***Title of the Project:***
Development of a Transportation Index: Breaking Barriers to Accessing Services

***Timing:***
Fall Semester

***Client:***
The Allegheny County Department of Human Services (DHS) is responsible for providing and administering publicly-funded human services to County residents. DHS provides a wide range of services, including services for the older adults; mental health services (includes 24-hour crisis counseling); drug and alcohol services; child protective services; at-risk child development and education; emergency shelters and housing for the homeless; non-emergency medical transportation; and referrals for supports coordination for individuals with a diagnosis of intellectual disability. We are a government organization with ~1000 employees.

***Issue Definition:***
The Allegheny County Department of Human Services (DHS) serves many clients who rely on public transportation to access work, amenities, and social services. However, DHS does not currently have a standardized method of identifying clients who face especially high transit barriers, or clients for whom transit is not adequately meeting their needs. This lack of knowledge hinders DHS from developing better approaches for addressing the mobility needs of Allegheny County's disadvantaged populations.

***Goals (in order of priority)***
- To develop a tool that will allow DHS to identify clients who face high transit barriers
- To integrate this tool into our "Data Warehouse"
- To provide/promote the use of this tool to other stakeholders
- To provide policy recommendations on how to reallocate resources to assist consumers with transit barriers

***Actions***
DHS would like a CMU student team to construct a tool that classifies each DHS client according to how well their life needs are being met by public transit. This tool would ideally be embedded within DHS's integrated data warehouse, in order to generate a transit needs indicator in real time based on refreshable data. This transit needs indicator can be comprised of one or more scores, indices, or qualitative categories. The results could be generated by a geospatial analysis tool that draws upon DHS service records, client demographics and locational data, transit system information, and other sources of socioeconomic data that shed light on a person's level of reliance on public transit.

Some particular dimensions of transit need that could be captured in the tool are:
- Identifying pairs of geographies in Allegheny County that have a high concentration of low-income commuters, meaning a place where many low-income people live and a corresponding place where many of those same people work. This can be derived from the Census Bureau's LEHD LODES dataset.

- The percentage of all opportunity occupation jobs in Allegheny County that are reachable from a client's home address within 60 minutes via public transit with no more than 20 minutes of walking, as measured at various times of the day.

***Internal Data:***
DHS organizes our data using a Data Warehouse – a common client management technology system that integrates and consolidates data from our different program offices, as well as external partners. Data is analyzed by staff at DHS, shared with researchers, and provided to external stakeholders in a variety of different manners. Data is refreshed daily, and is at the client/service level. Read more about the warehouse here:
https://www.alleghenycountyanalytics.us/index.php/dhs-data-warehouse/

***Ae you aware of any public data sources that would be useful for this project?***
There is a great deal of public data available for this project, including information from the Census Bureau (LEDH) as well as many other sources.

***What data would the team need in addition to the ones above?***
Additional data would be made available from our partners at the Port Authority of Allegheny County (PAT), including data on ridership, routes, and bus availability.

***Analysis:***
We would expect that the team would spend a substantial amount of time analyzing other tools that have been built in this space, and providing guidance on the best approach. After the tool is built, and if time permits, DHS would welcome the use of this tool by the team to provide policy recommendations on how to reallocate resources to assist consumers with transit barriers.

***Skills Required:***
Economics, statistics, policy analysis, data analytics, and of course GIS would be helpful skills.

***Advisory Board:***
Members could include representation from PAT, advocacy groups such as the Southwest PA Commission, and think tanks such as Metro21 (https://www.cmu.edu/metro21/)

***Faculty Advisor:***
Sean Qian

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# Measuring Transit Accessibility in Allegheny County

## Methods and findings from a study of opportunity employment

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In collaboration with
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Carnegie Mellon University
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## Abstract

This research explores the impact of existing bus service provided by the Port Authority of Allegheny County (PAAC) on access to opportunity occupation jobs in Allegheny County, Pennsylvania. Accessibility is operationalized by bus travel time, a comparison to car travel time, number of transfers, cost, frequency, walkability, and the availability of opportunity occupation jobs for each combination of defined origins and destinations on a 0 - 100 scale.

Residential origins were selected by block group based upon populations identified through Allegheny County Department of Human Services (DHS) input, U.S. Census data, and interviews with those working with populations of interest. Populations of interest included low-income, employment status, and other indicators. Destinations were selected through an analysis of job data and use of kernel density analysis of opportunity job counts and locations. The resulting accessibility between the origin and destination results in an aggregate accessibility score from each origin and destination pair. Further spatial analysis occurred using ArcGIS to visualize the accessibility index scores.

The research concluded that several identified origins were not generally accessible to many opportunity zones even when they were geographically close. Distance from the county center was associated with lower scores and fewer accessible routes for both origins and destinations. Because of this, high potential opportunity zones on the fringe of the county were often times unreachable. It is recommended for decision-makers to explore last-mile/first-mile solutions for really high-potential proximal origins and destinations. The project also encourages the use of the accessibility index and intermediate transit helper tools for advocacy related to expanded transit access.

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# 1. Introduction

Allegheny County is the second largest county by population in Pennsylvania. With over one million people living in the county,[1] reasonable and reliable means of transportation are essential. In fact, recent research has found a link between geographic and economic mobility.[2] The Allegheny County Department of Human Services (DHS) is interested in measuring how the Port Authority of Allegheny County's (PAAC) transit system impacts access to employment.

This led to the research question: How accessible are opportunity occupations in Allegheny County by public transit?

In order to answer the main research question, the following sub-questions were developed:

1. How can accessibility be defined?
2. How can accessibility measures be quantified, combined and compared?
3. Where are DHS's populations of interest?
4. Which industries have the highest opportunity employment?
5. Where are opportunity occupation zones located?
6. What percent of opportunity occupation jobs are accessible by the existing bus transit system?
7. How can DHS intervene and provide assistance to clients with poor transit accessibility? (e.g., policy recommendations, support programs)

Using multiple data sources (including anonymized data supplied by DHS, real-time historical PAAC service data, American Community Service data, Reference USA, and the Western Pennsylvania Regional Data Center), employment accessibility via public transit was defined through an index tool that evaluates how public transit serves different opportunity occupation zones of Allegheny County relative to areas of interest. In response to stakeholder input, the index was designed to capture several different aspects of the transit experience, including time, reliability, cost, and physical setting. Finally, ArcGIS visualized key findings of the accessibility index. The results of the study were integrated into a publicly available ArcGIS Operations Dashboard. Accessibility index findings include a number of surprising origins and destinations that were inaccessible, including zones which were geographically close. The paper discusses these findings before making policy recommendations for future study and first-mile/last-mile solutions.

### Definitions

- **Census Block Group**: U.S. Census Bureau geographic unit of analysis that is a combination of census blocks, the smallest geographic unit of analysis that the Census Bureau uses. Block groups usually have a population between 600 to 3,000 people.

[1] U.S. Census Bureau. "U.S. Census Bureau QuickFacts: Allegheny County, Pennsylvania." (2018). Accessed November 17, 2019. https://www.census.gov/quickfacts/alleghenycountypennsylvania.
[2] Chetty, Raj, Nathaniel Hendren, Patrick Kline, and Emmanuel Saez. "Where is the Land of Opportunity? The Geography of Intergenerational Mobility in the United States," *The Quarterly Journal of Economics* 129, Issue 4 (November 2014): 1553–1623. https://doi.org/10.1093/qje/qju022.

- **Expected travel time range**: The distance between average travel time and an upper-bound of travel times (based on scheduled data).
- **Opportunity occupations**: Full-time, year round jobs that offer more than the median annual wage without requiring a bachelor's degree[3]
- **Opportunity (occupation or employment) zone**: Custom geographic area representing a high density of estimated opportunity occupations identified using spatial analysis
- **Port Authority "Walkshed"**: Map layer indicating 5 minute walking distance from the centerline of the road. This communicates a reasonable walking distance from the routes.**
- **Buffer**: Usually a quarter-mile radius around bus stops or geographic locations, a standard found in the literature
- **Walkability**: An indicator for the presence of pedestrian-friendly intersections

## 2. Literature Review

The literature review was divided into three parts to understand the type of analyses that has already occurred in the space. Opportunities to combine findings and methods from different sources were explored. The three areas were 1.) origin/population selection, 2.) opportunity occupations, and, 3.) transit accessibility.

### Origin Selection

This project explored several different sources to understand areas of "high need" in Allegheny County. A few sources to highlight include the PAAC Equity Report and the 412 Food Rescue GIS Study.

**412 Food Rescue GIS Study**.[4] In September 2018, 412 Food Rescue, an Allegheny County nonprofit which seeks to address food insecurity, released a study demonstrating that lack of access to transportation was a key issue in accessibility to food access. The study used publicly available Census data to examine how much of the population they or their food rescue partners reached, focusing on food and transit deserts in Allegheny County. Of the population studied, they found approximately 277,000 people living in transit deserts, an area with a high need of transit service. This study resulted in maps that show areas and neighborhoods with a high need of public transit in Allegheny County, a key starting point for this study's research of public transit accessibility and connecting to opportunity zones.

**PAAC Equity Report**.[5] The 2019 Equity Index of Mobility Need by Port Authority of Allegheny County was foundational to understanding where the county believes there is opportunity to provide improved

[3] Wardrip, Keith. "Identifying Opportunity Occupations in Pennsylvania, New Jersey, and Delaware." Philadelphia: Federal Reserve Bank of Philadelphia, 2015. https://www.philadelphiafed.org/-/media/community-development/publications/special-reports/identifying_opportunity_occupations/identifying_opportunity_occupations_complementary_report.pdf?la=en.

[4] 412 Food Rescue. "Food Insecurity and Resource Access in Allegheny County, Pennsylvania: Using GIS to Identify High Need Communities and Assess Food Recovery and Redistribution Efficacy." Pittsburgh: 412 Food Rescue, 2018. Accessed September 23, 2019. https://412foodrescue.org/wp-content/uploads/2018/04/412-Food-Rescue-GIS-Study-.pdf.

[5] Port Authority of Allegheny County. "Equity Index of Mobility Need." Pittsburgh, PA: Port Authority of Allegheny County, 2019. Accessed September 22, 2019. https://www.portauthority.org/link/631978a20a6948acb50cb608e4f908c4.aspx.

service. The PAAC index was constructed considering a number of factors important to equitable transportation- including poverty status, households with  persons with disabilities, racial/ethnic minorities, and the elderly. Using several of the PAAC equity index indicators as a starting point for data compilation, our origin team downloaded and processed relevant U.S. Census ACS data for Allegheny County for the use of our project. Moreover, our group leveraged the Final Equity Index of Mobility Need section from the PAAC report to help us identify the areas of the county with high transportation needs.

## Opportunity Occupations

Opportunity occupations are defined as jobs paying more than median annual wage; not requiring a Bachelor's degree; offering full employment (50-52 weeks of the year); and offering between 35 - 60 hours per week.[6] Some of the top growing jobs that don't require a bachelor's degree include technicians, health-care related fields, and occupational therapy.

Computing the number of opportunity occupations is often challenging due to the lack of a publicly available centralized database. Some approaches, like a method by the Federal Reserve Bank of Philadelphia, explore job vacancy information from Burning Glass to detect opportunity occupations and project their growth[7]. When looking observing the occupation-level data, a few trends stand out. A few of the most prevalent jobs which offered more than the median wage included sales representatives, business operations specialists, a number of healthcare related positions, and jobs related to construction, maintenance, and repair.[8]

Importantly, opportunity occupations are strongly associated with specific industries. Industry-related information, combined with ACS information, can approximate opportunity occupation mix in a locality. By coupling this data with information from the Longitudinal Household Employer Dataset, it becomes possible to map this information spatially at the census block level. The main mechanism for this conversion is called an industry opportunity share.[9]

$$\text{Opportunity Share} = \frac{\text{Opportunity Employment } \textit{for each industry}}{\text{Total Employment}}$$

Identifying individuals holding opportunity occupations is possible by subsetting a random sample of individual responses from the American Community Surveys data set. Importantly, identifying and

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[6] Wardrip. "Identifying Opportunity Occupations in Pennsylvania, New Jersey, and Delaware."

[7] Fee, Kyle, Keith Wardrip, and Lisa Nelson. "Opportunity Occupations Revisited: Exploring Employment for Sub-Baccalaureate Workers Across Metro Areas and Over Time." Cleveland: Federal Reserve Bank of Cleveland, April 2019. Accessed September 3, 2019. https://www.clevelandfed.org/~/media/content/newsroom%20and%20events/publications/a%20look%20behind%20the%20numbers/albtn%20opportunity%20occupations/opportunity%20occupations%20revisited.pdf?la=en.

[8] Ibid.

[9] DeMaria, Kyle. "Getting to Work On Time: Public Transit and Job Access in Northeastern Pennsylvania." Philadelphia: Federal Reserve Bank of Philadelphia, 2018. Accessed September 3, 2019. https://www.philadelphiafed.org/-/media/community-development/publications/special-reports/public-transit-and-job-access-in-northeastern-pennsylvania/getting-to-work-on-time.pdf?la=en.

quantifying these desirable employment opportunities involves understanding the unique industry composition of a particular geographic area.[10]

This study followed the second approach, using opportunity shares to understand the unique industry opportunity "mix" for Allegheny County. While borrowing from this initial approach of using ACS data to understand industry trends, the current analysis made an important deviation. The ACS data only provides industry information at the block group level; because our goal was ultimately transit analysis, we needed more granular data that would be conducive to selecting bus stops. The ReferenceUSA business database was in order to access specific business location, industry and employee count information.

