



Electrification of CTA Buses: Health Implications of Inaction

Acknowledgements

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1. Introduction: Pollution, Health, and Chicago Buses

Research has clearly established that air pollution has a negative impact on respiratory health^{i,ii,iii}. As one of the nation's largest urban areas, there are many sources of pollution in Chicago and a large vulnerable population for whom targeted government actions can reduce exposure threats to lung health.

One of the most harmful forms of air pollution is fine particulate matter (PM_{2.5}) created by cars, trucks, and buses. Fine particulate matter refers to extremely small particles that are suspended in air.^{iv} Those particles enter and penetrate deeply into the respiratory system, leading to illness and death, most notably from diseases of the lung and heart.

Reducing the amount of emissions from diesel-powered public transportation vehicles, particularly in dense urban areas like Chicago, can improve local air quality and reduce health risks. It is already well established that bus transit reduces overall contribution to pollution from transportation sources. Buses move greater numbers of people on less fuel and emit proportionately less greenhouse gases. Buses can also emit proportionately less ozone smog-forming and fine particle pollution compared to single occupant vehicles, but this can be highly variable. By carrying more people in a single vehicle, they also reduce congestion on roadways, hence reducing the emissions of the vehicles around them as well.

However, this is not to say Chicago's transit buses are non-polluting. They still operate primarily on diesel fuel and use internal combustion engines, releasing emissions that contribute to ozone smog, fine particulate matter, and global warming^v. A recent report noted that replacement of the Chicago Transit Authority's (CTA) fleet of more than 1,600 diesel-only buses with 100 percent battery-powered electric buses would save nearly 55,000 tons of greenhouse gases every year, equal to removing more than 10,600 cars from the road^{vi}. In addition, as the number of electric light-duty vehicles is expected to increase at an accelerating pace as the cost of such vehicles falls to the equivalent of internal combustion light duty vehicles in the next 3-5 years^{vii}, transit buses will have to electrify to maintain any tailpipe emissions advantages over single occupant, cab, and rideshare vehicles.

The Chicago Transit Authority and Electrification

The Chicago Transit Authority (CTA) currently has over 1,860 buses in its fleet, including more than 230 hybrid buses and eight electric buses. In October 2014, CTA became the first major U.S. transit agency to begin running daily electric bus service with the introduction of two electric buses manufactured.^{viii} In late 2020, the CTA will begin running six additional new electric buses. The deployment of these buses is the first step in CTA's plan to electrify all bus service on Chicago Avenue (Route 66) – a high-ridership route that runs between Navy Pier at the lakefront and Austin Boulevard on the city's western border. In 2021, CTA anticipates introducing 17 additional electric buses on this route. CTA's selection of Chicago Avenue as its first fully electric bus route was informed by analysis of the air quality benefits that electric bus service will provide in communities along the western portion of this route where, as reflected in Map 3 below, the prevalence of respiratory illness is among the highest in Chicago.

In April 2019, the Chicago City Council passed a resolution^{ix} that established a commitment to complete electrification of the CTA's entire bus fleet by the year 2040. CTA is working toward this target – not only with recent and near-term electric bus deployments – but also through the development of a strategic plan that will guide diesel bus replacement, charging infrastructure installation, garage facility upgrades, and electric bus operations and maintenance over the next 20 years. This strategic planning study, in process now through late 2020, will include an analysis of where to deploy electric buses first to benefit communities most vulnerable to, and adversely affected by, the health impacts of vehicle emissions.

These recent examples are not the first time the CTA has used electric buses. Transit companies that predate CTA in Chicago first started using electric trolley buses powered by continuous overhead wires in 1930. Those operations were later put under the control of CTA. At one time, the CTA was running over 700 electric buses on 16 major routes through the city. However, the last electric bus using overhead trolley wires ran in 1973, after which all CTA buses ran on fossil fuels until the addition of modern battery-powered electric buses in 2014^x.

Lung Health Study: Living Near Diesel Bus Transit Routes

With support from the Joyce Foundation, Respiratory Health Association collaborated with the University of Chicago's Center for Spatial Data Science (CSDS) and the Chicago Department of Public Health (CDPH) to better understand the link between Chicago Transit

Authority diesel bus emissions and health outcomes, specifically for asthma and chronic obstructive pulmonary disease (COPD).

Analyzing existing public health and CTA data, the Center for Spatial Data Science (CSDS) examined the ‘excess disease prevalence’ on residents living in proximity to high volume CTA bus routes, maintenance locations, and garages.

Key findings include:

- Proximity to ‘high’ bus routes and bus garages was associated with higher asthma and chronic obstructive pulmonary disease (COPD) rates.
- Areas at highest priority for electrification are census tracts with socially vulnerable populations within 500 meters of a ‘high’ route.
- The ‘high’ routes that pass nearby the most residents living within socially vulnerable populations are routes 9 (Ashland), 4 (Cottage Grove), and 49 (Western).

