Future Fleets:

The Potential for Vehicle Based Pollution Mapping

GEOTAB
management by measurement

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EDF
ENVIRONMENTAL DEFENSE FUND™

Finding the ways that work

About this report

This research was prepared by Environmental Defense Fund and Geotab.

Environmental Defense Fund combines cutting-edge science, economic expertise and unexpected partnerships to help high-impact companies transform business as usual in their products, operations, supply chains and advocacy.

Geotab connects commercial vehicles to the internet, providing advanced web-based analytics to better manage fleets. Processing billions of data points a day, Geotab leverages big data and machine learning to improve productivity, optimize fleets through the reduction of fuel consumption, enhance driver safety, and achieve stronger compliance to regulatory changes.

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Table of contents

Definitions

Roads: A road is defined as a road that a Geotab-equipped vehicle has traveled on or a road included in the Open Street Maps (OSM) data set. A road is then converted into a road geohash. Geohash is a public domain geocoding system, which divides the world into a hierarchy of grids and encodes them into a short string of numbers and digits. This analysis employs geohash level 7, which describes a grid of approximately 150 m by 150 m.

Top vehicles: Vehicles are ranked according to the number of passes they have made on all the road geohashes within a particular city or county.

Road coverage: A road is defined as "covered" when one or more of the top vehicles have passed a road geohash a minimum number of times within a set period of time.

Road coverage %: # of unique road geohashes covered / total unique geohashes.

Limitations

- *Road coverage.* Some small residential roads may not be included in the OSM data set or be passed by a Geotab-equipped vehicle.

- *Selection bias.* It is not possible to determine whether the driving patterns of Geotab customers differ in material respects from non-customers, or whether geographic characteristics such as road density differ in customer and non-customer locations.

- *Geohash 7.* Grid of approximately 150 m by 150 m is larger than the 30 m road segments that formed the smallest stable air pollution measurement in hyperlocal mapping pilots. Coverage at opposite corners of a geohash may not obtain the desired granularity of hyperlocal mapping. It is still far more granular than the coverage obtained by fixed networks.

- *Minimum passes for coverage.* This analysis employs 15 or 25 as the minimum number of passes. 25 passes may be more reflective of passes required in real-world driving conditions to obtain a stable measurement.

b Executive Summary

The following report introduces public and private leaders to the potential of fleet vehicles to collect hyperlocal insights into air pollution. Understanding the local, personal impact of air pollution could generate unprecedented urgency to protect public health and the climate. The goal of this report is to motivate new partnerships and innovation to improve the lives of hundreds of millions of people around the world.

Key Insights

- **New data shows new possibilities.** This first-of-its-kind analysis, based on a rich dataset generated from over 1 million Geotab-connected vehicles, demonstrates that private and public fleets have an untapped opportunity to help solve one of the most pressing environmental and health challenges of our time. A fleet could map 50% or more of a city with just 10 vehicles driving their regular routes. In Washington, District of Columbia, the top 20 public vehicles covered almost 70% of the entire city in 6 months.

- **New science shows the significant impact of air pollution.**[1] Air pollution costs the global economy $225 billion every year in lost labor income.[2] Measuring air pollution from **stationary** instruments located miles apart is insufficient, as dangerous air pollution can be eight times higher from one end of a block to another. An estimated 6 million premature deaths were due to air pollution in 2016.[3] Living in the vicinity of elevated traffic air pollution increases the risk of heart disease, surgery and death in the elderly by at least 15%.[4]

- **Hyperlocal data can motivate urgency that prompts new actions to protect health and the environment.** At a local level, hyperlocal insights could enable powerful new interventions, for example to plan clean transportation investments, enforce air quality laws, and demonstrate results of new policies and actions. As people organize, local success may inspire new coalitions to tackle audacious national and global goals.

- **A small number of vehicles can provide extensive coverage.** The modest number of public vehicles required to collect hyperlocal insights makes it clear that hyperlocal insights are within reach. Further partnerships are needed to achieve this potential, transform vehicles into an urban sensing platform, and accelerate innovation to improve the lives of hundreds of millions of people around the world.

The Houston Health Department is working with EDF on an air pollution mapping project using telematics and innovative mobile sensor technologies.

Credit: Marie D. De Jesús

According to a recent UPS and GreenBiz survey, the highest ranking concerns for business in the urban environment are air pollution and traffic congestion.[5] As 2.5 billion more people are expected to live in urban areas by 2050, traffic congestion and air pollution will only worsen without concerted action — further affecting business growth, employee health, and sustainability.

The status quo for tracking air pollution is not sufficient. To date, air pollution has been challenging to track and measure, in part because pollution data is collected by stationary monitors that are often dispersed miles apart. However, groundbreaking work in Oakland demonstrated that air pollution can be eight times higher within one city block.[6]


Figure 1: On the left, a traditional sensor. On the right, hyperlocal air pollution data from mobile sensors.

This feasibility analysis relies on advanced telematics and connected vehicle technologies. *Over 1 million commercial and public sector vehicles are equipped with Geotab telematics, representing over 50 million miles of driving every day.* These devices collect rich GPS location data, engine diagnostics, and a myriad of other sensor data to give users a detailed understanding of a vehicle's internal and external environment. For this project, Geotab and EDF collaborated to scope research questions that could clarify the feasibility of hyperlocal mapping for air pollution while still protecting customer privacy.

It is now clear that fleets have an untapped potential to make air pollution visible. In five of the cities evaluated, (see Figure 2: two fleets operate in the same city in California) a fleet could map 50% or more of the city with just 10 vehicles driving their regular routes, and almost 80% of the city with just 20 vehicles.

Figure 2: Examples of high road coverage from municipality or private fleets operating in small and medium sized cities.

