How Sensory Technologies Could Be Leveraged to Drive Analytics & Combat Urban Pollution

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The Sensory Era

The 21st century has been a revolutionary era of technology. First came the smartphone, then shopping from that smartphone, then getting a cab from that smartphone, all the way to jet packs, self-driving electric vehicles, and even the first flight to Mars. Despite all the advancement in the world, cities are more difficult to manage than ever, with agglomerations of overburdening activities as well as lagging energy infrastructure and urban waste systems being key issues in many metropolises around the world. To simplify the complexity of urban living, cities must adapt with smart technology. The leading resource in smart technology for the past decade has been sensory technology. Electronic sensors are used to collect, measure, and analyze data. The sensors use insights gained from that data to manage assets, resources, and services efficiently. City planning has undergone great changes in the past century, altering the urban grid. Urban planners must come to the realization that smart city technology is necessary to ensure health in the modern city. In highly populated and fast-developing India, implementing smart city infrastructure can combat rising levels of urban pollution. India could implement smart sensor programs using previously successful models from global smart cities.

Comprehensive Pollutants

The most detrimental form of urban pollution to India is air pollution, which becomes a problem requiring innovative entrepreneurial thinking, so that we could help solve it with low-cost scalable solutions across its many fast-growing cities and urban areas. Air pollution refers to the release of pollutants in the air that are harmful to human health and the environment as a whole. We will specifically be focusing on the air quality of India using PM 2.5 and PM 10 levels (particulate matter) as a measurement. Particulate matter is a specific pollutant most deleterious to human health. The Indian city of Ghaziabad has high PM rates in the air according to the Air Quality Index (AQI). The AQI measures multiple air pollutants consisting of ozone levels, nitrogen dioxide levels, relative humidity levels, carbon dioxide levels, and PM 2.5/ PM 10 levels (https://www.iqair.com/us/india/uttar-pradesh/ghaziabad). To give you an idea of the problem of air quality in the United States and Ghaziabad, on April 26, 2021 the highest AQI in the US was 98 in San Diego, while the highest in Ghaziabad was 506 (https://www.iqair.com/us/india/uttar-pradesh/ghaziabad/vasundhara-ghaziabad-up-uppcb). This AQI trend is persistent across the two countries. It is necessary to understand the scale of the AQI to understand the value of these numbers.

There are six separate levels of air quality, with an AQI level past 300 considered inappropriate for outside exercise, due to the high risk of potential adverse health effects. On the other hand, the moderate AQI level in San Diego is considered to be relatively acceptable, still with exponential space for improvement with the facilitation of data-driven assessments and strategic allocation of resources. Many people who are sensitive to air quality may undergo light health concerns and advocate for innovative technologies to address this problem, therefore making this a shared challenge across borders in need of a collaborative environment for entrepreneurial thinking and practice-sharing, as here are indeed incentives in undertaking this venture (https://aqicn.org/scale). Now that the scale of AQI is understood, it is time to explain the background on particulate matter and the consequences that come with it.

Health Devastation

The pollutants referred to as particulate matter are PM 2.5 and PM 10. Particulate matter is a complex mixture of soot, smoke, metals, nitrates, sulfates, dust, water and rubber that are microscopic and hazardous to human health when ingested. The main difference between PM 2.5 and PM 10 is size. To explain its diminutive nature, we will compare the diameter of the particulate matter to a grain of fine beach sand and a strain of hair. Human hair ranges from 50-70 microns in diameter and a grain of fine beach sand sits at 90 microns in diameter, which in itself seems miniscule. When compared to PM 2.5 which is less than 2.5 microns in diameter and PM 10 which is less than 10 microns in diameter, you really understand the implications of the particulate matters' size. As a result of the size, PM 2.5 and PM 10 act as a gas resulting in mist or fog in high concentrations in India (https://www.jagranjosh.com/

general-knowledge/what-is-pm-25-and-pm10-and-how-they-affect-health). Due to the size of the matter it is able to travel deep into the respiratory tract, reaching the lungs when breathed in. The health services in India are unfortunately struggling, especially with the spike in Covid-19. Indian public health officials are starting to be aware of the multi-causal effect of air pollution when responding to Covid, so therefore it is necessary to stop air pollution at the root of the issue.

