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Transit Equity & Environmental Health in Baltimore: Interim Report

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Introduction

Public transit provides access to jobs, food, and healthcare, while also reducing pollution and greenhouse gas emissions. People who use public transit also typically get more physical activity each day due to walking or biking to and from transit stops.

Despite these benefits, public transit in Baltimore struggles to safely get people where they need to go in a reasonable amount of time. The majority of people in Baltimore using transit are low-income and black or brown people. During the COVID-19 pandemic, many transit riders served as “essential workers”.

This project aims to better understand the relationship between the public transit system, key air pollutants linked to transit, and key health impacts related to transit in the Baltimore region. As Peter Drucker said years ago: “you can’t manage what you can’t measure”. The goal is to make recommendations as to which areas would benefit the most from investments to improve public transit.

In order to accomplish these objectives, our first step was to create maps of key transit and equity indicators. Our next step will be to create maps of transit-related pollutants and health outcomes. After that we will expand the analysis to include counties outside Baltimore City. The various maps will be combined to help identify areas with the greatest need for investment and to make recommendations to the City Council, the Maryland legislature, and the Transportation and Climate Initiative.

This interim report focuses on transit equity in Baltimore City.

Advisory Board

As this was a community-based project, the first step was to assemble an Advisory Board of community members to help answer key questions. The Advisory Board was recruited through the primary community partner, Baltimore Transit Equity Coalition. The Advisory Board’s responsibilities include attending meetings, voicing concerns, and providing feedback. The meetings serve as a touchstone to ensure that the research team is in contact with the community and conducting research that truly addresses their needs and desires.

Methods

For the initial analysis we started off with three themes: Transit, Social Vulnerability, and Safety. Each theme had various indicators based on readily-available data. For each indicator, we calculated a percent rank, such that a higher rank value indicated an area more in need compared to the rest of the city. Each theme’s score was simply the average of all its indicators.

Our analysis focused on Baltimore City. The unit of analysis was typically census block *groups*. Census *blocks* are the smallest unit of analysis for the US Census. Census block *groups* represent contiguous census blocks, with an average population of 1,000, and are approximately equal in area[1]. Census tracts generally have a population between 1,200 and 8,000, with an optimum size of 4,000 people. A census tract usually covers a contiguous area; however, the spatial size of census tracts varies depending on the population density.[2]

There are exactly 200 census blocks in Baltimore City. Maps were kept at the fine resolution (census block groups) if possible. If we didn't have block group info, we assigned it a value based on its census tract.

Transit Analysis

The existing BaltimoreLink traverses the city and surrounding suburbs. The spatial coverage of the BaltimoreLink service is illustrated in Figure 1, but the temporal distribution of the demand is ignored. For simplicity, in this study it is assumed that all trips originate from the centroids of census blocks and ended in a centroid of another census block.

The Advisory Board determined which indicators were the most useful and relevant to measure. The transit score was broken into Access and System Performance, which were further broken into various indicators listed below. The research team used various resources, including current maps of the MTA transit system, Census (aka American Community Survey or ACS) data, and General Transit Feed Specification (GTFS) data.

This last resource (GTFS) was developed in 2005 by Google and TriMet for transit agencies to share their schedules, trips, routes, and stops data in an open-source platform that can be used for Google Transit Web-based trip planner. A GTFS dataset consists of several plain text files which have been formatted as Comma-Separated Values (CSV). The team used Google spreadsheets and Geographic Information System tools to collect data and analyze data. Specifically, ArcGIS Pro 2.6.3 and R Studio 3.6.1 were used for geoprocessing of spatial data and statistical analysis.

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1 https://www.federalregister.gov/documents/2018/11/13/2018-24570/block-groups-for-the-2020-census-final-criteria

2 https://www.census.gov/programs-surveys/geography/about/glossary.html#:~:text=Back%20to%20top-,Census%20Tract,Bureau's%20Participant%20Statistical%20Areas%20Program.