Fleet 1, City in NY
Fleet 2, City in CA
Fleet 3, City in DC
Fleet 4, City in CA
Fleet 5, City in FL
Fleet 6, City in CA

Road Coverage from Aug-Oct 2017, Minimum Passes: 15

Road Coverage (%)

Top X Vehicles

Executive Summary
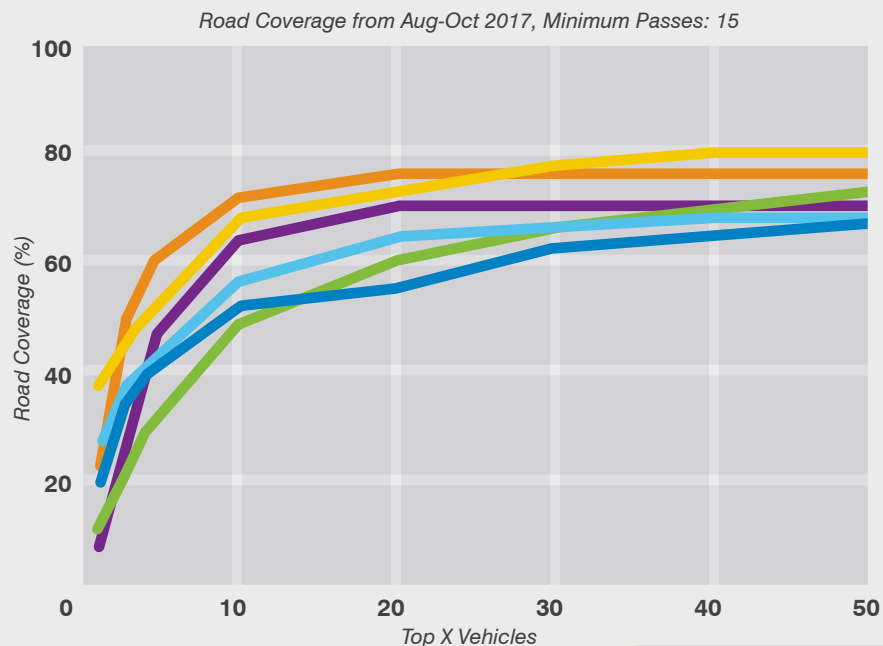
For example, in Washington, DC, the top 20 utility vehicles cover almost 70% of the city.

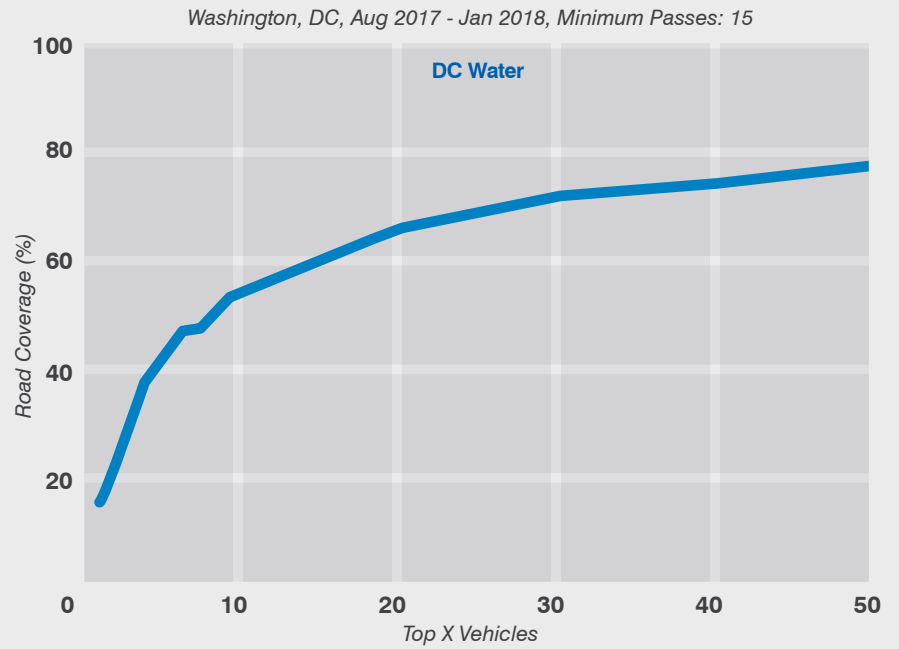Washington, DC, Aug 2017 - Jan 2018, Minimum Passes: 15

DC Water

Figure 3: The percentage of road geohashes covered in Washington, DC, from DC Water's top vehicles over the period of 6 months, with road geohashes having a minimum of 15 passes.

Enrique Cervantes with the Houston Department of Health and Human Services is collecting air quality data via sensors placed atop his municipal vehicle.

