Transit Equity Analysis: Baltimore Region

September 2024

BALTIMORE TRANSIT EQUITY COALITION

JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

BEAD Biostatistics, Epidemiology And Data Management

Table of Contents

Transit Equity and Environmental Health: Baltimore Region

Executive Summary

This project, a collaboration between the Johns Hopkins School of Public Health, Johns Hopkins University, and the Baltimore Transit Equity Coalition (BTEC), aimed to **better understand the relationship among transit access, social vulnerability, air pollution, and health in the Baltimore region**.. The information can be used to determine which communities in this region might benefit the most from investments in transit. This report expands on work published in 2021, which showed areas in Baltimore City needing investment in better transit mirror the 'Black Butterfly' pattern of neglect that arose from Baltimore's redlining policies. This project was made possible by the Bloomberg Health Initiative.

Methods

The study area for this report comprises Baltimore City, Baltimore County, Anne Arundel County, Howard County, and Harford County. We ranked each census track in the region for each of our four themes: transit access, social vulnerability, air quality, and health. The data came from a variety of open access sources. Using the summed scores by theme, we created a Transit Investment Need Index (TINI) score, where a higher score indicates communities more in need of transit investment. We also identified disconnected communities with long commutes and high unemployment.

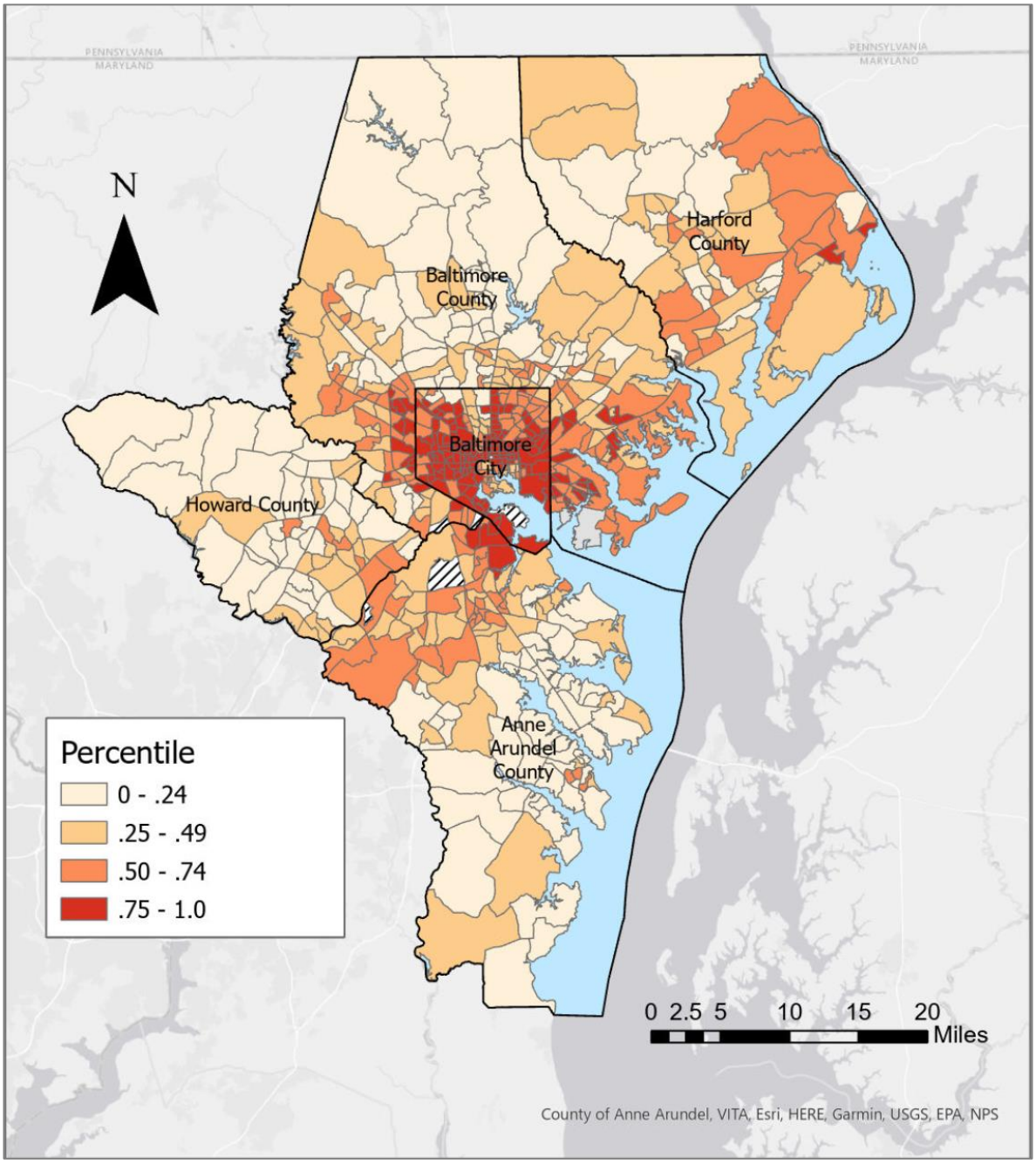
Results and Recommendations

The culmination of all four component themes, our TINI map (Figure 1) presents a striking pattern of investment needs across the greater Baltimore region. Public transit in the Baltimore region often fails to get people to their destinations in a reasonable amount of time, incentivizing personal vehicle use and compounding effects on air quality and health.

The TINI map shows the highest concentration of census tracks in need of investment lie within Baltimore City– particularly mirroring the 'Black Butterfly' seen in our previous report. Other concentrations of high-need census tracts include northern Harford County bordering Cecil County, Baltimore County to the east and west of the city, and Anne Arundel directly to the south of the city. Disconnected communities, not represented in the figure, also tended to have a high TINI score.

The TINI can help target investments in transit to improve efficiency, reliability, and expanded access for those who need it the most. Increasing access to close, reliable, efficient transit will lead to improved access to jobs, education, healthcare, and healthy food. Additionally, increased efficiency, reliability, and access should lead to fewer personal vehicles on the road, lower pollution, and reduced carbon emissions. For the region to flourish, policy makers, transportation professionals, and planners must support expanding transit options in these neglected communities.

Figure 1: Transit Investment Need Index (TINI)



This report is a collaboration between Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Johns Hopkins Biostatistics, Epidemiology and Data Management (BEAD) Core, and The Baltimore Transit Equity Coalition. To learn more, watch our videos, and access all materials, please visit this website: [https://moretransitequity.com/regional-report/]

Introduction

A well-functioning transit system connects people to places in a timely and reliable manner. With limited access to efficient public transit, many individuals find it challenging to accomplish essential daily tasks without a personal vehicle, including commuting to work, running errands, or engaging in recreational activities [1]. This impacts their ability to maintain employment, appointments, and social connectivity [2–4]. Such negative outcomes disproportionately affect already vulnerable groups, e.g. people with a disability [5]. Public transit closes the gap while producing far less pollution and greenhouse gases per person, per trip than single-occupancy vehicles [6]. Those who use public transit also typically get more physical activity each day due to walking or biking to and from transit stops [7–10].

Despite these benefits, public transit in the greater Baltimore region – which we define as Anne Arundel County, Baltimore County, Baltimore City, Harford County, and Howard County – struggles to get people to their destinations in a reasonable amount of time, and many in the region live a prohibitive distance from a high frequency transit stop [11,12].

This is especially concerning since low-income people of color not only represent the majority of transit users but they're also less likely to have access to a personal vehicle and more likely to live in neighborhoods lacking resources accessible by pedestrian means [13]. Unreliable public transit further compounds the issues faced by these already vulnerable communities [14].

This project looked for associations between public transit, social vulnerability, air pollutants, and health in the Baltimore region. Building on a prior report that focused only on Baltimore City [15], the goal of this report was to expand the analysis to counties surrounding the city.

Four individual maps describe transit access, social vulnerability, air quality, and health, focusing on how these factors vary throughout the Baltimore region. Combined, the maps create a single composite map to help identify areas with the greatest need for investment, quantified by a Transit Need Investment Index, or TINI. We hope to work with those areas with high TINI scores, to make policy and investment recommendations to Maryland policymakers, environmental justice organizations, and regional research and advocacy groups.

Background

Intersectionality of Transit, Social Vulnerability, Air Quality and Health

The transportation sector accounts for 31% of the United States' carbon footprint with the majority being emitted from personal vehicles and long-haul trucks [16]. These vehicles also emit pollutants, such as Particulate Matter 2.5 (PM 2.5), which contribute to acute and chronic health conditions, especially for populations living near high volume roadways [17,18]. The prioritization of personal vehicles over investments in public transit only furthers the reliance on automobile transit through induced sprawl. When highways and roadways are the primary mode of transit, congestion relief efforts, typically lane widening, continue to cut into natural areas and existing neighborhoods [19]. This dedication of land to roads and highways detrimentally affects the environment, and ultimately public

health[20].

Lung and heart diseases are linked with poor air quality [21–23]. Those with illnesses such as Asthma and Chronic Obstructive Pulmonary Disease (COPD) are at risk for inflammation events with short-term exposure, with vulnerable populations, such as children, being especially at-risk [24]. These health impacts add up; one estimate found 6.8 billion USD worth of health damages, and 664 premature deaths in Maryland from transit-related emissions alone in 2016 [25,26]. Furthermore, not having reliable and efficient public transit further reduces access to primary health clinics, hospitals, or urgent care clinics, having major implications for the health and well-being of residents in the region [4,27].

Un- or under-employment are both major factors of social vulnerability affected by mobility. Those without access to reliable transportation have difficulty reaching areas of employment dispersed through the region. This creates barriers to maintaining employment and economic stability [2,28]. Investments in public transit infrastructure not only create more reliable access to employment centers but also incentivize businesses to relocate near major transit stops in what is called "transit-oriented development".

Accessible public transit also correlates with social connectedness where the ease of travel and time expenditure is a major factor in the socialization and recreation of the population [29]. These characteristics have implication on social cohesion and mental health, especially for vulnerable populations such as senior citizens [3,30]. Investments in public transit and transit-oriented development have been associated with increased social connectedness and capital [31].

Racism and Pollution

The Baltimore region continues to struggle with hyper-segregation related to historically racist policies. Through a long history of discriminatory mortgage lending – a practice known as *redlining* – and housing covenants, Black Baltimoreans were limited in where they could live. The neighborhoods where they lived were intentionally targeted to be uprooted and bulldozed for highways [32,33]. Such policies served to concentrate and displace Black communities over generations and led to unequal wealth distribution, disinvestment in infrastructure, and disproportionately poor health outcomes still seen to this day [34]. Black communities are also more likely to be located near high-traffic areas, toxic waste sites, municipal dumps, and other health hazards. Even the number of street trees in a neighborhood correlates with historic redlining [35].

