Beyond the East Busway

Extending BRT-Style Improvements to the Mon Valley, Monroeville, and Eastern Suburbs to Enhance Transit in the Short-Term

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2020 Heinz College Systems Report
Pittsburghers for Public Transit, Client

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Beyond the East Busway

Executive Summary

Background

The following transit alternatives study was commissioned by Pittsburghers for Public Transit (PPT) as a part of the "Beyond the East Busway" survey and campaign. The Beyond the East Busway survey, designed by CivicMapper, and the associated campaign were created to address the need for data-driven, community-supported, feasible bus service improvements in the Mon Valley, Monroeville, and Eastern Suburbs. Previous feasibility studies have focused on cost-prohibitive infrastructure improvements to the MLK Jr. East Busway. As the Port Authority of Allegheny County (PAAC) develops a Bus Rapid Transit (BRT) system in the Downtown-Oakland corridor, this study analyzes the impact of extending similar BRT-style improvements to the Mon Valley, Monroeville, and Eastern Suburbs region. Overall, this study finds several equitable, efficient, and effective alternatives that will both improve transit in the Beyond the Busway region and maximize the investment of the Pittsburgh BRT.

Demonstration of Need

Prior to generating system improvement alternatives, transit improvement needs were identified by combining demographic analysis with Beyond the Busway survey results. Our study first divides Allegheny County into five regions – North, South, East (Beyond the Busway interest area), West, and the City of Pittsburgh. In analyzing PAAC Equity Index of Mobility Need scores, we find that the Beyond the Busway interest area is second only to the City of Pittsburgh in terms of the magnitude and count of highest-need census block groups. The Beyond the Busway interest area shows the highest relative need measured by households without vehicles, number of minority race and ethnicity persons, people in poverty (low-wage jobs, rent-burdened households, and low-income households), number of people with disabilities, and female-headed households. Furthermore, 8 of the top 10 highest-need municipalities in Allegheny County are in the Beyond the Busway interest area.

The Beyond the Busway survey identified municipalities and points of interest which comprise origins and destinations of top priority. A sample of municipalities considered throughout this study include Braddock, Swissvale, Monroeville, Rankin, Turtle Creek, McKeesport, and Duquesne. Key points of interest were identified as medical facilities, shopping centers, housing, and recreational facilities with clusters in Monroeville, Homestead, Braddock & East Pittsburgh, Edgewood, Wilkinsburg, and McKeesport. Survey respondents also identified their most frequented bus-routes including the P-routes which utilize the East Busway, the 61ABCD, the 59, 67, and 69 routes, which are each core to the region.

The Beyond the Busway survey included nine candidate corridors developed by PPT and CivicMapper for fast and frequent, BRT-style transit improvements. Survey preferences for corridors were combined with demographic analysis and transit improvement research to generate a long list of alternatives (found on page 61). This long list was refined with feedback

from our advisory board including expert transit planners, researchers, bus operators, representatives of Councils of Governments, traffic engineers, and community members. From this long list, several alternatives were analyzed in depth using metrics including service time/coverage, operations and maintenance costs (O&M), projected ridership, and capital costs.

Alternatives were grouped into three categories – "service changes," "on-street improvements," and "infrastructure improvements." It was found throughout the study that while Service Changes can be immediately implemented with great impact, investments in on-street and Infrastructure Improvements will save costs in the long-term with comparable or better results.

Recommendations

Based on our findings, we identify the following possible transit improvement alternatives for implementation or further study.

Service Changes

Extend the P68 to UPMC East and Forbes Hospital. This service change has the potential to expand transit access to Forbes Hospital, currently unreachable from within the PAAC system. This connectivity is projected to yield 461 additional daily weekday riders or 120,000 additional annual weekday trips. Annual operations and maintenance costs could be as much as $477,000 to maintain current headways.

Add off-peak and weekend service on the P7 and re-route entirely on the East Busway. Since the P7 currently only operates during peak hours, this would add fast and frequent service all day and on weekends of 40 minutes headway between McKeesport and Downtown. For an increase of $459,000 in operations and maintenance costs, the P7 could add 980 daily trips, or 294,000 annual trips.

Extend the 71 to the Waterfront. To strengthen the 71 route by adding additional stops and increased connectivity to riders could cost $403,900 in annual operations & maintenance costs, while adding 449 additional daily trips or 164,000 additional annual weekday and weekend trips.

Develop a Monroeville route via Braddock and Turtle Creek. As the top identified corridor of interest from the survey, a one-seater to Monroeville from Braddock also has potential to connect many riders in between. A new route could cost on the order of $1.4M but could see significant ridership of 1,615 daily weekday and 440 weekend trips, for 465,000 annual total trips. This does not take into consideration shifted riders from other routes, such as the P68, so further analysis and community input is recommended to proceed with this option.

On-Street Improvements

Commission an implementation study to deploy Transit Signal Priority (TSP) throughout the Beyond the Busway interest area. TSP was shown to have large potential savings of up to 4 minutes on certain routes in the best case, with an average of 2-4% time savings on each route. TSP implementation on the 61ABCD was found to be particularly cost-efficient, because seventy seven traffic lights are shared by numerous routes. Further, TSP on the fifty traffic lights used by the 61C and 61D is highly recommended, as minor improvements in travel time could lead to peak vehicle reduction (over $350,000 in projected annual savings). TSP on the 61ABCD could yield 210 daily weekday riders or 54,468 annual daily riders, distributed across all impacted routes. Because costs for implementation range from $2M-$40M, depending on the needs of specific traffic lights, further study is suggested to prioritize lights of top congestion to achieve cost-efficiency. Queue jumps should be grouped into this study.

Implement feasible Dedicated Bus Lanes. A dedicated bus lane on South Ave. in Wilkinsburg could save between 1-3 minutes per trip on six impacted routes for just $130,000. This is one of the most cost-efficient findings of the entire study, at $40,000 per trip minute saved. Additional candidate sites should be investigated, such as on East 8th Ave. in Homestead, which could save up to half a minute per trip on the 61C, 53, and 52L. Additional lanes may be identified through congestion analysis which may be a component of a TSP implementation study.

