Location Targeting: Spots for Air Purification Units in India's National Capital Region

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INTRODUCTION

Background:

Air pollution is a great environmental and social risk in our world today, contributing to an estimated 7 million premature deaths every year.[1] The issue disproportionately affects vulnerable groups -- such as those with preexisting health conditions, the poor, and children. At a more macro level, air pollution has harmful impacts on countries' economies by increasing brain drain and decreasing productivity and tourism.[2]

Air pollution includes many different types of harmful particles and chemicals, but perhaps the most detrimental to health is PM2.5 -- particulate matter with a diameter under 2.5 micrometers.[3] This pollutant is pervasive as it is difficult to capture at the source and often sits in the outdoor air. The World Health Organization (WHO) estimates that the target level for breathable air should be 10μg/m3, but many urban areas exceed this.[4]

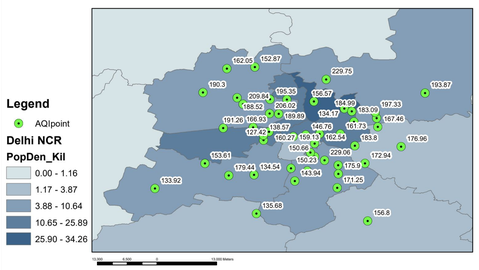
India experiences dangerously high levels of PM2.5, the average estimate is 58.1 μg/m3, nearly 6x the WHO target, but many cities in the northern region of India can climb many times above this.[5] Air pollution in India is seasonal, with the peaks from October to December coinciding with seasonal crop burning and the Diwali festival. Likewise, because of topographical considerations, air pollution in India is also geographically patterned, affecting the northern region more than anywhere else. Of the world's most polluted cities, 21 are in India and six Indian cities are in the top ten, all from the Delhi National Capital Region (Delhi NCR).[6] As you can see in **Map 1** below, every sensor in the Delhi NCR region exceeds the WHO target by more than 12x during the peak season, with many exceeding by over 20x.

This project is an effort to understand where the best location for these new technologies would be. I begin by outlining the most important criteria for a solution that will maximize social, environmental, and economic impact. Then I use ArcMaps GIS software, data from the Indian Census, and air quality data from OpenAQ to show locations with high impact potential in the Delhi NCR region. Finally I end with recommendations for specific sites based on the site assessment criteria and the information shown on the maps generated.

RESEARCH QUESTION

Where in the Delhi NCR region of India should a new air purification technology be implemented in order to maximize economic, social, and environmental impact?

Delhi NCR Population Density and PM2.5



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2. "Air Pollution Deaths Cost Global Economy US$225 Billion." World Bank, September 8, 2016. http://www.worldbank.org/en/news/press-release/2016/09/08/air-pollution-deaths-cost-global-economy-225-billion.
3. Urban PM2.5 Atlas Air quality in European Cities, European Commission, 2017.
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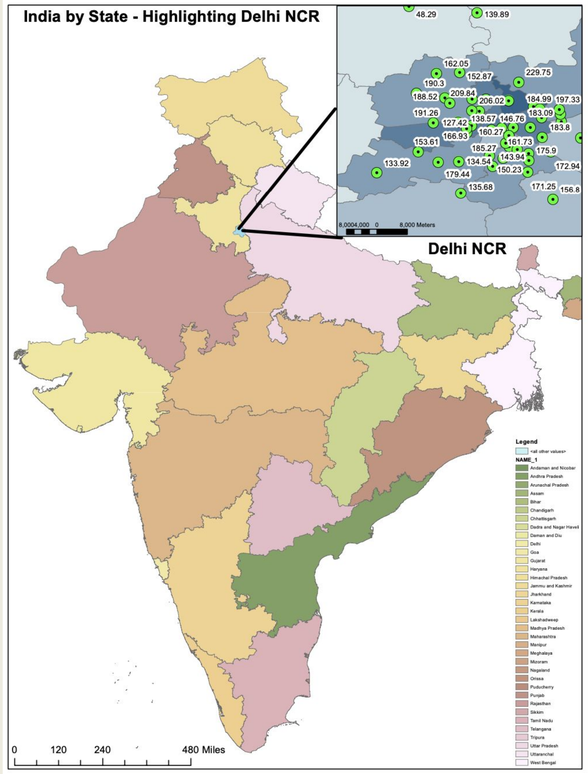
5. *Id.*
6. *Id.*