Credit: Marie de Jesús

5

Executive Summary
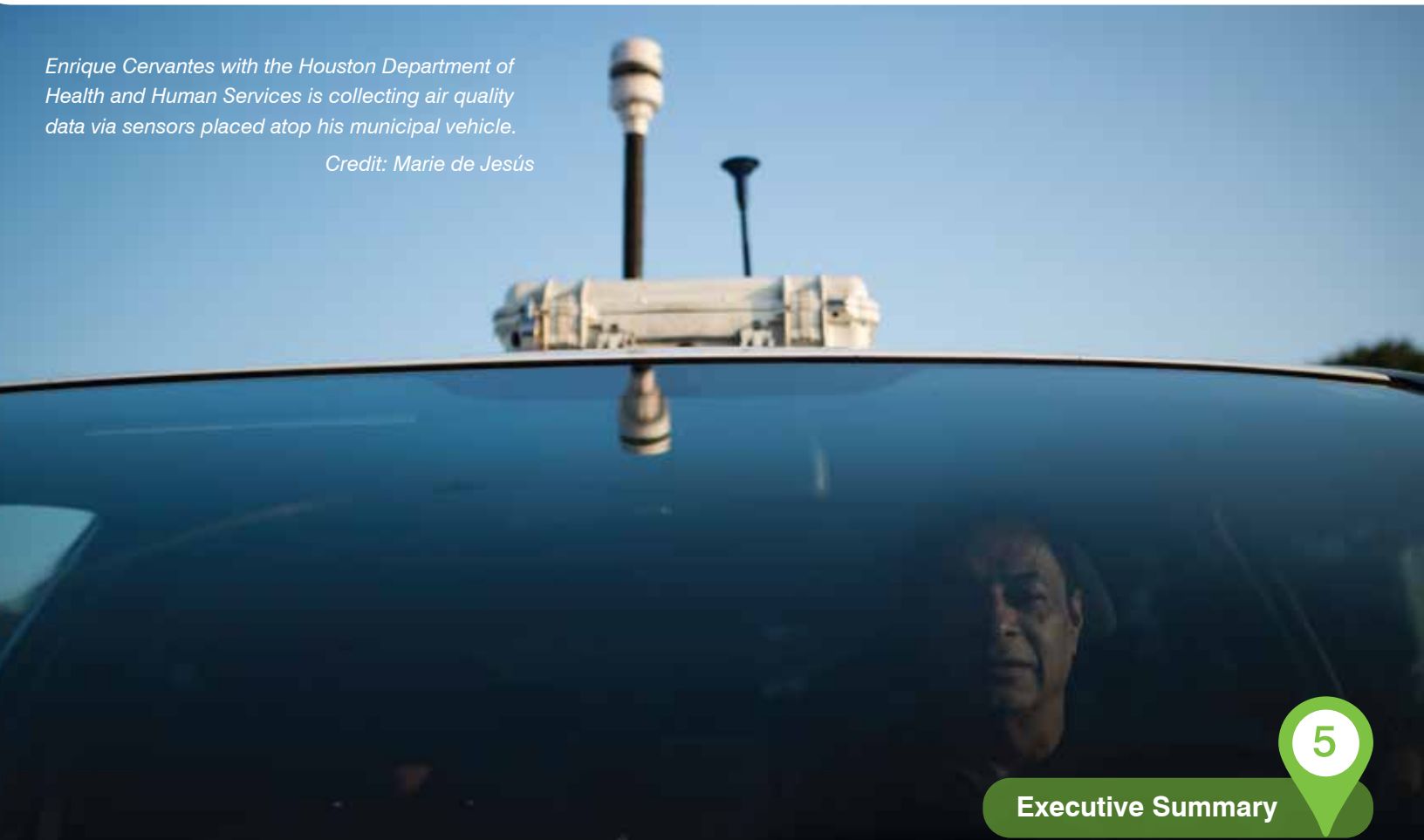
Hyperlocal insights—including pollution, its impact, and its sources—could generate urgent motivation to act at a local, regional, and national level. At a local level, hyperlocal insights could enable powerful new interventions. Cities are experimenting with policies, for example to support bike infrastructure, enable healthy communities, inclusive ride-sharing, establish climate-friendly building codes, and reduce traffic. Hyperlocal air pollution insights could infuse urgency and build consensus for funding and implementing those policies. As local organizing generates results, hyperlocal insights may inspire new coalitions to support national policies such as advanced fuel efficiency and electrified shared transportation.

For leading companies, hyperlocal insights provide a powerful tool to implement climate-friendly actions where they can make the most significant difference for public health. Companies with $16.7 trillion in market capitalization have committed to bold climate action.[7] *Ninety-one percent of C-suite executives agree that emerging technology can help the bottom line as well as the environment.*[8] Hyperlocal insights can help design and show impact of actions that bridge the gap between climate commitments and future-ready business models for mobility, decarbonized electricity, and safe, healthy buildings.

This analysis comes at a time of transition for public fleets. Fleets are investing not just in the move away from fossil fuels, but in technologies that enable vehicles to be smarter and safer. *Even with all this investment, fleets are still an under-appreciated resource in the fight against air pollution.* Understanding the potential of fleet vehicles to make air pollution visible may provoke new questions and areas for further innovation. Leaders can examine their own fleets and identify the few vehicles that are needed to create an urban sensing platform. As the demand for hyperlocal insights becomes more apparent, innovators can develop new sensor systems, analytics methodologies, and business models to make hyperlocal insights more widely available. As fleets become a comprehensive platform for insights—the eyes and ears of safer, smarter cities—the sensor revolution will start to live up to its potential to improve the lives of hundreds of millions of people around the world.

What has Hurricane Harvey got to do with air pollution? Hurricane Harvey was the strongest storm to hit Texas since 1961. It was also one of the wettest storms in US history — dumping over four feet of rain at one point in Houston.[9] Houston is home to extensive industrial and petrochemical facilities located on extremely flat land and interspersed with homes and businesses.

After the hurricane, EDF partnered with a tech startup to investigate suspicious smells using a specially equipped van. EDF found a plume of benzene, which is a toxic, flammable chemical found in crude oil and gasoline. Benzene is carcinogenic and can cause central nervous system damage and bone marrow damage.[10] The plume was coming from the Valero Energy refinery, which had been damaged by the deluge. Alarmingly, the Environmental Protection Agency reported that Valero Energy "significantly underestimated" the amount of benzene and other volatile organic compounds released from its refinery.[11]

This is an extreme example of a position many cities find themselves in every day. Managers may feel like they are always a little behind, responding to complaints of angry or scared residents after a danger has already started. They may not be sure if they are sending the right resources—such as sophisticated screening equipment and enforcement teams—to the right places at the right time. *Even when challenges are understood, leaders may be unable to convince stakeholders that local action is warranted, or may be frustrated by lack of momentum for change at a national or global level.*

Sometimes, leaders make policies and plans, and then cannot tell how well they are working. *There may be persistent, hard to explain gaps between the anticipated impact of a policy and the reality.* On the other hand, city leaders may believe a policy was quite effective, but do not have a way to prove that to residents. Many cities are trying to deploy new technology platforms in a way that actually makes a difference, and at the same time, incubate a community of leading entrepreneurs creating solutions that could be adopted around the world.

