatively in a similar stage as it was in 2009 to 2014, when the usage of the subway greatly increased from approximately 1.6 billion to 1.78 billion ridership (Figure 2). Considering the decline in air pollutants in the same timescale of the increases in public transportation usage, it is possible to assume that the higher the use of public transportation as the commuting behavior, and lower the utility of private vehicles, the better the air pollution level will be.

Figure 1: $PM_{2.5}$ Emission in New York City[5]

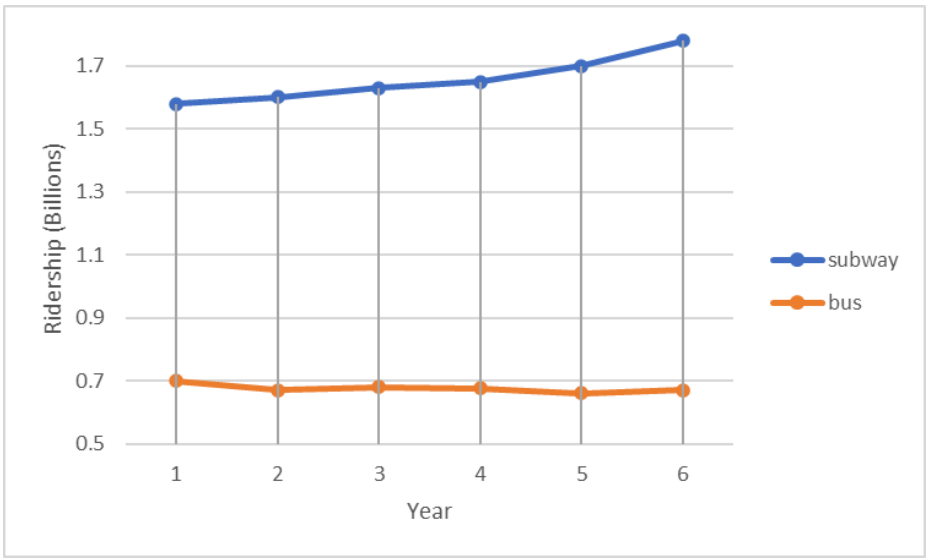

Figure 2: Public Transportation Ridership in New York[8]

London

London, shows a very similar movement of air pollution levels as New York did. London, also being one of the biggest cities in the world, shows a great density of population of 5598/km2, but shows a miraculous level of air quality, as its $PM_{2.5}$ level hits lower compared to many other major cities around the globe.

London is a city that shows high usage of public transportation, which has been steadily increasing over the years. The usage of buses, rails, and other public transportation shows a steady rise over the years, when the utility of private transportation in London is not as popular as it is in other cities. In fact only 37% of citizens in London utilizes private transportation as their main source of commutation. The Public transportation numbers within London show a very steady rise, such as the number of buses increasing nearly 50% over the 30 years between 1987 to 2017 and the underground railroad's usage increasing as well by approximately 25% (Figure 4). Correspondingly, the $PM_{2.5}$ levels of London declined sharply from 80 micrograms per cubic meter to less than 15 micrograms per cubic meter (Figure 5).

London, being a very old city which first formed during the ancient year of 43 AD, its structure as a city is quite different from the modern-built urban. London's structure has a center in the city, and this city center made London to have most of its major functions to be compacted to the middle, providing public transportation to become much more efficient. In fact, the city having its double decker bus as a symbol illustrates the crucial importance public transportation has to the people of London.