Man Versus Nature

The issue with combating PM is that it is produced both by human activity and natural processes. There are sources of outdoor and indoor PM. This indicates that for high PM areas, a sensory purifier to sustain breathable air and to avoid health concerns is seen to be a viable technology-based solution. Sources of indoor PM consist of cooking smoke, wood burning stoves (indoor and outdoor), tobacco smoke, burning candles, oil lamps, etc. On the other hand, we have outdoor sources of PM which are classified in primary and secondary sources. The primary sources of outdoor PM pollution come from vehicle exhausts, burning wood, heating oil or coal and natural sources like forest fires. Apart from that, there are secondary sources of PM due to reactions of chemicals like sulfur dioxide and nitrogen oxide. These chemicals are products of power plants: the gases then mix together reacting to produce PM (https://www.health.ny.gov/environmental/indoors/air/pmq_a.htm#:~:text=Fine%20particulate%20matter%20(PM2.5,hazy%20when%20levels%20are%20elevated).

Now that we know the sources of these pollutants, we can strategize for solutions. First we must be aware of the natural pollutants and focus on what humans can measure and have direct control over. Before that can be done effectively, we must investigate the healthy standards of PM exposure and compare those to India's current situation. The standards set by the US Environmental Protection Agency (EPA) will be the representation of a relatively healthy standard due to the generally low AQI levels in the US. The EPA's 24 hour average standard is set at 150 μg/m3 for PM 10 and 35 μg/m3 for PM 2.5 (https://www3.epa.gov/region1/airquality/pm-aq-standards.html). The US finds it relatively simple to enforce these standards;, for example the top pollutant San Diego, described above, displayed a high of 13.9 μg/m3 PM 2.5 and had PM 10 levels at a lower level (https://www.iqair.com/us/usa/california/san-diego). Comparatively, in the past week Ghaziabad has had a high of 126.8 μg/m3 PM 2.5 and a high of 419.6 μg/m3 PM 10 (https://www.iqair.com/us/india/uttar-pradesh/ghaziabad). This surpasses the relevant standards and provides clear evidence of the divergence in air quality between the US and India. There is still one more step before proposing any policy or action: we must examine what India is currently doing and its inadequacies to prevent or slow air pollution.

Efficient Allocation

A program put into place to combat air pollution is the National Clean Air Programme (NCAP) in India. This program aims to cut PM 2.5 and 10 levels by 20-30% from 2017 to 2024. In order to do this, power plant emissions as well as vehicle exhaust must be reduced with the goal of moving towards clean energy. This is an overly ambitious goal considering the irreversible reliance on power plants at this stage of Indian economic development. We speculate that the reason why the Indian government created this program, in cooperation with the Climate Summit hosted by the United Nations, was to extract funding and support, though due to the multidimensional nature of the issue, progress is often difficult to measure on the part of the UN. There are private sources of funding like the Indian-based Clean Air Fund that was granted more than $50 million in unrestricted funds from the 2017 Climate Summit (https://www.cleanairfund.org/publication/economic-impacts-india/).

The NCAP has so far not been able to hit its goals in the past years due to the difficulties arising from enforcement mechanisms. It is not only due to a failure of enforcement but a missed opportunity to tap into the powerful tool of sensory data and its positive effect as a game changer in combating emission-related issues in both the identification of the cause of excessive emissions as well as catered solutions in addressing the problems discovered. There is currently one monitoring station for air pollution for every 6 million people as of now, which is far less than what is needed, but indicating a potential for massive improvements and exponentially greater reduction of pollution if there were to be more. Some speculate the reason the NCAP has failed to reach any goals is because of the nationwide lockdown. Global emissions went down exponentially during the lockdown, making this argument invalid. The only real argument for failure is that it was not efficiently funded before this year. In 2019-2020 funding stood at $678,000 and just after one year funding has jumped to $63.01 million (https://www.orfonline.org/research/finding-solutions-to-air-pollution-in-india-the-role-of-policy-finance-and-communities).This seems like the NCAP would have a lot of money to work with for this year but after the funding is spread across 42 cities, each city is left with just about $1.5 million. Considering the magnitude of the issue this would only suffice for small projects.