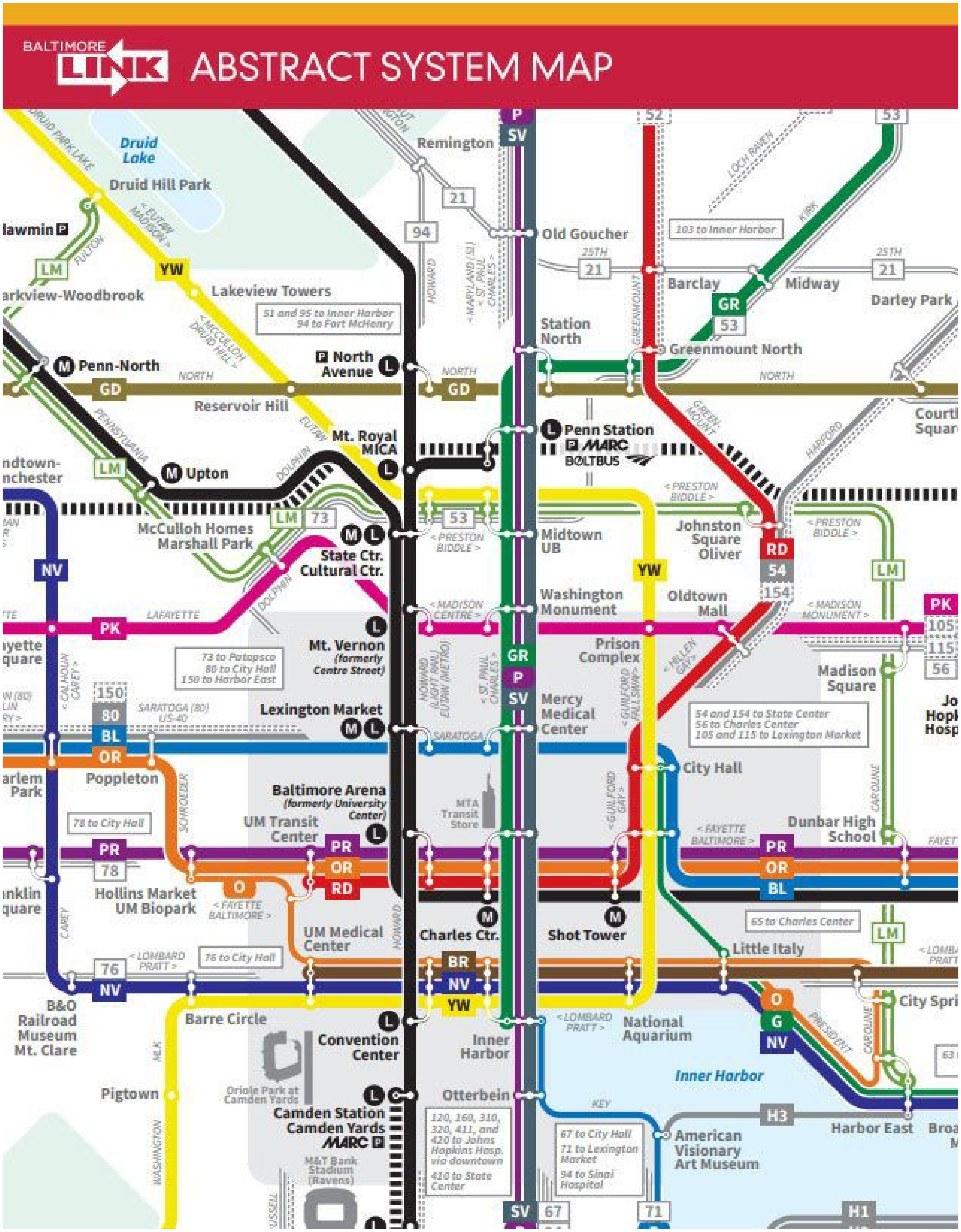


Figure 1. Baltimore Link Map

Access

Transit accessibility looks at potential opportunities to reach a destination and ease of travel. Elements may include population density, job availability, or service/facility availability at the destination. Transportation elements include the distance to transit, the frequency of the transit, the cost of travel (including time that it takes), and the comfort of service.

We measured accessibility using GTFS data to calculate transit travel time between census blocks. The idea was to find the fastest path using transit and later compare it with automobile travel time. We developed a travel time matrix (a csv file) to explore the impact of network connectivity on accessibility measures. The measures included:

Number of stops in the census tract

The resulting value was reversed in percentile, so that higher numbers indicated a need for greater investment.

Distance over a half mile to high frequency transit routes

A score of “0" meant that the census block centroid was within 0.25 miles of a high frequency transit route. Thus, a higher score meant that a census block centroid was farther from a high frequency transit route.

Percent of the workforce commuting by public transit

Data from the ACS was used to determine what percent of the workforce in each tract used public transit. A higher percentage of the workforce commuting by public transit in a given Census tract indicates that the estimated travel time data in that tract is more **reliable**.

System Performance

The performance of any transit system can be evaluated by service quality and operating costs. For this report we focused on indicators of service quality.

GTFS data was collected from MTA open source locations and displayed with ArcGIS by using the BetterBusBuffers toolbox, developed by Melinda Morang at ESRI (2015). The toolbox consists of routines for extracting service frequencies from transit data stored in the GTFS format and is used for travel time estimation. The functionality available in this toolbox applies SQL databases and stored query procedures intended to summarize incoming GTFS datasets. BetterBusBuffers toolbox (ESRI) is used to develop the SQL database storing a service frequency value for each MTA bus stop location in Baltimore. Centroids of each census block are considered as both the origin and destination points.

To travel from census block A to census block B using transit services, it is assumed that the walking speed of a person to reach the bus stop is 3 miles per hour and it will take 30 seconds to get on and off the bus. Travel times between census blocks have been calculated such that trips can occur in only one direction, meaning traversal is not allowed in the backwards direction. The following indicators were used to measure system performance:

Estimated Average Commute Time

For this indicator we calculated the average time for all workers to get to their various job locations in the City. Data sources for this included:

- LODES data[3] from Foursquare = block group real data
- Number of workers in any given block group commuting to any other block group
- ACS for census tract estimates
- Percent of population which commutes to work by any public transit
- GTFS for census tract estimates
- MTA network information for estimates of commute time between all combinations of census tracts by public transit and by private vehicle

By including non-transit commute time, average commute time shows people who choose not to use transit, who could use transit. The average commute time for block group A was calculated as # workers going to B/total # workers [(% commuting by transit*Time from A to B by public transit) +
% not commuting by transit*Time from A to B by vehicle)] +
# workers going to C/total # workers [(% commuting by transit*Time from A to C by public transit) + % not commuting by transit*Time from A to C by vehicle)] +
... to all block groups which workers go to.