Develop an equitable, far-reaching Off-Board Fare Collection system. Off-board fare collection throughout the Beyond the Busway interest area was found to save up to 8,000 annual vehicle hours and 300,000 rider-hours, with an average of 0.63 minutes saved per rider. These benefits would be distributed throughout the entire PAAC system. Maximum off-board fare collection can be established by a combination of ticketing locations ($25,000 each) and a new PAAC app, but studies and community buy-in would be necessary. Issues of concern include access for low-income, cash-paying riders and a non-criminal enforcement system. PPT's #FairFares platform provides further insight into these concerns.

Combine On-Street Improvements to achieve BRT-style transit. The study found that a reduction of peak vehicles (large annual cost-savings and additional systemic capacity) could be achieved by surpassing a trip speedup threshold. As shown by the efficiency graphs in figure 88, combining improvements provides over 100% increased bus hours saved at just 10% of the additional cost. That is, combining improvements can result in compound savings on each route, while creating a cost-saving multiplier effect.

Infrastructure Improvements

Conduct feasibility and community-interest studies for an Edgewood East Busway Station. Adding a busway station at the Edgewood Towne Centre would increase busway utilization while providing opportunities for transit-oriented development in the Beyond the Busway interest area. Additionally, if the recommendation of moving the P7 route to the busway is accepted, building this station would address potential ridership loss to and from Edgewood. Future feasibility and community-interest studies are recommended to determine whether this station should be pursued.

Conduct feasibility study for a Busway to I-376 ramps with Dedicated Bus Lanes. A ramp from the busway onto I-376 with dedicated bus lanes on the highway shoulder could resolve numerous structural issues in the delivery of PAAC service to the Beyond the Busway interest area. In a best-case scenario, the trip from Downtown to the Monroeville Mall could be as short as 30 minutes (currently 60-70 minutes on P68), and 40 minutes to Forbes Hospital. Routes such as the P67, P12, P16, and many more could be impacted by the new possible routings. Given the large structural nature of this improvement, future study would be necessary to better understand the feasibility and costs of ramp construction.

Responding to COVID-19

Conduct an equity and service analysis of disparate ridership and impact caused by COVID-19. While this study was conducted prior to the onset of the global COVID-19 epidemic, the disparate impact on riders from the Beyond the Busway interest area may be especially prominent. We suggest that rider-informed equity analyses be conducted to understand the impacts of the pandemic and new service. Some questions of interest include: who has been most impacted, which routes have been impacted in terms of ridership, and how many riders have received better or worse service. This analysis should be pursued by multiple stakeholders including both PPT and regional transit agencies.

Stakeholder Roles

For each of these improvements, our study recommends different courses of action by stakeholder.

Pittsburghers for Public Transit

PPT should work with its members to interpret the results of this study, which will inform the next phase of their advocacy campaign. PPT should consider a blend of service and capital improvements, including some combination of those listed here or elsewhere identified. Beyond sharing the report, opportunities for rider engagement include through town halls and alternative evaluation training.

Port Authority of Allegheny County / Southwestern PA Commission (SPC)

PAAC and SPC should commission future studies on the implementation of BRT-style service in the Beyond the Busway interest area, using this report as a foundation. These results may also be informative to long-range planning efforts by both organizations. Additionally, SPC should consider integrating the study's findings into their current draft 2022-2024 Transit Improvement Plan and future regional transportation plans.

Regional Leadership

Regional leaders should prepare to secure funding through local, state, federal sources to finance plans supported by PPT and the general public and analyzed by PAAC/SPC. Some possible funding opportunities are listed in the conclusion of this report.

Conclusion

Our study finds several effective, efficient, and equitable alternatives within and associated with those called for by PPT's Beyond the Busway initiative. These improvements are well-positioned to maximize the Pittsburgh BRT investment, extending its benefits throughout the region. No matter which improvements are pursued, in the spirit of the Beyond the Busway initiative, it is suggested that all future improvements center riders, their input, and their needs.

Top Alternatives	Service Benefit	O&M Cost/Savings	Projected New Riders	Capital Cost
P68 Extension to Hospitals - Scenario 1	Transit access to Forbes hospital (previously unserved)	$477,000 in additional O&M costs	461 additional weekday daily trips or 120k additional annual weekday trips	N/A
P7 Off-Peak + Express on Busway - Scenario 3	Faster, more frequent service	$459,000 in additional O&M costs	980 additional daily trips, or 294k additional annual weekday and weekend trips	N/A
71/59 - Scenario 1	Transit connection between Wilkinsburg and the Waterfront (previously unserved)	$403,900 in additional O&M costs	449 additional daily trips, or 164k additional annual weekday and weekend trips	N/A
Monroeville via Braddock & Turtle Creek - Feeder Route	Transit connection from Braddock to RIDC, Monroeville Mall (previously unserved)	$1,429,000 in additional O&M costs	~1615 weekday daily trips, ~440 weekend daily trips, or 465k annual trips	N/A
61ABCD TSP	1-2% savings on all routes, up to 4 minutes on 61C	Up to $500,000 saved on 61ABCD, not including other routes	241-590 daily weekday or 72,300- 177,700 annual trips	Low: $2M Medium: $20M High: $40M
Dedicated Bus Lane on South Ave, Wilkinsburg	1-3 minutes speedup on impacted routes	Future Study	Future Study	$130,000
Dedicated Bus Lane on East 8th Ave., Homestead	1 minute speedup on impacted routes	Future Study	Future Study	$50,000
System-wide Off-Board Fare Collection	0.63 minutes average savings on ALL routes	Over 5,000 annual bus-hours saved	112,009 new riders due to speedup	Variable, but potentially $1.5M for 25 ticket locations
Edgewood Towne Centre Station	Increased utilization of the busway	Future Study	Future Study	$5M+ with TOD/TRID Benefits
I-376 Bus Ramp	Significantly Decreased Travel Time	Future Study	Future Study	Future Study
East Busway Extension to East	Significantly Decreased Travel Time	Increased efficiency of routes	4,091 new daily or 1,227,300 annual trips	$371M (2016 dollars)