Data Sources:
1. India Census Data: https://www.censusindia.gov.in/DigitalLibrary/Tables.aspx
2. India Boundary Data: https://hub.arcgis.com/datasets/2b37b84e67374fb98577c20ef8be6c62_0
3. Air Quality Data: https://openaq.org/#/countries?_k=rw9lz7



METHODOLOGY

To understand which location in Delhi NCR would be the best application of an air purification unit, I assessed opportunity spaces based on ability for an air purification unit to maximize social, environmental, and economic impact. I focus solely on Delhi NCR as the cities in the NCR are among the most polluted and most densely populated and it seems this region has the most established market, political and media attention, and trial opportunities.

I assessed sites as high impact opportunity spaces based on the following criteria:

1. **High levels of pm2.5.** This data was sourced from OpenAQ's free data source. As pm2.5 is seasonal in Delhi NCR, I decided to focus on data from the peak season. I gathered data from the 76 sensors across Delhi NCR. The data collected for each sensor was the average of all hourly readings of pm2.5 levels from 10/1 to 12/31 of 2019.
2. **High population density.** Maximizing shared value requires the largest possible amount of people to be within the clean air radius of the air purification unit. This will allow us to maximize the social and economic impact. Population density in this study was calculated from census data (2010) and the units are persons per square meter.
3. **Estimated average time of exposure.** Not only do we want the greatest number of people benefiting, but an ideal application would involve persons spending a significant amount of time in the clean air radius.
4. **Estimated benefit to vulnerable persons.** Children are the most vulnerable group to air pollution exposure. Other vulnerable groups may include the poor, the sick, construction workers, pregnant women, among others.
5. **Access to electricity.** Air purification units require access to electricity to run fans that push air through the filters.
6. **Visibility.** Educational component of air purification. Will this application lead to increased pressure for air pollution mitigation efforts? Will it educate people, particularly the most vulnerable, about harms of breathing polluted air?

Maps and Data:

This analysis used census data and country boundary data from the Census of India website. The data used was from their most recent census (2011) and was local to the district level. I could not find any hyper-local data to do more targeted population analysis. Population density was calculated by dividing the number of persons in each district by the district area in meters.

Air quality data was sourced from OpenAQ.org's open data. As PM2.5 is seasonal in India, these maps show PM2.5 data from the peak season of October 1 to December 31, 2019. I downloaded the hourly PM2.5 readings for every sensor in the Delhi NCR region and took the average of their values. This data included latitude and longitude for each sensor.

Opportunity spaces were chosen based on the site selection criteria listed above. Once the spaces were chosen, I searched for the locations on google maps and cross-checked the accuracy with each location's website. Then I used a software to generate latitude and longitude and displayed the point layer. Some locations were manually added if there was an error when displaying the X/Y data.

Map 1 shows a point layer of PM2.5 levels over a chloropleth map of population density. They are labeled with values to show the severity of the issues in every part of Delhi NCR. **Map 2** shows India, shaded according to state, with a cut away to indicate where Delhi NCR is located to provide more context on the project. **Map 3** provides a new way of visualizing the air quality and population density data without displaying the numbers themselves and **Map 4** adds in points of interest by type -- highway, market, metro station, school, and university. **Map 5** shows these points of interest with their names so they can be identified easier. Recommended locations are highlighted in the site analysis section.

OPPORTUNITY SPACES

Schools

Considering all of the site selection criteria, schools are one of the most high impact opportunity spaces. Schools exist in all areas of India and Delhi NCR, so it is quite easy to target schools in areas that experience high pm2.5 concentrations. Likewise, it is easy to maximize targeted population size as school size will also indicate our population density. With this in mind, it is best to target large schools in highly polluted areas. Children are the most vulnerable group to air pollution, and children spend a lot of time at school each day, this also maximizes benefit to vulnerable persons and time exposure. Visibility is also likely to be high as tying air pollution mitigation efforts to children's health is a strong message that would resonate across many groups of people.