- Inputs:
    - # of workers in each block group going to various other block groups for employment
    - % of workers commuting by public transit by census tract (ACS estimate)

We repeated this process for all block groups, iterating through all real destinations of workers from that block group to those of job location. This assumes:

- Travel times from block group A to B are between the centroids of the census tracts which A and B each fall into.
- ACS estimates for percent of workforce commuting by public transit are homogenous across block groups within each census tract; also those in a block group equally use public transit (PT) regardless of destination.

The limitations of this calculation include:

- This only looks at the distribution of workers who both reside and work within the city.
- GTFS estimates were limited to census tract-census tract commute times due to memory/processing limitations.

[3] https://lehd.ces.census.gov/data/

- This uses a private vehicle commute estimate for those not commuting by public transit (doesn't account for carpooling, walking, other forms of commuting which are specified in ACS survey).

Estimated difference between average commute by public transit versus by car

The indicator provides insight into what drives people's decisions as they choose their commute. This was calculated similarly to average commute time in terms of set up with LODES data and Connection Matrix (GTFS) estimates, but no longer uses the ACS estimate of percent of workers commuting by public transit. This value represents the average commute time between anyone using public transit versus anyone using a car, regardless of how many people are doing either of those things. It still factors in how many people are realistically going to certain places (mean commute was still weighted by worker destinations).

Key assumptions included:

- that the workers not taking public transit use a private vehicle (when in fact they could bike or walk, for example).
- that estimated travel times by public transit and by personal vehicle generated using census tract centroids as the origin and destination points are reasonable estimates for residents and employers within a given census tract (potentially excluding the last mile barrier).

Percent of population commuting by transit whose commute is >45min

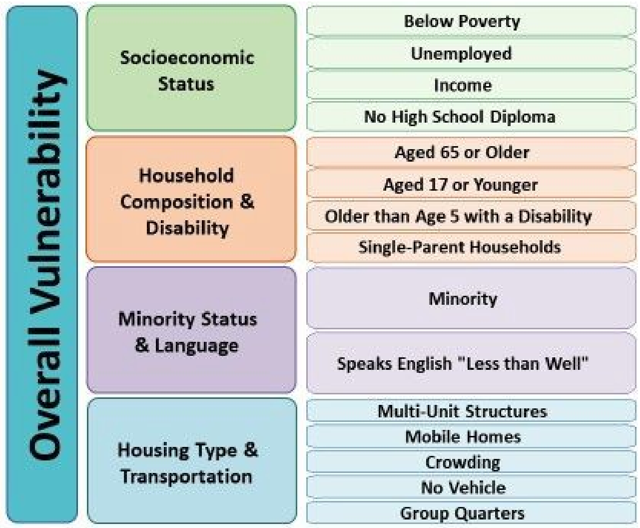
The ACS provides commute times by census tract in five-minute intervals between 10 and 60 minutes by type of transportation. Considering only the population who commuted by public transit, we calculated the percent of people whose commute time was more than 45 minutes (summed up the people in intervals above 45 and divided by the total population).

Social Vulnerability Analysis

Communities' ability to access resources and opportunities not only relates to local infrastructure but is also impacted by factors such as poverty, which can impose drastic hardships on individuals living in those communities. To better understand the social vulnerability of the communities in Baltimore the research team decided to use the Social Vulnerability Index (SVI) developed by the U.S. Centers for Disease Control and Prevention.

SVI indicates the relative vulnerability of every U.S. Census tract based on 15 factors, including unemployment, minority status, and disability. Each tract received a ranking for each variable and for each of the four themes (Socioeconomic, Household Composition & Disability, Minority

Status & Language, Housing Type & Transportation), as well as an overall ranking.[4] For our purposes, we used the overall score and recalculated percentiles relative to Baltimore City.



Safety Analysis

Transit use can be driven by perception of safety - safety while waiting for a bus and safety while riding the bus. Safety is one of the most debated factors impacting transit-dependent users' travel behavior. With properly established safety metrics, local officials can measure their progress in establishing an equitable transit system. Continuous monitoring of safety performance data in transit can help address safety-related challenges and properly allocate resources. The purpose of the safety measures is to understand which factors impact transit commuters' everyday life in the Baltimore metro area.

We were able to find data on accidents between automobiles and pedestrians, as well as data on accidents between automobiles and bicycles, and data on overall crime. However, this data did not address safety while using transit, so in the end we decided to exclude this theme from the current analysis. Hopefully, future iterations of this report will include indicators of safety (perhaps 911 and 311 calls related to transit). Such data could help make recommendations about lighting, presence of peace officers, or other interventions to improve safety.

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[4] Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. CDC Social Vulnerability Index 2018 Database Maryland. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html.