In this complex web, one unique resource is available to cities: public fleets. What if the next dangerous plume could be detected by regular fleet vehicles doing their regular job? What if quicker detection enabled city interventions that keep citizens out of harm's way?

Public fleets are an essential part of the fabric of any city. Buses, public works, animal control, utilities, and food inspection vehicles travel city streets all day and often into the night. Add onto that the private fleets under contract to or authorized by a public agency, including waste management and transportation, taxis and for-hire services, and a city is blanketed by vehicles it controls or influences.
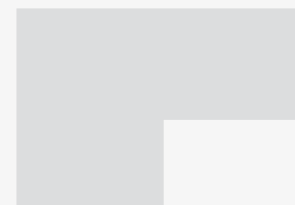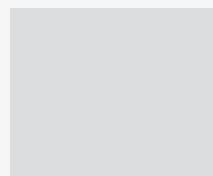
ii. Progress to watch for

Innovation and science will make it faster and cheaper to turn data into insights. EDF and others are developing a number of important tools:

- Data management and analysis tools to create combined insights from fixed and mobile sensing, and from high- and low-quality instruments

- Lower-cost, better quality air pollution sensors and methods

- Methodologies to attribute pollution to sources

- Methodologies to identify local health and economic impacts from air pollution

In addition to lower cost, validated instruments, a helpful improvement would be the development of a rental or lending model for mobile air pollution instruments. The combination of lower cost instruments and a rental or lending operational model would enable a city to prioritize vehicles that travel in high risk or high vulnerability neighborhoods and gather data at unprecedented granularity. As a result, leaders will be able to combine hyperlocal data about air pollution with tools to understand local health impacts and the sources of risky pollutants.

Analysis: Coverage within reach

What makes a public vehicle useful for air pollution mapping is a combination of factors that result in a sweet spot for hyperlocal insights. In terms of drive patterns, picture on one extreme a vehicle that repeatedly covers a tiny section of a city's roads, like a horse on a carousel. This vehicle may gather very accurate data on one spot, but it is likely not worth the expense of outfitting it with instruments. On the other extreme, a vehicle that ranges far and wide through the city. This vehicle will not gather enough data for a stable air pollution measurement. With one or two visits to any location, and the risk of being stuck behind a truck, or catching a strange gust of wind, the data is unreliable. Research shows that 10 - 20 passes at a minimum are needed for stable measurements.[12] *This analysis further demonstrates that a subset of 10 to 30 vehicles may offer that sweet spot of balance between repetition and variety of coverage to enable an urban sensing platform.*
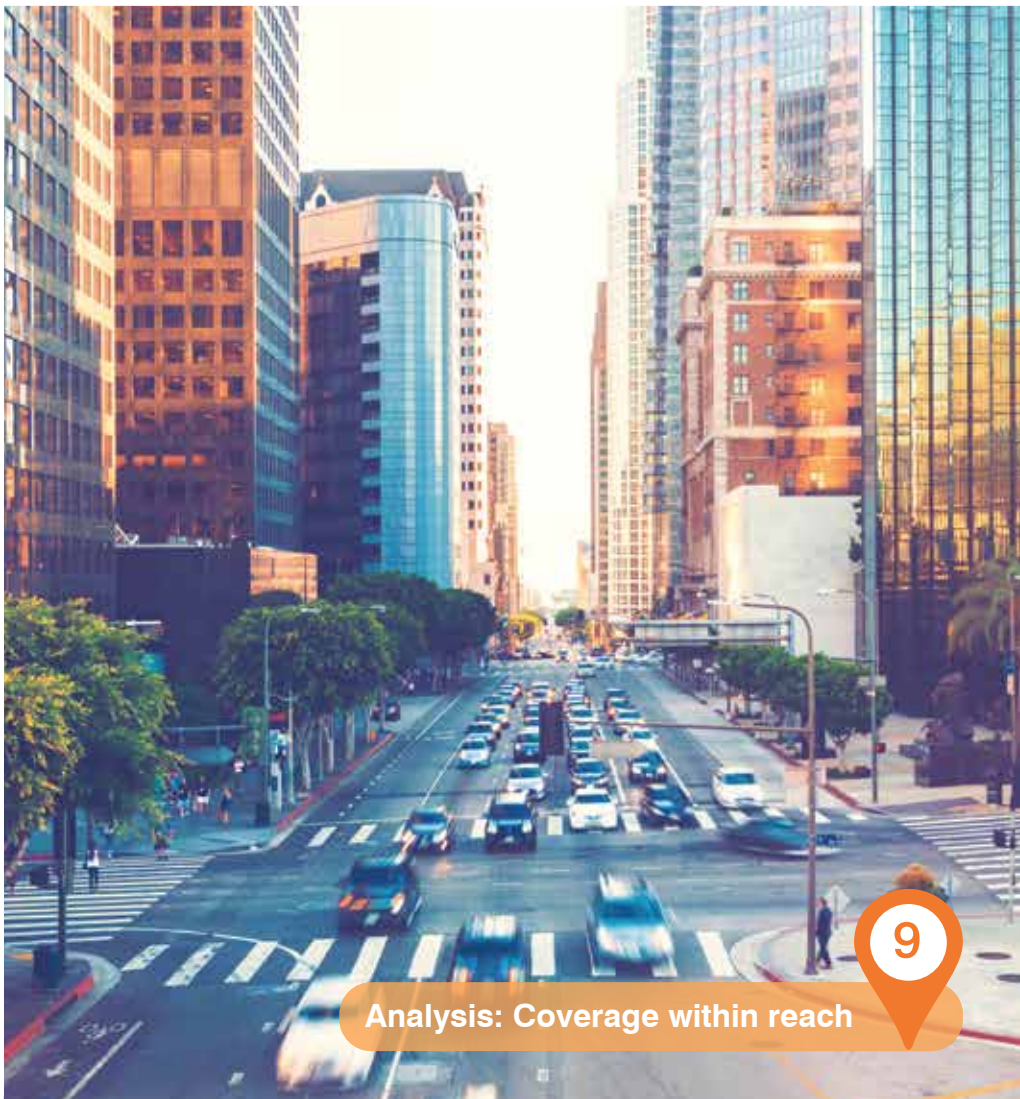
i. Objectives and methodology

The research objective was to use aggregate drive histories to evaluate how much of the urban footprint is covered by the most useful fleet vehicles achieving minimum repetitions of the same road segments over reasonable periods of time. Three and six month time periods were tested to determine how long it took for vehicles to cover a minimum of repeated passes on road segments. Drive histories of fleets in North American cities were grouped by the population size of the underlying cities or counties and averaged. In these groupings, population density was inversely related to population size.