Priorities

The Indian government so far has not allocated budgets adequately under the current circumstances of not sufficiently applying ample sensory data technologies. It spent over $345 billion in 2019, the same year that the NCAP had just over $500,000 in funding (https://www.theglobaleconomy.com/India/government_spending_dollars/). It is evident from our research that a lot more money needs to be devoted to alleviating the problem and addressing the root causes. Funding for clean air should be at least $146 billion – the reason being that this is the downside to which air pollution burdened the Indian economy in 2018. This is 5.4% of total Indian GDP in 2018, thus creating a massive economic incentive to move to clean energy. This should be the main incentive for the Indian government to contemplate implementing at the next climate summit due to its urgency and potentially innovative solutions and employment opportunities. This minor proposal is miniscule compared to the models we plan to suggest.

Bandwidth Limitation

Three models we would like to take key aspects from are Santander's sensor system, the energy street display of Brighton in the United Kingdom, and the air purifying skyscraper still being tested. Santander is Europe's smartest city with over 20,000 sensors keeping eternal watch over the human hive. These sensors help the city become more efficient in many aspects, from monitoring sprinkler systems and moisture to dimming street lights when no one is around. This saves Santander 50% on water and energy, a substantial amount for a city. This is attributed to the artificial intelligence technology communicated to and from these sensors.

There are many other ways sensors can be used in a city, for example there are acoustic sensors that detect emergency vehicle sirens and communicate with stop lights. This intelligent technology helps everyday life run smoother and can also tackle large scale issues that humans cannot control on their own. These technologies are expensive, and therefore there would have to be smaller steps in mass implementation in India. There are already large companies that specialize in air pollution sensors. A company based in California called Aclima uses block by block measurements to get a micro understanding of air pollution in cities. This will be extremely helpful in identifying the difference in pollutants by neighborhood. Their technology can gain insights on many pollutants, most commonly PM 2.5. If Aclima does not have the capacity to sign a government contract with India, we would recommend the government of India invest around $65 million in a government organization that would replicate Aclima. This would be beneficial infrastructure for future generations. The suggested figure of $65 million is because this was the amount of funding raised for Aclima's successful launch. This will help the government measure air pollution and assist it in reaching target emissions and maintaining health standards for their citizens.

First, India should utilize these sensors in a few separate neighborhoods in Ghaziabad to then utilize Brighton's energy display. This will not only give insights to the high pollutant neighborhoods but also create social competition among neighborhoods to lower the internal pollutants of their households. Once the data pinpoints the high pollutant neighborhoods this can help the government decide where they can replicate the innovative and cost-effective air purifying skyscraper.

Social Sheep

The next model we intend on gearing towards is Brighton's energy street display. Brighton used sensors to measure energy consumption on Tidy Street and displayed the energy usage on the street using paint. This display was updated weekly as a sort of social game the citizens could play. Twelve residents immediately signed up for this social experiment. This lowered the amount of energy consumed per household due to the social pressure to be more aware of your own usage. This is a tactic to engage the locals and bring awareness to the issue of overconsumption of energy. The people are very capable of understanding the issue of air pollution but with more awareness generation, there can be concrete actions to deter pollution at its root (https://www.theguardian.com/environment/blog/2011/apr/12/energy-use-households-monitor-electricity).

It is all about starting a conversation among the people. This will then incentivize both the local government to put forward policy changes and entrepreneurs to generate innovative methods derived from useful insights that will promote clean air in India. There are now two problems we face with enacting this. First, how to build a low-energy system that measures energy usage that directly contributes to air pollution. Second, how to effectively display this information to the public. On Tidy Street they were able to develop a low-cost, low-energy system to measure energy consumption. This is only applicable to the measurement of energy consumption rather than the measurement of energy that contributes to air pollution, so therefore we must take insight from this model and develop a similar model that can be applied to air pollution.