National studies show that air quality on average is worse in Black neighborhoods, even controlling for income and region, leading to increased adverse health outcomes [36–38]. In 2020, Black children in Maryland had 5 times the number of emergency room visits due to asthma compared to white children [39]. ProPublica found that census tracts where the majority of residents are non-white experience around 40% more cancer-causing industrial air pollution on average than white-majority tracts [40]. These disparities do not relate to race - rather, they relate to *racism*, which also correlates with depression, anxiety, and psychological stress [41].

Climate Change: A Threat Multiplier

Climate change is not a single threat, but a threat multiplier and can increase frequency of

extreme weather events (heat waves, floods, wildfires), sea-level rise, poorer air quality, increased prevalence of infectious diseases, and disruptions to food and water systems.

Vulnerable people and communities who may already struggle with food and energy insecurity, poverty, lack of infrastructure, and mobility limitations are the most likely to suffer the greatest impacts of these changes [41].

For instance, the urban heat island effect is notably higher in predominantly Black neighborhoods [42]. Those living in urban heat islands are at risk of heat related illness and emergencies [43]. As climate change intensifies these heat waves, the related health issues for residents of those neighborhoods will similarly increase.

The intersection between historical injustices, environmental disparities, public health, transportation equity, and climate change emphasizes the need for comprehensive and equitable solutions. Addressing systemic inequities, such as the underlying problems within public transit, will allow us to begin to address a complex situation. **Investing in robust transit systems holds promise not only for reducing carbon emissions, but also for building community resilience related to the health effects of climate change.**

Methods

For detailed methods, see Appendix 1- Methods. For individual indicator maps for social vulnerability, air quality, and health, see Appendix 2- Thematic Indicators. Across all maps, a higher score–corresponding to a darker color–indicates an area of greater investment need. Scores are binned into quartiles. For example, the darkest colored tracts score in the 75th percentile and above, and the lightest census tracks score in the 25th percentile and below for the given indicator or composite.

Thematic Analysis

Theme 1: Transit Access

Public transit works best when it provides predictable commute times, stops near where people live and where they need to go, and includes high-frequency routes.

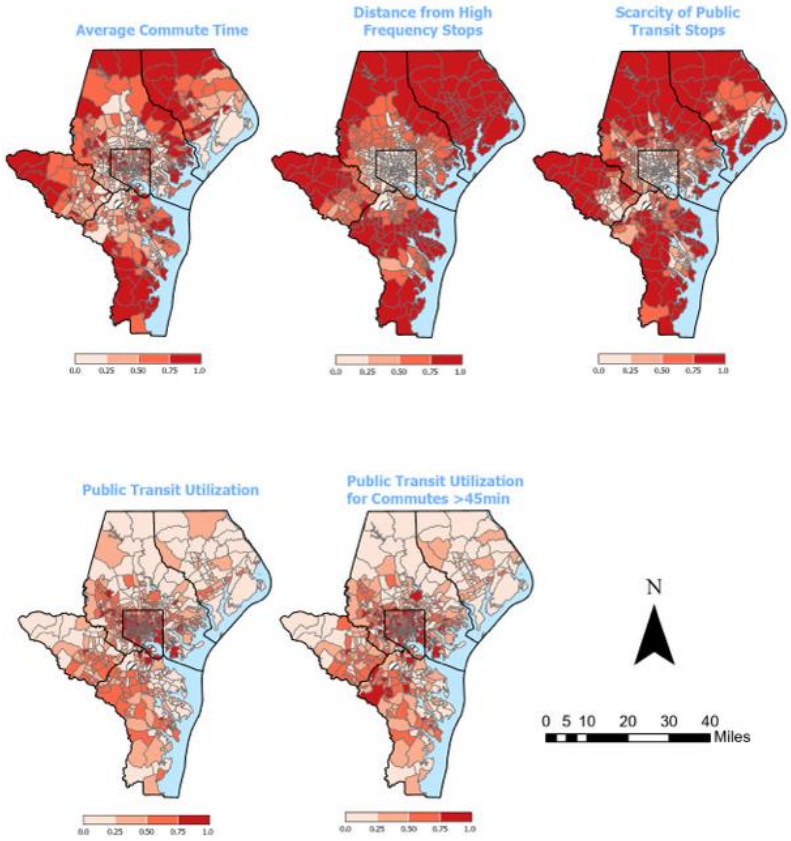
For our analysis, data on transit access came from a variety of sources, including the American Community Survey 2022 5-year estimates [44], OpenStreetMap via Geofabrik [45], and the ETC Explorer [46].

The transit indicators included in our analysis are:

- Estimated average commute time
- Public transit utilization for all commutes
- Distance from high frequency stops
- Public transit utilization for long commutes (over 45 minutes)
- Scarcity of public transit stops

The five maps below illustrate the stratified data for each indicator, to help better understand the components of the composite map (Figure 3). For larger indicator maps, see Appendix 2.

Figure 2: Regional Transit Access Indicators



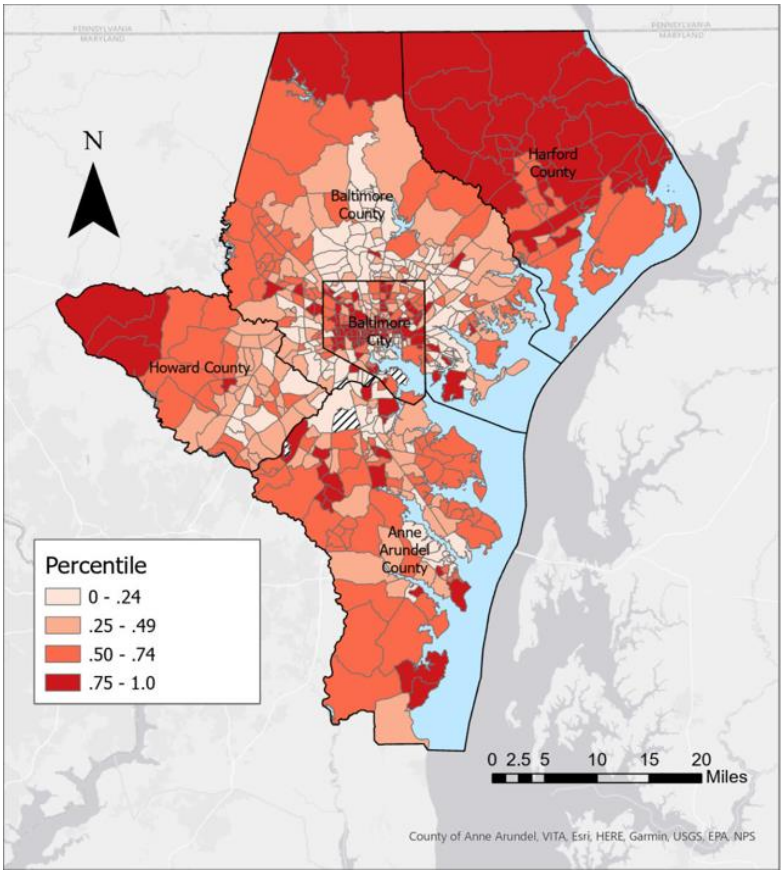
The lack of public transit stops across the region significantly hampers one's ability to travel without a car (see Scarcity of Public Transit Stops map). Additionally, while having access to public transit stops over a wide area is essential and important for the functioning of public transit, high frequency stops are most important in being able to get where one needs to go quickly (see Distance from High Frequency Stops map). For this report, a high-frequency transit stop is defined as any stop having an average headway of 15 minutes or less. Longer service gaps inhibit people from reaching their destinations in a reasonable amount of time. The path of the light-rail line into Baltimore County has a positive effect on access.

Areas toward the edge of the city display high average commute times, while areas

immediately outside of the city often show much lower commute times (see Average Commute Times map), with the pattern once again inverting at the furthest points from the city, with some exceptions near other job centers.

The use of public transit in the region once again shows a sharp drop-off the further one gets from the center of Baltimore City (see Public Transit Utilization map). This reduces connectivity and efficiency when it comes to commute time. Despite increased levels of access to public transit within the city center, many commutes by public transit are 45 minutes or more, reducing the amount of time people have to pursue other activities (see Public Transit Utilization for Long Commutes map).

Figure 3: Regional Transit Access Composite Map



When looking at our transit access map, there is a drop-off in transit access outside of Baltimore City, with the surrounding counties having little to no access to public transit, but depending on the area, having lower commute times than some of those within the city center.

Commuters within the City rely more heavily upon public transit, which, under the current system, often takes more time per mile traveled; however, in neighborhoods just outside the city boundary, most commuters must rely instead upon private vehicles [11]. This difference may help explain the areas that show lower percentiles directly outside the city. While 27% of households in the city lack personal vehicles, this drops to 10% in the region [47].

There is a major disconnect in access to transit between Baltimore City and its surrounding counties. We also see how the city, despite being a job center for the region and scoring well for high frequency stops, also lacks convenient, accessible commutes.

Theme 2: Social Vulnerability

The Social Vulnerability Index (SVI) was developed by the U.S. Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR) to measure social vulnerability in communities. The term social vulnerability refers to "the socioeconomic and demographic factors that affect the resilience of communities [49]." It considers factors related to:

- Socioeconomic status
- Household composition and disability,
- Minority status and language
- Housing type
- Transportation

CDC/ATSDR's methodology [48] was used to calculate social vulnerability within the Baltimore region, using the latest available data from the American Community Survey's 2022 5-year estimates [44].

Figure 4: Baltimore City Social Vulnerability Composite Map

The social vulnerability map mirrors the notorious 'white L' and 'Black Butterfly' pattern associated with Baltimore City, as named by Dr. Lawrence Brown [33]. The lighter 'L' shape in the center of the map contains a disproportionately higher white population than the rest of the city, due to historic racism and redlining. Meanwhile, the darker colors that look like a butterfly's wings comprise neighborhoods mostly populated by people of color [33].