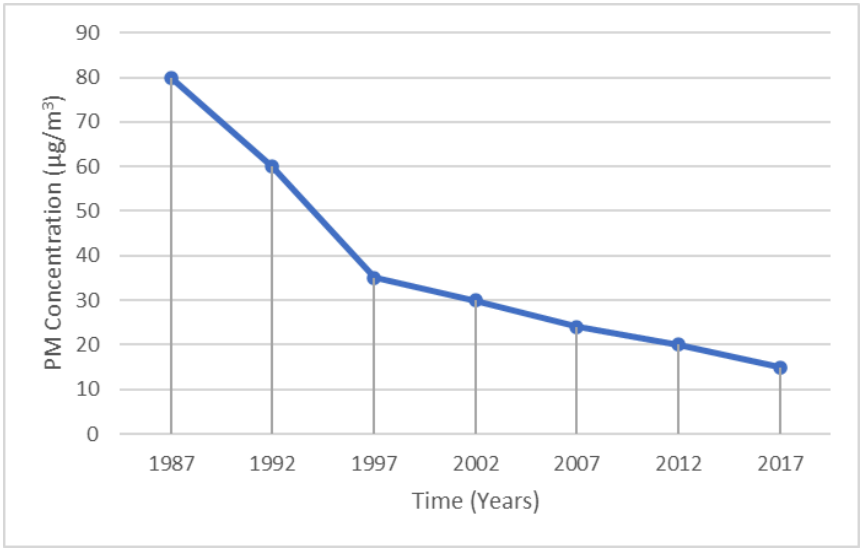

Figure 3: Particulate Matter Concentration of London[9]

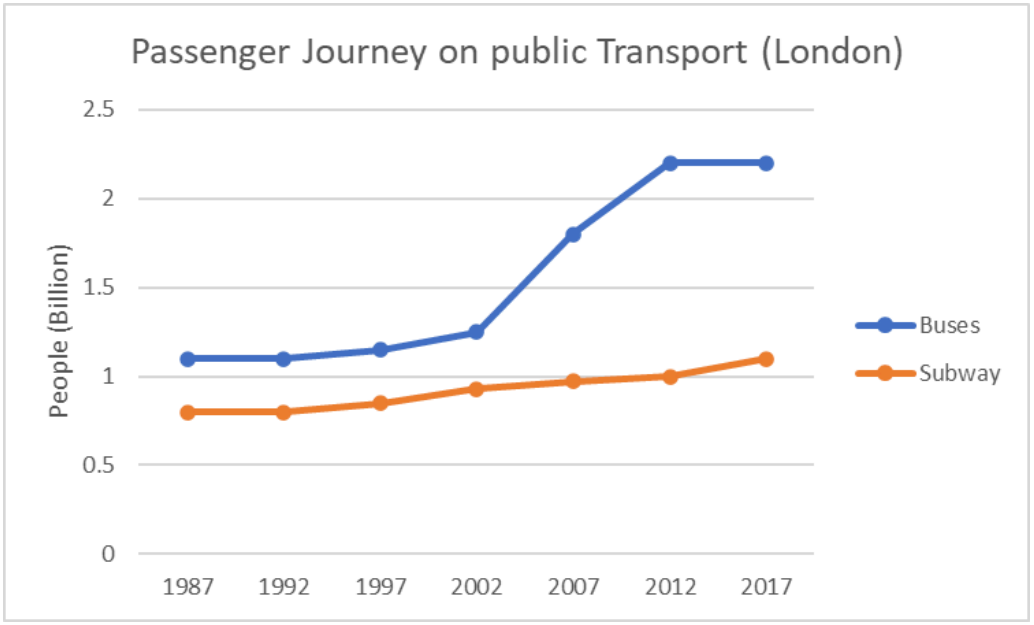

Figure 4: Public Transportation Ridership (London)[10]

Jakarta

Jakarta, the capital of Indonesia, is one of the most densely populated countries in the whole world. With a very high population density of 16152/km2. However, as seen from New York and London, it can be inferred that high population doesn't always result in extreme pollution levels. However, Jakarta on the other hand, shows a very different aspect in case of air pollution level compared to the other two cities.

Jakarta showed a $PM_{2.5}$ level of 42 $\mu g/m^3$, which is an extremely high number that surpasses the WHO level of 10 $\mu g/m^3$ by over 4 times (Figure 6). However, this unbelievable level of particulate matter continues to increase, increasing from 29 $\mu g/m^3$ in 2017 to 2020 ug/m^3, increasing by nearly 40% within the 3 years. Then what causes such a difference in air pollution level in Jakarta compared to the other two cities?

London and New York show a very active usage in public transportation. However, in Jakarta, an extremely infinitesimal amount of the daily commuting is done through public transportation such as buses, as studies show that only 241 thousand buses were utilized in 2020, which is miniscule compared to the usage of other private transportation such as cars, trucks, and motorcycles. As a matter of fact, the usage of motorcycles shows to succeed the usage rate of public buses by nearly 500 times, reaching 125,267,000 in numbers, which is an amount increased from the year 2018 to 2022 by 20% (Figure 7). Coincidentally, the number of particulate matter, a particle made from gasoline engined vehicles, also showed a sudden increase in the years when the usage of motorcycles increased.