A summary of the methodology and preliminary analysis are presented below.

2. Approach and Methodology

To quantify the impact from diesel buses on residential health outcomes, a comparative analysis was conducted with matching to compare disease prevalence across both ‘high’ and ‘low’ volume bus routes. Higher pollution levels from diesel buses were approximated by identifying areas with more traffic from the bus fleet, using high ridership as the best available proxy. Bus garages and turnarounds were also identified, and 500 meter buffers were applied to capture maximum pollution effects. The health impacts of truck routes and distance to expressway were also considered.

It should be noted that buses can make up a relatively small proportion of the vehicles on a roadway. CTA has noted that along some busy roadways with CTA bus routes, their buses account for between 1.3 and 1.8 percent of the vehicles, in term of the Annual Average Daily Traffic Count from the Illinois Department of Transportation^{xi}. Yet, while buses may make up a relatively small fraction of the number of vehicles on the road, they are large, run on diesel fuel, and operate primarily on congested Chicago arterials.

Data Sources and Definitions

Daily bus ridership data, bus routes, garages, and turnaround shapes were sourced from Chicago Transit Authority data products made available via the City of Chicago Data Portal^{xii}. Truck routes were considered using data from the Illinois Department of Transportation (IDOT), and expressways using OpenStreetMap data. To approximate truck route exposure, census tracts were classified according to total length of truck routes intersecting each tract. To approximate the impact of expressways, for each census tract the distance from the center of the tract to the nearest expressway was calculated.

Asthma and COPD rates data was sourced from the U.S. Centers for Disease Control and Prevention's (CDC) "500 Cities: Local Data for Better Health Initiative" as small-area estimates approximating disease prevalence (percentage of population) at the census tract level for 2016.

High/Low Route Classification

Our goal was to identify and compare 'high' and 'low' bus ridership routes that intersected a similar number of census tracts, were located throughout the city, and except for bus ridership volume would be otherwise similar. CTA 'high'/'low' routes were identified using four-year (2013-2016) averages of daily weekday ridership numbers. Any routes with less than 13 months of data were removed. After data cleaning, a total of 125 bus routes were included for further analysis. Following an exploratory data analysis of bus route characteristics, ridership and route length thresholds were identified. Route length exhibited a weak relationship to ridership numbers and was included as a second dimension for 'high'/'low' classification.

Bus routes were classified as follows (Map 1):

'High' Routes (7)

- Average ridership greater than or equal to 20,000 riders per day, and
- Route length was greater than or equal to seven miles

'Low' Routes (12)

- Average ridership was between 7,000 and 10,000 riders per day, and
- Route length was greater than or equal to seven miles