Pittsburgh)[1]				
East Busway Extension to Monroeville Mall	42 minutes Downtown to Monroeville Mall	Increased efficiency of routes	4,900 new daily Or 1,470,000 annual trips	$476M (2016 dollars)

Project Overview

Introduction

Since the early 1990's, there has been a long standing public demand for extending the Martin Luther King Jr. East Busway to improve transportation access to and from the Monongahela Valley. 2003 saw the opening of the East Busway Extension that extended the busway from Wilkinsburg 2.3 miles to Swissvale/Rankin. In 2016 and 2017, the Port Authority of Allegheny County, in partnership with Gannett Fleming and the TRIP research groups, released feasibility and economic analyses of doing just that. The study, as well as supplementary Heinz College Systems Synthesis reports, found the East Busway extension proposals to be highly effective in terms of ridership. In the East Busway's current alignment, the corridor from downtown Pittsburgh to Swissvale serves over 24,000 of all the East Busway/Mon-Valley's 34,657 daily alightings.[2]

However, like many of the large-scale transportation infrastructure proposals in the region, most notably the Mon/Fayette Expressway extension between PA Route 51 and I-376, and expanding light rail service to the region, the feasibility of a busway extension has been constrained by its significant price tag. While previous feasibility studies have focused on expensive infrastructure improvements, there is good potential for service, on-street, and more-minor structural improvements to feasibly expand transit access to Mon Valley residents.

To address the need for a cost-effective extension of the MLK Jr. East Busway, Pittsburghers for Public Transit (PPT) developed the "Beyond the East Busway" initiative. PPT is a grassroots nonprofit organization of transit riders, workers, and residents who defend and expand public transit. Their goal is to keep the public in public transit by mobilizing communities to advocate for equitable, affordable, and sustainable transportation systems as they outline a Transit Bill of Rights for all residents of Allegheny County.

PPT's Beyond the Busway initiative is composed of two parts:

> **The Survey:** In summer 2019, PPT developed one of the nation's first integrated Geographic Information Systems (GIS) and volunteer-based participatory planning

[1] "Martin Luther King Jr. East Busway Extension Feasibility Study." Port Authority of Allegheny County, May 2017. http://wyep.org/files/wesa/files/EastBuswayExt_FeasStudy_05302017.pdf.

[2] "Martin Luther King Jr. East Busway Extension Feasibility Study." Port Authority of Allegheny County, May 2017. http://wyep.org/files/wesa/files/EastBuswayExt_FeasStudy_05302017.pdf.

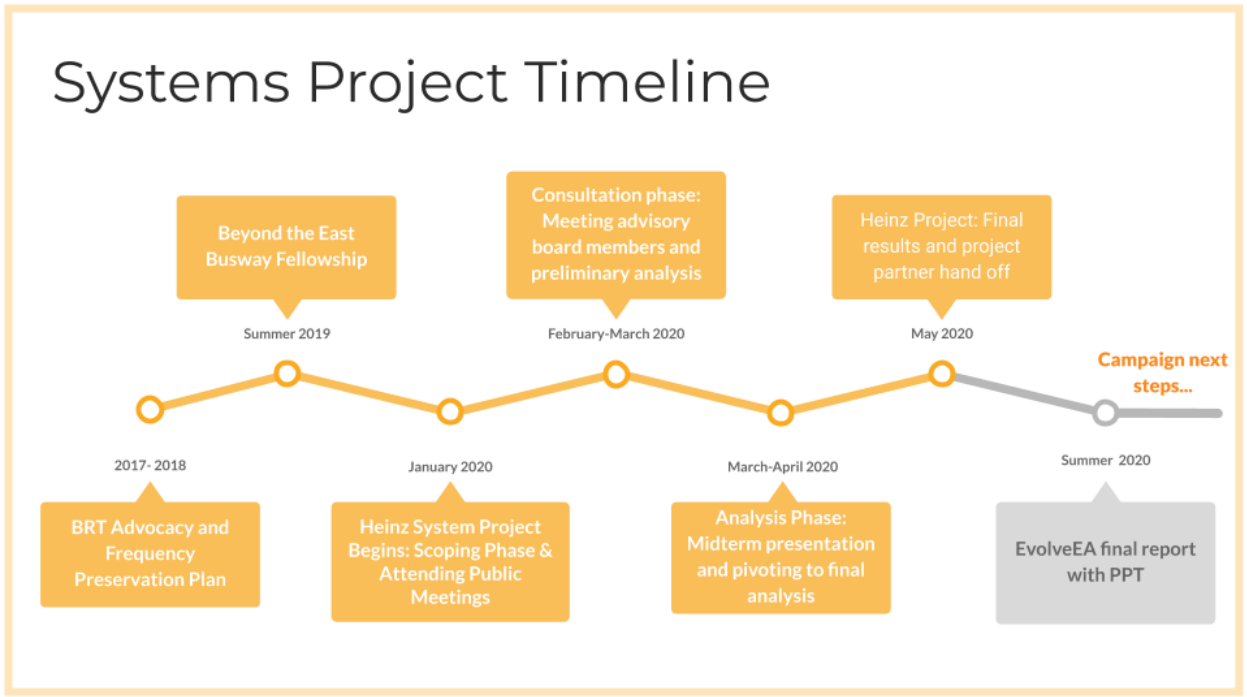
processes. In their groundbreaking survey, 15 volunteers collected over 500 responses from transit and non-transit riders that highlight community points of interest within and outside of communities, as well as their desired vision for the transit system in the region.

The Campaign: PPT is now aggregating the survey results in partnership with EvolveEA and our team at Carnegie Mellon University's Heinz College. The results and the recommendations from both reports will be developed to support future PPT initiatives in the region to mobilize meaningful investment now.