The analysis also weighed road coverage by census-tract level population density in order to determine whether coverage was greater in denser neighborhoods. Population densities were binned into five groups. Distribution of road coverage by decile for each bin was then calculated. Typically, areas with higher population density have higher road coverage. This is largely due to the fact that dense population areas typically reside near major roadways, which is a significant factor.

Fleets have an untapped potential to make air pollution visible. In five cities, a fleet could map 50% or more of the city with just 10 vehicles driving their regular routes, and up to 80% of the city with just 20 vehicles.
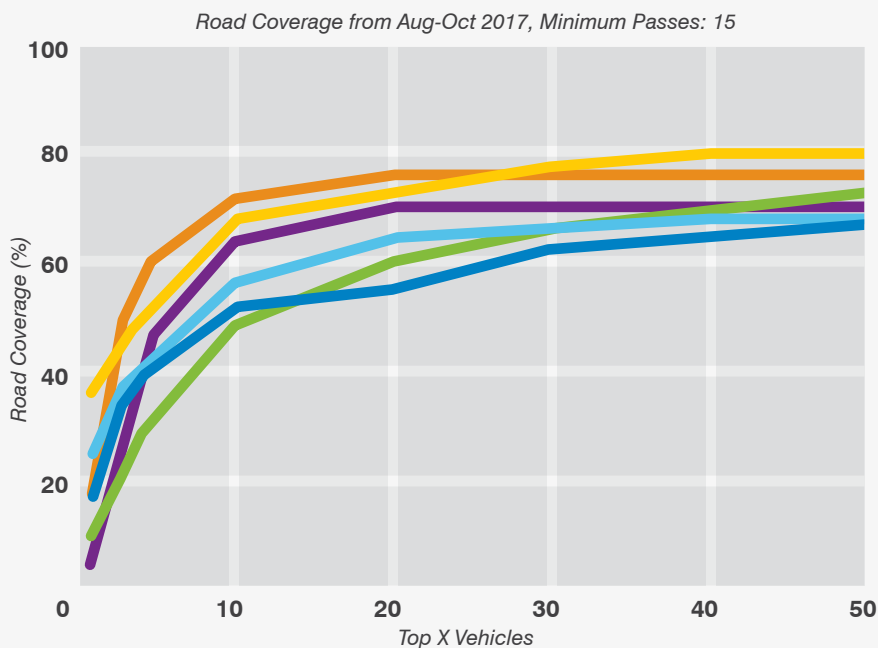
Road Coverage from Aug-Oct 2017, Minimum Passes: 15

Figure 4: Examples of high road coverage from municipality or private fleets operating in small and medium sized cities.

Fleet 1, City in NY
Fleet 2, City in CA
Fleet 3, City in DC
Fleet 4, City in CA
Fleet 5, City in FL
Fleet 6, City in CA

Analysis: Coverage within reach

ii. Case study: Washington, DC

Washington, DC, provides a window into what could be accomplished when fleets are enabled as sensing platforms. At 68 square miles, with a population of almost 700,000,[13] its population density is moderate.[14]

DC Water distributes drinking water and collects and treats wastewater. A fleet of 610 vehicles treats water main breaks, delivers drinking water, and maintains the infrastructure both above and below ground.

In six months, the top 20 utility vehicles covered almost 70% of the city (with minimum 15 passes). Much of the territory not covered by the city utility vehicles was federal and military land, and public parks.

In contrast, there are only five ambient air pollution monitors in the city, located miles apart.[15] *Imagine what new insights about hyperlocal air pollution the city could utilize if public vehicles collected air pollution data.*

Figure 5: A map illustrating the road geohashes covered in Washington, DC from DC Water's top 50 vehicles over a period of 6 months. The minimum number of passes for a road geohash to be considered covered is 15.
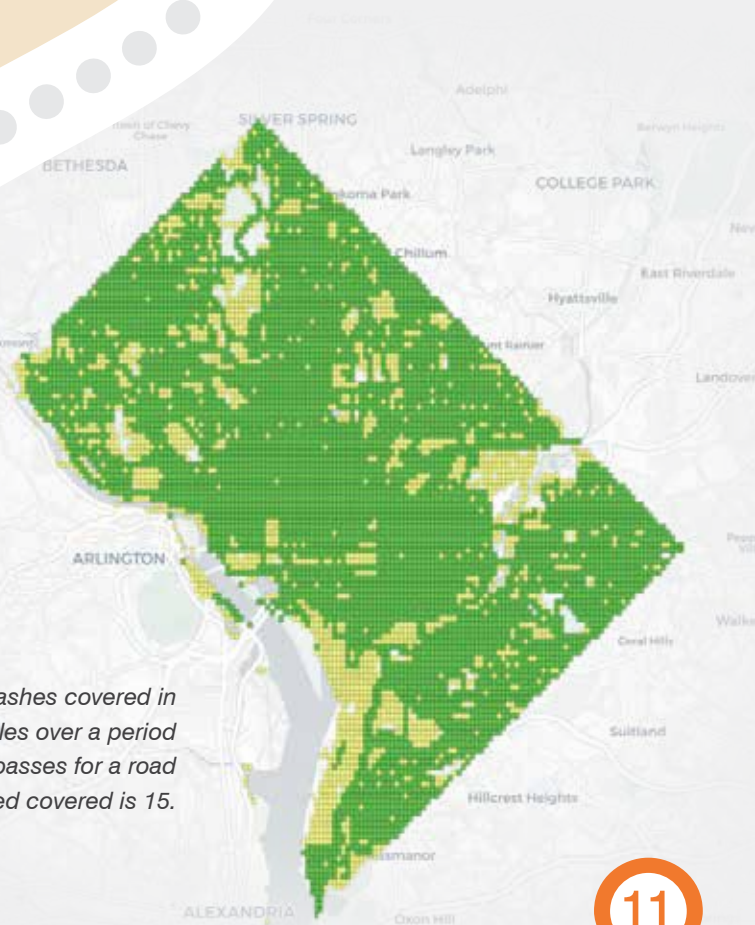
Hyperlocal air pollution insights could infuse urgency and inform actions to reduce congestion, support bike infrastructure, and electrify freight as well as shared transportation.
Credit: Marie D. De Jesús