### Transit Accessibility

Most existing methods for transit accessibility use either time or distance based metrics. Policy-makers tend to consider accessibility in terms of location-based measures to analyze transit access and land use: "Location-based metrics typically account for the number of opportunities that can be reached from a specific location, based on the travel costs to destinations using a specific mode. Travel costs are generally measured based on travel time or distance."[11] There are three other common metrics of transit performance:

1. Opportunity- based: Relates to how many destinations can be reached from a certain point at a given time using an identified mode of transportation
2. Gravity-based: Modification of opportunity based that considers distance
3. Utility-based: Calculates options the respective value and utility of corresponding destinations. [12]

Of key importance for this study were not only location and time-based factors but also issues of interest to Allegheny County stakeholders. These included metrics related to physical access, trip cost, comparison to car travel time, and reliability of service.

## 3. Data Sources

This project defined origins, destinations, transit access, and accessibility using a number of tools. While relevant data sources will be discussed at length in the following sections, this graphic (figure 1) may be helpful to understand how the sources tie together. More granular information can be found in the Appendix.

[10] Ibid.

[11] Boijoly, Genevieve, and Ahmed El-Geneidy. "Measuring Performance: Accessibility Metrics in Metropolitan Regions around the World." August 2017. https://www.brookings.edu/wp-content/uploads/2017/08/measuring-performance-accessibility-metrics.pdf.

[12] Deboosere, Robbin, and Ahmed El-Geneidy. "Evaluating Equity and Accessibility to Jobs by Public Transport across Canada." *Journal of Transport Geography* 73 (2018): 54–63. https://doi.org/10.1016/j.jtrangeo.2018.10.006.

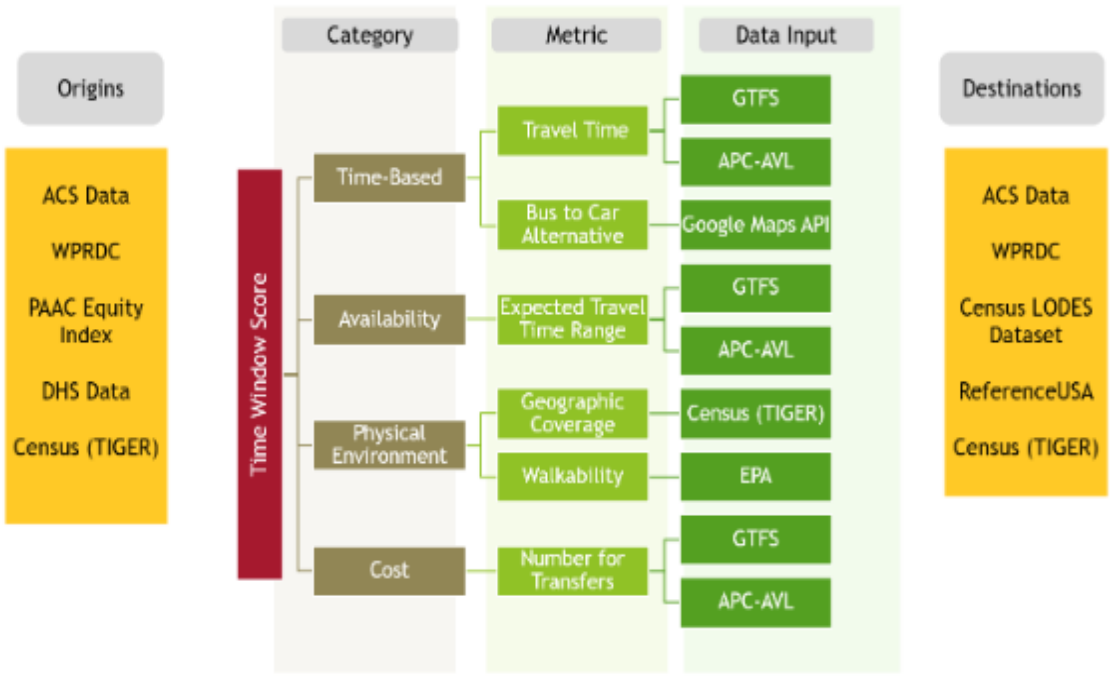


*Figure 1: Project Data Sources*

## 4. Methodology

Similarly to the literature review, the methodology of completing the index was divided into three parts of origin selection, opportunity employment zone selection, and transit analysis, in addition to stakeholder interviews as incorporated into all of the sections as necessary.

### Stakeholder Interviews

A variety of stakeholders were interviewed in order to incorporate information and gather research insights. The project aimed to include as many perspectives as possible due to the complex nature of the project. Interviews were conducted to gather qualitative information to corroborate against any data collection and/or further explain what was found in the data. These interviews were generally concerned with appropriately identifying populations/ and origins of interest and perceived barriers to transit accessibility.

Sixteen individuals were interviewed from a variety of organizations. Some of the organizations included:

1. Allegheny County Department of Human Services
2. Port Authority of Allegheny County
3. Federal Reserve Bank of Cleveland
4. RideACTA
5. Southwestern Pennsylvania Commission
6. Local Chamber of Commerce
7. Pittsburghers for Public Transit
8. Neighborhood Allies
9. Partner4Work
10. Carnegie Mellon University
11. PAAC Transit User

The interviews were conducted with a set of sixteen questions. (See Appendix for the full set of questions). There was variability among the interviews depending upon each interviewee's area of expertise. Many interviewees added additional information based upon their experiences that were outside of the scope of the questions. For the purposes of keeping the interviewees anonymous, simplified and most common interview results are as follows:

*General Transit Accessibility:*

- Walkability
- Frequency/reliability
- Cost

*Populations generally underserved by public transit:*

- Single parents
- Low-income
- No car ownership
- Minority populations

*Distance to travel to a bus stop:*

- Ten to fifteen minute walk maximum
- Less than a half mile walk to a bus stop

*Geographic areas of Allegheny County that are underserved by transit:*

- Penn Hills
- Northview Heights
- Mon Valley

*Additional key takeaways from interviewees:*

- Think about Allegheny County's unique and varying topography and how that relates to the full transit experience.
- The entire trip should be about an hour to be considered reasonable.
- Consider alternatives forms of transportation such as existing shuttle services.

These results provided valuable insights and validation into the data-driven analysis. The following sections detail how these interview findings were incorporated into the research.

## Origins: Identifying Areas of Interest

After identifying populations of interest, data was collected and analyzed to identify U.S. Census Bureau block groups with a potential high need to access opportunity occupations. Key indicators included poverty, income, car ownership, and employment status. Given the targeted nature of this project's analysis, specifically the connection of populations of interest to opportunity occupation zones, three primary data sources were considered when identifying block groups where populations of interest are living. Those data sources were:

1. The 2019 Equity Index of Mobility Need by the Port Authority of Allegheny County
2. Allegheny County data from the American Community Survey (2013-2017 ACS 5-year estimates) [13]
3. Proprietary anonymized data about DHS clients - including residence and employment location data aggregated and to the block level - supplied by DHS.

Data from the sources above was processed and visualized in ArcGIS Pro. Based on the results of this analysis, 17 block groups were identified. These selected block groups typically feature communities that are of lower income, face transportation barriers, and have higher numbers of DHS clients than the rest of the county. A geographically diverse set of block groups was selected in order to analyze and test accessibility against a variety of locations throughout Allegheny County (figure 2).

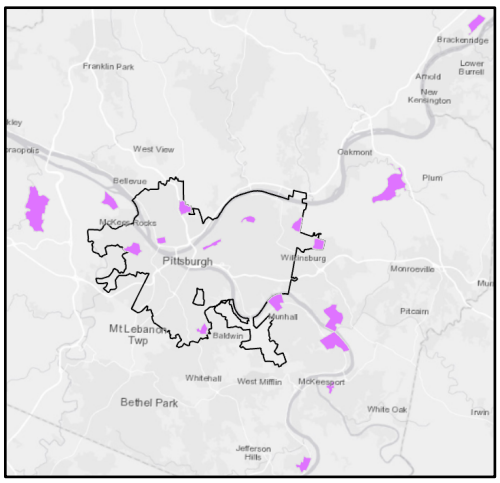


*Figure 2: Selected Origins*

Selected origin block groups in Allegheny County are located in Clairton, McKeesport, Duquesne, Carrick, North Braddock, Homestead, Crafton Heights, Bedford Dwellings, East Hills, Manchester, Robinson Township, Lincoln-Lemington- Belmar, Garfield, Northview Heights, Stowe Township, Penn Hills, and Harrison Township.

Considerations were made for areas with high numbers of DHS clients. For example, while block group 420034591023 in Robinson Township has a relatively high rate of education and a relatively low rate of poverty, it was selected based on the high number of DHS clients living there.

**Note**. Neighborhood labels are added to enable interpretation and context to the block groups, although the block groups themselves rarely fully encapsulate an entire neighborhood and may overlap slightly. Generalizations about an entire neighborhood based on these smaller units of analysis are discouraged.

[13] Note that U.S. Census Bureau ACS estimates at the block group level have a high margin of error.

## Destinations: Identifying Opportunity Occupation Zones

Central to the project scope is a pivotal question: Where are opportunity occupations in Allegheny County? Our team used two major methodologies to 1.) approximate the proportion of opportunity occupations by industry, and 2.) plot this same information spatially for Allegheny County. To do this, the team utilized the method from the Federal Reserve Bank of Cleveland, mentioned earlier in the literature review.

*Using Industry Opportunity Shares to Approximate Labor Market Composition*

We used publicly available Census data to identify opportunity occupation from demographic data and individual responses. Once our team computed the proportion of opportunity occupations observed within Allegheny County industries, these proportions were applied to the Census Bureau's LODES data set, which provides spatial information about job counts. These opportunity shares allowed our team to adjust recorded job counts to roughly approximate the number of jobs that would be eligible for opportunity occupations. This initial analysis allowed the team to preliminarily map Census block groups with high opportunity occupations. A chart of findings is in the Appendix.

*Refining Zones Using Raw Business Data*

For a more accurate, local picture of the Allegheny County labor market, the team utilized Reference USA's database to manually download a full record of registered Allegheny County businesses and their employee counts. Because these businesses corresponded with a NAICS code, the same opportunity shares were applied to understand what portion of these jobs might be applicable to the project's population of interest. With this brute force approach, we then mapped the physical location of all registered businesses with 10 or more employees in the applicable 20 industry categories in Allegheny County.

Using a number of spatial analysis tools in ArcGIS, the team used these adjusted job counts to create a Kernel Density map. This jobs-based heat map allowed us to visualize centers which were predicted to be relative hot spots for opportunity occupations. After isolating unique hot spots, we created a threshold for our opportunity occupation density and then created custom polygons that encapsulated the area associated with high density of opportunity occupations. These polygons became the project's opportunity zones.

*Environmental Factors in Opportunity Employment Zones*

To translate these destinations for public transit tool, we then identified bus stops within these areas; these served as the team's "Opportunity Bus Stops." In order to calculate logistics factors for the index, the following analyses were completed:

**Walkability**: Understanding the environment around the bus stop and how it relates to commuters' ability to safely get to and from the bus stop is an important measure. The EPA has walkability metrics for every block group in the United States. Not all metrics for walkability are relevant to our analysis (for example, the mix of residential and business development does not apply). However, the EPA does score each block group on its density of pedestrian-oriented intersections on a 1-20 scale. Destination "zones" were

joined to block groups, and average 'intersection scores' for zones were estimated depending on the area of the zone each block group represented.[14]

**Job Access**: To estimate how many jobs within each opportunity zone are within a reasonable walking distance of PAAC bus stops, the PAAC official "walkshed" was overlaid with business location and employee count data to estimate the proportion of jobs accessible within each zone.

*Developing Opportunity Shares for Industry*

No existing dataset provides spatial information for opportunity occupations at the county level for Pennsylvania. To approximate opportunities within the Allegheny County labor market, our team borrowed the concept of an "industry opportunity share" from by the Federal Reserve Bank of Philadelphia.[15] This method uses individual demographic and response data to identify individuals who currently hold opportunity occupations, and then map those roles and individuals out to specific industries to understand the total opportunity compositions. This method utilizes data from two major sources:

1. American Community Survey Public Use Microsample (PUMS) 2017, and
2. U.S. Census Bureau's 2017 Longitudinal Employer-Household Dynamics (LEHD) program's Origin-Destination Employment Statistics (LODES) dataset.

Once we computed industry opportunity shares, we could then adjust jobs numbers provided from the LODES data set, which supplies for each Census block, the total number of associated jobs by NAICS code.

*Visualizing Using LODES Data and ArcGIS*

The Longitudinal Origin-Destination Employees Statistics dataset captures the number of jobs associated with an industry at the block group level To glean some initial insights into the placement of jobs, we adjusted LODES numbers based on Allegheny County's industry opportunity shares. This allowed us to understand on average, what proportion of an industry's jobs can be categorized as opportunity occupations alongside their location. The initial map is crisply defined by the edges of block groups (figure 3).