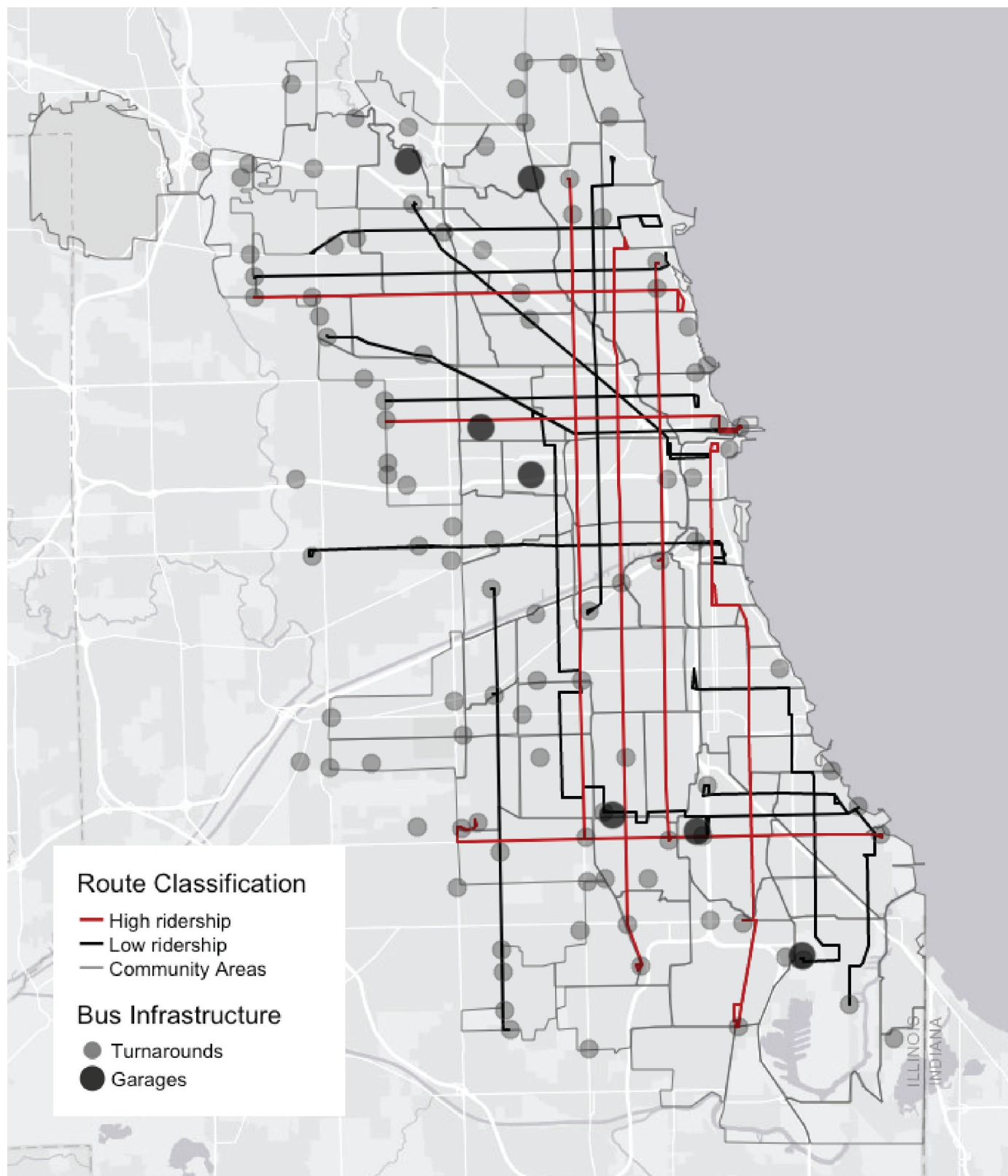
Other Routes (106)