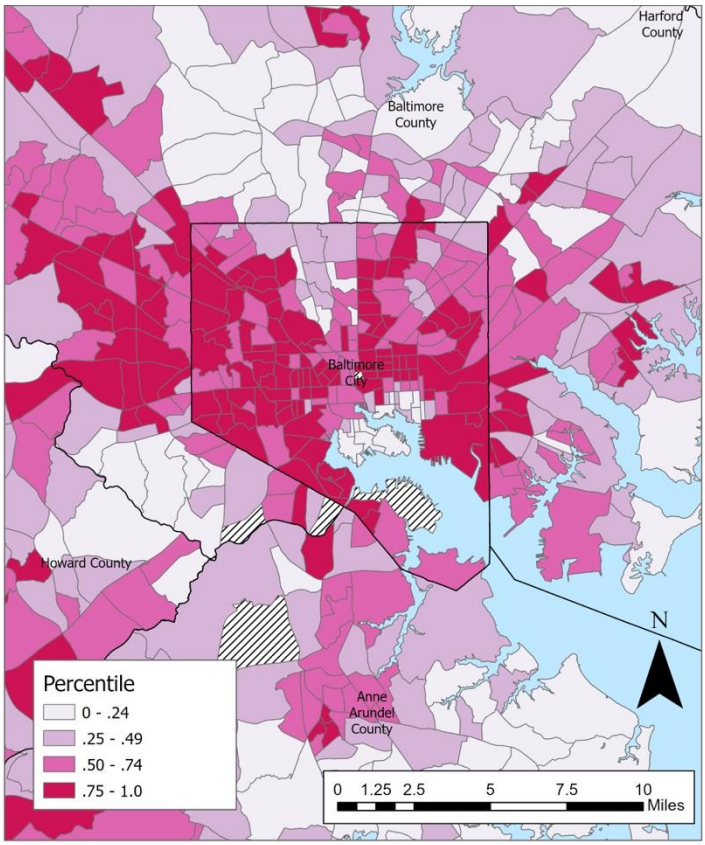
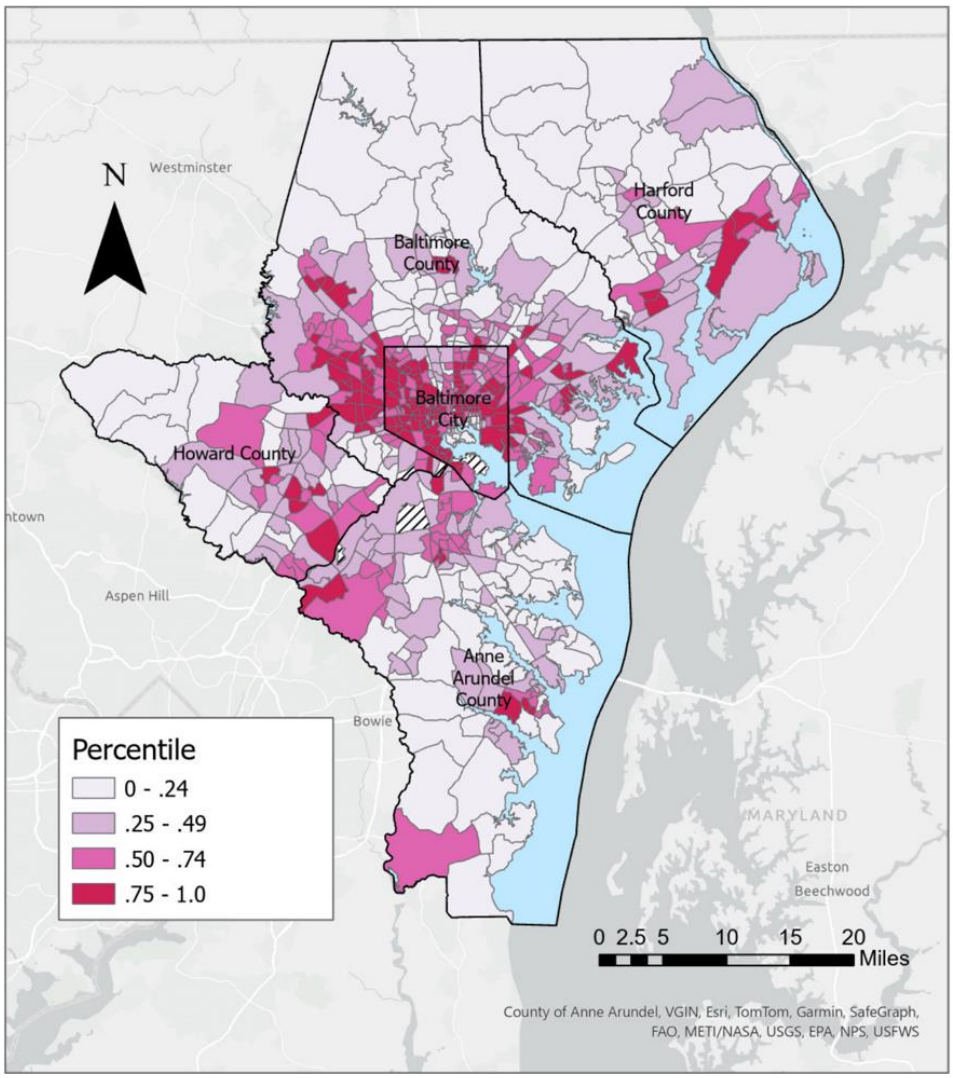


Figure 5: Regional Social Vulnerability Composite Map



The regional analysis shows this 'Black Butterfly' extends well beyond the city, most clearly visible in Baltimore County. Apart from the butterfly pattern, in Harford County we see higher social vulnerability along the Route 40 corridor up to the border with Cecil County, and in Anne Arundel County on its borders with the other counties in the region, among other areas.

Despite the end of legal segregation and redlining, these maps still reflect historic divisions by race, which correlate with measures of social vulnerability such as unemployment, and lack of access to reliable transportation.

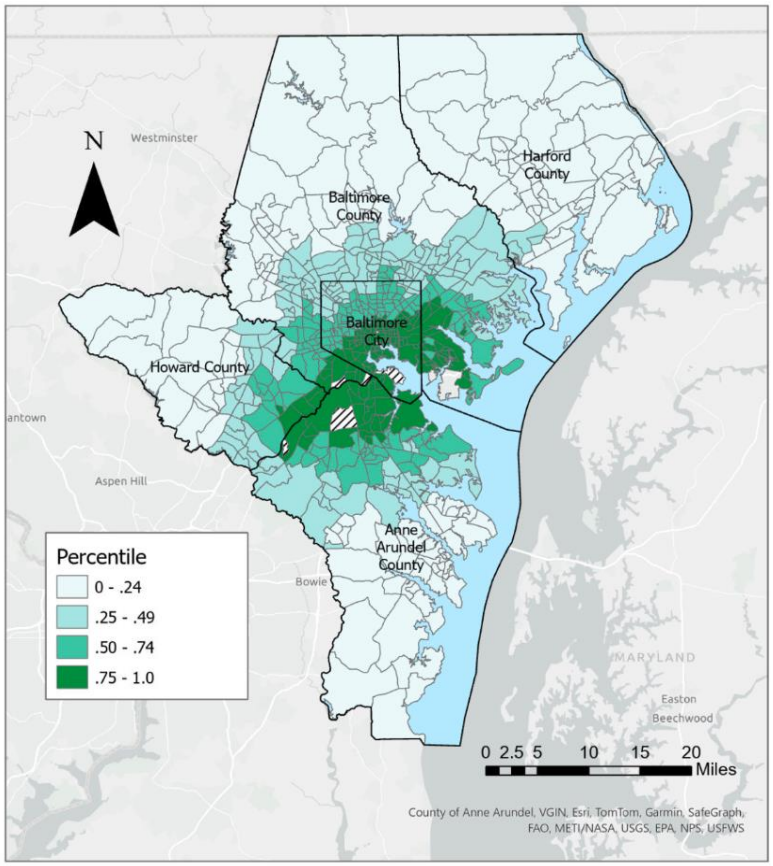
Theme 3: Air Quality

In 2015, the Environmental Protection Agency (EPA) released the EJScreen, a mapping and screening tool that includes 13 environmental and seven socioeconomic indicators to examine how environmental and socioeconomic factors interact [49]. The sensors that measure Air Quality in our region are from the Maryland Department of Environment.

The air quality indicators included in our analysis, all from EJ Screen and linked to transportation are:

- Air Toxics Cancer Risk
- Diesel Particulate Matter
- Respiratory Hazard Index
- Ozone
- Toxic Releases to Air
- Particulate Matter 2.5

Figure 6: Regional Air Quality Composite Map



The resulting map reveals increased pollutants in Southern and Eastern Baltimore City, and South/Southwest of the City into Ann Arundel, Baltimore, and Howard Counties. This is likely due to highways with heavy vehicle traffic and industrial sites in locations such as Sparrows Point and Curtis Bay. Historically Sparrows Point was the location for Bethlehem Steel which had a long legacy of environmental violations [50]. The pollution from industry continues to affect nearby residents [51]. Meanwhile, pollution in South Baltimore City represents a central issue for many residents in Curtis Bay, Brooklyn, and Hawkins Point. Their concerns include issues such as coal depots, trash incinerators, and trucking routes [52].

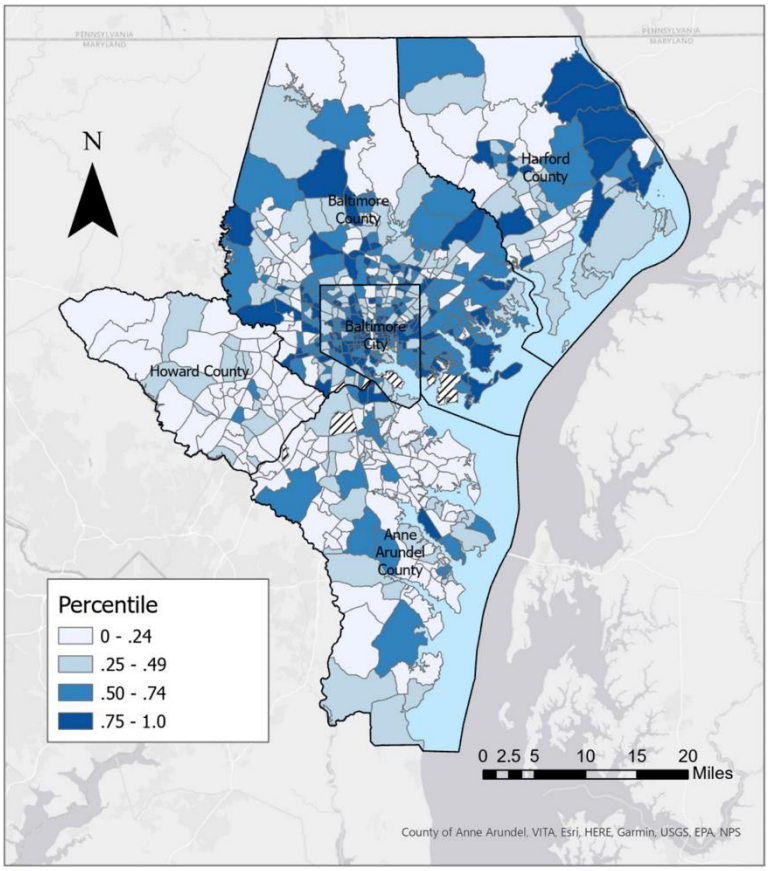
It is important to note that the number of EPA air quality sensors in the Baltimore region is limited. The distance between the sensors creates data that portrays regional differences in air quality and can only provide rough estimates at the local level. Robust local monitoring systems are needed for more accurate maps.

Theme 4: Health

The indicators that make up our composite health map are rates of:

- Asthma
- Cancer (all types except skin)
- Coronary Heart Disease
- Chronic Obstructive Pulmonary Disease (CPOD)

Figure 7: Regional Health Composite Map



Are indicators for were chosen for their relation to transportation, air pollution, and data availability. All indicators were sourced from the CDC's 2023 PLACES project [53], which provides health outcome data for various conditions at the census tract level nationwide.