Results

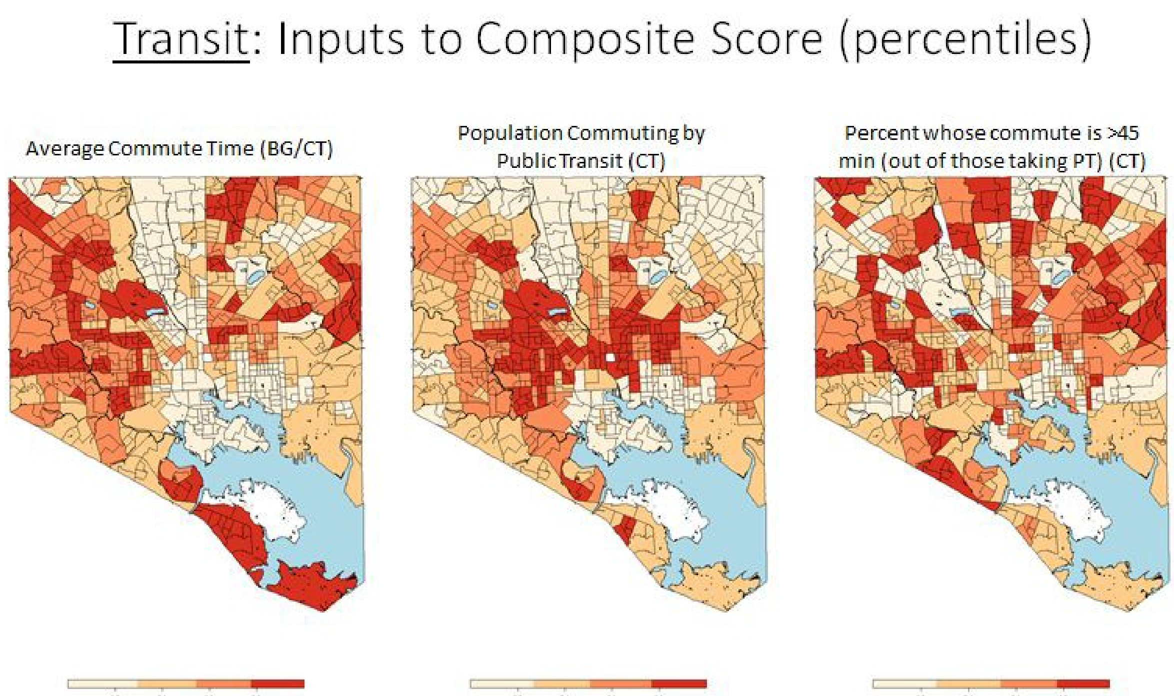
Transit Score

The results were mapped by each transit indicator. In all the maps, the higher score (darker color) indicates areas of greater need. For example, as mentioned in the methods section, a higher number of transit stops would be a positive attribute, but for the sake of mapping, the values were reversed so that a higher score indicates fewer transit stops (meaning an area in need of greater investment).

All of the following seem to increase further away from the city center:

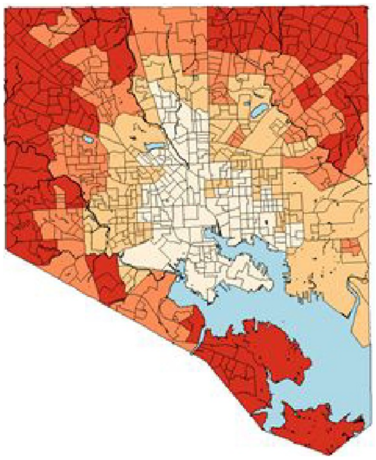
- Average commute time
- Percent of public transit-utilizing population whose commute is greater than 45 minutes
- Difference in average commute time between public transit and personal vehicle use
- Distance to high frequency transit stops

This is logical, however, there are noticeably some tracts that have a disproportionate need for investment. Their locations relative to the city job center do not reasonably align with average commute time, commute time greater than 45 minutes, and number of transit stops. The map comparing the percent of population with commute times greater than 30 minutes versus 45 minutes shows that commute times are not only high in these tracts, but that those who do have long commutes have unreasonably long ones. Thus, these neighborhoods have the highest need for transit investment.

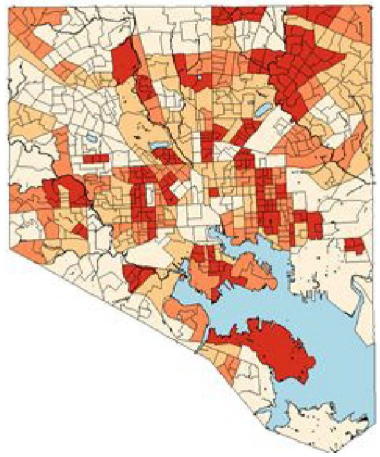


Transit: Cont'd Inputs to Composite Score (percentiles)

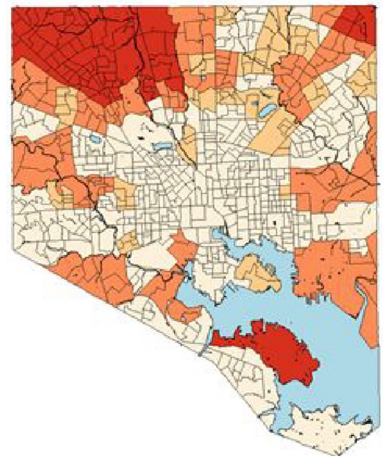
Difference in Average Commute Time



Number of Transit Stops (CT)