- All other routes

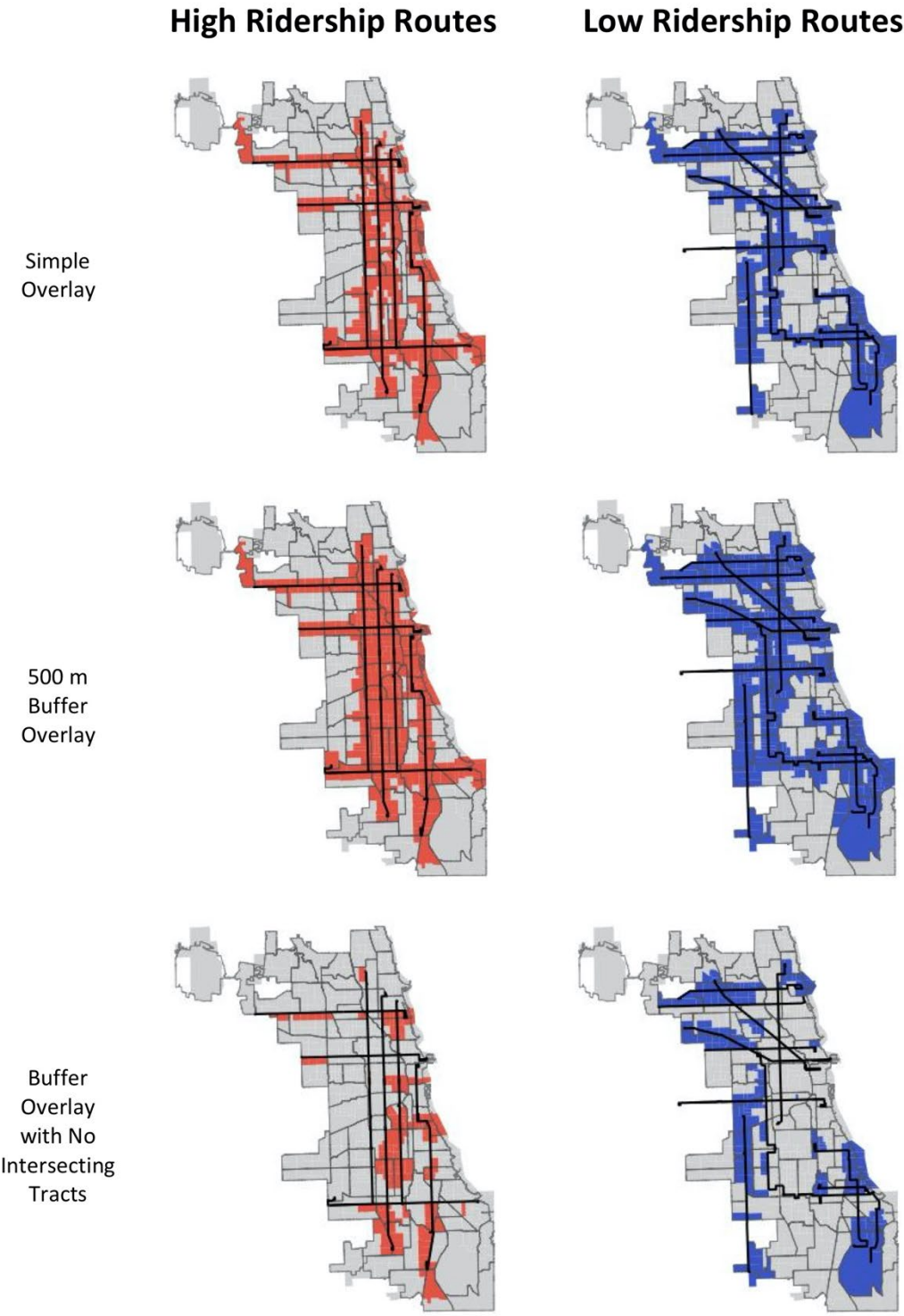
Census Tract-level Analysis

For census tract-level analysis, the 19 classified routes were overlaid on tracts in three ways (Map 2):

- A simple overlay with no buffer included 283 'high' and 307 'low' census tracts.
- Adding a 500-meter buffer around each route captured 410 'high' and 449 'low' census tracts. The buffer distance of 500 meters was selected following the findings from Karner et. al. (2010), a meta-analysis on 37 road monitoring studies. The same distance is used in EJSCREEN, the U.S. Environmental Protection Agency's Environmental Justice Mapping Tool (2019), to define proximity to traffic.
- Subsetting to exclude overlapping tracts with a 500-meter buffer around each route resulted in 152 'high' and 191 'low' census tracts. In this case, each tract could only be in a 'high' or 'low' route. This was the most conservative approach and while resulting in a smaller number of tracts, it may provide the clearest picture when considering health impacts.

Map 1: CTA Infrastructure: High/Low Ridership Bus Routes, Turnarounds, and Garages

Map 2 Panel: High/Low Route Classification Approach



Descriptive Statistics

To identify any significant changes due to bus ridership classification, average asthma and COPD prevalence rates and variability were calculated for ‘high’/‘low’ ridership route census tracts and compared to the rest of the city. Impacted geographies were based as calculated populations living within 500 meters of ‘high’ bus routes. Summary statistics included the total length of truck routes and minimum distance to expressway for tracts.

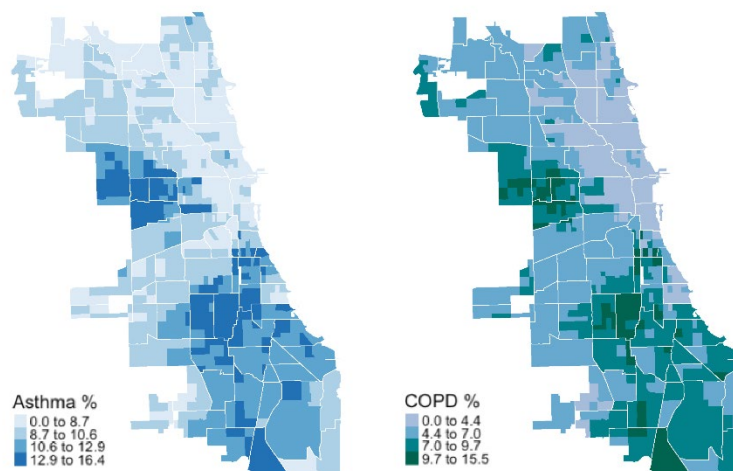
CTA route electrification recommendations were based off estimated population living within 500 meters of ‘high’ bus routes that also reside in socially vulnerable areas, defined as those whose social vulnerability index (SVI) is above average city levels. The SVI refers to the demographic and socioeconomic factors that affect the resilience of communities, as further described below.

3. Findings

Asthma and Chronic Obstructive Pulmonary Disease Prevalence in Chicago

In Chicago, 10.2 percent of adults have been diagnosed with asthma. Across census tracts, prevalence ranges from 0 percent to 16.4 percent (Map 3)^{xiii}. Chronic Obstructive Pulmonary Disease (COPD) rates range from 0 percent to 15.5 percent of census tract residents, with a citywide rate of 6.05 percent. It is widely believed that COPD prevalence is largely under-diagnosed in the U.S. and that the actual number of persons living with COPD could be twice as high as what is reported.