This campaign marks one of the first of its kind in community-led planning proposals. Partnership on this project has provided a unique opportunity to merge community-generated data with service planning strategies and methodologies to improve access for some of Allegheny County's most isolated residents in the Mon Valley, Monroeville, and the Eastern Suburbs. These communities define the area of interest in this study.

Our analyses explore the current community transit coverage using service metrics of the Port Authority system in the region. These methods were used to create a "no build" (keeping the system as is) scenario upon which a series of service changes and "build" (adding system improvements or changes) alternatives were modeled. Short and long lists of transit improvement actions were developed, which were then evaluated among the metric categories of ridership, service, operations and maintenance (O&M) costs, and capital costs. This evaluation culminated in a series of recommendations and areas of further study to complement and supplement this report.

Figure 1. Systems Project Timeline



Study Purpose: Beyond the East Busway Campaign

The purpose of this study is to conduct a preliminary transit study of the "Beyond the Busway" campaign region to investigate and model transit improvements to extend a feasible, Bus Rapid Transit (BRT) style system to the Mon Valley, Monroeville, and Eastern Suburbs of Pittsburgh. The basis of this study is in prioritizing the experiences and demand of area riders found in the survey results.

Moreover, the purpose of this study is to look "Beyond the Busway." As a guiding principle, this phrase is not just a way to align our project with PPT's work or geospatially define the project's area of study. Rhetorically, moving Beyond the East Busway means a divergence from the large-scale infrastructure proposals of the past, and moving toward service delivery and technology deployments that can feasibly be implemented in the short-term.

The *MLK Jr. East Busway Feasibility Study (2017)* highlights the challenge of balancing costs with improved service in the region. The study found that an extension from Swissvale Station to East Pittsburgh alone would cost $371M. Dependent on the eventual completion of the Mon/Fayette extension, the busway extension to I-376 is projected to cost $476M. This does not include the $900M projected cost of the expressway extension itself.[3]

As local authorities continue to develop the funding resources for the $225M Pittsburgh BRT project connecting Oakland and Downtown Pittsburgh with 7.4 total miles (inbound and outbound) of dedicated, signal prioritized bus lanes, a new transit improvement philosophy is emerging - one that uses sensible on-street improvements to work within existing geographic constraints. Feasible improvements called for in the Beyond the Busway initiative are well-positioned to maximize the Pittsburgh BRT investment, extending its benefits throughout the region.

It is critical that the region's transit needs are met sooner than later. Following sections of this report will discuss those needs in great depth. As we assessed the needs of the region, and designed our methodologies for evaluating and modeling no build and build scenarios, our analyses were guided by three key objectives and questions:

1. **Equity:** Which transit strategies are most prioritized by riders in the East Busway region?

2. **Effectiveness:** Which transit improvements are feasible, relative to an extension of the busway, that protects and expands the current level of service for riders?

3. **Efficiency:** Which transit strategies offer the most improvement to the riders through service quality relative to the resources required to actuate the improvement?

The answers to these questions have been the primary acceptance criteria for our recommendations, as well as the key metrics used to assess the success of this project.

[3] "Martin Luther King Jr. East Busway Extension Feasibility Study." Port Authority of Allegheny County, May 2017. http://wyep.org/files/wesa/files/EastBuswayExt_FeasStudy_05302017.pdf.

Beyond the Busway in Context: Pittsburgh BRT, PAAC Developments, the Kenmawr Bridge, and SPC Plans

Pittsburgh BRT

Overview and Brief History

The Pittsburgh Bus Rapid Transit (BRT) is the Port Authority of Allegheny County's (PAAC's) current large-scale transit improvement project. PAAC states that the BRT is "a rapid transit system that uses buses to move thousands of people in dedicated bus lanes on Port Authority's busiest corridor (Downtown to Oakland). Separated from general traffic, BRT buses will run faster and more reliably without adding to congestion."[4]

According to the Federal Transit Administration Small Starts funding program there are two types of BRT: *Corridor-Based* and *Fixed-Guideways*.[5] *Corridor-Based* BRT systems do not necessarily include a bus-only right-of-way throughout the entire corridor, though they do include "defined stations, Traffic Signal Priority systems, short headways, and full-weekday service." *Fixed Guideway* BRT systems share the same conditions, except primarily "operate [on] a separated right-of-way for public transportation use." Operating primarily in bus-only lanes between Downtown and Oakland, the Pittsburgh BRT falls largely into the *Fixed Guideway* category, though it does include some aspects of a *Corridor-Based* system as well. Improvements to the Beyond the Busway region would fall largely in this latter category.

Just as MLK Jr. East Busway studies are plentiful, there have been many studies on rapid transit alternatives between Downtown and Oakland. The following write-up draws historical insights from the 2014 BRT Definitions of Alternatives study.[6] The Spine Line Corridor study, completed in 1993 considered "extending light rail from Downtown Pittsburgh… [and] express bus service to Oakland via the East Busway." The Eastern Corridor Transit Study in 2006 considered six alternatives including "three different alternatives for a Downtown Pittsburgh transit investment." From 2007-2009, under budgetary constraints, PAAC developed a Transit Development Plan (TDP), which included a total network reorganization and recommendations "to implement a Rapid Bus service between Downtown Pittsburgh, [Oakland, and the East End]."

In 2009, a Pittsburgh delegation toured the Cleveland Health Line BRT project for inspiration. In 2010, PAAC convened a local BRT Symposium to build interest for a possible BRT in Pittsburgh. From 2011-2014, PAAC commissioned a study conducted by PB Americas to analyze possible BRT alternatives and conduct a National Environmental Policy Act (NEPA) review. This study included a Stakeholder Advisory Committee of over 40 institutional and non-profit partners, and two rounds of community meetings. The study developed station concept designs and developed a neighborhood-based list of BRT alternatives (Downtown, Uptown, Soho, Hill District, Oakland,

[4] "BRT Service." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/inside-Port-Authority/projects-and-programs/bus-rapid-transit/brt-Service/.
[5] "About the Program." About the Program | FTA. Accessed May 19, 2020. https://www.transit.dot.gov/funding/grant-programs/capital-investments/about-program.
[6] "Definition of Alternatives: Pittsburgh, Oakland, East End Transit Study." Port Authority of Allegheny County, December 2017. https://www.portauthority.org/link/9843f10c3c244c87a0948e0e948a1c15.aspx.