[14] U.S. Environmental Protection Agency, "National Walkability Index." United States Environmental Protection Agency. Accessed October 20, 2019. https://www.epa.gov/smartgrowth/smart-location-mapping#walkability.
[15] DeMaria, "Getting to Work On Time: Public Transit and Job Access in Northeastern Pennsylvania."

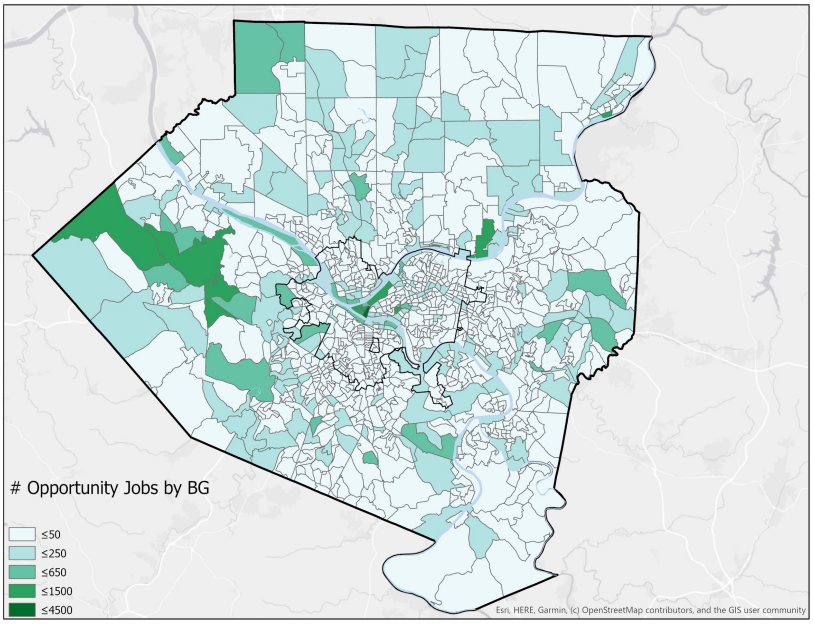


*Figure 3: Top Opportunity Block Groups*

While this was somewhat informative, block groups may not be an appropriate geographic unit of analysis for understanding transit access because some have much larger areas than others. Because of this, the team looked for alternative methods of quantifying the number and exact location of opportunity occupations.

*Bruteforce Data Collection and Custom Polygon Creation with ReferenceUSA*

To create spatial areas that were both interesting in terms of opportunity employment but were also small enough to analyze meaningfully, individual business data was acquired from ReferenceUSA. The team plotted some 12,000 businesses by their actual coordinates. A kernel density analysis then established the location of opportunity occupation zones. More detailed information on how this was accomplished is captured in the Appendix.

As a result of the density analysis, the zones in the following destinations were selected: South Park Twp, Bethel Park, Wilmerding, Green Tree, Monroeville, Middle Hill, Upper Hill, Robinson Twp, O'Hara Twp, Brackenridge, and Central Business District (figure 4).

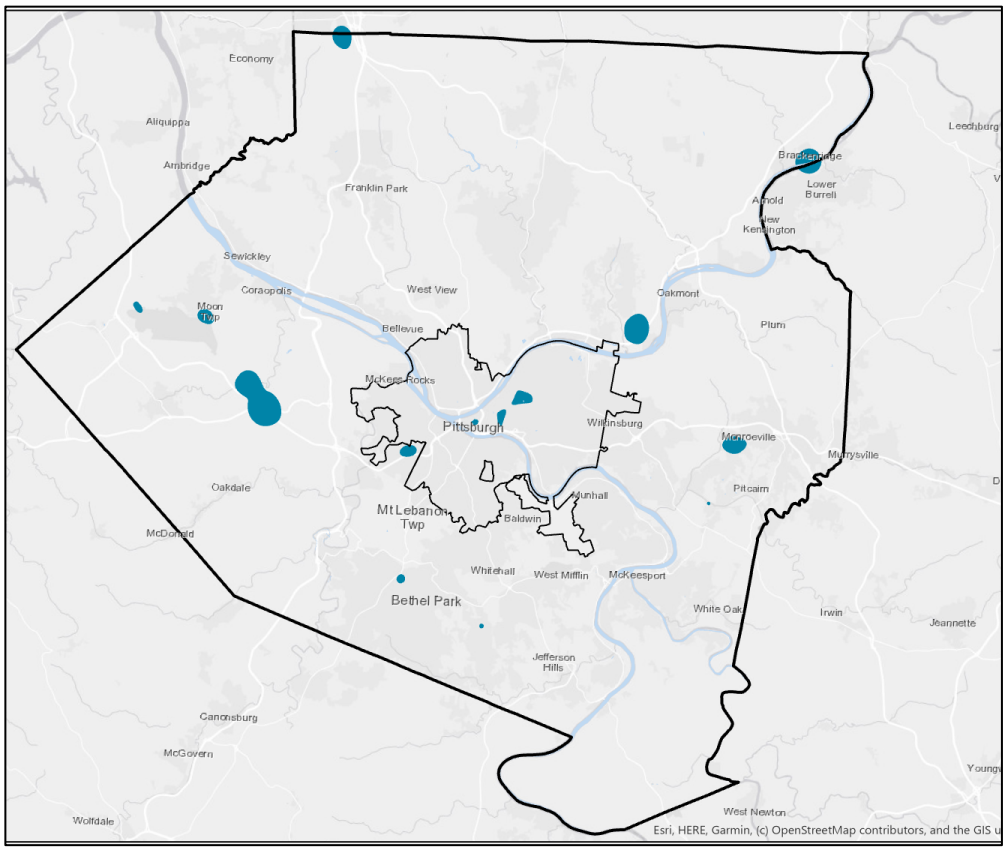


*Figure 4: Most Dense Opportunity Occupation Areas (not block groups)*

Destinations which had no bus stops within range and were excluded from O/D pairing include Moon Twp, Findlay Twp, and Marshall.

**Note**: It is important to note that the neighborhood labels are added to enable interpretation and context to the areas of interest, although the polygons themselves do not fully encapsulate an entire neighborhood and may even overlap neighborhoods. Generalizations about an entire neighborhood based on these smaller units of analysis are discouraged. For a list of neighborhood overlaps, see the Appendix.

## Transit Route Analysis

Transit route analysis was conducted by analyzing General Transit Feed Specification (GTFS: scheduled routes) and Automatic Passenger Counter - Automatic Vehicle Locator (APC-AVL: Real-time Data). The analysis sought to answer two key questions:

1. How long does it take for riders to get from origins of need to destinations of opportunity?
2. How reliable is public transit in addressing opportunity zones?

*Computing Bus Travel Times*

Analysis of transit travel was computed using a variety of R functions and packages (see Appendix). Most notable however was the tidytransit open source package. Tidytransit enabled us efficiently query the

GTFS feeds and generate travel time distributions within any two given origins and destinations. Tidytransit uses the RAPTOR-RoundbAsed Public Transit Optimized Router.[16] More details about RAPTOR information can be found in the Appendix.

Analyzing APC-AVL data required some custom code to approximate the RAPTOR algorithm and specifically to handle the case of transfer transit riders. Our methodology in this analysis followed the steps:

1. User selects an origin and destination
2. Program defines a catchment area as the region within 0.25 miles (1320ft) of a transit stop, and the area within which transfers are most possible
3. Program identifies unique routes from origin to destination identifying possible transfers along the way
4. Compute the travel times of the prior identified unique routes
5. Compute a distribution of travel times and compare to GTFS computed travel times

*Observed Time Windows*

| | |
|---|---|
| Morning Peak | 6am - 10am |
| Morning Off-Peak | 10am - 3pm |
| Evening Peak | 3pm - 7pm |
| Evening Off-Peak | 7pm - 10pm |
| Night | Midnight - 6am |
| Weekend | 6am - 6pm |

*Computing Car Travel Times*

Origin to destination car travel times were calculated using the Google Maps API. The API was accessed through the gmapsdistance package in R. As the package required latitude/longitude coordinates, the origin and destination centroids were used as proxies for origin and destination bus stops. Using the API travel times were extracted for O-D at hourly intervals for the selected time slots and averaged to estimate the expected travel time within the time window. Car travel time matrices were then exported into the index spreadsheet for incorporation into the final index worksheet.

## Accessibility Index Development

Like much else in this project, the accessibility index is highly customized. Much of the literature defines accessibility as a function of physical distance and travel time. However, stakeholder feedback provided additional aspects of accessibility, including concerns about:

- Availability of ConnectCard kiosks
- Cost of fare related to transfers
- Physical location of stops
- Reliability of bus schedule
- Distance to bus stops

[16] Delling, Daniel, Thomas Pajor, and Renato F. Werneck. "Round-Based Public Transit Routing." *2012 Proceedings of the Fourteenth Workshop on Algorithm Engineering and Experiments (ALENEX)*, 2012, 130–40. https://doi.org/10.1137/1.9781611972924.13.

- Bus travel time compared to car trip (e.g. personal car, Lyft, Uber).

Accordingly, data was collected from a number of sources to capture four unique aspects of the transit experience:1.) Cost, 2.) Time, 3.) Reliability, and 4.) Physical Environment. These components are further broken down into six distinct categories (figure 5):.

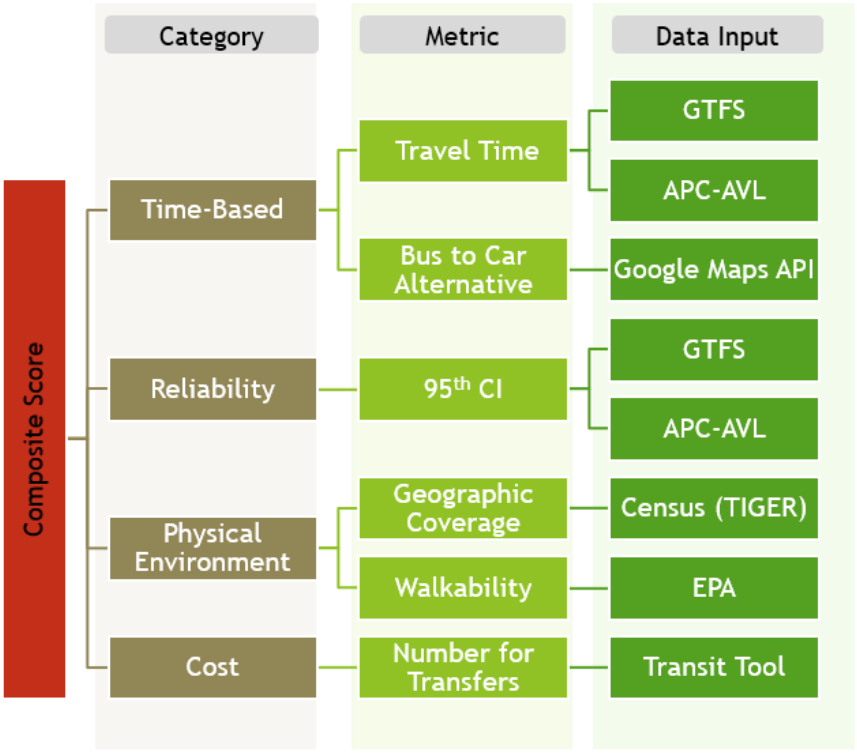


*Figure 5: Mapping the Inputs*

Cost, time, and reliability information were gathered from the custom transit tool mentioned earlier in this paper. Due to the nature of transit and how access may be dependent on time windows, these metrics were captured at unique times of day. These categories were further broken-down into the below measures:

*Key Measures*

- ***Travel Time.*** Captures the average travel time from an origin and destination. This includes wait time and time between stops. This is captured at all six time windows.
- ***Bus/Car Alternative.*** Captures the opportunity cost of riding the bus. This is simply the bus travel time divided by the car travel time and communicates how much longer (or shorter) a car ride would be if an individual had the option to use a car instead of ride a bus. This is captured at all six time windows.
- ***Reliability***. Captures variation by extracting the 95th Confidence Interval for expected travel time. This value communicates the spread of the data, so this information was captured at all six time windows.
- ***Geographic Coverage.*** Captures how much of the area (proxy for population) lives within 0.25 miles of the bus stops.
- ***Walkability.*** Captures if a location has pedestrian-friendly intersections.
- ***Cost.*** Captures how much a trip will cost on average in dollars for a person who does not have a ConnectCard, especially if there are multiple transfers. This is captured at all six windows.

*Creating Weights*

To reflect stakeholder and rider preference, we assigned weights based from Port Authority Ridership Customer Satisfaction surveys and internal discussion from client feedback.[17] The top priorities for riders include:

1. On-Time Performance
2. Fares
3. Travel Time.

A snapshot of the full Top Customer Importance Factors chart is in the Appendix.

Categories were weighted as closely as possible to the survey results, given the overlap observed between metrics (table 1). While on-time performance was the top factor in customer importance, it was deemphasized in scoring due to the scheduled nature of GTFS. Instead, bus-car ratio was selected to communicate the opportunity cost associated with riding the bus compared to other options.