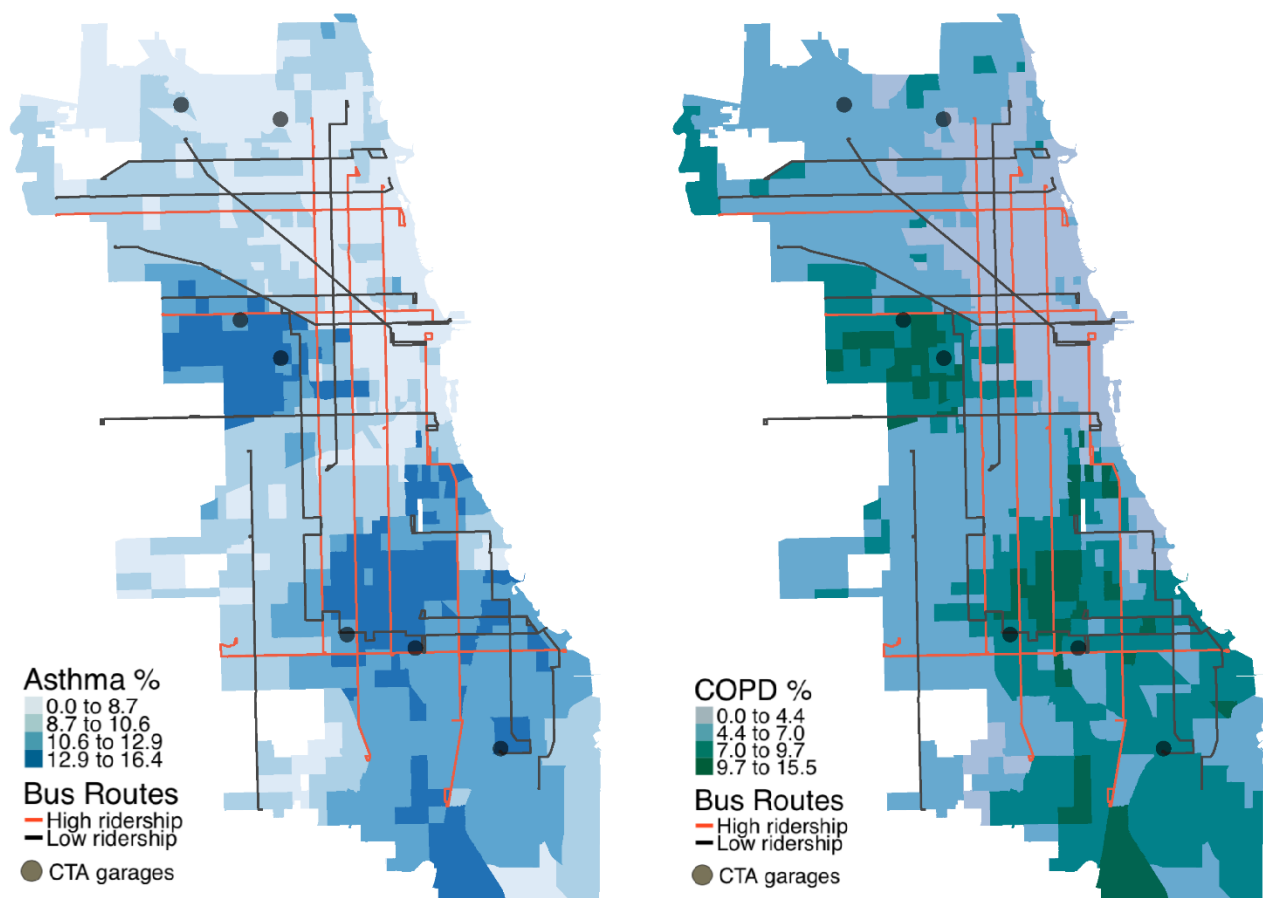
Map 3 Panel: Asthma and COPD Prevalence (%) by Tract with Community Area Boundaries



Asthma and Chronic Obstructive Pulmonary Disease Prevalence Relative to CTA Garages, 'High'/'Low' Routes, and Turnarounds.

While the findings detailed in Figures 1 and 2 below focus on the 'high'/'low' routes with no overlapping census tracts, in all three groupings of 'high'/'low' census tracts, areas nearest high-ridership routes had a significant association with increased asthma and chronic obstructive pulmonary disease (COPD) rates (Map 4).