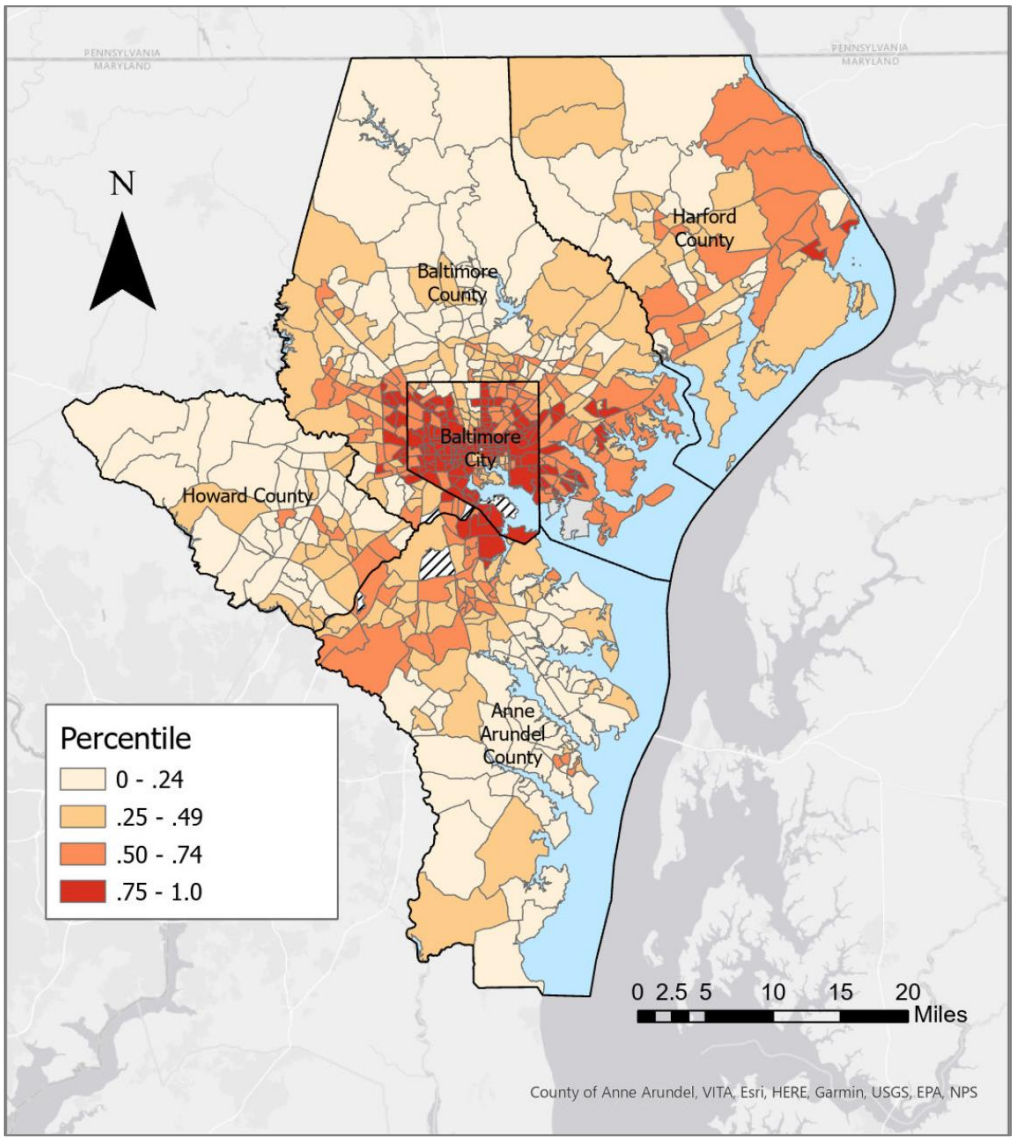
Areas experiencing increased health risk in Baltimore City extend to the southernmost census tracts such as Hawkins Point. We can also see

In Harford County on the border with Cecil County, worse health outcomes may stem not only from pollution but also substance use issues, which are prevalent in the area [54].

In Anne Arundel County census tracts in the top quintile of negative health outcomes includes part of Arnold, which sits across the Severn River from the city of Annapolis. According to the individual indicator maps (Appendix 2), that section of Arnold has the highest quintile of cancer and coronary heart disease. This area does not score high in social vulnerability or air pollution according to our methods and does not light up as disconnected (see Disconnected Communities) or in high transit investment need. This shows that while overlap generally exists between our themes, there are exceptions.

Transit Investment Need Index (TINI)

Figure 8: Regional Transit Investment Need Index (TINI)



All four themes went into creating the transit investment need index map, which shows areas in the Baltimore Region with populations most impacted by inefficient transit, pollution, and adverse health outcomes. The Black Butterfly is apparent within the city, and locations south of the city such as Brooklyn and Curtis Bay are also among the highest-ranking. Areas outside of the city that reached middle-to-high percentile rank include census tracts around Laurel and southern parts of Bel Air. These localities were similarly highlighted areas on the disconnected communities map, discussed in the next section.

Disconnected Communities

We also looked at "disconnected communities," a concept defined by Central Maryland Transportation Alliance (CMTA) as neighborhood where (i) at least 1 in 5 residents have a commute to work longer than 45 minutes in one direction and (ii) unemployment rates rise to 5% or greater [11]. We used the ACS variable "Public transit for all commutes and long commutes" to first identify Disconnected Communities with the greater Baltimore Region (Figure 9, then overlayed the results of the disconnected neighborhoods with the composite TINI map (Figure 10).

Figure 9: Regional Disconnected Communities Map

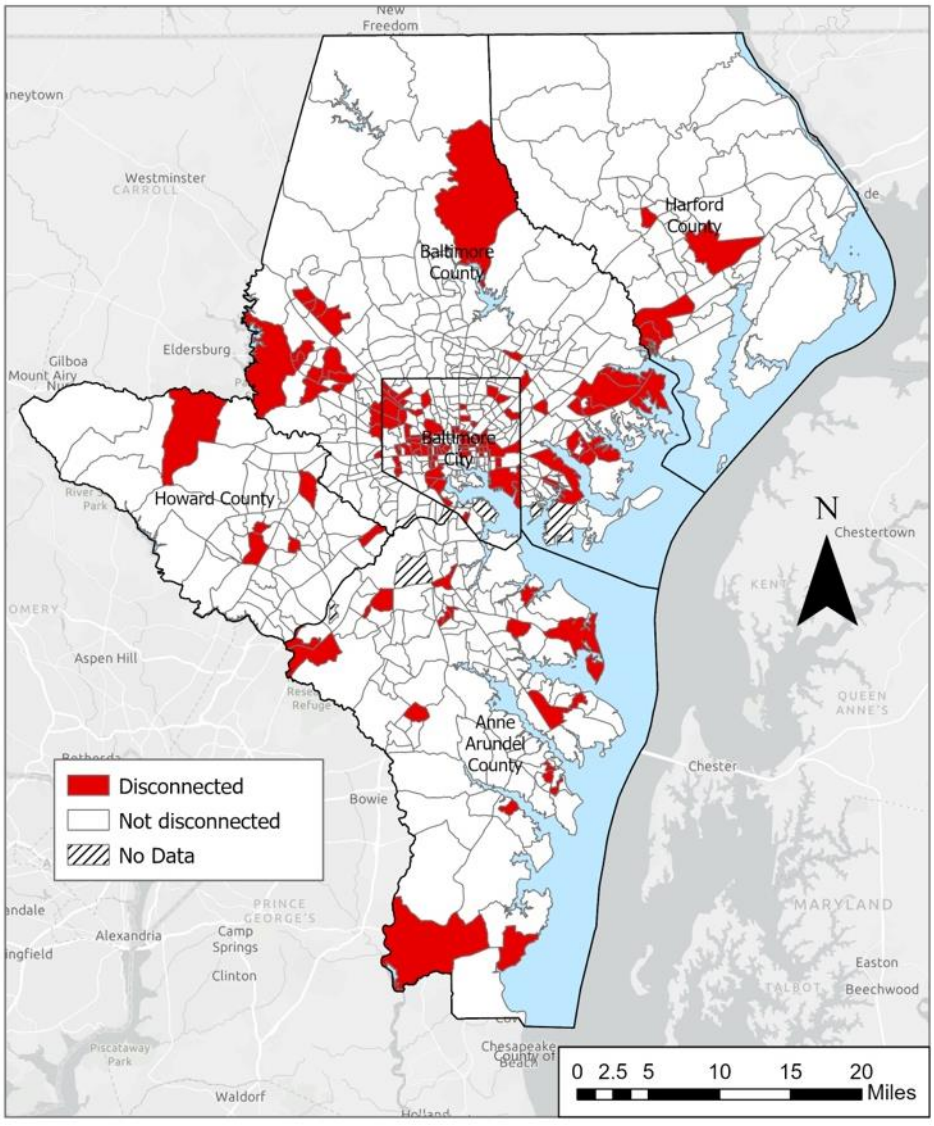
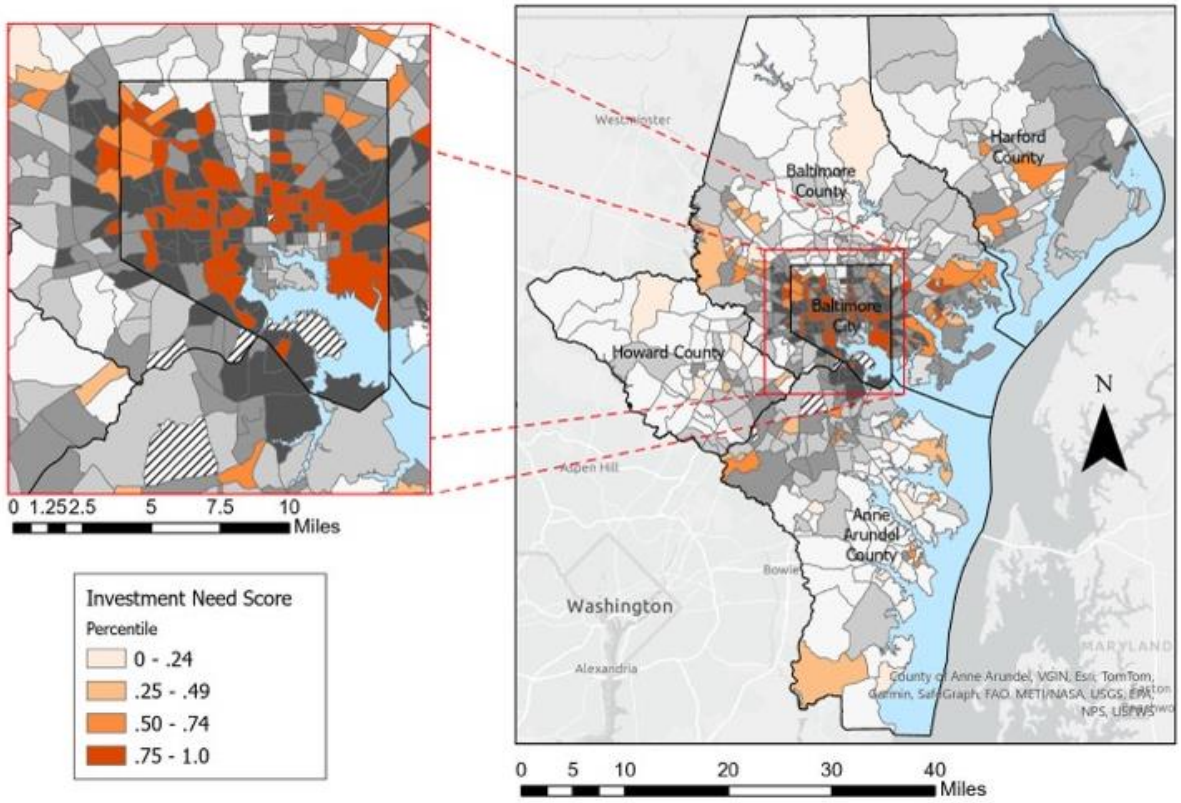