*Table 1: Intermediate Score Weights*

| Category | Factors | Weight |
|---|---|---|
| **Cost** | Trip Cost | 30.0 |
| **Time** | Travel Time | 20.0 |
| | Bus/Car Ratio | 20.0 |
| **Availability** | 95th CI | 15.0 |
| **Physical Environment** | Geographic Coverage | 7.5 |
| | Walkability | 7.5 |
| **Final Score** | | **100.0** |

*Scoring and Normalizing*

These raw values were normalized based on the performance of all other pairings. Importantly, a high score does not mean a origin-destination pair is intrinsically favorable. A high score does capture that a specific pairing performed well relative to other pairings the team identified for analysis. Once these scores are computed, the values are weighted by the above table and then summed to create a time-window score.

[17] Port Authority of Allegheny County. "Port Authority Rider Satisfaction Survey." Pittsburgh, PA: Port Authority of Allegheny County, June 2018. https://www.portauthority.org/siteassets/inside-the-pa/surveys-and-reports/ridersatisfactionsurveybus.pdf.

*Origin-Based Community Scores*

Scores for a particular origin were calculated by understanding all possible pairings related to that origin, and weighing those scores based on the number of opportunity occupations associated with the respective destinations. Therefore, if one route connects to 400 opportunity occupations and another connects to 4000, the score for the larger amount of jobs will be weighed proportionately.

## Validating the Index with DHS Data

*Observations on Status-Quo Transportation Patterns of DHS Clients*

Anonymized DHS data allowed our project to analyze where DHS clients, many of whom are low-income individuals, work relative to where they live. The visualization of this data provided several insights on the employment-related transportation patterns of DHS clients.

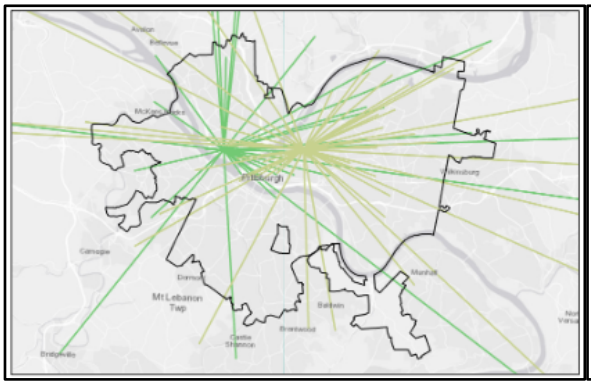

*Figure 6: Work/transit pattern from Manchester, Bedford Dwellings origins*

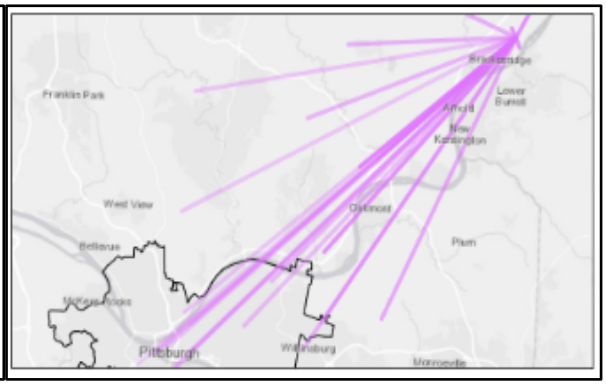


*Figure 7: Work/Transit pattern from Harrison Township origin*

Many observations obtained from the data are intuitive - DHS clients who live in the city center also have greater access to public transportation (figure 6). Individuals who live near downtown Pittsburgh are able to travel to work locations throughout the county. Meanwhile, DHS clients who live on the edges of the county (see Harrison Township, figure 7) are traveling in narrow corridors in higher numbers. This may be a function of 1) limited public transportation access (in the direction of downtown Pittsburgh) and 2) higher numbers of jobs are generally located downtown.

*Figure 8: Penn Hills travel patterns & bus line*

The Penn Hills origin is a particularly interesting case. This origin, like Harrison Township above, displays transit patterns (orange) focused towards downtown Pittsburgh (figure 8) . The red line marks the only easily accessible Port Authority bus service. This bus option only provides direct travel towards downtown. Most notably, no individuals in the dataset seem to travel to the blue box - the opportunity occupation zone of O'Hara Township. Although geographically

close to this opportunity zone, no DHS clients work there.

DHS clients living in the Garfield and Lincoln-Lemington origins have transit access to the O'Hara Township opportunity zone. Accordingly, many of these clients reported having employment within the opportunity zone. Altogether, this observation suggests there may be an opportunity to connect Penn Hills to a nearby opportunity zone.

This is just one isolated example - similar DHS client transit observations were used to inform findings from the index and our policy recommendations.

## 5. Conclusions/Findings

### Summary

Once we had values for all origin-destination pairs, analysis was conducted to discover general trends. Some key findings from the accessibility index are below:

- Only 6 of the identified origins could reach more than 3 opportunity employment zones.
- Of the 14 opportunity "hotspots", three offered no bus stops to opportunity zones at all.
- Even when opportunity zones were deemed accessible, the bulk of the occupations within that zone were frequently outside of the Port Authority walkshed.
- While it is relatively easy to reach opportunity occupations in the Central Business District, there is huge latent opportunity in geographic areas that are underserved by the public transit system.

### Zones

*Origins*

Only 6 of the identified origins could reach more than 3 opportunity employment zones. An interesting, consistent high performer was Crafton Heights. Most of this related to the Busway nearby and the availability of some trips between 12am to 6am. On the far end of Origins is Clairton, which offered no bus stops at all. Duquesne and Harrison Township seemed to have some stops within their general neighborhoods, but none towards our identified zones for any of our selected windows.

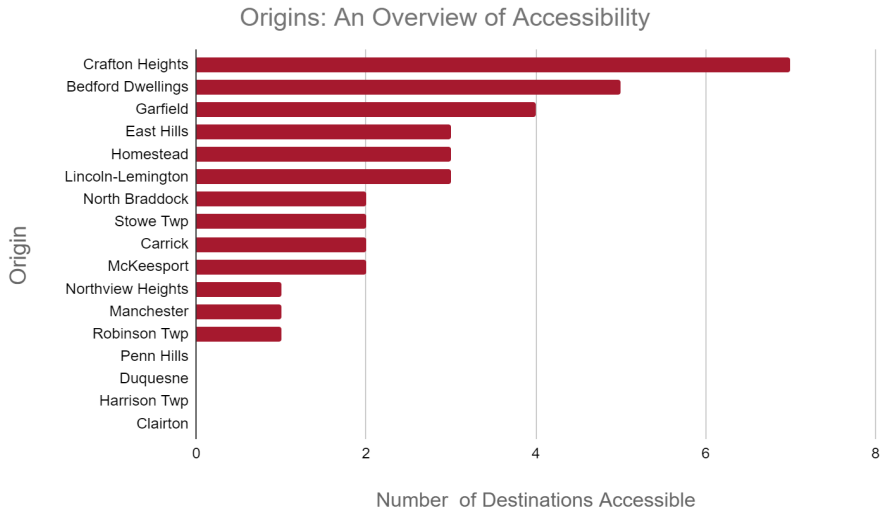


*Figure 9*

*Origin-Based Scores*

Origins received a specific composite score based off the jobs associated with each origin-destination pair. Essentially, those scores were weighted by the opportunity represented at the end of the route. These scores closely follow the rankings in the above image. The Crafton Heights block group, associated with the West Busway, performs admirably. Meanwhile, the bottom four in accessibility (Harrison Township, Penn Hills, Duquesne, and Clairton), remain lowest on community-based rankings. Origin scores can be found in the Appendix, but closes overlap with the above chart.

*Destinations*

Of the 14 opportunity occupation "hotspots", three offered no bus stops to opportunity zones at all (figure 10). Most high-scoring origin-destination pairs described routes heading downtown. The Central Business District had the most connections to origins. Six of our opportunity zones had no connections at all based on the quarter-mile buffer described in the literature. While these weights could be adjusted, they nevertheless communicate either the absence of bus stops or the absence of bus stops within the reasonable quarter-mile distance from residential areas. These areas were usually on the fringe.

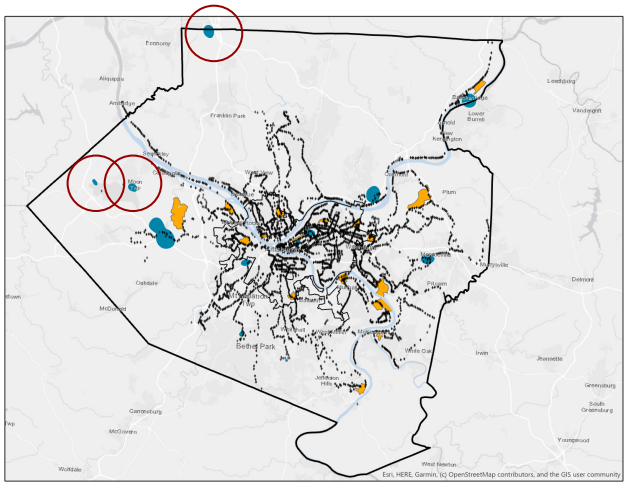

*Figure 10: Inaccessible Destinations*

## Origin-Destination Pairs

*Top Performing Pairs*

The majority of high-performing origin-destination pairs describe routes that are close to the Central Business District. Middle Hill describes the area between the Strip District and the University of Pittsburgh, with Upper Hill just north of downtown. All three of the locations  frequently recur within top rankings. Importantly, these centrally located business centers appear to be relatively well-connected to many geographies even on the fringe of Allegheny County. A table of top pairs is below (table 2).

*Table 2: Best Composite Origin-Destination Scores*

| Best COMPOSIT O-D SCORE | | | | | |
|---|---|---|---|---|---|
| ARCGIS Join Columns | | Pairing | Polygon | Polygon | O - D Index |
| Origin BG | DEST_ID | ID | Origin | Destination | Composite |
| 420032814002 | 14 | 84 | Crafton Heights | Central Business I | 85 |
| 420032814002 | 8 | 85 | Crafton Heights | Robinson Twp | 80 |
| 420035619002 | 7 | 150 | Garfield | Upper Hill | 76 |
| 420035619002 | 6 | 147 | Lincoln-Lemington-E | Middle Hill | 74 |
| 420030509001 | 7 | 100 | Bedford Dwellings | Upper Hill | 76 |
| 420030509001 | 14 | 97 | Lincoln-Lemington-E | Upper Hill | 70 |
| 420030509001 | 6 | 96 | Bedford Dwellings | Middle Hill | 68 |
| 420031016001 | 7 | 163 | Manchester | Central Business I | 67 |
| 420032904002 | 14 | 47 | Bedford Dwellings | Central Business I | 70 |
| 420032609001 | 14 | 173 | Northview Heights | Central Business I | 70 |

*Bus / Car Ratio*

Many of our origins are geographically close to the destinations that can offer them the most numerous opportunity occupations (table 3). Unfortunately, trips that represent only a 15 min car ride away can take as much as 7.5 times longer using the public transit bus system. One such example is the connection between McKeesport and Monroeville. According to Google Maps, this destination is roughly 20min drive by car, but takes two hours on average by bus. These locations represent huge opportunities because they are already in such close proximity to the opportunity employment areas.

*Table 3: Worst bus/car travel time ratios*

| Origin | Destination | Bus / Car Ratio |
|---|---|---|
| McKeesport | Monroeville | 7.5 |
| Crafton Heights | Upper Hill | 5.8 |
| Bedford Dwellings | O'Hara Twp | 4.9 |
| Crafton Heights | Middle Hill | 4.5 |
| Bedford Dwellings | Robinson Twp | 4.0 |
| Homestead | Monroeville | 3.6 |
| Garfield | Green Tree | 3.5 |
| Crafton Heights | Wilmerding | 3.4 |
| Homestead | Central Business District | 3.3 |
| Bedford Dwellings | Wilmerding | 3.2 |

## Opportunity Occupations

Ultimately, the purpose of our study is to understand where opportunity occupations are in Allegheny County and ascertain if their locations are accessible to our populations of interest. Unfortunately, many

of these high potential jobs which do not require a college degree do not appear to be very available to individuals who may lack a college degree. The below table 4 demonstrates this finding.

*Table 4: Jobs within walkshed*

| Destination | Polygon Job Count | Walkshed Job Count | % Jobs Inaccessible |
|---|---|---|---|
| South Park Twp | 370 | 0 | 100.0% |
| Brackenridge | 747 | 19.52 | 97.4% |
| Wilmerding | 332 | 13.7 | 95.9% |
| Robinson Twp | 2124 | 407.71 | 80.8% |
| O'Hara Twp | 822 | 296.24 | 64.0% |
| Monroeville | 513 | 367.06 | 28.5% |

A few opportunity occupation zones, such as the Central Business District, received perfect scores in the opportunity occupation metric. This indicates that each opportunity occupation resided within the Port Authority's walkshed, an indicator of an accessible distance from a bus stop. In the above table, however, we see that for at least 5 of the 11 destinations with bus stops, most opportunity occupations reside beyond the Port Authority's walkshed. In short, almost half of our opportunity zones cannot provide reasonable access to half of that zone's available opportunity occupations. This represents another challenge to decision-makers; even if a route exists between two pairs, are the desired jobs within a reasonable distance from those bus stops? Our findings seem to suggest that this may not be the case.