Map 4 Panel: Asthma and COPD Prevalence (%) by Tract with High/Low Ridership Routes and CTA Garages

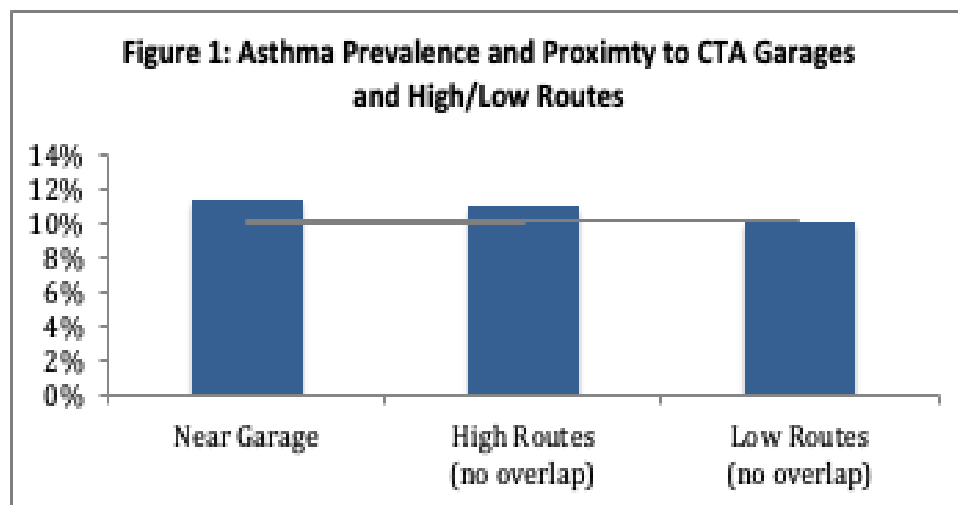


Relative to the rest of the city:

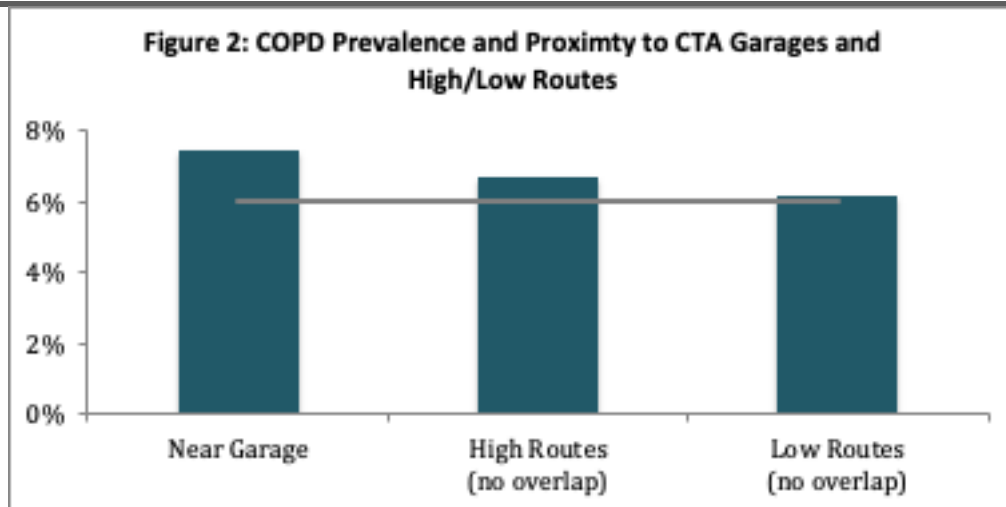
- Higher asthma and COPD prevalence rates were found in census tracts overlapping high ridership routes, and
- Higher asthma and COPD prevalence rates were seen for tracts near Chicago Transit Authority garages.

Notably, lower asthma and COPD prevalence rates were observed for census tracts nearest the 106 Chicago Transit Authority (CTA) bus turnarounds. This finding was unexpected as one would expect more bus idling at turnarounds.

As previously noted, an estimated 10.2 percent of Chicago's adult population is living with asthma. As reflected in Figure 1, residents living nearest to one of the seven CTA bus garages have asthma rates of 11.49 percent, a rate more than 12 percent greater than the citywide average. Persons living within 500 meters of the seven high-ridership routes have asthma rates of 11.08 percent, 8.4 percent greater than the overall city rate. Asthma rates among those living near low-ridership routes are slightly lower than the citywide rate.



While fewer Chicago adults have been diagnosed as living with chronic obstructive pulmonary disease (6.05 percent) than asthma, the disparities among those living nearest to CTA garages and high ridership routes are greater (Figure 2). COPD rates among residents living near garages (7.48 percent) are 23.6 percent greater than the citywide average, while rates among those living within 500 meters of high-ridership routes (6.69 percent) are 10.6 percent higher. Unlike asthma, where people living near low-ridership routes have rates lower than the city average, the rate of COPD among residents near such routes (6.21 percent) are less than 3 percent greater than Chicago's average COPD rate.