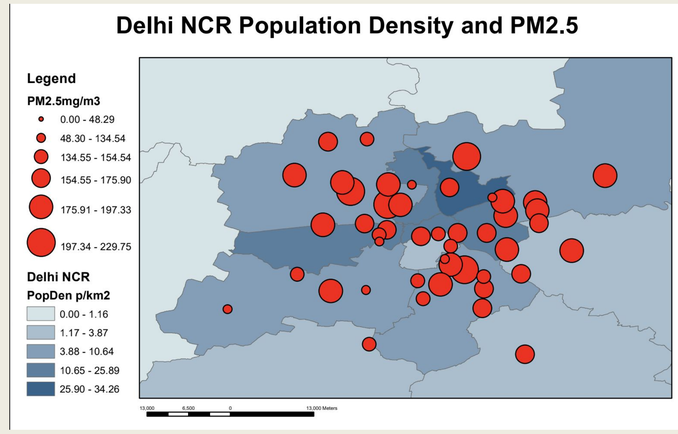
Public Transport and Highways

Delhi NCR is a region that experiences a great deal of traffic and road congestion. Many roads experience more traffic than their capacity limits. Highly congested highways and public transportation stops exist in all areas of the city and therefore can easily be chosen for high population density (traffic) and high pm2.5. This application may be the one that reaches the greatest number of people. Although not specifically targeting a vulnerable population, this application would be very equitable -- targeting all groups of people who use roads and public transport. The biggest weakness of this application lies in exposure time -- people may only spend 30 minutes at the bus or train station on their way to work. Though this application would reach the most people, it may not have a significant impact on any one individual. Despite the question of individual impact, this application may be the most visible opportunity. It would reach the most people and the most diverse groups of people, and it would be something people would see every day.

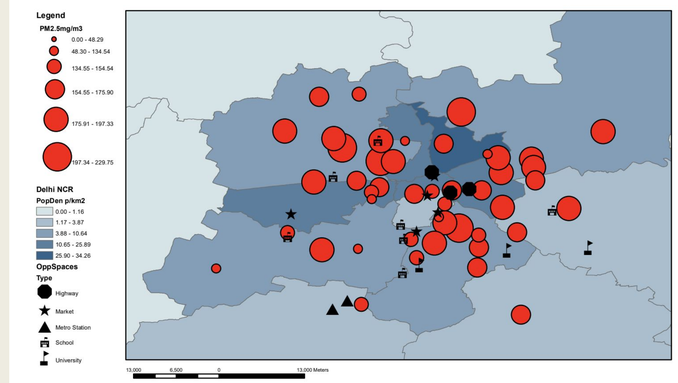
Shopping Centers - Malls/Markets

Shopping centers, malls, and markets are often large semi-enclosed or outdoor spaces in India. As these exist in all areas of the city, this application could target high pm areas. They are likely to have high population density as shopping centers and markets are often highly crowded in India. However the time exposure for most of the population would be relatively low as shopping is not an activity that consumes a large time frame in peoples' days. For workers in the malls or markets, exposure time would be high. This could be a socially equitable application as it would target diverse groups of people. This application benefits from likely having good access to electricity and water, as the mall and/or market would also need these to function, and high visibility. This application was chosen as the pilot site for the first smog tower.