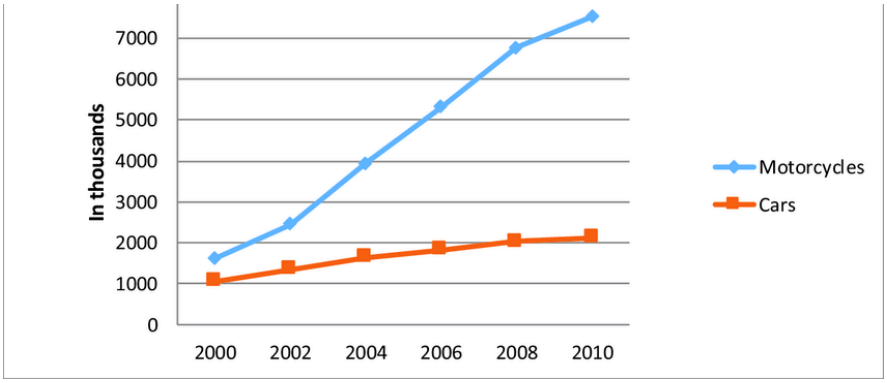

Figure 5: Private Transportation Ridership (Jakarta)[11]

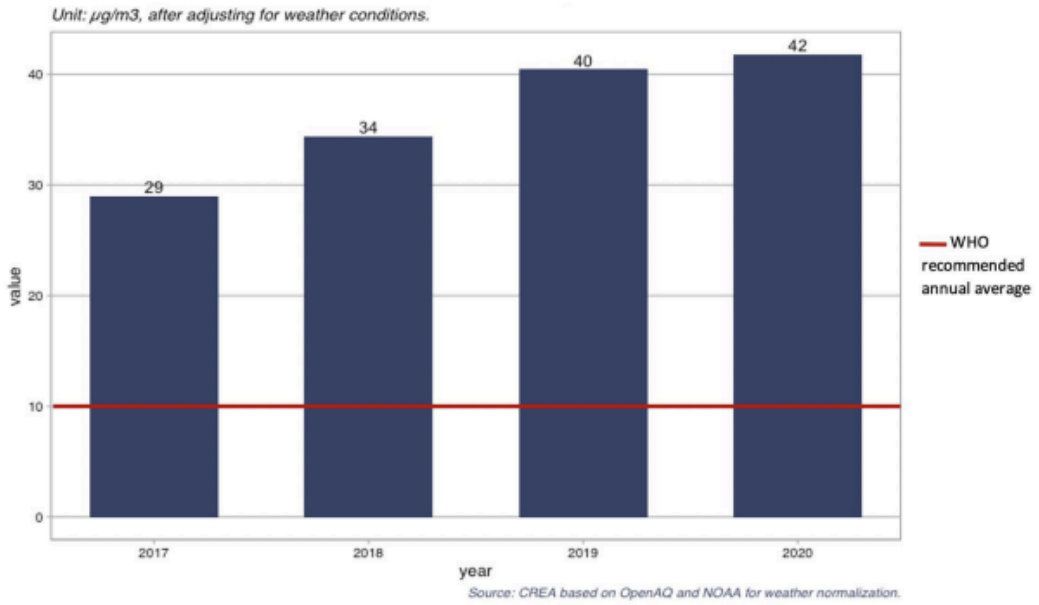

Figure 6: $PM_{2.5}$ concentration of Jakarta[12]