Washington, DC, Aug 2017 - Jan 2018, Minimum Passes: 15
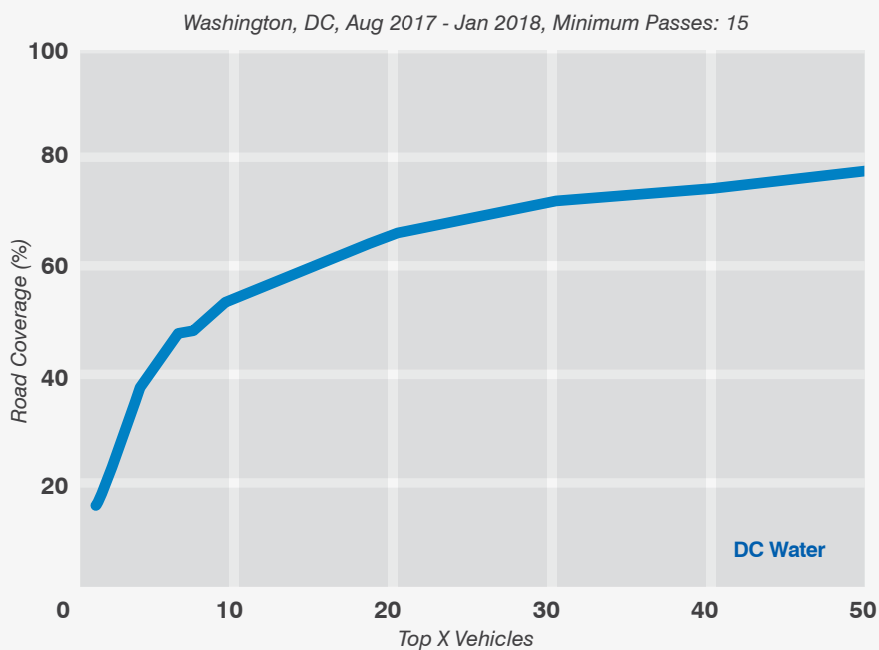
DC Water

Figure 6: The percentage of road geohashes covered in Washington, DC, from DC Water's top vehicles over the period of 6 months, with road geohashes having a minimum of 15 passes.

Analysis: Coverage within reach

iii. Small North American cities

In small North American cities, under 500,000 in population, averaging 60 square miles and a population density of 4,000 people per square mile, the top 20 public vehicles achieve 65% coverage in three months. If 25 passes are required to achieve a stable measurement, the coverage range drops slightly, to 55%. Even in a month, a small city could cover 45% using 20 public vehicles with 15 passes.

Average Road Coverage from City-Based Municipality Vehicles in Small North American Cities

Figure 7: The average percentage of road geohashes covered in small North American cities from the top vehicles from each municipality fleet considered. A period of one and three months with a minimum pass of 15 and 25 were analyzed.

Oct 1 - 31, 2017, MinPasses: 15
Oct 1 - 31, 2017, MinPasses: 25
Aug 1 - Oct 31, 2017, MinPasses: 15
Aug 1 - Oct 31, 2017, MinPasses: 25

Analysis: Coverage within reach
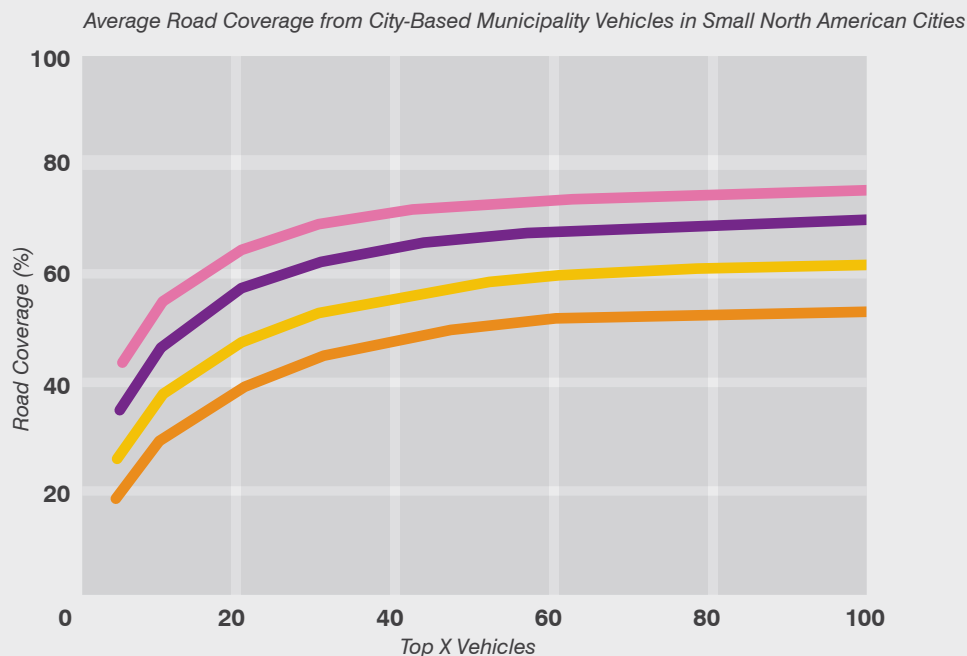
iv. Medium North American cities / counties

In medium North American cities and counties, 500,000 to 1 million in population, average 590 square miles and a population density of 1,800 people per square mile, lower population density corresponds to lower coverage of vehicles driving the requisite repeated passes in the time periods analyzed. Still, they can achieve almost 25% - 35% coverage in three months with 20 to 40 vehicles.