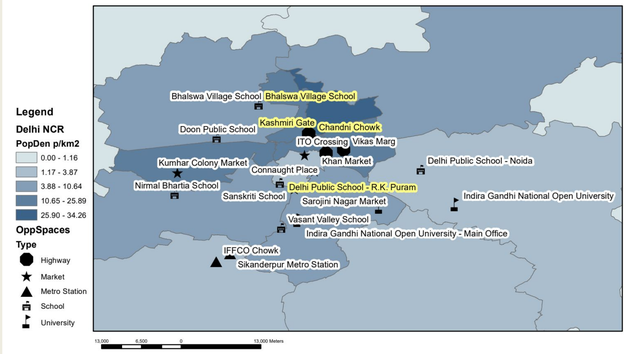
Delhi NCR Population Density and PM2.5



Delhi NCR Opportunity Spaces by Population Density and PM2.5



Highlighted Opportunity Spaces



RECOMMENDATIONS

Location Targeting:

Considering all of the site selection criteria, I have provided preliminary recommendations for locations that would create the most shared value: Bhalswa Village, Delhi Public School - R.K. Puram, Kashmiri Gate, and Chandni Chowk. Each of these locations has their unique opportunities and drawbacks, listed below.

1. **Bhalswa Village:** This residential area of Delhi has some of the post polluted air in the city. It also has very high population density in a small area. This location likely has the highest potential for creating social impact in the Delhi NCR region, however it does face challenges in other key criteria. First, this is a low visibility site as Bhalswa is a residential and non-tourist area. Likewise, it may have concerns with electricity availability, and these are criteria that can only be evaluated with on-the-ground knowledge.
2. **Delhi Public School - R.K. Puram:** This school was chosen as and ideal application as it is the largest school in Delhi, maximizing population density. Likewise this school seems like a compromise among the schools listed in targeting more vulnerable children. There is no sensor indicating air quality near this school, but this serves as an opportunity to increase monitoring at the same time that the unit addresses air quality.
3. **Kashmiri Gate / Chandni Chowk:** I combined these locations as they are very close in proximity and offer similar positives in their site evaluation criteria. Both are in a very highly trafficked tourist area and therefore are top of the list for population density and visibility. Chandni Chowk, as a market, may have higher time exposure for those who shop there, and the Kashmiri Gate may have higher PM2.5 with its location closer to traffic emissions.

Key Considerations and Next Steps:

1. **Expanding of monitoring:** The location analysis on this poster is only as good as the data available and currently there is a great demand for increasing monitoring of air quality in Delhi NCR and the whole of India. If monitoring were to increase, more hyperlocal recommendations and analyses would be able to inform policy decisions.
2. **Using the assessment criteria to measure impact:** Regardless of the site ultimately chosen, location analysis should be based on the criteria set out in the methodology section to maximize social, environmental, and economic impact.
3. **Air purification as an education tool:** One key consideration in site assessment was visibility. This is because increasing education about air pollution and the harmful effects of breathing PM2.5 is a good thing even if no air purification system is implemented. This means that educational campaigns either in conjunction with, or separate from, implementation efforts will increase the impact of the unit. This also applies to increasing monitoring of air quality.
4. **Partnership opportunities:** Each location offers unique opportunities for partnerships. Partnerships could be with the government (national, state, city), civil society (research institutions or universities), and/or other companies (real estate developers, private educational institutions, manufacturers). Each of these potential partnerships offers a different benefit, but all of them would increase the scope and impact of the application.

Limitations/Areas for Future Research

Limitations:

1. **Lack of Monitoring:** There is currently a great need for increased monitoring for air quality. With more air quality sensors, there would be more hyperlocal and accurate air quality data for Delhi NCR and the rest of India.
2. **On-the-ground Knowledge:** This project would be greatly enhanced with more on-the-ground knowledge. In depth understanding of each of the neighborhoods and locations unique challenges may be major considerations in location targeting for an air purification technology unit.

Future Research:

1. **Socio-Economic Data:** For this project I chose not to include socio-economic data because I felt it would overstretch the scope of the project and the data was not easy to find and/or download. This project could be greatly enhanced by using socio-economic data to aid in targeting of vulnerable groups by considering poverty levels in each neighborhood.
2. **Water and Electricity Mapping:** This data was not easily available but would greatly enhance this project. Understanding the status of electricity (including sources) and water (including water quality), at each location would be very helpful for understanding the suitability of each site. This would be aided with the on-the-ground knowledge mentioned under limitations.