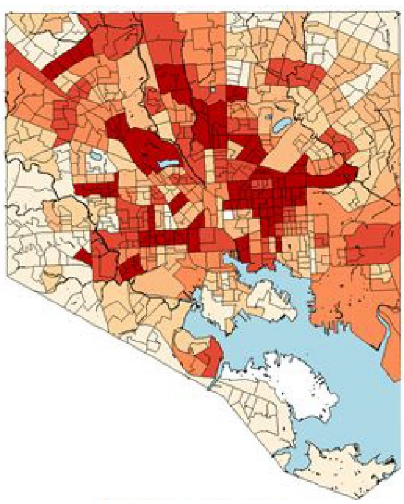


Distance to High Frequency Transit Stops (manual breaks)

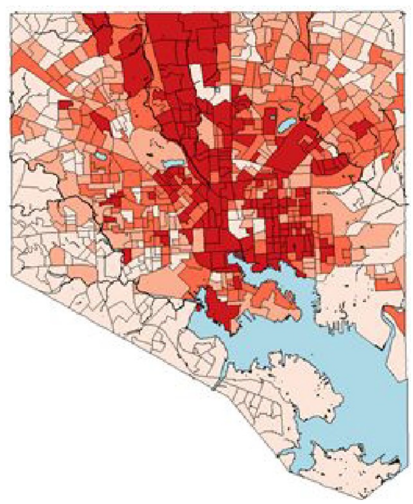


Percent (of employed) working in the City

- for whom the commute & difference in commute times are calculated for -



ACS estimate

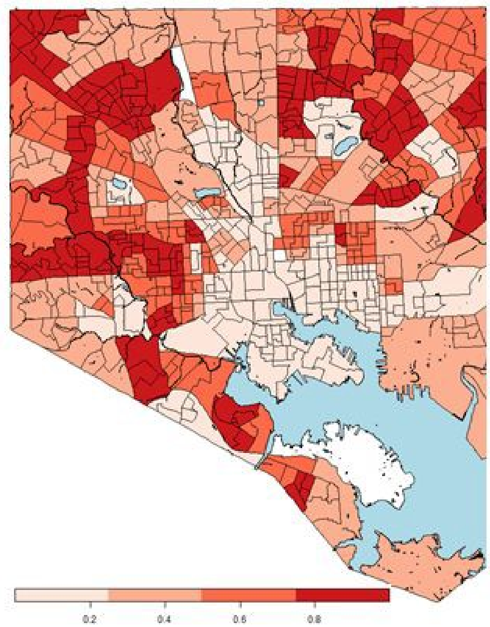


LODES estimate

Transit Indicator

Inputs

- Estimated average commute time
- Percent of population commuting by public transit
- Percent of population commuting by transit whose commute is >45min
- Estimated difference between average commute by public transit versus by car
- Number of transit stops in census tract (*reversed in percentile)
- Distance over a quarter mile to high frequency transit routes



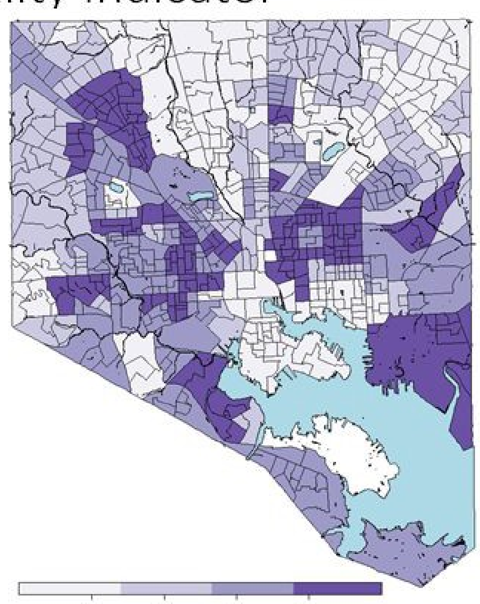
Vulnerability Score

The composite social vulnerability map showed the notorious white ‘L’ and black ‘butterfly’ associated with Baltimore. The lighter ‘L’ shape in the center of the map is mostly populated by whites and those with higher incomes, due to historic racism and redlining, while the darker colors that look like a butterfly comprise of neighborhoods mostly populated by people of color and of lower income.