Average Road Coverage from County-Based Municipality Vehicles in Medium North American Cities/Counties
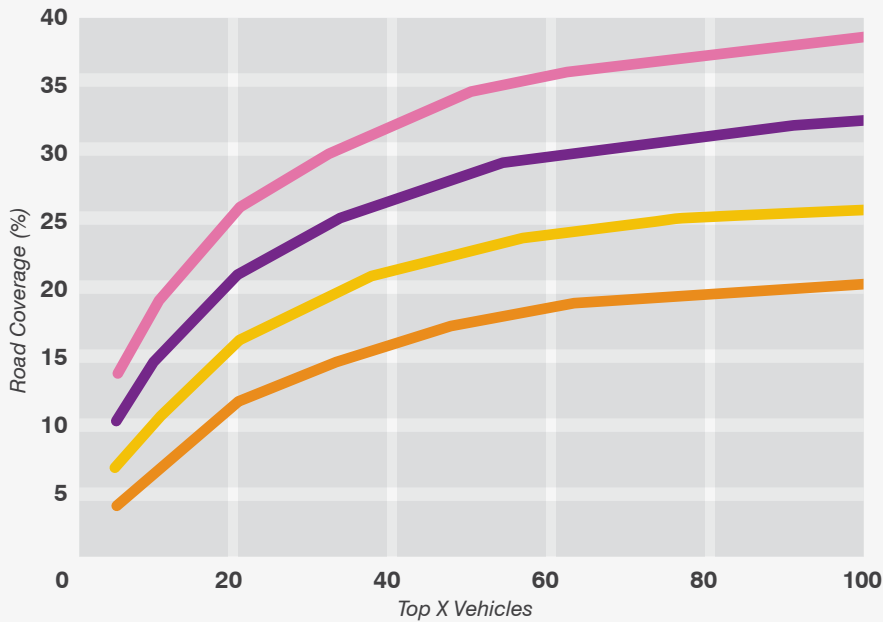

Figure 8: The average percentage of road geohashes covered in medium North American cities/counties from the top vehicles from each municipality fleet considered. A period of one and three months with a minimum pass of 15 and 25 were analyzed.

Oct 1 - 31, 2017, MinPasses: 15
Oct 1 - 31, 2017, MinPasses: 25
Aug 1 - Oct 31, 2017, MinPasses: 15
Aug 1 - Oct 31, 2017, MinPasses: 25

v. Large North American counties

Large cities and counties analyzed had an average population of 1.1 million and a land area of 950 square miles, resulting in a population density of 890 people per square mile. This analysis differs from small/medium-sized cities in that the "large" category assessed only county vehicles. The county vehicles tend to travel on larger roads, while the municipal vehicles assessed in small and medium cities have a denser and more varied drive pattern. Only looking at county vehicles in large cities and counties, the best 20 to 40 vehicles achieved 20%-30% coverage over six months.

Average Road Coverage from County-Based Municipality Vehicles in Large North American Counties
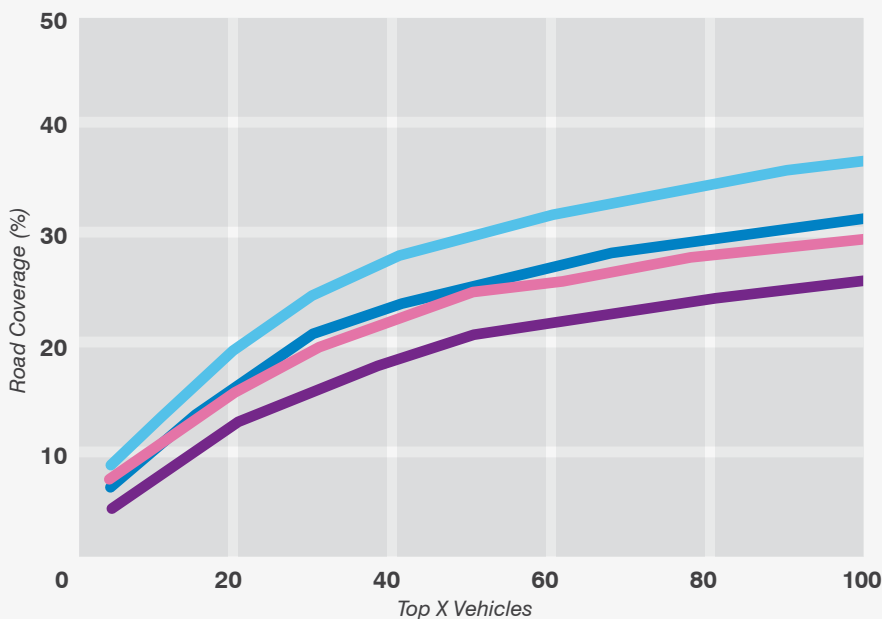

Figure 9: The average percentage of road geohashes covered in large North American counties from the top vehicles from each municipality fleet considered. A period of three and six months with a minimum pass of 15 and 25 were analyzed.