East End). In 2017, the study report was released, which refined two alternatives and charted a path forward for FTA Capital Investment Grant Funding. Allegheny County officials selected the longest alternative in 2017, a route connecting "Downtown with Oakland, East Liberty, Homewood and Wilkinsburg."[7]

Pittsburgh BRT & Beyond the Busway

In May of 2017, PAAC released the BRT Operating Plan. The plan included service changes to the 61A, 61B, 61C, 71A, 71C, and 71D, which would have those routes end in Oakland, forcing a transfer to the BRT-routes 61D, 71B, or P3 to reach Downtown.[8] This would result in a 45% cut in service for 61 and 71 riders and particularly affect the portion of ridership on these routes that travel downtown. With high shares of cash-paying riders, transfers in Oakland would also mean more expensive one-way trips ($5.50 one-way). In response to this announcement Pittsburghers for Public Transit partnered with Mon Valley residents, the Mon Valley Initiative, and Just Harvest to push back against the cuts.[9] Other local groups also expressed concerns with the initial BRT service plans.

In April 2018, at a community meeting with over 100 residents in the Mon Valley, PAAC responded to the community feedback and announced a new "Frequency Preservation Plan" which would preserve almost all service on the 61 or 71 routes in the BRT plan.[10] With less protest from riders on the 71A and 71C, BRT-routes were switched and re-designated as the 61A, 61B, 61C, 71B, and P3. PAAC was still projected to save $7M/year due to operating improvements. After the community engagement process, PAAC and the URA planned additional community meetings to discuss other BRT impacts. In August 2019, PAAC re-submitted the BRT proposal for $99.5M in FTA Small Starts Funding, incorporating these changes.[11]

The Beyond the Busway survey and grassroots campaign aimed to take the successful advocacy a step further, asking the question – **how could Pittsburgh BRT-style improvements be extended into the Mon Valley, Monroeville, and Eastern Suburbs to best serve residents?**

Pittsburgh BRT Plan Specifics: On-Street Improvements & Service Changes

The Pittsburgh BRT will provide on-street and service improvements to provide fast, frequent, high-quality, comfortable, reliable, cost-effective transit service. The Pittsburgh BRT "network includes 7.4 miles (inbound and outbound) of dedicated bus lanes with 44 stations and 72

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[7] Clift, Theresa. "Allegheny County Selects Longest Bus Rapid Transit Route Option." TribLive, May 31, 2017. https://archive.triblive.com/local/pittsburgh-allegheny/allegheny-county-selects-longest-bus-rapid-transit-route-option

[8] Krauss, Margaret J. "Starting From Scratch: New BRT Proposal Quells Fears About Service." 90.5 WESA. Accessed May 19, 2020. https://www.wesa.fm/post/starting-scratch-new-brt-proposal-quells-fears-about-service#stream/0.

[9] "BRT Campaign Victory! No Cuts to the 61 Buses." Pittsburghers for Public Transit, April 13, 2018. https://www.pittsburghforpublictransit.org/brt-campaign-victory-no-cuts-to-the-61-buses/.

[10] Clift, Theresa. "Mon Valley Bus Riders Cheer Port Authority Decision Not to Cut Routes When BRT Is Built." TribLive, April 13, 2018. https://archive.triblive.com/local/pittsburgh-allegheny/mon-valley-bus-riders-cheer-port-authority-decision-not-to-cut-routes-when-brt-is-built/.

[11] "Small Starts Application: Project Narrative." Port Authority of Allegheny County, September 2018. https://www.portauthority.org/siteassets/inside-the-pa/bus-rapid-transit/pittsburgh-brt-project-narrative_10-1-18.pdf

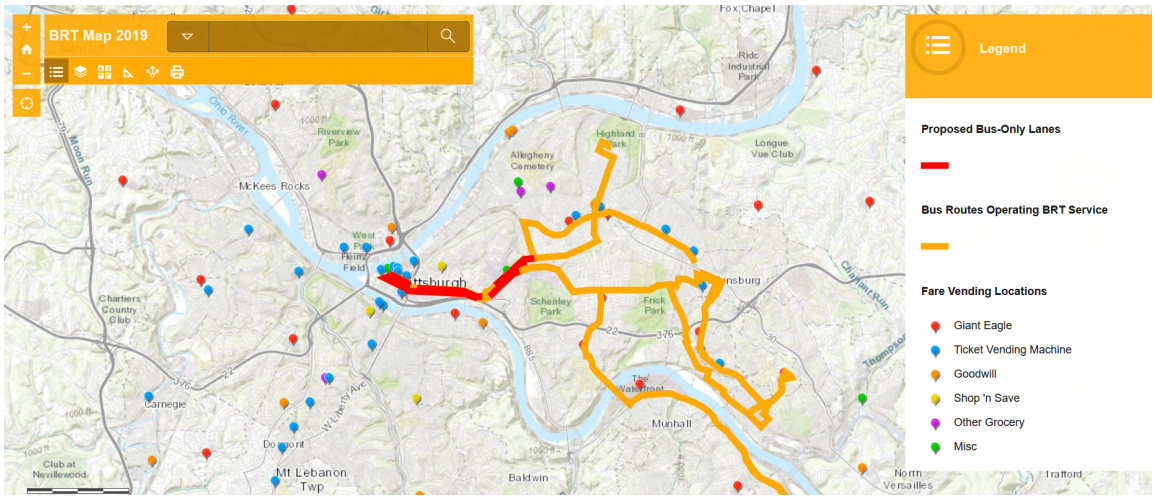
platforms."[12] Bus-only lanes begin Downtown through Uptown and Oakland.[13] Parallel bike-only lanes are proposed on Forbes and Fifth in Uptown and on Fifth in Oakland. PAAC is presently working with PennDOT and the City of Pittsburgh to incorporate TSP along the corridor. In a TSP system, the arrival of a bus triggers lights to turn green early or extend a longer green phase. Some intersections will also have queue jumps. Off-board fare collection will consist of ticket vending machines, but not paid zones at stations. Models for these types of on-street improvements will be discussed in the analysis section. PAAC recently estimated BRT Service Headways and Span as shown in the table below.[14]

Figure 2. Service Headways and Spans for the Pittsburgh BRT routes.