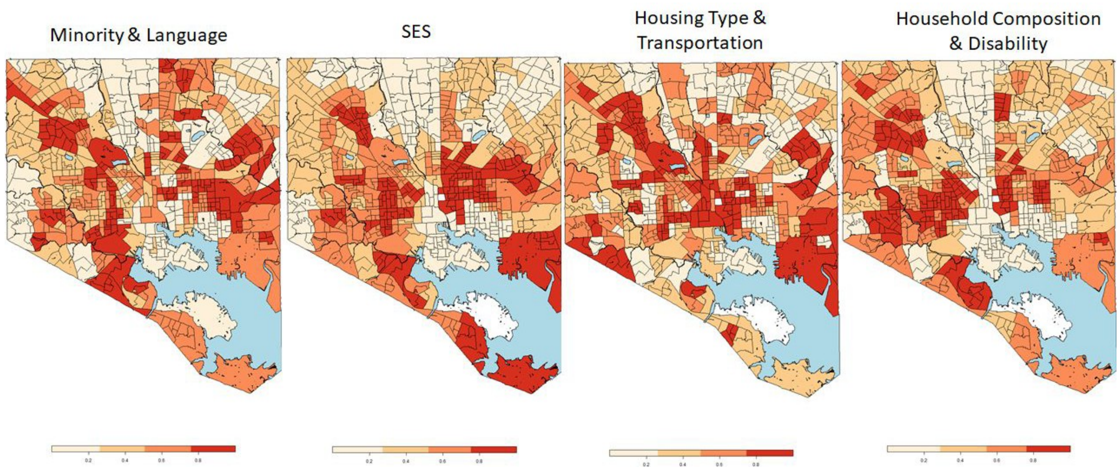
Social Vulnerability Indicator

Inputs

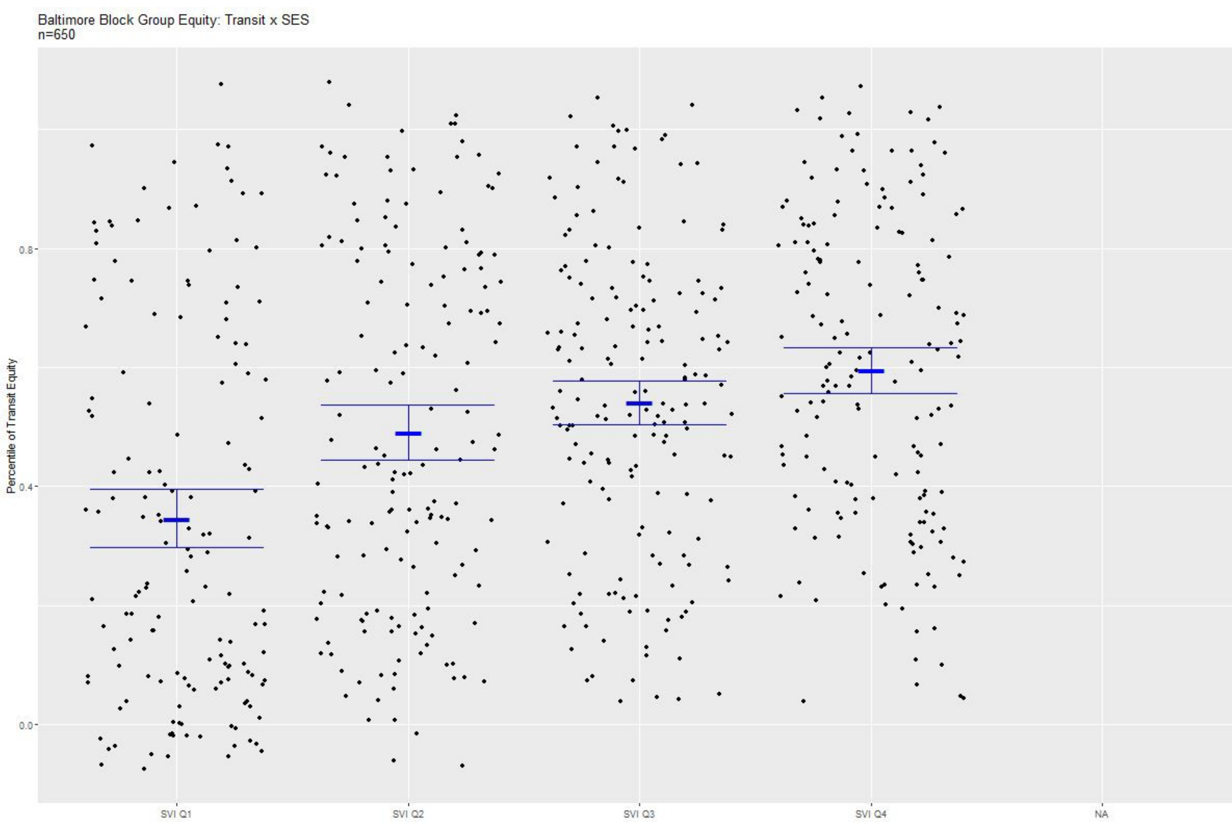
- Minority & Language Composite Score
- Socioeconomic Status Composite Score
- Housing Type & Transportation Composite Score
- Household Composition & Disability Composite Score



Below, we also show the four components of the composite score so that readers can see that the same pattern holds true for all three indicators, except housing type and transportation. This is likely due to many multi-unit dwellings in the downtown area, along with fewer people having cars due to their proximity to transit and many downtown amenities.