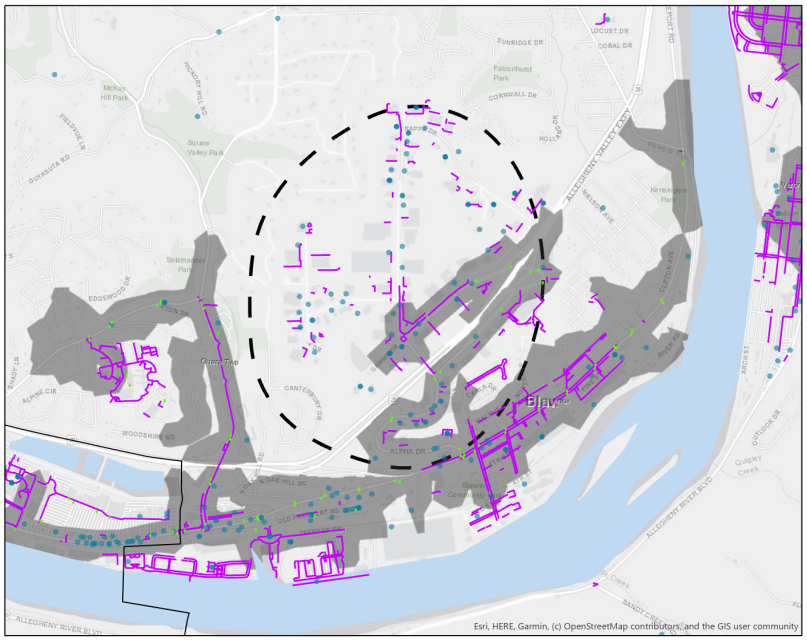


*Figure 11: Jobs located outside of the walkshed*

## 6. Recommendations

Finding and maintaining employment for those who are able is an essential part of someone's self-sufficiency and well-being.[18] Although it is understood that DHS is not directly assisting someone in finding employment, DHS is very interested in understanding vulnerable populations' access to employment and how that impacts their overall livelihood.

### Brackenridge: A Case Study

One unique outcome of the index was identifying opportunity employment zones in which a lot of the jobs fell outside of the Port Authority's walkshed. Brackenridge (in the blue area inside the red rectangle, figure 12) was one such opportunity zone that most of the jobs fell outside of the walkshed. Brackenridge is interesting because it is in a far corner of the county and also adjacent to one of the selected origins of interest (Harrison Township). Although geographically close at only three miles apart, the pair has a score of zero due to the low transit frequency as well as walkability. The score was zero due to the lack of bus frequency. There is only very early morning service (approximately 5:00am – 7:30am), and no weekend or nighttime service. Seeing as Brackenridge to Harrison Township was scoring poorly, it is not surprising that it did not score well at all with any other origin-destination pair. Figure 13 shows the existing route between Harrison Township (orange area) and Brackenridge (blue area).

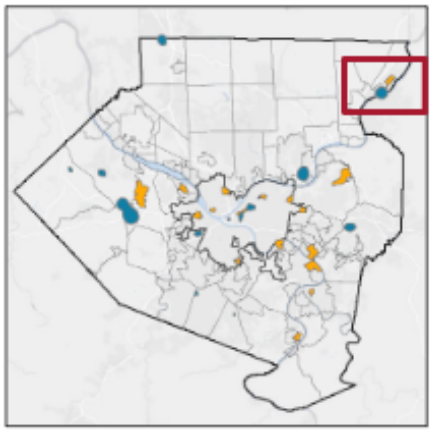

*Figure 12: Origins and Destinations*

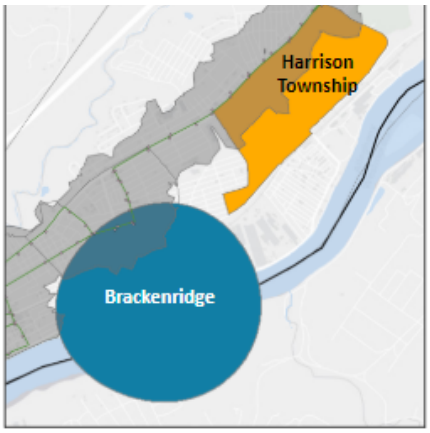


*Figure 13: Harrison and Brackenridge*

It is unfortunate that the area is relatively inaccessible because in Brackenridge is approximated 750 opportunity occupation jobs (primarily manufacturing) within the zone and only 20 jobs fall within the walkshed. This means that 97.4% of the opportunity occupation jobs are not accessible once someone arrives to the area via transit.

As another point of interest, Harrison Township and Brackenridge DHS data was analyzed. It was found that approximately nine DHS clients with high school degrees travel into Brackenridge from the Pittsburgh area (as seen in figure 14; the blue lines show travel to the Brackenridge/Harrison Township area). There are approximately twenty-five total observations of DHS clients in the Harrison Township

[18] Allegheny County Department of Human Services. "2016 Allegheny County DHS Local Government Case Competition Improving Systems to Help People with Barriers Gain and Sustain Employment," 2017. https://www.alleghenycountyanalytics.us/index.php/2017/05/05/2016-allegheny-county-dhs-local-government-case-competition-improving-systems-help-people-barriers-gain-sustain-employment/.

area. About nine people are traveling from areas south of Brackenridge and the other sixteen are coming from surrounding areas.

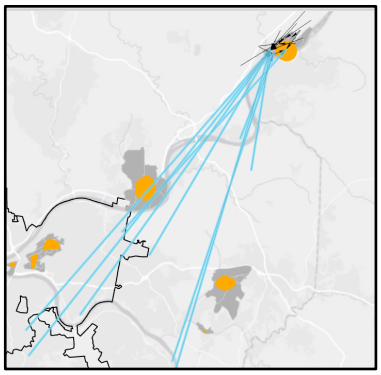

*Figure 14: Brackenridge travel patterns*

Few people traveled from around the county to get to Brackenridge. Initially this finding is logical in that the region is remote relative to the rest of the county. However, the lack of DHS clients traveling to the area in addition to the index's identified inaccessibility led to a hypothesis that it may be transit inaccessibility that is preventing people from getting to these regions.

An obvious solution to increasing accessibility to this region is improving the frequency of transit. However, this is an expensive solution[19] that DHS does not have control over. Thus, a first-mile/last-mile solution[20] may improve the accessibility in this region to supplement the existing transit system. The following case study identifies an area in which many jobs fall outside of the walkshed but an existing first-mile/last-mile solution is already successfully implemented in the area, and an optimal approach to duplicate.

## Robinson Township: A Case Study

*About Robinson Township*

Robinson Township (the large blue area in the red rectangle, figure 15) was identified as an opportunity employment zone. The top industries in the area are tourism/hospitality, food service, and retail. Similarly to Brackenridge, many jobs were outside of the walkshed; 80% of the jobs were outside. However, as seen on the map below, there is an existing service that covers these areas called RideACTA.

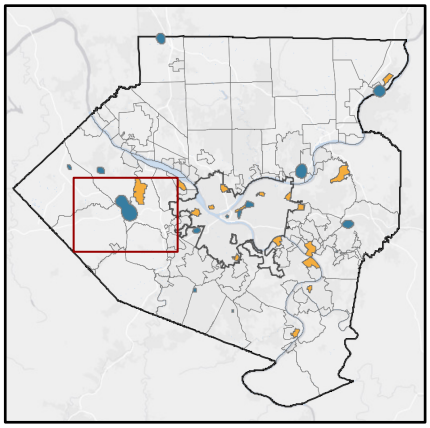

*Figure 15: Robinson & RideACTA*

*About RideACTA*

RideACTA (ACTA) is a non-profit transportation management association started in 2009.[21] It is a "flex-route" shuttle service that primarily serves the airport corridor. One of the core reasons for its inception was to better connect the existing transit infrastructure with employment opportunities.[22]

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[19] Port Authority of Allegheny County. "Annual Service Report 2017." Pittsburgh, PA: Port Authority of Allegheny County, 2018. Accessed September 22, 2019. http://www.portauthority.org/paac/portals/0/ServiceGuidelines/2017/2017ASR.pdf.

[20] LA Metro. "Metro First/Last Mile." LA Metro Home. Accessed December 12, 2019. https://www.metro.net/projects/first-last/.

[21] Airport Corridor Transportation Association. "About ACTA." Accessed November 13, 2019. https://actapgh.org/about-acta/.

[22] Airport Corridor Transportation Association. "Ride ACTA." Accessed November 13, 2019. https://actapgh.org/rideacta/.

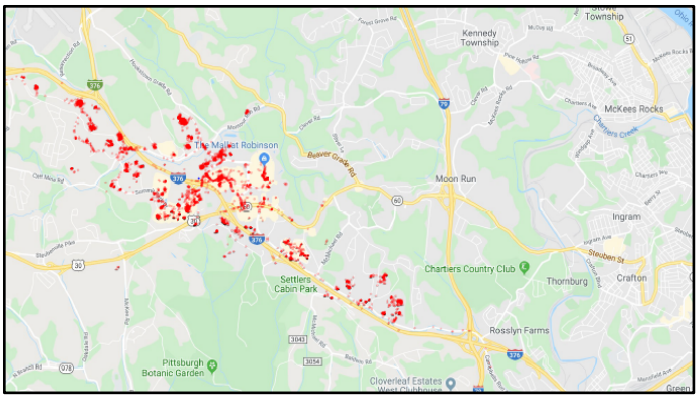


*Figure 16: RideACTA stops*

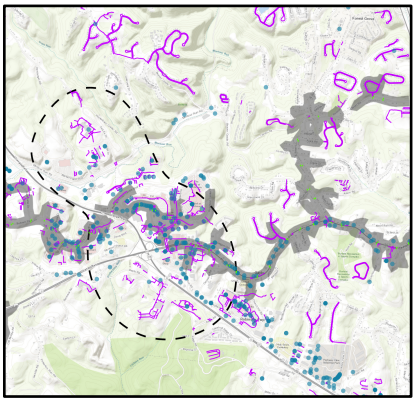

*Figure 17: Opportunity zone, jobs and walkshed*

RideACTA offers membership, and members receive transportation-related information as well as contribute to conversations with RideACTA. Examples of members are those organizations within the airport corridor such as businesses and local government.[23] The ACTA shuttle is currently servicing workers at a variety of businesses such as IBEX, Walgreens, Walmart, Pittsburgh Airport, Marriott, Homewood Suites, Cigna, and more.[24] In order to best serve all of the businesses, there are different route frequencies for different routes (figure 16). The uniqueness of a small transportation service is its customizability to fit the need of the specific region. Especially when considering employment: night shifts, weekend shifts. ACTA also continues to expand routes and stops every year.[25] Lastly, ACTA advocates for a full range of mobility options such as walking, biking, and carpooling.

*RideACTA Funding and Collaboration*

The shuttle is funded from PA Section 1513 program.[26] This program supplements transportation activities, and applicants must be a transportation organization, non-profit, or government agency.[27] Additionally, the shuttle collects a fare of twenty-five cents per trip, but fares are cheaper for those with disabilities, Medicare ID, children, and senior citizens.[28]

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[23] "About ACTA - Airport Corridor Transportation Association," Airport Corridor Transportation Association, accessed April 13, 2019, https://actapgh.org/about-acta/.

[24] Airport Corridor Transportation Association. "ACTA by the numbers: Annual Report 2017 - 2018." Robinson Township, PA: Airport Corridor Transportation Association, 2018. Accessed December 12, 2019. https://actapgh.org/wp-content/uploads/ACTA-AnnualReport1Online.pdf.

[25] Ibid.

[26] Airport Corridor Transportation Association. "RideACTA Fare Information." Accessed December 12, 2019. https://actapgh.org/rideacta/rideacta-fare-information/.

[27] Pennsylvania General Assembly. "Consolidated Statutes: Title 74: Transportation, Section 1513: Operating program." Accessed December 12, 2019. https://www.legis.state.pa.us/cfdocs/legis/LI/consCheck.cfm?txtType=HTM&ttl=74.

[28] Airport Corridor Transportation Association. "RideACTA Fare Information - Airport Corridor Transportation Association."

RideACTA is also made possible by collaboration from other organizations. For example, "ACTA continues to partner with the Oakland Transportation Management Association (OTMA) and the Pittsburgh Downtown Partnership TMA to make Pittsburgh one of America's most walkable cities — by improving pedestrian safety, promoting the health and economic benefits of walking, and ensuring that walkability is factored into transportation and development plans."[29]

*Benefits of RideACTA and Last-mile/First-mile Solution*
The benefits from the shuttle service are relatively profound. The 2017 – 2018 annual report stated that 292 rides are provided per day, and servicing an average of 250 businesses.[30] There are also massive savings of vehicle miles traveled, gasoline, and $CO_2$ emissions.[31] Mostly importantly, over 80% of the riders said they would not be able to get to work if they did not have RideACTA.[32]

*Last-mile/First-mile Solution for Brackenridge or other Opportunity Employment Zones*
A robust model like what RideACTA is today may not be feasible for DHS. However, depending on DHS' desire and future plans for services, small-scale last-mile/first-mile solutions may have a large impact on opening up opportunities for geographically close areas. Additionally, these types of programs are great examples of collaboration among a variety of organizations. A partnership similar to RideACTA and with multiple perspectives represented may allow DHS and other stakeholders to most effectively serve the populations of focus.