Figure 10: Investment Need Score within Disconnected Communities



The results show a clear overlap between disconnected communities and areas of high investment need. This highlights how vulnerabilities, such as transit access, negative health outcomes, exposure to pollution, and low socioeconomic status, do not exist in a vacuum, but correlate with patterns of historic underinvestment. Within the city limits, the pattern of the "Black Butterfly" shows in both the disconnected communities and TINI composites. Pockets within the eastern and western edges of Baltimore County also showed overlap between the disconnected communities and TINI composite score. Similar patterns extend from the city northwest along Reisterstown Road and northeast towards Middle River. Localities such as Laurel and Bristol in Anne Arundel County were also highlighted along with portions of Harford County such as southern Bel Air and Joppa Towne.

Recommendation

The identification of census areas experiencing disproportionate environmental and health impacts has been done through many different tools. These tools can help to identify population areas experiencing socioeconomic barriers or health impacts related to such inequities. Examples used in this report include the Environmental Justice (EJ) screening tool and the Social Vulnerability Index (SVI) that utilize publicly accessible data on census tracts or areas. By identifying areas experiencing the greatest challenges, strategic investments can help mitigate those harms.

We propose that our Transit Investment Needs Index (TINI) can be used as a tool to facilitate community efforts to address transit access for communities identified as having high need. An improved transit system can facilitate better access to work, healthcare, education, and nutritious food. It can improve environmental air pollution levels, and related health outcomes.

The TINI-combines the EJ screening tool and SVI while adding layers of transit and health data. The focus on transit is important, given that a mere 8.5% of jobs in the Baltimore Region are accessible within an hour when relying only on public transit [11]. Recognition of this accessibility issue is important for creating a more efficient system for better job stability.

The overlap between the TINI index and disconnected communities can be used for strategic investments for identified areas that experience long and unreliable commutes and the associated health disparities. Using these tools, the transportation systems that service these areas can be a policy focus for more investments to make commuting to and within these areas more reliable and efficient. We hope that policy makers and advocates will utilize this tool and methodology for other regions to hone in on areas with higher transit needs and allocate the resources required to create a reliable, efficient, equitable transit system.

Team Members

- Marium Sultan, Associate, Bloomberg School of Public Health
- Samuel Jordan, President of Baltimore Transit Equity Coalition (BTEC)
- Taylor Craig, Biostatistics, Epidemiology and Data management (BEAD) Core, Johns Hopkins School of Medicine
- Evan Gombert, Administrator, Baltimore Transit Equity Coalition
- Claudia Paszek, Epidemiology and Data management (BEAD) Core, Johns Hopkins School of Medicine
- Havana Mullaly, Student at Johns Hopkins University
- Jacky M Jennings, Biostatistics, Epidemiology and Data management (BEAD) Core, Johns Hopkins School of Medicine
- Neka Duckett-Randolph, Environmental Justice Director of Baltimore Transit Equity Coalition
- Darryn Waugh, Department of Earth and Planetary Sciences, Johns Hopkins University
- Megan Weil Latshaw, Associate Scientist, Bloomberg School of Public Health

Appendix 1- Methods

Data Sources

This study focused on four component themes, each drawing from various sources. The four themes were Transit Access, Social Vulnerability, Air Quality, and Health. The Transit Access theme utilized data from the Maryland Transit Administration, the Baltimore Metropolitan Council (BMC) Regional Data Center, and Geofabrik. The Social Vulnerability theme reconstructed the Social Vulnerability Index (SVI) created by the Agency for Toxic Substances and Disease Registry. The Air Quality theme drew from EJScreen, the environmental justice screening and mapping tool from the Environmental Protection Agency (EPA). The health theme utilized data from the PLACES project through the Centers for Disease Control and Prevention (CDC).

Indicators were chosen based on several criteria. They had to be (1) publicly available, allowing our study to be reproduced; (2) recently updated within the last two years, and (3) relevant to assessing transit equity in the Baltimore region.

Analysis and Mapping

For each indicator within each of the four themes, we calculated the percentile rank of each census tract relative to all other census tracts within the study area. We then summed the rankings of each indicator within each of the four component themes and percentile ranked the sums to create a component score. Finally, we summed each of the four component scores and percentile ranked the sums one final time to create the composite Transit Investment Need Index (TINI), where a higher score indicated a community more in need of investment compared to the rest of the region.

Transit Investment Need Index (TINI)

The Transit Investment Need Index (TINI) compared all neighborhoods, at the census tract level, across five counties in Maryland: Anne Arundel County, Baltimore City, Baltimore County, Harford County, and Howard County. This identified which census tracts had a greater relative need for transit investment, compared to other census tracts in the region. Percentile ranking values ranged from 0 to 1, with higher values indicating greater investment need.

General Analysis steps

After acquiring data for each indicator at the census tract level, in R (version 4.3.3 we:

- Normalized within each indicator
- Percentile ranked within each indicator
- Summed percentile ranks of all indicators within the component
- Percentile ranked the sum to get the component score. Done twice for SVI.
- Summed each component score, then percentile ranked the sum again to get final investment need score

Then, in ArcGIS Pro (version 3.3), we:

- Joined all percentile-ranked indicators to the census tract layer to produce individual maps

- Joined component scores to census tract layer to produce component score maps
- Joined final investment need score to census tract layer to produce the final investment need map

For mapping, we:

- Downloaded all shapefiles and loaded them into ArcGIS
- Removed fill from county layers, darkened borders to form county borders
- Filtered the water layer to only larger water bodies, then merged 5 county layers together to get one regional layer
- Pulled out census tracts with 0 resident population (industrial areas, airport, detention centers, parks, etc.) and created a hatched layer
- Mapped all analysis variables onto GEOID field, which is given for all census tracts

Table 1: Components, Indicators, and Data Sources

Component	**Sub-Component**	**Indicator Name**	**Indicator Description**	**Data Source**
Transit	Transit Access	Scarcity of public transit stops	Point locations of all public transit stops in the Baltimore region	Baltimore Regional GIS Data Center [55]
		Distance to high frequency stops	Defined as stops with a minimum headway (the amount of time between transit arrivals at each stop, given in GTFS data) less than or equal to 15 minutes.	OpenStreetMap via Geofabrik [56] Methodology from Esri
		Average commute time	Calculation derived from the population of workers 16 years and over who commute to work, inclusive of all modes of transportation	ETC Explorer Documentation Data [46]
	Transit Utilization	Public transit utilization for all commutes	A percentage showing how many workers 16 years and over commute by public transit divided by all the estimated workers living in that Baltimore.	ACS 2022 5-year estimate data [44]
		Public transit utilization for long	Long commutes defined as commutes	ACS 2022 5-year estimate data

		commutes	over 45 mins. A percentage measured the estimated number of workers with long commutes who take public transit or use private vehicles.	[44]
Social Vulnerability Index	Socioeconomic Status	Below 150% poverty	Percentage of persons below 150% poverty	CDC/ATSDR Social Vulnerability Index (CDC/ATSDR SVI) [47]
		Unemployed	Unemployment rate	
		Housing cost burden	Percentage of households that spend at least 30% of income on housing costs	
		No high school diploma	Percentage of persons with no high school diploma (age 25+)	
		No health insurance	Percentage uninsured in the total civilian non-institutionalized population	
	Household Characteristics	Aged 65 and older	Percentage of persons aged 65 and older	
		Aged 17 and younger	Percentage of persons aged 17 and younger	
		Civilian with a disability	Percentage of civilian noninstitutionalized population with a disability	
		Single-parent households	Percentage of single-parent households with children under 18	

		English language proficiency	Percentage of persons (age 5+) who speak English "less than well"	
	Racial and Ethnic Minority Status	Percentage minority	Hispanic or Latino (of any race); Black and African American, Not Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino	
	Housing Type & Transportation	Multi-unit structures	Percentage of housing in structures with 10 or more units	
		Mobile homes	Percentage of mobile homes	
		Crowding	Percentage of occupied housing units with more people than rooms	
		No vehicle	Percentage of households with no vehicle available	
		Group quarters	Percentage of persons in group quarters	
Air Quality		Particulate matter 2.5 (PM 2.5)	Annual average PM2.5 levels in air	EJScreen: Environmental Justice Screening and Mapping Tool [49]
		Ozone	Average of the annual top ten daily	

			maximum 8-hour ozone concentrations in air	
		Diesel particulate matter	Diesel particulate matter level in air	
		Air toxics cancer risk	Lifetime cancer risk from inhalation of air toxics	
		Air toxics respiratory hazard index	Ratio of exposure concentration to health-based reference concentration	
		Toxic Releases to air	Risk-Screening Environmental Indicators (RSEI) modeled toxicity-weighted concentrations in air of TRI listed chemicals.	
Health Outcomes		Asthma	Population count of reported asthma cases	PLACES: Local Data for Better Health, Census Tract Data 2023 release [53]
		Cancer	Population count of reported cases of all types of cancer except skin.	
		Coronary Heart Disease	Population count of reported coronary heart disease cases	
		Chronic Obstructive Pulmonary Disease (COPD)	Population count of reported COPD cases	

Basemap Data Sources [57]:

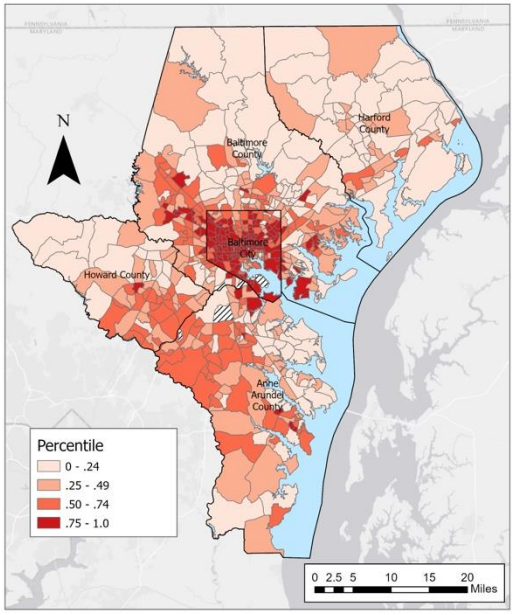
- Census tract shapefile: TIGER/Line 2022
- County shapefile: TIGER/Line 2022
- Water shapefile: TIGER/Line 2022 (can only download by county; downloaded 5 relevant counties)

Appendix 2- Individual Indicator Maps

Transit Access Indicators

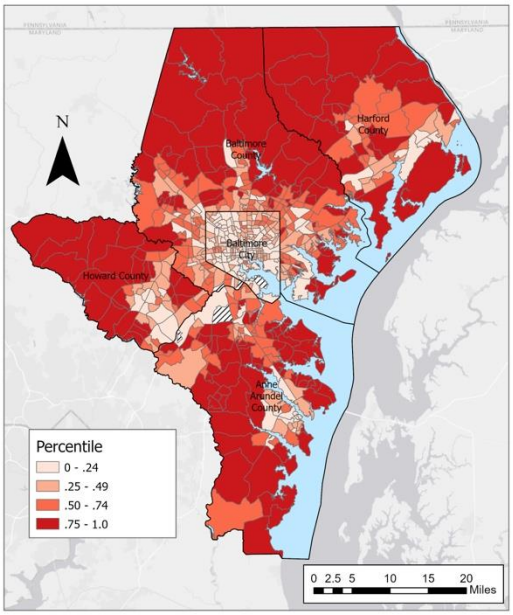
Transit

Public Transit Utilization (All Commutes)



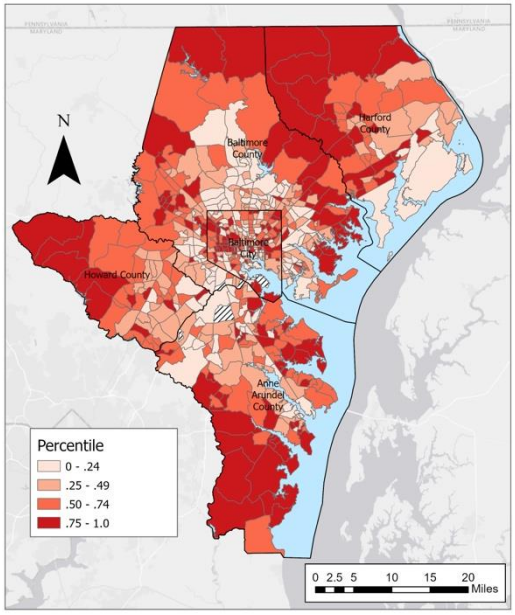
Transit

Scarcity of Public Transit Stops



Transit

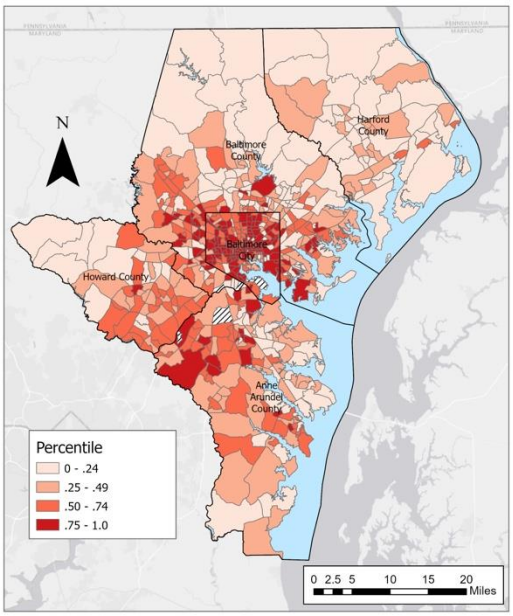
Average Commute Time



Transit

Public Transit Utilization (Long Commutes)

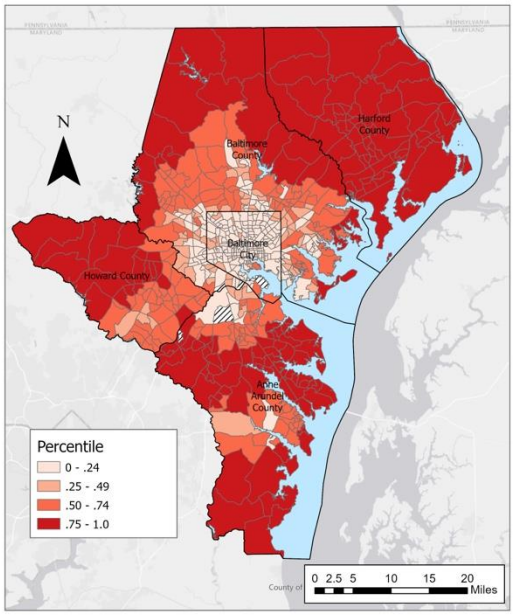
Biostatistics, Epidemiology And Data Management



Transit

Distance from High-Frequency Stops

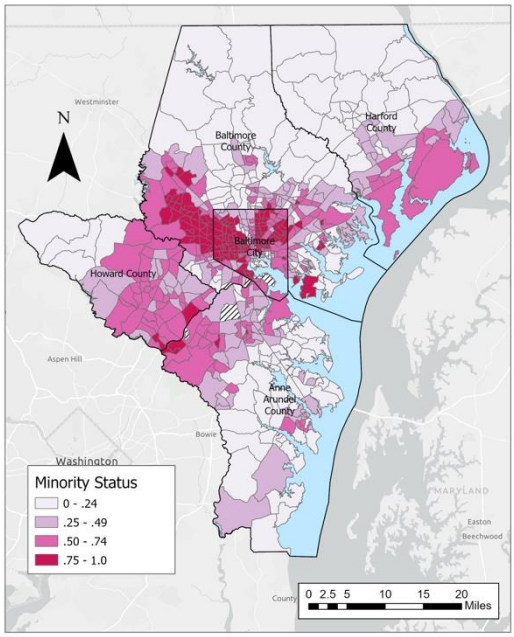
Biostatistics, Epidemiology And Data Management