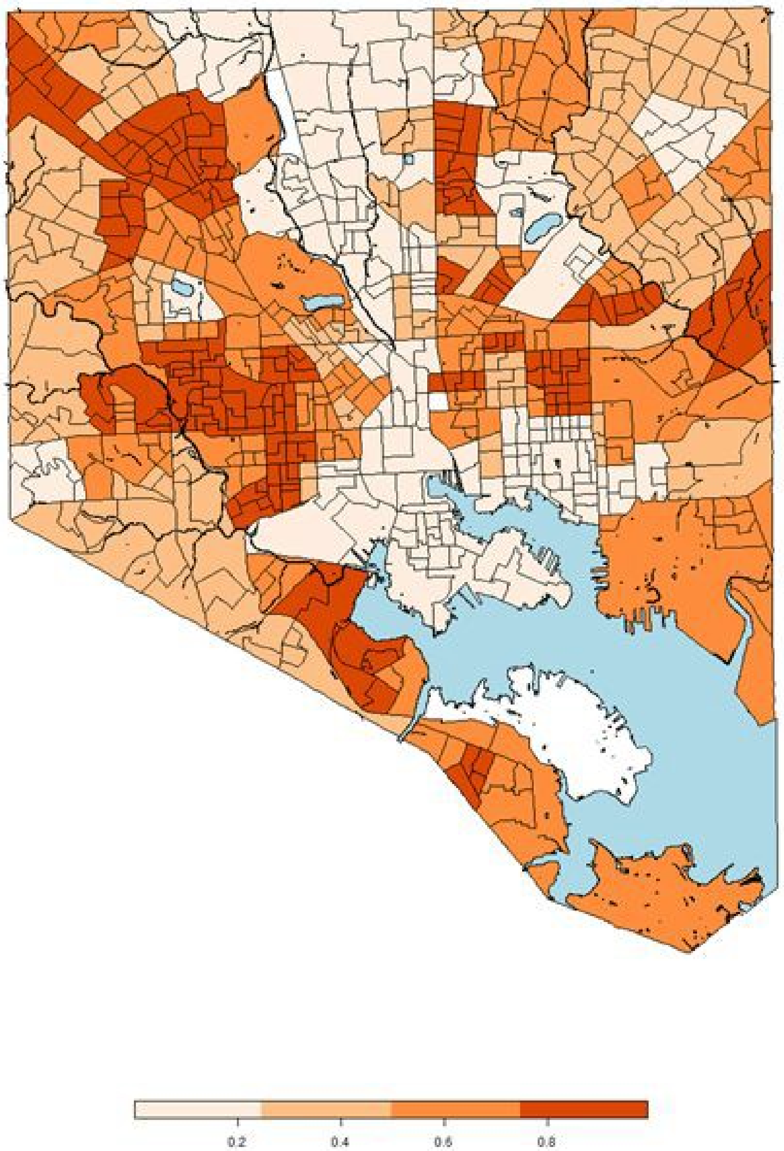


Seeing these maps in combination with the transit maps, it is clear that neighborhoods in the "black butterfly" with higher social vulnerability are more likely to have greater transit needs. Furthermore, the below graph relates transit and social vulnerability themes, indicating that those who are more socially vulnerable also have less access to high quality transit.



Interim Transit Investment Need Map

Finally, after all the data was processed using ArcGIS Pro 2.6.3 and R Studio 3.6.1, the maps were overlaid to determine which areas have the greatest need for investment.



Discussion

Transit impacts health in many ways – from the air pollution generated by the burning of fossil fuels, to the fact that reliance on cars leads to decreased physical activity, and even the lack of access to reliable transit having detrimental effects on mental health and the ability to maintain a job or feed your family.

Public transit is an underutilized but important tool in improving health. Using one vehicle for multiple people at a time reduces the number of vehicles in transit, and thus congestion that can lead to motor vehicle crashes and air pollution. It also increases physical activity as users walk to and from public transit stops. Public transit can also increase access to parts of a region otherwise not accessible– including areas with healthy food, medical care, jobs, and education.

This is especially important from an equity perspective since low-income households are less likely to own cars and are more dependent on alternative methods of transportation[1]. Communities planned around mobility rather than accessibility systemically benefit more affluent people, which in turn perpetuates racial, socio-economic, and health disparities[2]. Hence, access to public transit is a crucial determinant of health that must be studied further.