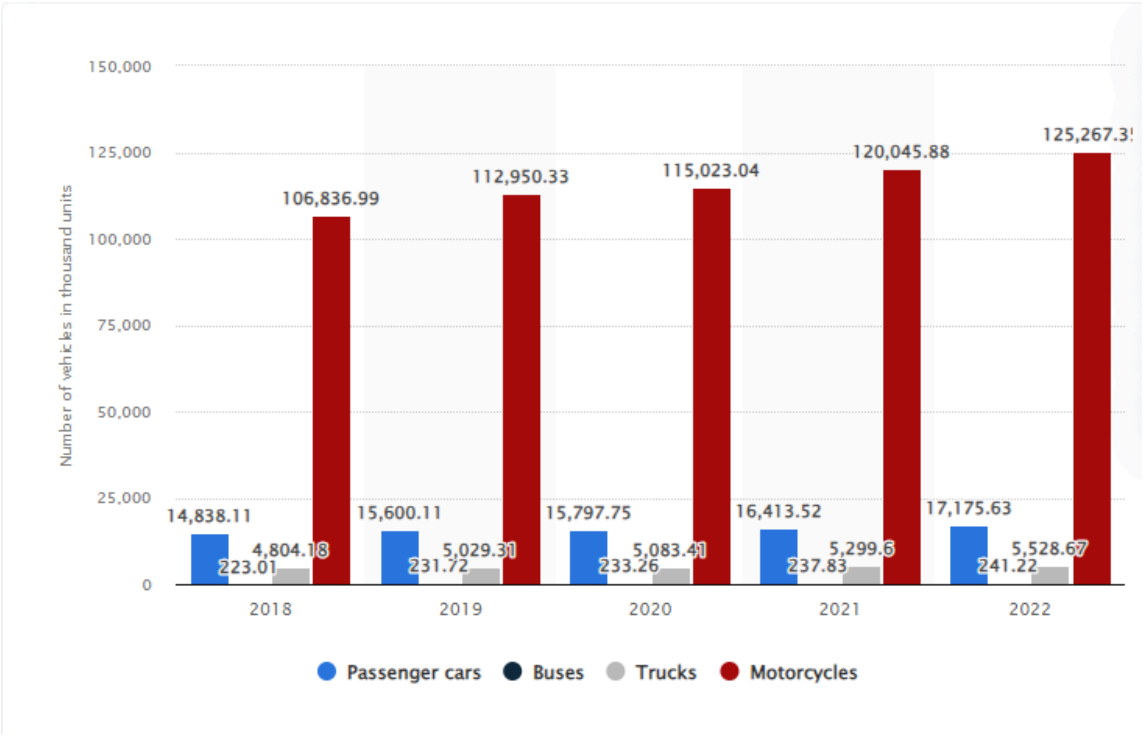

Figure 7: Commuting Behavior in Jakarta[13]

Discussion and Results

All three cities shown above have a very similar trait of being highly dense cities with over 5000/km2, with high levels in daily commuting amounts. However, a significant difference that can be seen within the three cities are their air pollution levels and usage of public transportation.

New York and London both show miraculously low levels in their air pollution levels, London, having $PM_{2.5}$ level below 15 $\mu g/m^3$, and New York below 8 $\mu g/m^3$. However, Jakarta on the other hand, shows far superior numbers in air pollution level compared to the other two cities, having a $PM_{2.5}$ level of 42 $\mu g/m^3$ in 2020.

The gigantic difference can be hypothesized with the difference in the usage rate of public transportation within the three countries. In New York and London, the use of public transportation is very active, as more than 40% of the population in both cities uses public transportation as their main source to commute, while in Jakarta, only around 30% of the population utilizes public transportation as their commuting behavior.

When both New York and London showed gradual reduction in $PM_{2.5}$ level, within a few years, the actual level and density of particulate matter in Jakarta increased immensely by nearly 40% within the years of 2017-2020. And the usage of public transportation shows a direct corresponding with the levels of Particulate Matter, as the number of public transportation commuting stayed low and steady over the years, when private transportation increased by nearly 20%. Between the years 2009 to 2014, the average subway usage in New York increased by 180 million, when the average PM density decreased from 11.8 $\mu g/m^3$ to 8 $\mu g/m^3$. London, similar to New York, had a decrease in $PM_{2.5}$ level, from 80 $\mu g/m^3$ to below less than 15 $\mu g/m^3$ between the years of 1980-2016, when the bus usage increased by up to a near 900 million.

With regard to the research question “Can higher use of public transportation result in decrease in air pollution level within the city?” it is feasible to draw a conclusion that public transportation can be substantially decreased with the use of public transportation.

Conclusion

The findings of the paper strongly suggests that the public transportation usage has a strong correlation with the increase and the decrease in the air pollution level, more specifically, the density of Particulate Matter in the city.