This type of transportation model may be lead by DHS and invite other partners in order to make the connections between underserved areas and areas of employment.

## Future Use Cases

Outside of opportunity employment, future use cases using the accessibility index were identified. All of these future use cases were based off of conversations with DHS employees. Using the index as a base, the following are opportunities for DHS to customize and use the tool:

1. Change the index from opportunity employment to another area of interest and measure transit access to:
    a. Childcare
    b. Grocery stores
    c. DHS services

    A common theme among the stakeholders interviews was the desire to know more about access to places other than employment hubs. Although very understandable, it was outside the realm of this research. However, the index was constructed in such a way that opportunity employment factors may be removed without affecting any of the transit accessibility measures. Then, the

[29] Airport Corridor Transportation Association. "Walk Pittsburgh." Accessed December 12, 2019. https://actapgh.org/programs/walk-pittsburgh/.
[30] Airport Corridor Transportation Association. "ACTA by the numbers: Annual Report 2017 - 2018."
[31] Ibid.
[32] Ibid.

destination and appropriate weighting metrics of any other area of interest may be inputted. This process does take some intermediate data analysis and manipulation.

2. Analyze Affordable Housing
   Affordable housing is a key concern within DHS. The organization seeks to promote each individual's own self-sufficiency, and part of such is stable housing. This tool may be used to understand if people are living in accessible areas. Specifically, understanding where those participating in any of the voucher programs are living. In addition to other affordable housing research and organization knowledge, the transit accessibility information may be used to inform future decisions at DHS regarding affordable housing programming.

3. Analyze Family Support Centers
   Currently, the DHS Family Support Center system is undergoing a reevaluation process. These centers provide a variety of services and seek to be more grassroots in approach to assisting families; there are multiple centers, including "lite" centers, in order to best serve clients. This index may be used in order to:
   a. Inform transit accessibility from where clients are living to the current support centers
      i. Inform barriers to getting to the support centers such as walkability or frequency of routes
      ii. Inform if DHS can act on the problem if there are transit issues, such as a van service for participating families

4. Advocate for Transit Change and Collaboration
   The final and most extensive use case for the transit accessibility index is to advocate for transit change. PAAC, among many other important organizations, was an active participant in this research,. This tool may have the ability to quantify the issues different riders are facing and be another source of information for advocates and decision-makers alike. Issues such as not enough bus times, expensive transfers, or lack of routes in an area. Although the index is not providing profound results, it is able to quantify the anecdotes that many riders and/or transportation advocates express. In such a way, it is thought that decisions can be more directed and prioritized.

## 7. Research Limitations

This project covered a wide breadth of material and data sources. To ease computation and also incorporate metrics from the literature, several demarcations or assumptions were utilized. Limitations of the research are discussed below.

***Future of Work.*** The tool as it currently exists captures current areas of estimated opportunity employment. It does not make any projections about the future of work, or if current jobs will exist beyond five years. Because many opportunity occupations might be uniquely susceptible to automation, a Burning Glass approach might yield more insights by analyzing job vacancies.

***Relative Scoring and Geography Sampling***. All scores between an origin and destination are based on how that pairing ranks relative to selected pairings in this study between 0 and 100. This project only looked at connections between identified areas of interest. Methodology would have to be replicated for

different origin/destination pairs. Similarly, a high score does not necessarily reflect the greatest route pairs in Allegheny County, but rather the highest performing pairs among those we observed for this study.

***Boundaries and Buffers.*** At several points of the analysis, the project performed calculations based on membership in or outside of a given boundary. A quarter-mile buffer from a bus stop means that a job or unit of area a few feet shy of that buffer may not be captured. This can be perceived in the cases of North Braddock and Moon Township. Decisions to use these boundaries are justified based on the literature, although distance is rarely as cut and dry. Future researchers may choose to be more lax or more strict based on definitions of a reasonable boundary. Index scores would change accordingly.

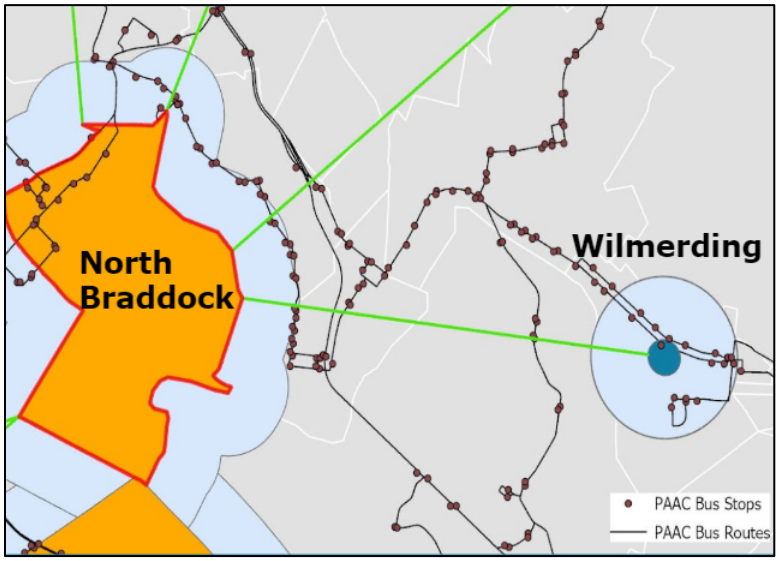


*Figure 18: Wilmerding to North Braddock*

***Work Sites versus Business Locations.*** Using granular business data including business addresses allowed for a more nuanced assessment of the transit experience. However, business addresses are single points which may not correspond to where employees actually report to work. For example, airport-related jobs were mapped to two specific locations which scored poorly on the index because the nearest bus stops were outside the .25 mile buffer and there was no overlap with the PAAC walkshed. However, realistically airport workers are not reporting to work at only these specific locations within the airport complex.

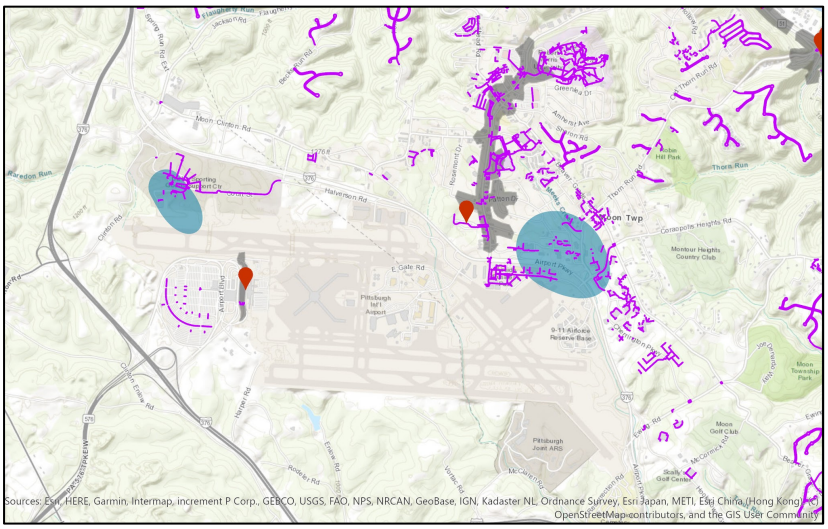


*Figure 19: Airport jobs & bus stops*

***Opportunity Occupations***. This study utilized one of the latest techniques in approximating the location of opportunity employment. The team does acknowledge that estimates based on industry mix involve some error. While we have raw company and business information, exact numbers for each business are expected to deviate reasonably.

***Other Methods of Transit.*** This study and the accessibility index only used scheduled and real-time arrival data on Port Authority of Allegheny County busses, when in fact PAAC operates three methods of transit: bus routes, a light rail system that extends from downtown Pittsburgh to the southern and western parts of the county, and two funicular inclines.[33] As such, the index does not account for connections to areas that may be accessible via the Red and Blue light rail lines. These lines run through or close to some of our chosen origins and destinations. As such, people could theoretically reach the Central Business District and Bethel Park opportunity occupation zones or the Carrick origin block group using the light rail.

***A Snapshot in Time***. This study only captures data from a specified period of time. All public or open data sources are from the years 2017 to 2019, except for U.S. Census Bureau ACS 5-year data, for which we used the 2013-2017 estimates. Based on the relative recency of each data source, we do not believe this variation invalidates our results. Nevertheless, the team recognizes that the unique combination of the various data sources complicates interpretation of our results. See Appendix for more information on the dates of our data sources.

## 8. Future Research

There are also several promising areas for future work. These are detailed below.

[33] Port Authority of Allegheny County. "Inclines." Accessed December 13, 2019. https://www.portauthority.org/services/inclines/

***Topography and Terrain***. While the team received sidewalk data pretty late in the analysis, additional topographical layers could be utilized to provide even more nuanced understanding of the terrain around unique origins and destinations.Pittsburgh has a uniquely hilly topography, which could provide an initial dimension to the index. More granular information about the unique context and setting around specific bus stops could also be helpful to decision-makers, though outside the scope of this project.

***First-Mile / Last-Mile Solutions.*** The proposed recommendations need additional information in order to be best implemented. For example, no financial feasibility or program evaluation was done for a specific location. Very specific parameters of the program would need to be decided in order to develop any sort of estimations and/or cost-benefit analysis. These specifics are heavily dependent upon DHS' desires for program expansion and specific populations they wish to serve.

## Conclusion

Data analysis combined with GIS provides a surprisingly nuanced and informative picture of the transit experience in Allegheny County. Living or working in or near downtown seems to be rewarded with better transit options, although access to areas beyond downtown may lend better employment possibilities. This is especially true for individuals who do not possess a car or college degree.

An interesting finding is the degree to which access to an opportunity zone does not necessarily imply access to all the occupations within that zone. This discovery suggests that beyond routes to location, additional research may be needed to understand First Mile and Last Mile Solutions.

Ultimately, this exploratory analysis can be used to draw insights into key areas of interest and inform possible policy decisions related to accessibility and the bus system. The goal is that this index can provide the foundation for even greater and more granular analysis related to the transit experience in Allegheny County.

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# Appendix

## (5.a.1) Methodology - Stakeholder Engagement

**Stakeholder Interview Questions**

Background:

1. What is the goal of your organization?
2. What communities and/or geographic areas do you represent?

General Transit Accessibility Questions:

1. How do you define public transit accessibility?
2. How do you quantify public transit accessibility within your organization?
3. How far away from a bus stop do you consider to be "inaccessible"?

Accessibility to Work:

1. What groups of people do you feel are underserved by public transit as a means to get to work or work opportunities?
    i. Age, income, work experience, gender, single parents, disability, race, etc?
    ii. What are the barriers?
        1. Physical
            a. Location of stops
            b. Scheduled timing of buses
            c. On-time performance
            d. Bus routes to important destinations, work or work opportunities
            e. Crowding
        2. Economic
            a. Bus fare
            b. PAAC ConnectCard kiosk/purchase locations
        3. Other
    iii. Which of these issues are most important?
    iv. Who is impacted by each barrier?

2. How far (distance and/or time) are people in your community (or those you represent) willing to travel to get to work?
    i. How many transfers does your community usually have to do to get to work?

3. What specific geographic areas of Allegheny County do you feel are underserved by PAAC in terms of accessing work or work opportunities?

4. Are there any geographic areas you know of that people would like to get to work, but can't reach via public transit?

Opportunity/Industry Specific:

5. What are the types of work are prominent in your communities, and what do you think they would prefer to be doing if they could?
    i. Any trends in available employment?

6. List of opportunity occupation industries from literature (for reference)
    i. Education
    ii. Financial Activities
    iii. Office Administration
    iv. Sales
    v. Healthcare
    vi. Installation/Maintenance Repair
    vii. Construction

Conclusion:

7. Is there anything else you think we should know or you would like to discuss?
8. Is there anyone else you think could provide us insight on this project?