	Peak	Off-Peak	Evening
Weekday	2.5 minutes	4 – 7 minutes	4 – 7 minutes
Weekend	5 – 7 minutes	5 – 7 minutes	5 – 7 minutes

BRT-designated routes will include the 61A, 61B, 61C, 71B, and P3. These routes will continue to operate along their current scheduled routes, with speedup, along these dedicated lanes with the only potential change being the downtown loop. Non-BRT routes will stop at Craft Avenue and Oakland and turn around rather than going Downtown: 61D Murray, 71A Negley, 71C Point Breeze, 71D Hamilton. In order to account for the new schedules and on-street improvements, the following routes will be impacted by minor service changes: 28X, 54, 58, 75, 81, 83, 93. ACCESS vehicles will be able to use the bus-only lanes, but ideally not for pickups.

Figure 3. Planned Pittsburgh BRT. Note dedicated bus-lanes inbound Downtown on 6th, looping via Liberty onto Fifth outbound, down Forbes in uptown and onto Forbes in Oakland before looping back around via Bellefield onto Fifth inbound.



[12] "BRT Service." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/inside-Port-Authority/projects-and-programs/bus-rapid-transit/brt-Service/.

[13] "BRT Map 2019." paac.maps.arcgis.com. Port Authority of Allegheny County. Accessed May 19, 2020. https://paac.maps.arcgis.com/apps/View/index.html?appid=a5e696327dd34084970b05fd2d4746f0&extent= -80.0307, 40.3973,-79.8940,40.4752.

[14] "Small Starts Application: Project Narrative." Port Authority of Allegheny County, September 2018. https://www.portauthority.org/siteassets/inside-the-pa/bus-rapid-transit/pittsburgh-brt-project-narrative_10-1-18.pdf

Funding and Project Status

The project is currently in the design phase which, before COVID-19, was expected to complete in September 2020.[15] Construction was planned for 2021 with completion by 2023. The total budget for the project was initially budgeted for $195.5M and is now $225M. The project is being financed through a diverse set of sources. Federal sources include FTA Federal Small Starts grants and FTA Formula Funds in TIP for Bus Procurement.[16] This federal funding has not yet been disbursed, and is to be released when the design phase is finished. PA Commonwealth funding sources include State Technical Assistance and Consolidated Capital Grants, State Capital Budget Transportation Assistance Program Authorization, PA Department of Transportation Multimodal Transportation Fund, and PA DCED Funding**.** City of Pittsburgh funding includes Transit Revitalization Investment District (TRID), CMAQ (Oakland BRT Signalization Improvements), and in-kind station improvements. Allegheny County funding includes Capital Budget BRT Pre-Development funds and Implementation funding. Despite these investments, there is currently a $27M funding gap, which PAAC pledges to close by the completion of the design phase, in one form or another. All funding and application details related to the Pittsburgh BRT project can be found on the PAAC website.[17]

PAAC Long-Range Plan

In January 2020, PAAC signed a $1.6M, two-year contract with Michael Baker International Inc.[18] to facilitate generating a Long Range Transportation Plan (Vision Plan).[19] The plan will set a 25 year vision for PAAC services and, in alignment with this study, has a particular focus on identifying fast and frequent corridor opportunities. The scope of work is to consist of significant public engagement – 36 public engagement meetings, "80-hours of in-field public engagement," incentives for 1,000 people to engage in events, and a map-based online engagement platform." The first round of these meetings has already commenced, focusing on the Pittsburgh BRT, fare structure, app-based IT improvements, PAAC funding, and goals for this long-range plan.

PPT and community members have been notably present as a part of the #FairFares campaign.[20] The process will include an analysis of the current system taking all changes from 2020-2023 as the current baseline. It will also involve a ridership estimation model using the SPC travel demand model, identification of new infrastructure programs, transit corridors, fast/frequent service

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[15] Blazina, Ed. "Port Authority Will Seek Grants for Remaining $27 Million Needed for Bus Rapid Transit." Gazette. Pittsburgh Post-Gazette, February 12, 2020. https://www.post-gazette.com/news/transportation/2020/02/16/Port-Authority-Bus-Rapid-Transit-Downtown-Pittsburgh-Oakland-dedicated-bus-lanes/stories/202002200011.

[16] "Small Starts Application: Financial Plan." Port Authority of Allegheny County, September 2018. https://www.portauthority.org/link/b6c62ce8e59e4a4b8ee6c91dc84528c7.aspx .

[17] "BRT Service." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/inside-Port-Authority/projects-and-programs/bus-rapid-transit/brt-Service/.

[18] Blazina, Ed. "Port Authority to Hire Consultant for 25-Year Service Plan." Gazette. Pittsburgh Post-Gazette, January 21, 2020. https://www.post-gazette.com/news/transportation/2020/01/22/Port-Authority-25-year-plan-Michael-Baker-International-Inc-future-transit-service/stories/202001210099.

[19] "Long Range Transportation Planning Services Agreement." Port Authority of Allegheny County, 2019.

[20] "PAAC's New Public Engagement Series 'Public Transit: A Community Discussion.'" Pittsburghers for Public Transit, January 23, 2020. https://www.pittsburghforpublictransit.org/paacs-new-public-engagement-series-public-transit-a-community-discussion/.

opportunities, prioritization of investments, and three investment scenarios factoring variable funding availability.