Social Vulnerability Indicators

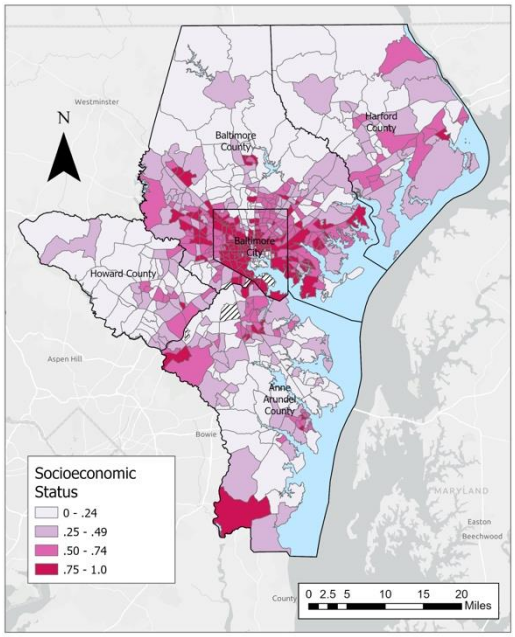
Social Vulnerability Index

Minority Status



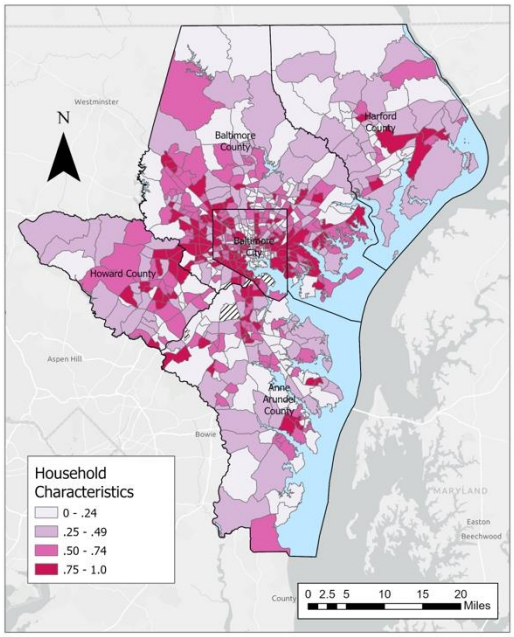
Social Vulnerability Index

Socioeconomic Status



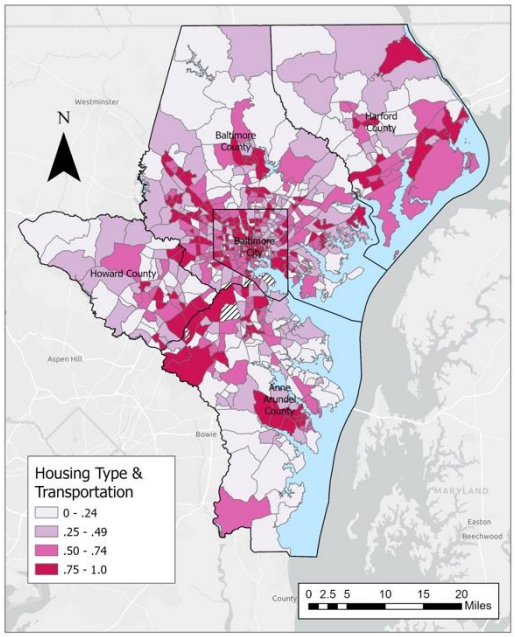
Social Vulnerability Index

Household Characteristics



Social Vulnerability Index

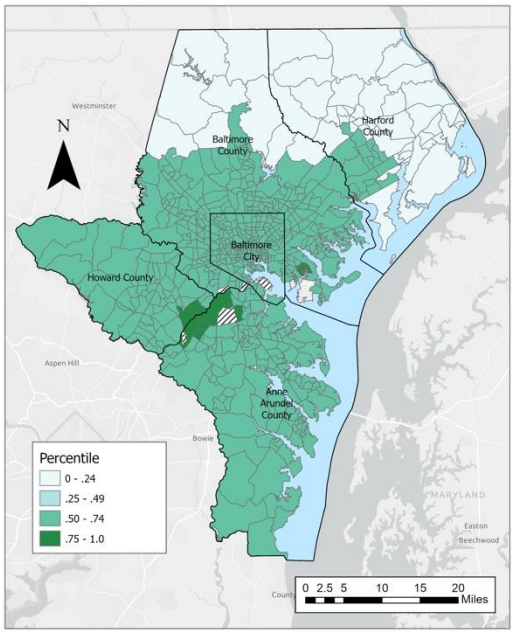
Housing Type & Transportation



Air Quality Indicators

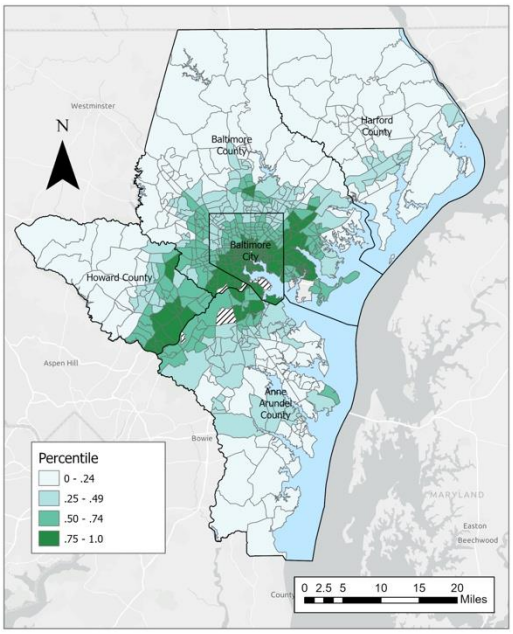
Air Quality

Air Toxics Cancer Risk



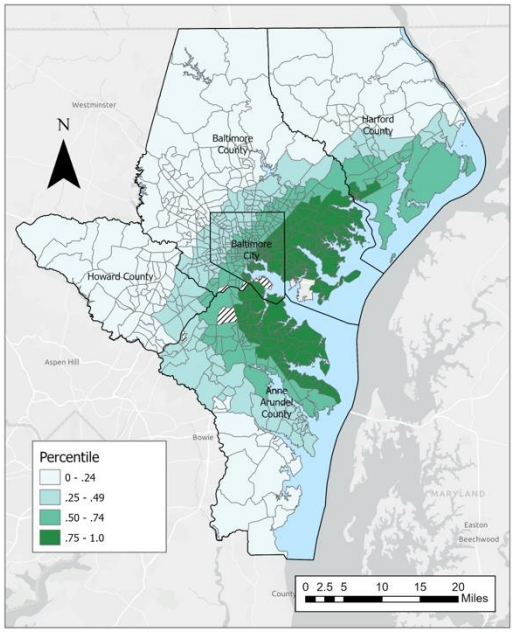
Air Quality

Diesel Particulate Matter



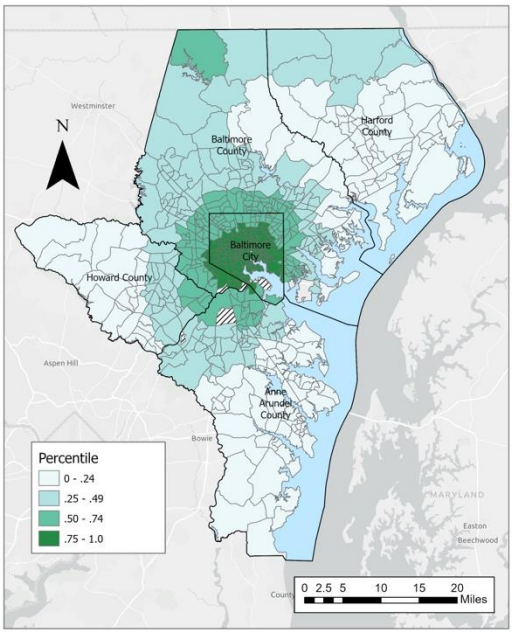
Air Quality

Ozone



Air Quality

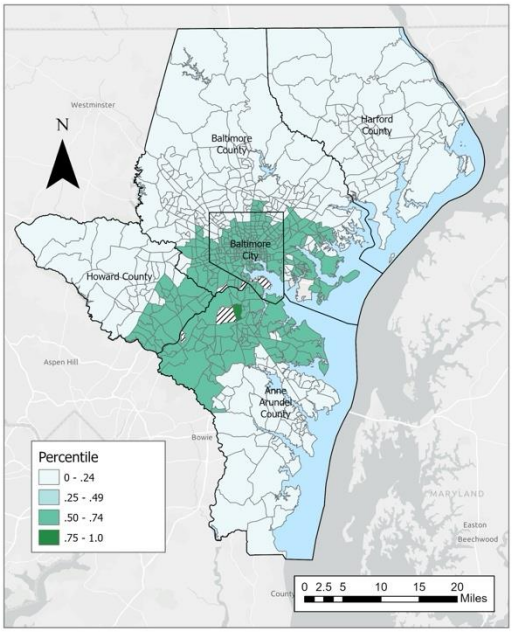
Particulate Matter 2.5



Air Quality

Respiratory Hazard Index

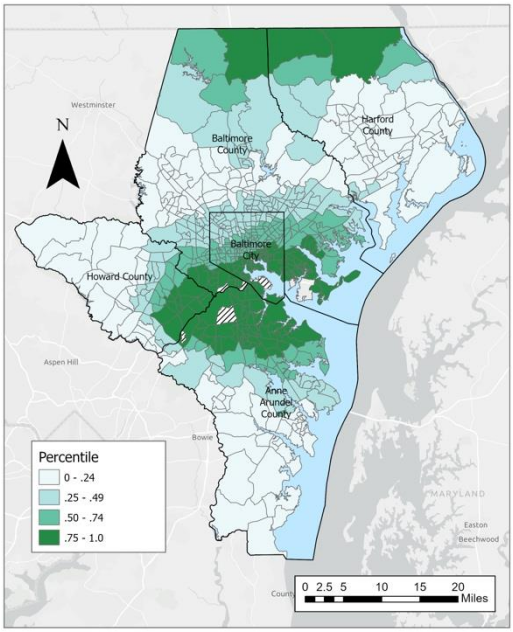
Biostatistics, Epidemiology And Data Management



Air Quality

Toxic Releases to Air

Biostatistics, Epidemiology And Data Management

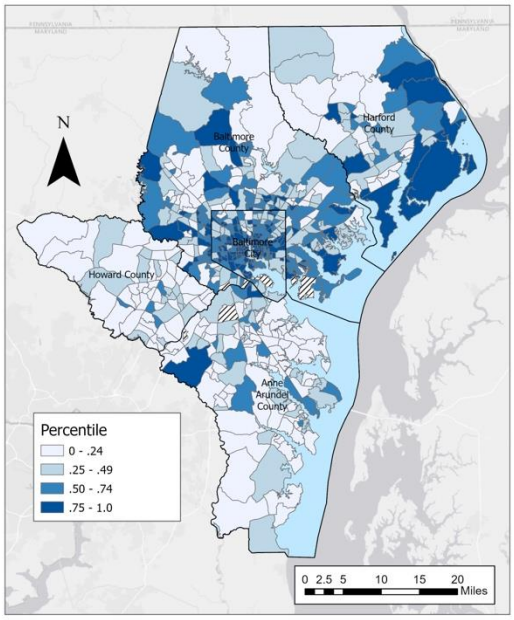


Health Indicators

Health

Asthma

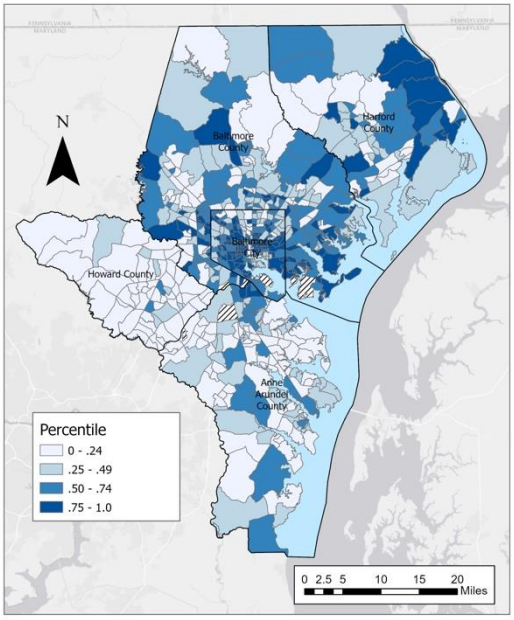
BEAD Biostatistics, Epidemiology And Data Management



Health

Chronic Obstructive Pulmonary Disease

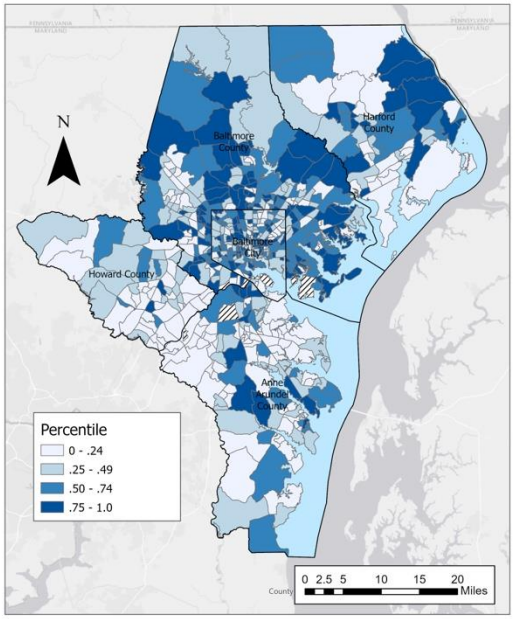
BEAD Biostatistics, Epidemiology And Data Management



Health

Cancer (all types except skin)

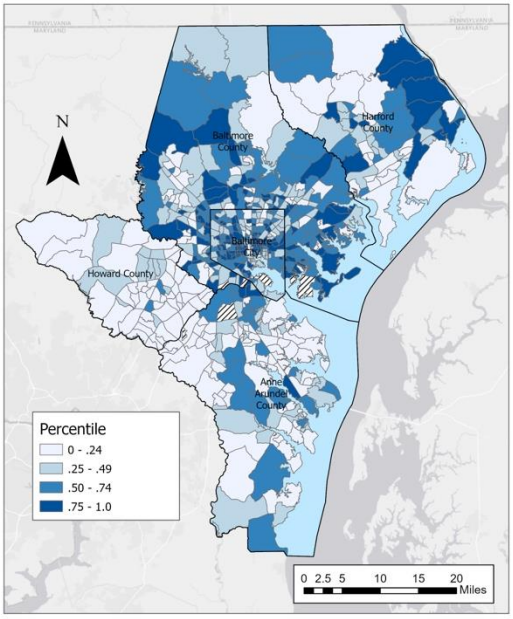
BEAD Biostatistics, Epidemiology And Data Management



Health

Coronary Heart Disease

BEAD Biostatistics, Epidemiology And Data Management



References

1 Public Transportation in the US: A Driver of Health and Equity. HealthAffairs 2021.

2 Joseph Mengedoth. Transportation Access as a Barrier to Work. *Econ Focus*. Published Online First: 2023.

3 Paffenroth S. 'Transit is the lifeline for people' – How public transportation encourages social cohesion and offers post-pandemic solutions. The Scope. 2022. https://thescopeboston.org/7800/news-and-features/transit-justice/transit-is-the-lifeline-for-people-how-public-transportation-encourages-social-cohesion-and-offers-post-pandemic-solutions/ (accessed 14 July 2024)

4 Syed ST, Gerber BS, Sharp LK. Traveling Towards Disease: Transportation Barriers to Health Care Access. *J Community Health*. 2013;38:976–93. doi: 10.1007/s10900-013-9681-1

5 The Dawn of the 'Non-Driver' Movement: A Conversation with Anna Zivarts — Streetsblog USA. 2024. https://usa.streetsblog.org/2024/05/09/the-30-of-non-driving-americans-should-form-a-movement-a-conversation-with-anna-zivarts (accessed 14 July 2024)

6 Litman T. Evaluating Public Transportation Health Benefits. Victoria Transport Policy Institute 2020.

7 Inequitable Public Transit & Community Health. TransLoc. 2021. https://transloc.com/blog/inequitable-public-transit-community-health/ (accessed 14 July 2024)

8 Rissel C, Curac N, Greenaway M, *et al.* Physical Activity Associated with Public Transport Use—A Review and Modelling of Potential Benefits. *Int J Environ Res Public Health*. 2012;9:2454–78. doi: 10.3390/ijerph9072454

9 Welle B, Kustar A, Tun TH, *et al.* Post-pandemic, Public Transport Needs to Get Back on Track to Meet Global Climate Goals. Published Online First: 14 December 2023.