## (5.b) Methodology - Origin Selection Appendix

### Identification and Processing Method

Census American FactFinder Data:

1. Identified populations of interest
    - Based on stakeholder interviews and a research review, we determined populations of interest. These included:
        - Low-income individuals
        - Individuals with low educational attainment (particularly less than a bachelor's degree)
        - Single mothers
        - Low car ownership rates
2. Downloaded data from U.S. Census Bureau American FactFinder
    - Educational Attainment For The Population 25 Years And Over[34]
    - Means of Transportation To Work by Travel Time to Work[35]
    - Poverty Status in the Past 12 Months by Household Type by Age of Householder[36]
    - Poverty Status in the Past 12 Months of Families by Family Type by Presence of Related Children Under 18 Years by Age of Related Children[37]
    - Tenure by Vehicles Available[38]
3. Processed data using R and RStudio
4. Processed data and visualized key metrics using ArcGIS:
   *(draft working visualization)*

[34] United States Census Bureau, Educational Attainment For The Population 25 Years And Over (B15003), (ACS 2013-2017), https://factfinder.census.gov/ (accessed October 5, 2019)
[35] United States Census Bureau, Means of Transportation To Work (B08134), (ACS 2013-2017), https://factfinder.census.gov/ (accessed October 5, 2019)
[36] United States Census Bureau, Poverty Status in the Past 12 Months by Household Type by Age of Householder (B17017), (ACS 2013-2017), https://factfinder.census.gov/ (accessed October 5, 2019)
[37] United States Census Bureau, Poverty Status in the Past 12 Months of Families by Family Type by Presence of Related Children Under 18 Years by Age of Related Children, (B17010), (ACS 2013-2017), https://factfinder.census.gov/ (accessed October 5, 2019)
[38] United States Census Bureau, Tenure by Vehicles Available (B25044), (ACS 2013-2017), https://factfinder.census.gov/ (accessed October 5, 2019)

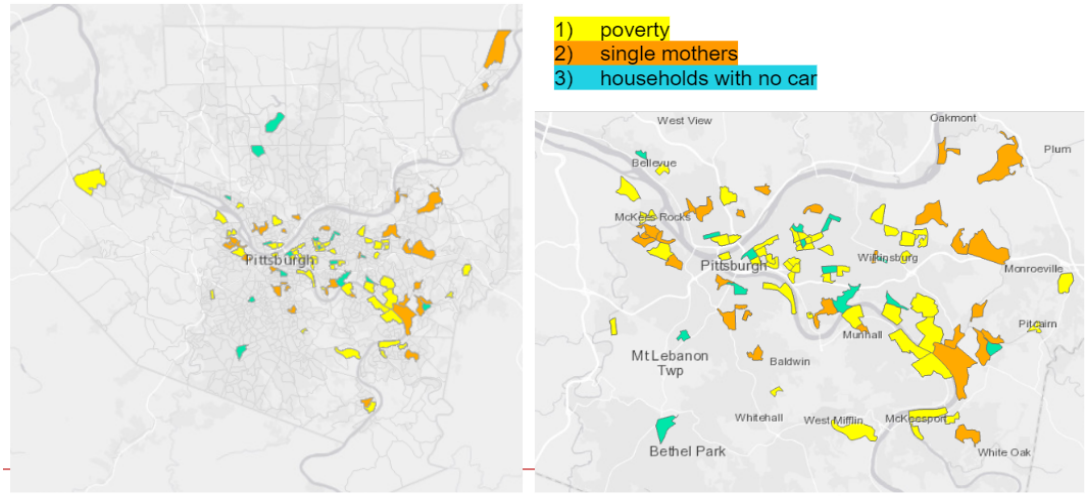


*Figure 20: Origin selection mapping*

5. Cleaning DHS client data
6. Mapping DHS client data (summaries)

**Analyzing DHS Client Data - Relevant visualizations:**

Count - Number of DHS Clients (block group level) - if home block identified. Selected block groups also visualized. DHS Client Data - Working-Age Individuals with High School Education Who Reported Unemployment (Under Age 40)

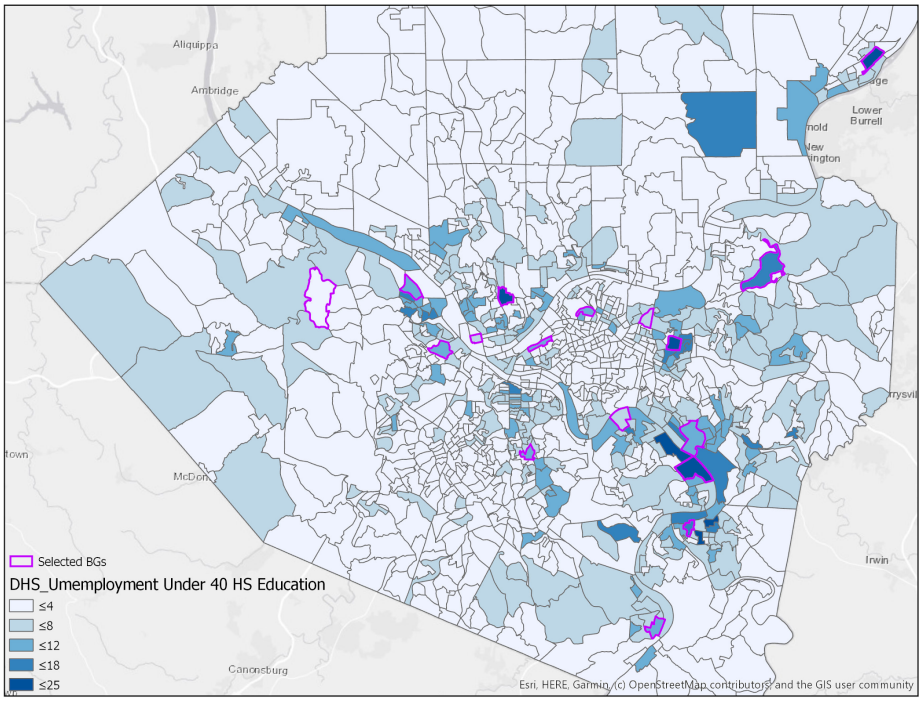


*Figure 21: DHS unemployment numbers map*

## (5.c) Methodology - Transit Route Analysis

### 1. General Transit Specification Feed (GTFS)

Publicly available through PAAC, the GTFS, provides detailed schedule information. The dataset is delivered as a zip file containing up to 15 individual files .csv files with standardized field names and descriptions. The files delivered include:

1. Agency
2. Route
3. Trips
4. Stop_times
5. Stops
6. Transfers
7. Frequencies
8. Calendar.dates
9. Calendar
10. Shapes
11. Fare_rules
12. Fare_attributes
13. Feed_info
14. Pathways (not used in PAAC)
15. Levels (Not used in PAAC)

### 2. APC-AVL (Acquired from PAAC 10/2019)

Real-time transit feeds acquired from PAAC spanned March 2016 through July 2019 in quarterly files.

*Table 5: APC-AVL data*

| Field Name | Short Description | Data Type |
|---|---|---|
| DOW | Day of week code | Integer |
| dir | Direction of trip along route | Integer |
| ROUTE | Route Code | Integer |
| TRIPA | Trip Number | String |
| BLOCKA | Block Number | Integer |
| VEHNOA | Vehicle Number | Integer |

| | | |
|---|---|---|
| DAYMOYR | Day/Month/Year of run | String |
| STOPA | stop sequential number | Integer |
| QSTOPA | PAAC stop alpha numeric ID number | String |
| ANAME | Stop Name | String |
| HR | Arrival Hour | Integer |
| Min | Arrival Min | Integer |
| SEC | Arrival Sec | Integer |
| DHR | Departure Hour | Integer |
| DMIN | Departure Min | Integer |
| DSEC | Departure Sec | Integer |
| ON | Observed Number of Passengers Boarding | Integer |
| OFF | Observed Number of Passengers Alighting | Integer |
| LOAD | Number of Passengers on Bus | Integer |
| DLMILES | Miles travelled from last stop | Float |
| DLMIN | Minutes travelled from last stop | Float |
| DLPMLS | Change in passenger miles from last stop | Float |
| DWTIME | Dwelling time (min) | Float |
| DELTA | Distance in feet from observed GPS coordinates of the record to GPS coordinates for the stop | Integer |

| | | |
|---|---|---|
| SCHTIM | Scheduled arrival time | Integer |
| SCHDEV | Difference in arrival time with schedule time if a timepoint | Float |
| SRTIME | Scheduled run time from previous time point to current timepoint | Float |
| ARTIME | Actual travel time from previous time point to current timepoint | Float |

## *(5.d) Methodology - Opportunity Occupation Destination Zones*

### Identifying Opportunity Employment Using ACS Data

To identify employees of opportunity occupations, we filtered ACS PUMS data to Pennsylvania. Following this, we filtered responses to those that fit a number of criteria. We restricted respondents to those aged between 16 and 40, to capture working age population without conflating wages with natural gains due to years of experience. We removed individuals enrolled in school. Using this information, we observed the total number of jobs in the dataset associated with a specific industry. We isolated individuals who worked 50-52 weeks in the year, and for each of these weeks worked 35-60 hours per week. Finally, we restricted respondents those with less than a bachelors degree but made more than the median annual wage in Pennsylvania (at the time of the study, this is roughly $59,195). With opportunity occupations defined, we then recomputed the number of opportunity jobs associated with an industry.With total industry occupation sums and opportunity occupations sum computed, we created an industry opportunity share for each of the observed industries in the NAICS category.

### Top Opportunity Occupations in Allegheny County

*Table 6: Top industries for opportunity employment by count*

| Top Industries for Opportunity Employment by Count for Allegheny County | | | | |
|---|---|---|---|---|
| Industry Code | Total Count | Opportunity Count | Percent Opportunity | Description |
| 23 | 975 | 196 | 20% | Construction |
| 31-33 | 1844 | 163 | 25% | Manufacturing |
| 44-45 | 1396 | 87 | 11% | Retail Trade |
| 48-49 | 566 | 83 | 27% | Transportation and Warehousing |
| 92 | 659 | 80 | 12% | Public Administration |
| 62 | 2194 | 77 | 4% | Health Care and Social Assistance |
| 54 | 1112 | 68 | 6% | Professional, Scientific, and Technical Services |
| 22 | 171 | 54 | 32% | Utilities |
| 42 | 426 | 45 | 11% | Wholesale Trade |
| 52 | 822 | 40 | 5% | Finance and Insurance |
| 56 | 480 | 33 | 7% | Administrative and Support and Waste |
| 81 | 556 | 33 | 6% | Other Services |
| 21 | 95 | 24 | 25% | Mining & Quarrying |
| 51 | 240 | 24 | 10% | Information |
| 72 | 645 | 17 | 3% | Accommodation and Food Services |
| 61 | 1047 | 14 | 1% | Educational Services |
| 53 | 182 | 10 | 5% | Real Estate and Rental and Leasing |
| 11 | 152 | 6 | 4% | Agriculture, Forestry, Fishing and Hunting |
| 71 | 192 | 6 | 3% | Arts, Entertainment, and Recreation |
| 55 | 17 | 2 | 12% | Management of Companies and Enterprises |