This Beyond-the-Busway study, combined with the PPT Beyond the Busway survey process, and the forthcoming EvolveEA report should constitute preliminary research and analysis used by PAAC's Long-Range Transportation Plan consultant. The Beyond the Busway survey process should complement Baker International's community engagement strategy well. Additionally, the analysis in this study and the EvolveEA report can provide the start of a short and long-list of Mon Valley, Monroeville, and Eastern Suburbs alternatives and preliminary analyses. Thus, in addition to the Pittsburgh BRT, this report is tailored with the PAAC Long-Range Transportation Plan in focus, with insights and models that can be replicated by the consultant.

Recent PAAC Service Changes

According to its service guidelines, PAAC "adjusts schedules four times a year," which are published here: *https://www.portauthority.org/schedules/quarterlyschedules/.* Service changes from the second quarter of 2020 (pre-Covid-19) that fall within the Beyond the Busway interest area include (direct quotations from PAAC Quarterly Schedule Adjustments):[21]

- 52L - Homeville Limited – Schedules have been adjusted and some time points have been removed to improve on-time performance.
- 53 - Homestead Park – Sunday service has been added. Schedules have been adjusted and some time points have been removed to improve on-time performance.
- 53L - Homestead Park Limited - Schedules have been adjusted and some time points have been removed to improve on-time performance.
- 60 - Walnut-Crawford Village – Saturday service has been added. Schedules have been adjusted and some time points have been removed to improve on-time performance.
- 67 - Monroeville – Weekend service has been extended to CCAC's Boyce Campus.
- 68 - Braddock Hills – Will no longer operate on the weekends. Weekend service will instead be provided by the P68. Schedules have been adjusted and some time points have been removed to improve on-time performance.
- 71 - Edgewood Towne Centre - Schedules have been adjusted and some time points have been removed to improve on-time performance.
- P7 - McKeesport Flyer - Schedules have been adjusted and some time points have been removed to improve on-time performance.
- P68 - Braddock Hills Flyer - Weekend service has been added.
- P71 - Swissvale Flyer - Schedules have been adjusted and some time points have been removed to improve on-time performance.

These changes are incorporated into our study analysis, as applicable.

[21] "Quarterly Schedule Adjustments." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/schedules/quarterlyschedules/.

Of additional interest to our study are the changes:

1. **O12 - McKnight Flyer** – New service was added traveling outbound in the morning and inbound in the evening along Babcock Boulevard and Perry Highway and serving CCAC's North Hills campus. Seven additional outbound AM trips and two inbound PM trips have been added to better connect the North Hills with downtown Pittsburgh.
2. **Blue Line Library** – The Blue Line Library has been renamed the Silver Line Library to avoid confusion with the Blue Line South Hills Village.

These changes are of interest, 1) as they signify that PAAC is open to transit solutions that include strategically rearranging transit resources of differential demand throughout the day, to maximize riders served and 2) that renaming routes is an option if it would provide clarity of purpose of a route.

Regional Improvement of Note: Kenmawr Bridge Reconstruction

The Kenmawr Bridge between Rankin and Swissvale has had a weight limit and closed sidewalks since 2013.[22] Ed Blazina with the Post-Gazette reports, the bridge is scheduled for construction in March 2020 to raise the height four feet, expand its span from 73 to 122 feet, with extra-wide 14-foot lanes and sidewalks. The project budget is $12.5M, with 80% federal funding, 10% state funding, $1M from Norfolk Southern, and $1.46M from PAAC. Upon bridge completion, Norfolk Southern intends to ship double-stacked freight cars. Regarding construction, "to maintain traffic, contractor golden Triangle Construction will build a temporary bridge on the Hawkins Village side. In September 2021, after Kennywood closes for the season, the road will be closed for 75 days for the approach work and to install a left turning lane from South Braddock Avenue to Woodstock Avenue, which was requested by Swissvale."

Completion of the Kenmawr Bridge reconstruction is exciting and important to our study for several reasons. First, due to the weight limit restrictions, many buses have been rerouted around the bridge along one of several bus routings, generating longer service times and headways. This also means that many routes are disconnected from the end of the East Busway, a crucial access point to fast and frequent service throughout Pittsburgh and the East End. Secondly, in its reconstruction, the Kenmawr Bridge is being raised in such a way that would allow room under the bridge for a future East Busway Extension to East Pittsburgh, as mentioned in the 2017 MLK Jr. East Busway Feasibility Study.[23] Several of our alternatives consider this bridge reconstruction and its potential impact.

[22] Blazina, Ed. "Long-Delayed Kenmawr Bridge Project in Rankin and Swissvale to Begin." Gazette. Pittsburgh Post-Gazette, February 27, 2020. https://www.post-gazette.com/news/transportation/2020/03/01/Kenmawr-Bridge-replacement-Swissvale-Rankin-Allegheny-County-Kennywood-Park/stories/202002290009.

[23] "Martin Luther King Jr. East Busway Extension Feasibility Study." Port Authority of Allegheny County, May 2017. http://wyep.org/files/wesa/files/EastBuswayExt_FeasStudy_05302017.pdf.

SPC's Long Range Transportation Plan—SmartMoves for a Changing Region

SPC's 25 year long range transportation plan captures regional improvement plans for the long term that aims to approach regional mobility and development needs in a holistic plan.[24] Within the long range plan, SPC implements four-year Transportation Improvement Programs (TIPs). A number of components of the SPC's current TIP and other initiatives are relative to our interest area. The TIP is a four year regional development plan created with SPC and PennDOT officials, along with 11 member governments. Currently, the 2019-2022 plan has been finalized, with the 2021-2024 plan in draft stage. A number of candidate projects from the plan have relevance to the Beyond the East Busway report.[25]

Relevance to I-376

The Parkway East Corridor Transportation Network improvement includes planned arterial traffic signal upgrades and roadway improvements at thirteen intersections. These plans are aimed primarily at reducing auto traffic and congestion on the I-376 corridor, and its implementation should consider the Beyond the Busway's transit improvement proposals in tandem as a possible set of Improvement Concepts to improve mobility for all modes, while improving congestion by converting auto-trips to transit trips.