New York, between 2009 to 2014, had a rapid rise in the use of subways, which was also when it had a decrease in its pollution level, especially their levels in $PM_{2.5}$. London showed similar phenomena as New York; between 1987 to 2017, its $PM_{2.5}$ level decreased dramatically from nearly 80 micrograms to 15 micrograms per cubic meter, which was around the time when their public transportation usage, especially buses and subways, rapidly increased. Jakarta, however, had great increases in their levels of $PM_{2.5}$, between the years 2017 to 2020, which was the same period when their private vehicle usage rose. This evidence points out one specific result, that the commuting behaviors do impact the pollution levels in a city–high usage rate of public transportation and low usage rate of private transportation would lead to a city with comparatively lower $PM_{2.5}$ level compared to a city with the opposite aspects.

One limitation that exists in the research is the lack of other possible factors of pollution. The main air pollutant that I researched, $PM_{2.5}$, is mostly created by gasoline usage within the city, but it may also be caused by other factors such as dust storms, forest fire, or other external sources.

References

[1]. L.C. Brinson & F. Guzman "How Much Air Pollution Comes From Cars?"(2012). HowStuffWorks.com. https://auto.howstuffworks.com/air-pollution-from-cars.htm

[2]. O.O. Amubieya "When Air Pollution Becomes a Health Equity Issue." *UCLA Health System*, (2021) www.uclahealth.org/news/air-pollution-health-equity-los-angeles.

[3]. "Transportation, Air Pollution, and Climate Change | US EPA." *United States Environmental Protection Agency*, (2023) www.epa.gov/transportation-air-pollution-and-climate-change.

[4] X. Basagana, M. Trigureo-Mas, D. Agis, N. Perez, C. Reche, A. Alastuey, X. Querol Effect of Public Transport Strikes on Air Pollution Levels in Barcelona (Spain). *Science of The Total Environment, Elsevier*, (2017), **610-611**, 1076-1082

[5]. I. Kheirbek, S. Johnson, K. Ito, K. Anan, C. Huskey, T. Matte, D. Kass, H. Eisl, J. Gorczynski, S. Markowitz, "Welcome to Nyc.Gov | City of New York." *NYC Health*, (2016) www.nyc.gov/assets/doh/downloads/pdf/environmental/comm-air-survey-08-14.pdf.

[6]. E. Tarigan "Jakarta Is the World's Most Polluted City. Blame the Dry Season and Vehicles for the Gray Skies." *ABC News*, ABC News Network, (2023) https://abcnews.go.com/International/wireStory/jakarta-worlds-polluted-city-blame-dry-season-vehicles-102194576

[7]. C. Hallman "U.S. Cities with the Highest and Lowest Vehicle Ownership." *TitleMax*, (2021) www.titlemax.com/discovery-center/planes-trains-and-automobiles/u-s-cities-with-the-highest-and-lowest-vehicle-ownership/.

[8]. S. Miller "As Subway Trips Climb, MTA Bus Ridership Continues to Stagnate." *Streetsblog New York City*, (2023) https://nyc.streetsblog.org/2015/04/23/as-subway-hits-new-records-mta-bus-ridership-continues-to-fall

[9]. H. Ritchie "What the History of London's Air Pollution Can Tell Us about the Future of Today's Growing Megacities." *Our World in Data*, (2017) https://ourworldindata.org/london-air-pollution

[10]. Dave "Bus Passengers Numbers Is Falling Dropping, Also - Bath & Bristol Area Trams Association." *Bath & Bristol Area Trams Association* , (2019) https://bathtrams.uk/nationally-bus-usage-is-declining-also-apparently-in-london/

[11]. D. Rukmana "Rapid Urbanization and the Need for Sustainable Transportation Policies in Jakarta." *OP Conf. Ser.: Earth Environ. Sci.* (2018), **124**, 012-017

[12]. I. Suarez, L. Myllyvirta, E. Uusivuori, H. Thieriot, A. Anhäuser, *Centre for Research on Energy and Clean Air* "Transboundary Air Pollution in the Jakarta, Banten, and West Java provinces" https://energyandcleanair.org/wp/wp-content/uploads/2020/08/Jakarta-Transboundary-Pollution_FINALEnglish.pdf

[13]. Statista Research Department. "Indonesia: Number of Vehicles by Type 2022." *Statista*, (2023) www.statista.com/statistics/1239274/indonesia-number-of-vehicles-by-type/.