Dec 1 - Feb 28, 2018, MinPasses: 15
Dec 1 - Feb 28, 2018, MinPasses: 25
Sep 1 - Feb 28, 2018, MinPasses: 15
Sep 1 - Feb 28, 2018, MinPasses: 25

Analysis: Coverage within reach

Broadening the scope to the top private fleets that travel within one of the large counties, the public fleet did not provide the greatest coverage. Combining 10 vehicles from the top four private customers — 40 vehicles in total — achieves over 30% coverage. There are added logistical difficulties involved in installing instruments and collecting data from diverse fleets.

Public vs Top 4 Customers, Aug-Oct 2017, Minimum Passes=15
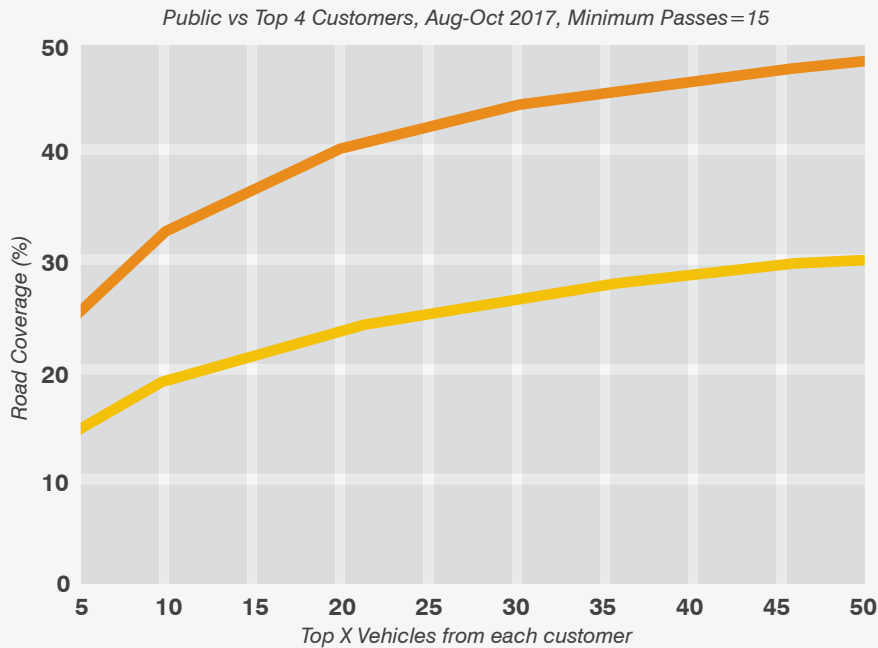
Figure 10: The percentage of road geohashes covered within a large county from public vehicles versus the top vehicles from the top 4 private fleets that operate within the county.

Public Vehicles
Top 4 Customers

Public vehicles on their own in large North American counties top out at less than 25% coverage using 40 vehicles in three months.

Average Road Coverage from County-Based Public Vehicles in Large North American Counties
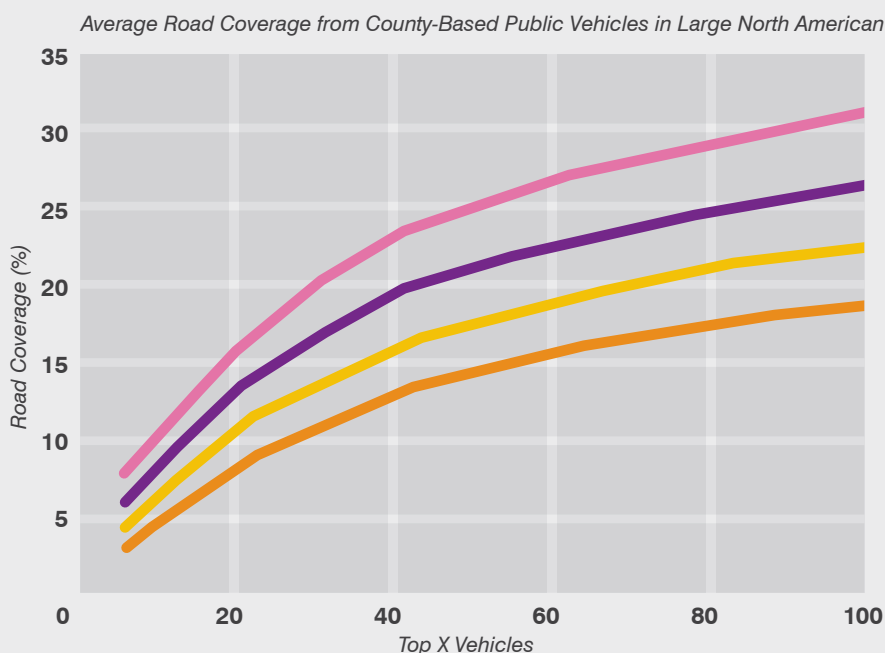
Figure 11: The average percentage of road geohashes covered in large North American counties from the top vehicles from each public fleet considered. A period of one and three months with a minimum pass of 15 and 25 were analyzed.

Oct 1 - 31, 2017, MinPasses: 15
Oct 1 - 31, 2017, MinPasses: 25
Aug 1 - Oct 31, 2017, MinPasses: 15
Aug 1 - Oct 31, 2017, MinPasses: 25

Analysis: Coverage within reach

Conclusion

Analysis and experience demonstrates that a modest number of public vehicles, enabled as urban sensing platforms, have the potential to transform the way a city understands air pollution.
Cities can investigate telematics data from their own fleets, and the fleets they directly influence, to identify those vehicles with the best balance of repetition and broad road coverage. In parallel, innovators can reduce the cost and improve the performance of mobile air pollution sensors. Combined with granular assessments of health and economic impacts and identification of sources, unprecedented air pollution insights could motivate urgent interventions. Public leaders viewing their fleets with curiosity and creativity, and innovator persistence, could direct the power of the sensor revolution to improve the lives of hundreds of millions of people around the world.

Public fleets can transform into urban sensing platforms and become heroes of a cleaner air story, notes Aileen Nowlan of EDF+Business.
Credit: Marie D. De Jesús

Endnotes

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