10 New rider data shows how public transit reduces greenhouse gas and pollutant emissions. ScienceDaily. https://www.sciencedaily.com/releases/2019/08/190826143407.htm (accessed 14 July 2024)

11 Transportation Report Card – Central Maryland Transportation Alliance. https://www.cmtalliance.org/report-card/ (accessed 14 July 2024)

12 Baltimore's Transit Future. Greater Washington Partnership. https://greaterwashingtonpartnership.com/regional-mobility/baltimores-transit-future/ (accessed 14 July 2024)

13 Ng AE, Adjaye-Gbewonyo D, Dahlhamer J. Lack of Reliable Transportation for Daily Living, United States 2022.

14 How the U.S. Transportation System Fuels Inequality. Inequality.org. https://inequality.org/research/public-transit-inequality/ (accessed 14 July 2024)

15 Transit Equity & Environmental Health in Baltimore City. Baltimore Transit Equity Coalition and Johns Hopkins Bloomberg School of Public Health 2021.

16 Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA). https://www.eia.gov/tools/faqs/faq.php (accessed 14 July 2024)

17 Feng S, Gao D, Liao F, *et al.* The health effects of ambient PM2.5 and potential mechanisms. *Ecotoxicology and Environmental Safety*. 2016;128:67–74. doi: 10.1016/j.ecoenv.2016.01.030

18 US EPA O. Health and Environmental Effects of Particulate Matter (PM). 2023. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm (accessed 14 July 2024)

19 Tennøy A, Tønnesen A, Gundersen F. Effects of urban road capacity expansion – Experiences from two Norwegian cases. *Transportation Research Part D: Transport and Environment*. 2019;69:90–106. doi: 10.1016/j.trd.2019.01.024

20 Frumkin H. Urban Sprawl and Public Health. *Public Health Reports*. 2002;117.

21 Guo J, Chai G, Song X, *et al.* Long-term exposure to particulate matter on cardiovascular and respiratory diseases in low- and middle-income countries: A systematic review and meta-analysis. *Front Public Health*. 2023;11:1134341. doi: 10.3389/fpubh.2023.1134341

22 Kaufman JD, Adar SD, Barr RG, *et al.* Association between air pollution and coronary artery calcification within six metropolitan areas in the USA (the Multi-Ethnic Study of Atherosclerosis and Air Pollution): a longitudinal cohort study. *The Lancet*. 2016;388:696–704. doi: 10.1016/S0140-6736(16)00378-0

23 Al-Kindi SG, Brook RD, Biswal S, *et al.* Environmental determinants of cardiovascular disease: lessons learned from air pollution. *Nat Rev Cardiol*. 2020;17:656–72. doi: 10.1038/s41569-020-0371-2

24 Who is Most Affected by Outdoor Air Pollution? American Lung Association. 2024. https://www.lung.org/clean-air/outdoors/who-is-at-risk (accessed 15 July 2024)

25 Arter CA, Buonocore J, Chang C, *et al.* Mortality-based damages per ton due to the on-road mobile sector in the Northeastern and Mid-Atlantic U.S. by region, vehicle class and precursor. *Environ Res Lett*. 2021;16:065008. doi: 10.1088/1748-9326/abf60b

26 Kurtz J. Study: Hundreds in Md. Die Prematurely From Vehicle Emissions. Maryland Matters. 2021. https://marylandmatters.org/2021/06/10/study-hundreds-in-md-die-prematurely-from-vehicle-emissions/ (accessed 15 July 2024)

27 Wolfe MK, McDonald NC, Holmes GM. Transportation Barriers to Health Care in the United States: Findings From the National Health Interview Survey, 1997–2017. *Am J Public Health*. 2020;110:815–22. doi: 10.2105/AJPH.2020.305579

28 Tyndall J. Waiting for the R train: Public transportation and employment. *Urban Studies*. 2017;54:520–37.

29 Bailey M, Farrell P, Kuchler T, *et al.* Social Connectedness in Urban Areas. *National Bureau of Economic Research Working Paper Series*. 2019;No. 26029. doi: 10.3386/w26029

30 Hua J, Mendoza-Vasconez AS, Chrisinger BW, *et al.* Associations of social cohesion and quality of life with objective and perceived built environments: a latent profile analysis among seniors. *Journal of Public Health*. 2022;44:138–47. doi: 10.1093/pubmed/fdaa217

31 Kamruzzaman Md, Wood L, Hine J, *et al.* Patterns of social capital associated with transit oriented development. *Journal of Transport Geography*. 2014;35:144–55. doi: 10.1016/j.jtrangeo.2014.02.003

32 Badger E. The long, painful and repetitive history of how Baltimore became Baltimore. Washington Post. 2015.

33 Brown LT. *The Black Butterfly: The Harmful Politics of Race and Space in America*. JHU Press 2021.

34 Huang SJ, Sehgal NJ. Association of historic redlining and present-day health in Baltimore. *PLoS One*. 2022;17:e0261028. doi: 10.1371/journal.pone.0261028

35 Burghardt KT, Avolio ML, Locke DH, *et al.* Current street tree communities reflect race-based housing policy and modern attempts to remedy environmental injustice. *Ecology*. 2023;104:e3881. doi: 10.1002/ecy.3881

36 Tessum CW, Paolella DA, Chambliss SE, *et al.* PM2.5 polluters disproportionately and systemically affect people of color in the United States. *Science Advances*. 2021;7:eabf4491. doi: 10.1126/sciadv.abf4491

37 McCormick E, Witherspoon A. US neighborhoods with more people of color suffer worse air pollution. The Guardian. 2023.

38 Study Finds Exposure to Air Pollution Higher for People of Color Regardless of Region or Income. United States Environmental Protection Agency. 2021. https://www.epa.gov/sciencematters/study-finds-exposure-air-pollution-higher-

people-color-regardless-region-or-income (accessed 15 July 2024)

39 Asthma. Maryland.gov. https://health.maryland.gov/phpa/OEHFP/EH/pages/asthma.aspx (accessed 15 July 2024)

40 Lylla Younes, Ava Kofman, Al Shaw, *et al.* Poison in the Air. ProPublica. 2021. https://www.propublica.org/article/toxmap-poison-in-the-air (accessed 15 July 2024)

41 Tracy Fernandez Raysavy, André Floyd. People of Color Are on the Front Lines of the Climate Crisis. *Green America*. 2016.

42 Hsu A, Sheriff G, Chakraborty T, *et al.* Disproportionate exposure to urban heat island intensity across major US cities. *Nat Commun*. 2021;12:2721. doi: 10.1038/s41467-021-22799-5

43 Phelan PE, Kaloush K, Miner M, *et al.* Urban Heat Island: Mechanisms, Implications, and Possible Remedies. *Annual Review of Environment and Resources*. 2015;40:285–307. doi: 10.1146/annurev-environ-102014-021155

44 Bureau UC. American Community Survey 5-Year Data (2009-2022). Census.gov. https://www.census.gov/data/developers/data-sets/acs-5year.html (accessed 15 July 2024)

45 GEOFABRIK // OpenStreetMap. https://www.geofabrik.de/geofabrik/openstreetmap.html (accessed 15 July 2024)

46 USDOT Equitable Transportation Community (ETC) Explorer. https://experience.arcgis.com/experience/0920984aa80a4362b8778d779b090723/page/Understanding-the-Data/ (accessed 15 July 2024)

47 Vital Signs Indicator: Percent of Households with No Vehicles Available. https://bniajfi.org/indicators/Sustainability/novhcl (accessed 28 August 2024)

48 CDC/ATSDR Social Vulnerability Index (CDC/ATSDR SVI). 2024. https://www.atsdr.cdc.gov/placeandhealth/svi/index.html (accessed 15 July 2024)

49 US EPA O. EJScreen: Environmental Justice Screening and Mapping Tool. 2014. https://www.epa.gov/ejscreen (accessed 15 July 2024)

50 Sparrows Point and Bear Creek. https://www.cbf.org/about-cbf/locations/maryland/issues/sparrows-point.html (accessed 15 July 2024)

51 Turner Station residents say Sparrows Point pollution is hurting the land and their health. Baltimore Brew. 2009. https://baltimorebrew.com/2009/12/03/turners-station-residents-say-sparrows-point-pollution-is-hurting-the-land-and-their-health/ (accessed 15 July 2024)

52 Willis A. Maryland finally agrees: That's coal dust on Curtis Bay homes. The Baltimore Banner. 2023. https://www.thebaltimorebanner.com/politics-power/local-government/curtis-bay-coal-csx-JUVDXDSI7REWZN56ZTYWY4WOI4/ (accessed 15 July 2024)

53 CDC. PLACES: Local Data for Better Health. Centers for Disease Control and Prevention. 2023. https://www.cdc.gov/places/index.html (accessed 15 July 2024)

54 Health Equity Report. Harford County Health Department 2023.

55 Regional GIS Data Center | Baltimore Metropolitan Council. https://www.baltometro.org/about-us/data-maps/regional-gis-data-center (accessed 15 July 2024)

56 Calculate Transit Service Frequency (Public Transit)—ArcGIS Pro | Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/public-transit/calculate-transit-service-frequency.htm (accessed 15 July 2024)

57 Bureau UC. TIGER/Line Shapefiles. Census.gov. https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html (accessed 15 July 2024)