Exposed Communities and the Role of Social Vulnerability

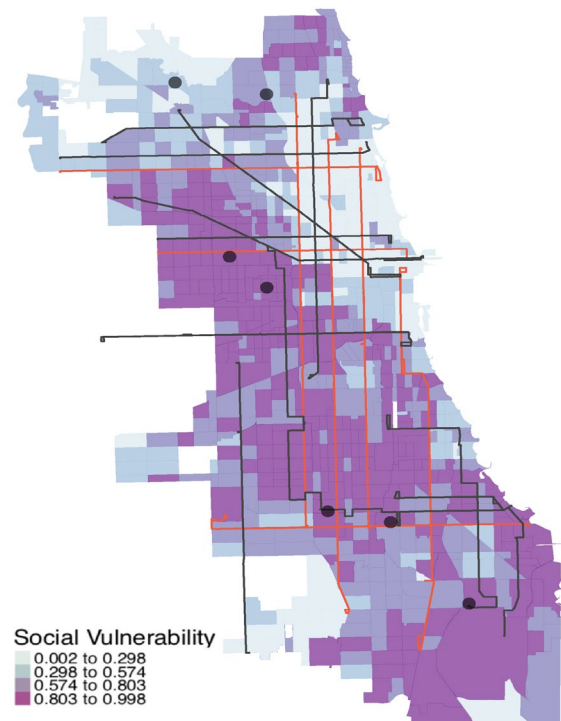
In 20 of Chicago's 77 formally designated community areas, a majority of residents are living within 500 meters of a high-ridership bus route. The communities with the highest proportions of residents living within 500 meters of a 'high' bus route were:

- Oakland, 97%
- Near South Side, 92%
- Lakeview, 89%
- Douglas, 80%
- The Loop, 77%

When considering respiratory disease rates reflected in these communities, the complex relationship between pollution exposure and underlying social vulnerability must also be considered. Research suggests a strong relationship between social vulnerability and health outcomes, including respiratory health conditions.

Disadvantaged communities generally face an increased risk of respiratory ailments in high traffic density areas.^{xiv,xv} Residents

Map 5: Social Vulnerability Index



The SVI is shown on a scale of 0-1, with higher values corresponding to higher social vulnerability.

experiencing higher stress in resource-deprived neighborhoods may thus be more sensitive to *any* pollution exposure, as compared to residents residing in wealthier, less stressed areas.

The Social Vulnerability Index (SVI) is incorporated to better account for these disadvantaged areas. The SVI was developed to help identify the locations of vulnerable populations.^{xvi} It refers to the resilience of communities when confronted by external stresses on human health, such as natural or human-caused disasters, or disease outbreaks.^{xvii} The SVI is compiled through a combination of 15 variables across four categories: (1) socioeconomic status, (2) household composition and disability, (3) minority status and language, and (4) housing and transportation.

When recommending bus routes for electrification, *both* exposure and underlying social vulnerability are considered. The most vulnerable areas were within 500 meters of a high traffic route, and also had a social vulnerability index value greater than the city's average.

Other Considerations and Limitations

For tracts used in the analysis, distance to the nearest expressway was associated with a mild increase in worse health outcomes. Truck routes were not associated with a change in either direction because they were located throughout the city; their impacts may thus be averaged out in a comparison study.

There are several limitations in the analysis. High-ridership routes were used to approximate high-traffic areas and emissions, though direct measurements of emissions were not available. While the health measures used estimated asthma and COPD prevalence, the dataset used imputed these rates and did not provide direct measurements. Because the analysis was conducted at the census tract-level, individual-level differences are missed.

To measure the *impact* on areas with higher pollution from diesel buses on residential health outcomes, the work done here was extended with a quasi-experimental analysis to compare disease prevalence across both 'high' and 'low' ridership routes, controlling for underlying social vulnerability. Preliminary findings showed that high ridership bus routes (relative to low ridership routes) were associated with a small but significant increase in respiratory disease incidence at the tract level. The interaction between underlying social vulnerability and exposure to high ridership routes was even more pronounced, though

more research is needed to account for total traffic volume. These findings and further decompositions of confounding factors will be published in future work.

While an association between higher ridership bus routes and health outcomes was found, this remains a correlation (not causation). Bus volume is only a fraction of street traffic and may vary by location, as well as along the route length. Routes with more CTA bus traffic likely approximate commuter corridors, expanding traffic pollution exposure across multiple transportation modes. More vulnerable populations may also live near these commuter corridors to increase transit accessibility, and/or take advantage of more affordable housing along some busy streets. At the same time, areas with less public transit options can see increased modes of other vehicular traffic, promoting increased traffic pollution. Localized pollution differences between areas close and far from major transportation routes may be a factor, as there are differences between the pollutants produced by diesel engines used primarily by bus and commercial truck vehicles and those produced by gasoline engines that overwhelmingly power light duty passenger vehicles.