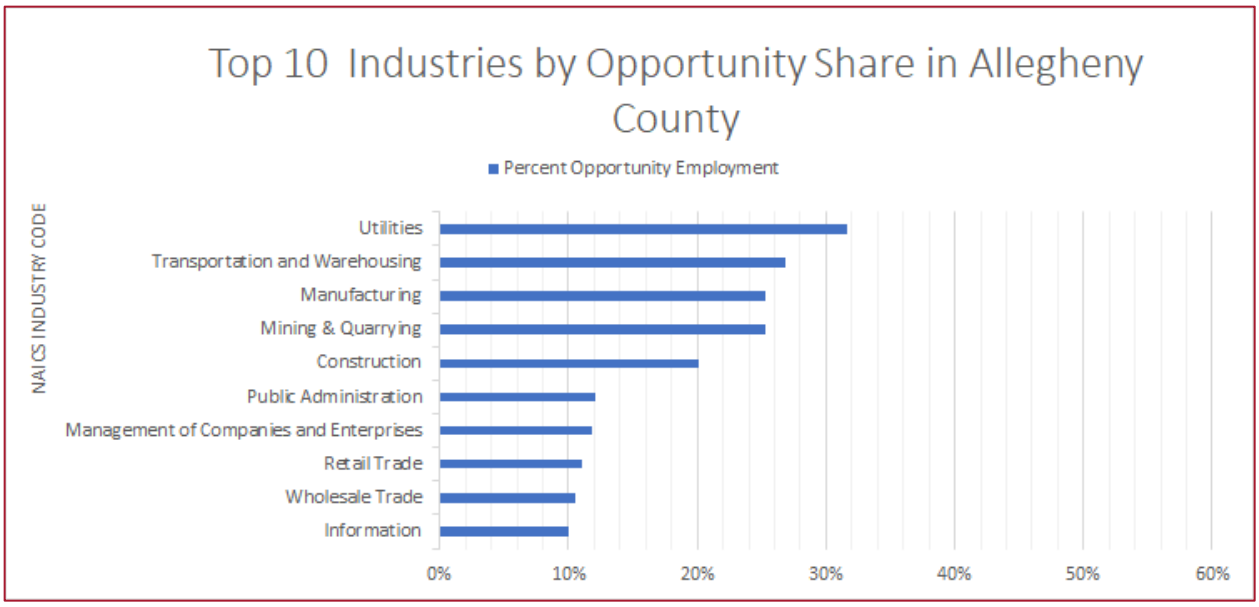


*Figure 22: Top 10 Industries by Opportunity Share in Allegheny County*

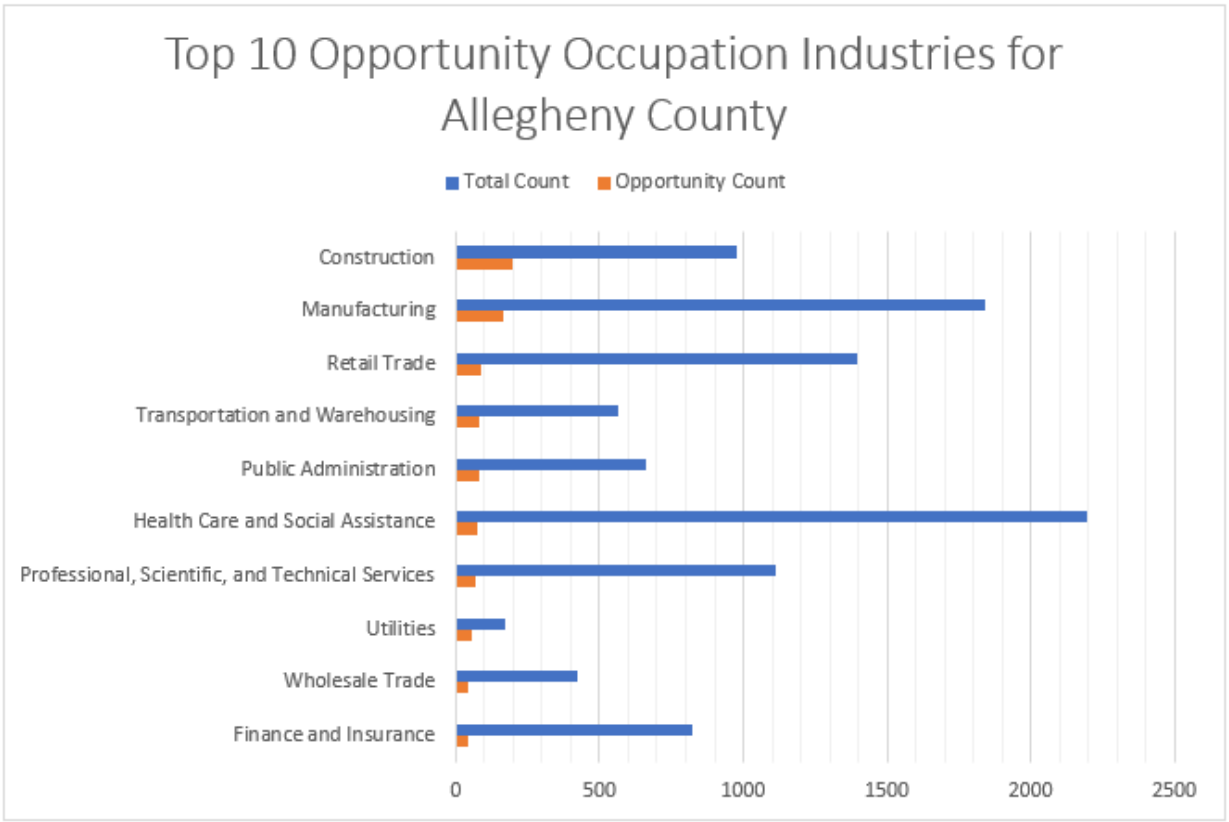


*Figure 23: Top 10 Opportunity Occupation Industries for Allegheny County*

**Bruteforce Data Collection and Custom Polygon Creation with ReferenceUSA**

Information about how business data was acquired from ReferenceUSA:

- Data Collection: From ReferenceUSA database, download every registered business in Allegheny County fitting the following criteria:
    - Under Number of Employees, select all except 1-4 and 5-9 (leaving out these very small businesses reduces the number of records returned from over 60k down to 12k)
    - Limit industry codes to
        - 11, 21, 22, 23, 31, 32, 33, 42, 44, 45, 48, 49, 51, 52, 53, 54, 55, 56, 61, 62, 71, 72, 81,92
        - Industries selected based on Method 1 results.
    - Select "Show More Options" and select "Location Only".

### Neighborhood Alternative Labels

| BlockGroup | Neighborhood Label | Other Associated Neighborhoods |
|---|---|---|
| 42003490003 | South Park Twp | |
| 42003475101 | Bethel Park | |
| 42003508000 | Wilmerding | |
| 42003469000 | Green Tree | East Carnegie/Oakwood, Ridgemont/Westwood |
| 42003521200 | Monroeville | |
| 42003050100 | Middle Hill | Bluff, West Oakland/Terrace Village, Crawford-Roberts, Terrace Village, Middle Hill, Bedford Dwellings |
| 42003050600 | Upper Hill | North Oakland, Bedford Dwellings, Bloomfield, Middle Hill, Polish Hill, Strip District, Lower Lawrenceville, |
| 42003459201 | Robinson Twp | North Fayette |
| 42003421100 | O'Hara Twp | Blawnox |
| 42003451105 | Moon Twp | |
| 42003452000 | Findlay Twp | |
| 42003402000 | Brackenridge | Tarentum |
| 42003411000 | Marshall | Bluff, Strip District |
| 42003020100 | Central Business District | *Other Names*: Golden Triangle-Civic Arena, Downtown |

*Figure 24: Block groups, neighborhoods and labels*

## (5.e) Methodology - Accessibility Index Development

**Port Authority Top Customer Importance Survey**

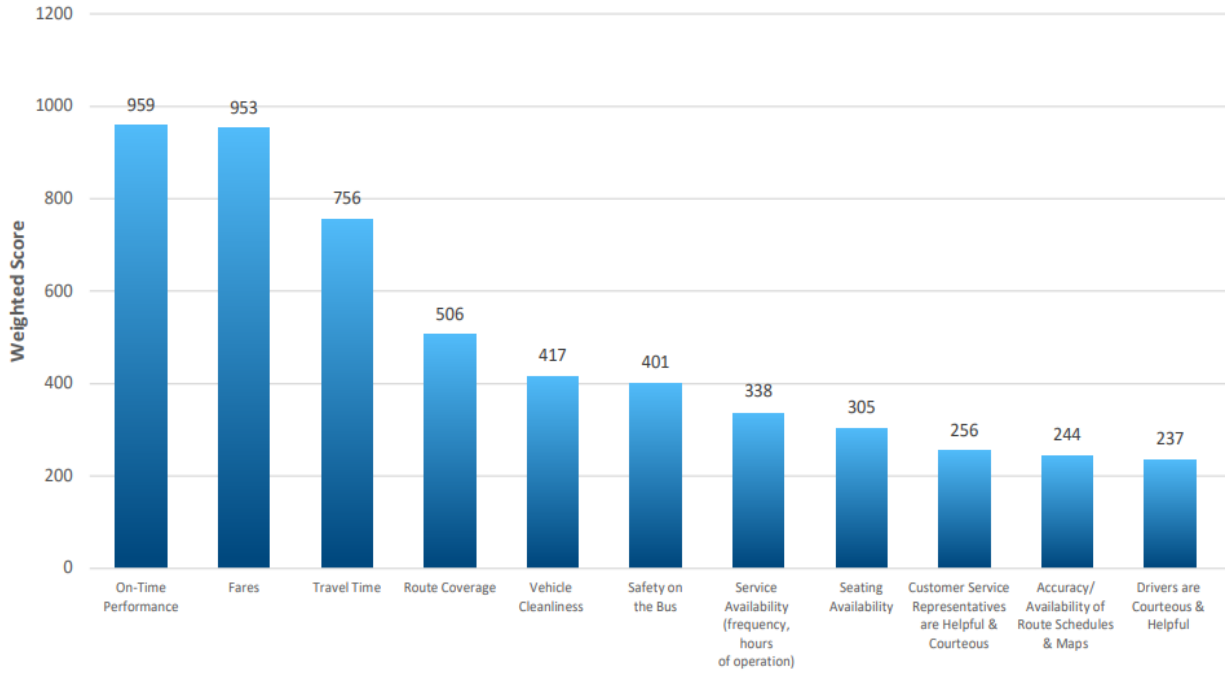


*Figure 25: Port Authority Customer Importance Survey*

## Community-Based Scores for Origins

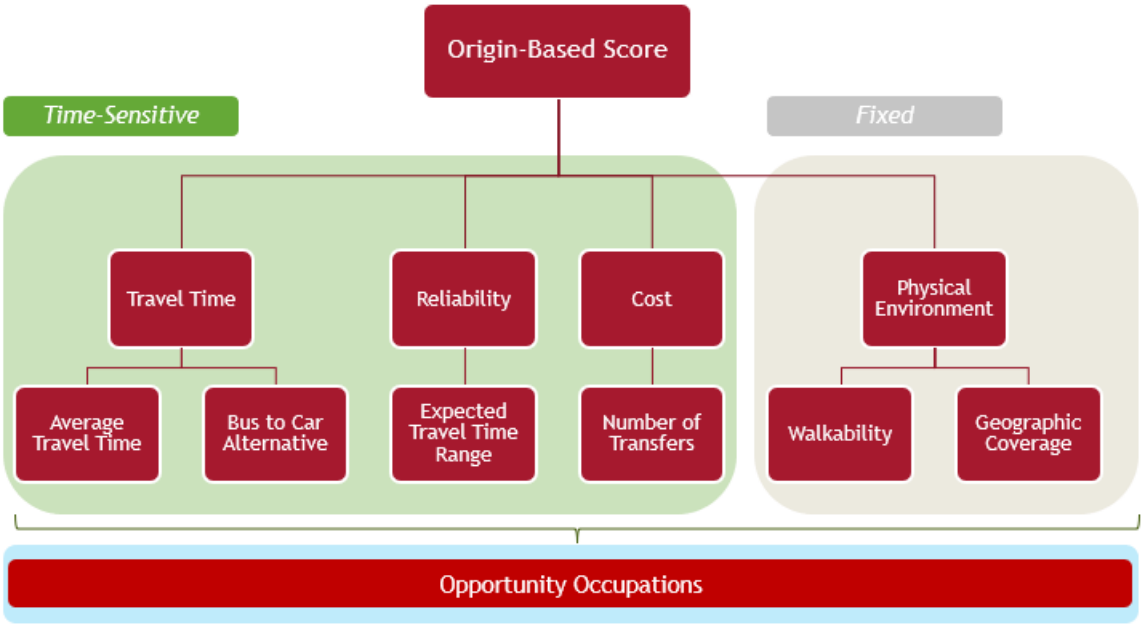


*Figure 26: Community based scores*

Figure represents the process for normalizing routes based on the number of opportunity jobs at a given destination. Results in Table 7.

*Table 7: Origin Scores*

| Origin Scores | |
|---|---|
| Origin Scores | Score |
| Crafton Heights | 72.49 |
| Bedford Dwellings | 50.26 |
| Manchester | 48.01 |
| Northview Heights | 47.26 |
| Carrick | 46.56 |
| Homestead | 45.15 |
| Stowe Twp | 18.77 |
| McKeesport | 14.57 |
| East Hills | 11.41 |
| Lincoln-Lemington- | 6.95 |
| Garfield | 3.99 |
| Robinson Twp | 3.52 |
| North Braddock | 3.17 |
| Clairton | 0.00 |
| Duquesne | 0.00 |
| Penn Hills | 0.00 |
| Harrison Twp | 0.00 |

## Count of Destination Connections

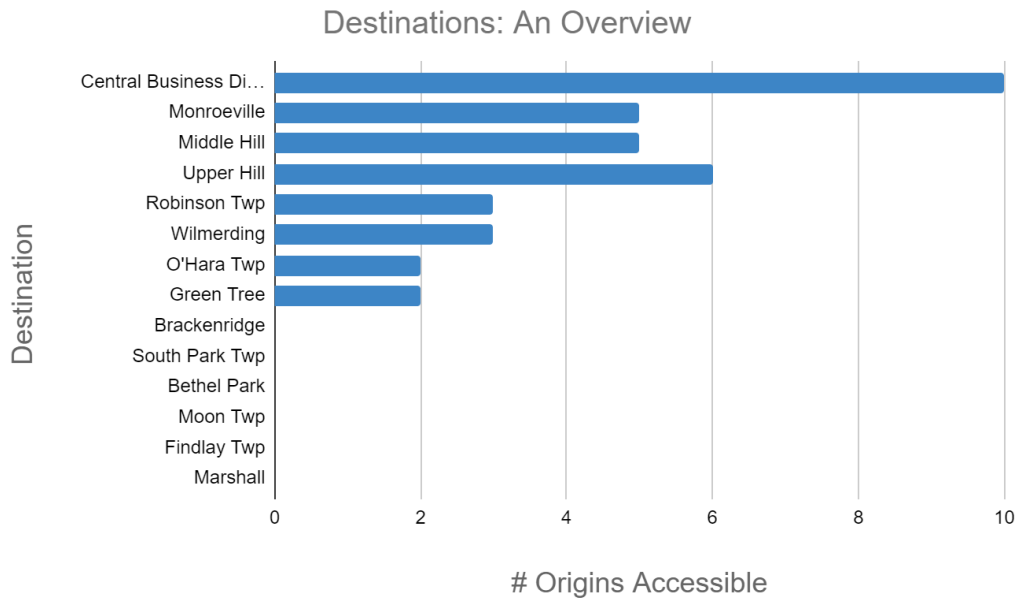


*Figure 27: Destinations Overview*

## (5.f) Methodology - Data Sources

*Table 8: Data Sources*

| Project Component | Data Source | Dates |
|---|---|---|
| **Origins** | U.S. Census Bureau American Community Survey 5-year estimates | January 1, 2013 to December 31, 2017 |
| | DHS Client data | Unknown |
| **Destinations** | ReferenceUSA | October 2019 |
| | U.S. Census Bureau American Community Survey Public Use Microsample (PUMS) | 2017 |
| | U.S. Census Bureau Longitudinal Employer-Household Dynamics (LEHD) program's Origin-Destination Employment Statistics (LODES) | 2017 |
| **Transportation** | APC-AVL | 2017 to May 2019 |
| | GTFS | November 2019 - February 2020 |