After looking into further policies around smart sensors in regard to air pollution, we found that many cities are utilizing the Internet of Things (IoT) to improve their efforts. In a Harvard article the authors explain the function of IoT as "networks of connected sensors that gather and send data. Using this data, cities can map areas of high pollution, track changes over time, identify polluters, and analyze potential interventions." (https://datasmart.ash.harvard.edu/news/article/how-cities-are-using-the-internet-of-things-to-map-air-quality-1025). Ghaziabad can utilize these technologies to develop better insight into where their air pollution stems from. Once they pinpoint these specific locations they can then implement models like Tidy Street and measure energy consumption in the high-pollutant areas, and then present this data in the city square to promote a sense of competition in the city. Each high-pollutant zone will be monitored and displayed separately. The end goal of this would be to lower energy consumption that contributes to air pollution from competitive energy displays.

Imperative Infrastructure

Last is a concept we were made aware of after finishing our article. After reflecting on the practicality of our previous proposal (sustainability models), modeling a skyscraper-sized 100-meter air purifier has seen preliminary success. This air purifier is one of the most cost-effective and a superb solution given it cost only $2 million dollars to build, and considering its size and preliminary, imperative function. "Built in 2016, the $2 million skyscraper, dubbed the solar-assisted large-scale cleaning system, stands atop an enormous glass-roofed greenhouse. Sunlight heats the air within the greenhouse, causing it to rise through the tower, where a series of air filters trap soot and other particles." One of the main particles that it is capable of filtering with its inbuilt technologies is PM 2.5, the largest air pollutant in India. So far, this air purifier implemented in many cities worldwide has reduced levels of PM 2.5 and drastically improved air quality, indicating the efficacy of this technology. The purpose of this purifier coincides with the goals of the NCAP. Considering the funding of the Clean Air Fund and NCAP it would be easily doable to build a fully functioning air purifier in Ghaziabad. Air pollution there is at a point where this would be necessary.

Before any plan is displayed, the Indian environmental department should raise funding of the NCAP exponentially and partner with the Clean Air Fund which has $50 million in unrestricted funds on its own. Once this is completed, the allocation and use of the funding should be displayed to the public after discussions with international environmental organizations. It is imperative that this funding is responsibly spent for the betterment of India's air pollution with expert opinions backed by international organizations and support from the local communities. Our plan will only require a fraction of the funding available to the Indian government and will be a scalable model for other cities. Air pollution sensors can cost anywhere from $100,000 to $300,000. We suggest a budget of $5 million for sensors, $1 million for a comprehensive display to the public and $3 million for the skyscraper-sized air purifier that costs $2 million. This would be an $8 million dollar project, only scratching the surface of the funds available to the Indian government.

A timeline for these expenses would look like this. Sensors would be implemented across Ghaziabad within a month; then it would be necessary to wait three months for data to be analyzed. Once we have the data on which neighborhoods produce the highest pollutants, we move to phase two, which is a public display of the data. This million-dollar endeavor would be displayed at the city hall in Ghaziabad for all citizens to see on their daily commutes. The display will take the sensory data and show a map of air pollution detection by AQI levels. This would make citizens aware of the level of effort required and hopefully create social competition amongst neighborhoods. The government can regulate energy-producing industries, but only habitual change will result in households limiting their air pollution.

Once the high-pollutant areas are made clear by the sensory data, phase three is ready for implementation. The highest pollutant neighborhood with available land will then be picked by government environmental scientists based on multivariate analysis. Once the air purifier is functional, the Indian public health department will closely monitor the impact of the purifier on the high-pollutant zone. If the results show that the purifier lowers pollutant levels then this experiment will be deemed a success. The remaining funds of the NCAP and the Clean Air Fund can be used to spread this model among the many Indian cities struggling to combat air pollution.

Depending on the initial insights from the sensors and social response of the city hall display, this plan could go in different directions. Regardless of the results, the data from the sensors will give Indian public health officials a good starting point on where the problems are coming from in Ghaziabad. The way that Indian public health officials can be convinced to move forward with this plan is by financial incentive. Air pollution costs Indian businesses about $95 billion per year, or 3% of India's total GDP. This cost is comparable to 50% of the taxes collected by the government (https://science.thewire.in/environment/air-pollution-costs-india-rs-7-lakh-crore-a-year). The reason the Indian government is yet to take action is due to the power in the hands of large energy companies. Our plan does not confront these companies, giving the government only an economic incentive to pursue lower PM 2.5 levels. An investment of less than $10 million will help lower the $95 billion burden of air pollution in the future. JS

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