The intersection of these factors is an important area of future research in the work of environmental justice and reducing health disparities. Reducing a component of traffic pollution via bus electrification remains an invaluable opportunity for the city.

4. Recommendations and Discussion

Routes for Electric Buses

There are seven high-traffic bus routes, six of which impact over 50,000 residents living within 500 meters of the route. The high-ridership routes that pass nearby the most residents living within socially vulnerable populations are routes 9 (Ashland), 4 (Cottage Grove) and 49 (Western). These routes, as illustrated in Figure 3, have the most pressing need for electric buses based on the potential exposure of bus-related air pollution to nearby residents.

It bears noting that all these routes intersect areas in the top three deciles of the city of Chicago's recently released Air Quality + Health Index, which is designed to highlight community level data on air pollution, health, and social factors to identify areas in the city that are most vulnerable to the effects of air pollution^{xviii}

High Ridership Routes and Estimated Population Impacted	
Most Vulnerable Routes	Population Impacted ^{xix}
Route 9: Ashland	98,222
Route 4: Cottage Grove	82,345
Route 49: Western	77,663
Route 79: 79 th Street	65,625
Route 77: Belmont	58,715
Route 8: Halsted	53,433
Route 66: Chicago	42,605

The Promise of Electrification

The Chicago Transit Authority has committed to reducing emissions from its buses, including pollutants that impact respiratory health as well as those that contribute to climate change. This commitment builds on the vital role that CTA's bus system already plays in reducing emissions from personal car use throughout the Chicago region, while also providing affordable access to jobs, education, healthcare and other services – especially for disadvantaged populations.

The CTA has recognized the environmental, health, and cost benefits of electric buses, reporting that the reduction in harmful emissions by operating just one electric bus reduces respiratory diseases and other illnesses at a value of \$55,000 annually or \$660,000 over the expected 12-year lifespan of a bus.^{xx} Additional net fuel cost savings are estimated at more than \$25,000 per bus, or more than \$300,000 over a bus's lifespan. Applying these savings to the remaining fleet of diesel buses translates into more than \$1 billion in health cost savings and \$495 million in saved fuel costs.

There are significant upfront costs for electrification. In recent years, electric buses had cost up to \$900,000 each, compared to the approximate \$500,000 cost of a new diesel bus. Yet, this compares favorably with the \$2.5 million price tag for the first two electric buses purchased by CTA in 2012. Prices for electric transit buses have come down due to increasing production and lower battery prices, with reports estimating average cost of \$750,000^{xxi}. Electric vehicle battery prices – a huge component and driver of the cost of any electric vehicle – fell 87% between 2010 and the end of 2019 and were projected to fall another 50 percent from that level by 2023 because of technological improvements and growing markets. Prices are also expected to continue falling for years beyond 2023^{xxii}. There are also additional anticipated costs for upgrading the CTA infrastructure, including charging stations and bus garage facilities. The CTA is currently conducting a study to get a more complete understanding of the financial and other requirements that must be met for a fully electric fleet.

Policies to Accelerate the Transition to an Electrified Chicago Transit Authority Bus Fleet

1. Ensure that electric bus charging facilities are incorporated into updated electrical codes and regulations to support timely and efficient construction of such facilities, which will accommodate additional electric buses on the system.
 - Provide that the city of Chicago's new franchise agreement with ComEd minimizes costs and delays in electrifying the CTA bus system.
2. Establish electric utility incentive programs to support the deployment of electric transit buses, particularly the development of charging infrastructure.
 - The Illinois Clean Energy Jobs Act (CEJA) pending in Springfield requires ComEd to invest \$25 million annually in electrifying diesel fleets, prioritizing charging infrastructure for public fleets and allowing for grants to purchase electric transit buses.
3. Prioritize electric transit buses and charging infrastructure in the allocation of existing one-time Illinois funding sources for clean transportation.
 - Approximately \$88 million from a court settlement with Volkswagen can be spent on electric buses and associated charging infrastructure.
 - \$70 million in the Illinois 2019 Build Illinois capital spending plan is specifically dedicated to transportation electrification infrastructure project and was appropriated by the General Assembly to the Illinois Environmental Protection Agency.
4. Pursue additional federal resources and funding that may become available in an expansion of the Diesel Emission Reduction Act that could be used to replace older diesel buses with electric versions.

Conclusion

Having a robust bus transit system that provides necessary levels of bus service should not come at the cost of sacrificing the tremendous health benefits and long-term savings that electric buses provide and that the Chicago area deserves. Federal, state, and local elected officials need to dedicate resources for the Chicago Transit Authority to accelerate the

transition to tailpipe-free battery-powered electric buses, so that city residents will enjoy the health benefit they provide.

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