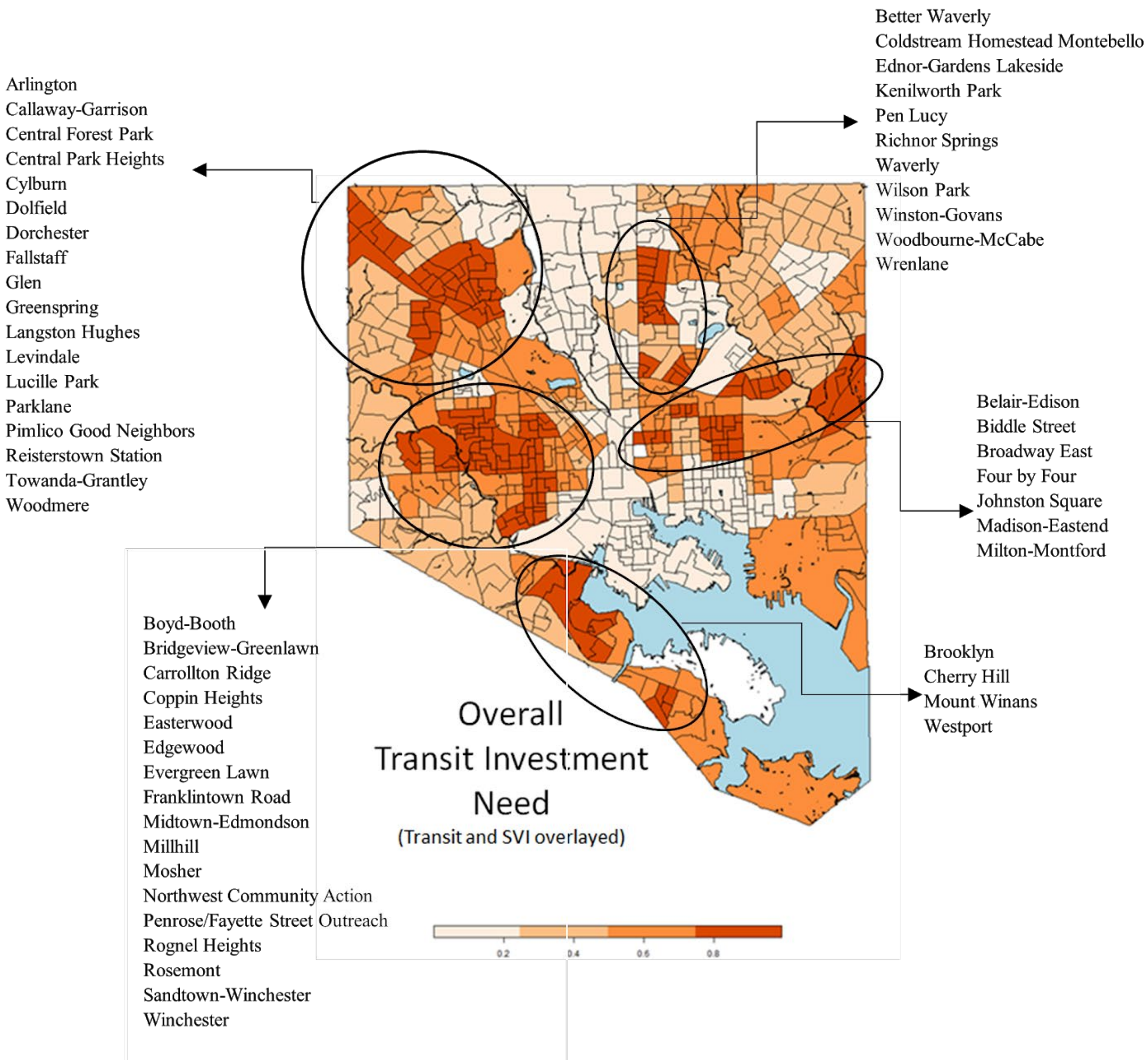
This study focused specifically on the accessibility and service quality of BaltimoreLink. The findings of this project can inform policy and investments to help alleviate the stress and undo a small part of the structural injustice woven into the fabric of Baltimore.

Many assumptions, as outlined in the methods section, were made, but the data is better than what's available from MTA now. The benefit of our approach is that we used LODES data, which included information about the location of people's jobs and their homes.

With a longer project duration and the use of real-time GTFS data, the project team would most likely have documented commute times likely longer than estimated commute times. In addition, our analyses would have been more robust, if stop-level and ridership and origins and destinations data had been available from MTA. In future studies of this type, we would recommend the use of bus routes and actual travel time rather than estimates. We also recommend that we determine which commutes exceed 90-minutes and how commute times vary for low-income jobs. Hopefully, future iterations of this report will include indicators of safety (perhaps 911 and 311 calls related to transit).

Recommendations

In combination with the transit maps, it is clear that neighborhoods in the "black butterfly" with higher social vulnerability have greater need. More specifically, this indicates the potential need for greater investment in transit in the neighborhoods highlighted below:



Acknowledgements

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- Mehri “Mehrsa” Mohebbi, PhD, Equity in Transportation Lead, University of Florida Transportation Institute

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- Denise Griffin, Director of Arch Social Community Network
- Sharif Rashid, member of the Baltimore Transit Equity Coalition

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[1] Evelyn Blumenberg and Gregory Pierce (2012), "Automobile Ownership and Travel by the Poor," Transportation Research Record 2320, Transportation Research Board (www.trb.org), pp. 28-36; summary at http://trb.metapress.com/content/c55v7w5212611141.

[2] https://vtpi.org/equity.pdf

[3] Banerjee, S., & Bhuyan, I. (2019, August). Correlation of Crime Rate with Transit Connectivity and Transit Demand at Census Block Group Level. In International Conference on Transportation and Development 2019: Innovation and Sustainability in Smart Mobility and Smart Cities (pp. 158-170). Reston, VA: American Society of Civil Engineers.

[4] Lee, Y. J., Choi, J. Y., Yu, J. W., & Choi, K. (2015). Geographical applications of performance measures for transit network directness. *Journal of Public Transportation*, *18*(2), 7.

[5] Bhuyan, I. A., Chavis, C., Nickkar, A., & Barnes, P. (2019). GIS-Based Equity Gap Analysis: Case Study of Baltimore Bike Share Program. *Urban Science*, *3*(2), 42.