Relevance to TSP

In addition to the signal upgrades planned as a part of the Parkway east Corridor Transportation Network project, a number of municipal-level safety upgrade projects are providing signal upgrades to the Beyond the East Busway interest region. The PennDOT sponsored Monroeville Blvd Safety Improvement project, is a $682,640 Safety Improvement project laying in groundwork for traffic signal upgrades on Monroeville Boulevard from Pitcairn Roadto James Street in Monroeville.

Another signal upgrade project is the PennDOT sponsored Ardmore Blvd Adaptive Traffic Signal System project, a $1,222,00 Safety Improvement project which will upgrade signals on Ardmore Boulevard from Penn Avenue to Avenue B in Forest HIlls Borough.

Coordinating with these planned improvement projects, along with the BRT PAAC , is important in order to account for pre-existing plans for signal improvements as they could apply to Transit Signal Priority.

[24]"SmartMoves: Long Range Plan & Transportation Improvement Program." Southwestern Pennsylvania Commission. Accessed May 19, 2020. https://www.spcregion.org/programs-services/transportation/smartmoves-long-range-plan-transportation-improvement-program/.

[25]"Welcome to the 2019 -2022 TIP." SPC GIS. Accessed May 19, 2020. https://spcgis-spc.hub.arcgis.com/app/e217c4efff39466e902aec14ad542d06.

Defining the Beyond the Busway Interest Area

Description of Study Area

The Port Authority of Allegheny County (PAAC) provides transit service throughout most of Allegheny County. The county is the second-most populous county in Pennsylvania with population density spreading out from downtown Pittsburgh and following the natural valleys created by the three main rivers: Allegheny River, Monongahela River, and the Ohio River.

With service throughout the county and the large number of people that would be impacted by the study, a few different methods were used to define areas of population and service for comparative analysis.

- ***County-wide***: At the largest scale, elements of demographics, service availability, equity of transit access, and system wide review were used. (see figure 4)
- ***Geographic Districts***: Using the dominant geographical and demographic boundaries within Allegheny county, four distinct quadrants and the city of Pittsburgh were identified within the county: (see figure 5)
    - North Allegheny County
    - East Allegheny County
    - South Allegheny County
    - West Allegheny County
    - City of Pittsburgh
- ***Southwestern Pennsylvania Commission (SPC) Districts***: Working with SPC, a series of 44 distinct "analysis" districts were created following neighborhood and municipality boundaries and population concentrations across the county and neighboring areas within the Pittsburgh Metropolitan Statistical Area (MSA). (see figure 6)
- ***Interest Areas***: Initially developed as part of the Beyond the Busway Survey hosted by Pittsburghers for Public Transit (PPT), two specific interest areas were defined in the communities just east of the city of Pittsburgh: (see figure 7)
    - Monroeville and Eastern Suburbs
    - McKeesport and the Mon Valley
- ***Communities***: This scale of study represents both the 90 neighborhoods of the City of Pittsburgh and 130 municipalities of Allegheny County. While these boundaries are clearly defined by local governments, their use for analysis was limited to identifying major destinations and points of interest as the scale was too large for useful population demographics and yet too small to offer useful transit analysis. (see figure 8)
- ***Service Walksheds***: These informal areas of focus represent the total area that is served by a single transit line or point of interest within an appropriate walking distance. These areas are irregular in shape as the distances are not calculated radially from the element in question, but rather calculated using distance needed to arrive at the element in question

(transit station, community node, etc.) using traditional walking paths such as sidewalks, streets, and alleyways. (see figure 9)

- ***Census Block Groups***: Using information obtained from the American Community Survey (ACS) 2014-2018 data, these small collection areas represent population clusters of roughly 1000-3000 people. (see figure 10)

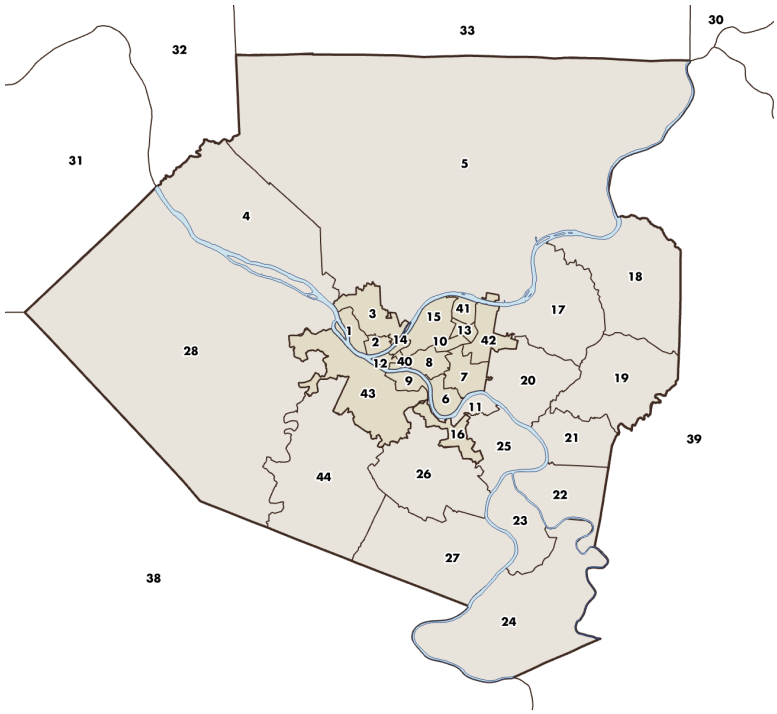
Figure 4. Map of Allegheny County with three main rivers and City of Pittsburgh Boundary Added.

Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/

Figure 5. Map of Allegheny County with five geographic districts indicated.

Boundary shapes for county, city, rivers, and districts created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/

Figure 6. Map of Allegheny County with SPC Districts numbered and outlined.



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. District shapes care of SPC https://www.spcregion.org/

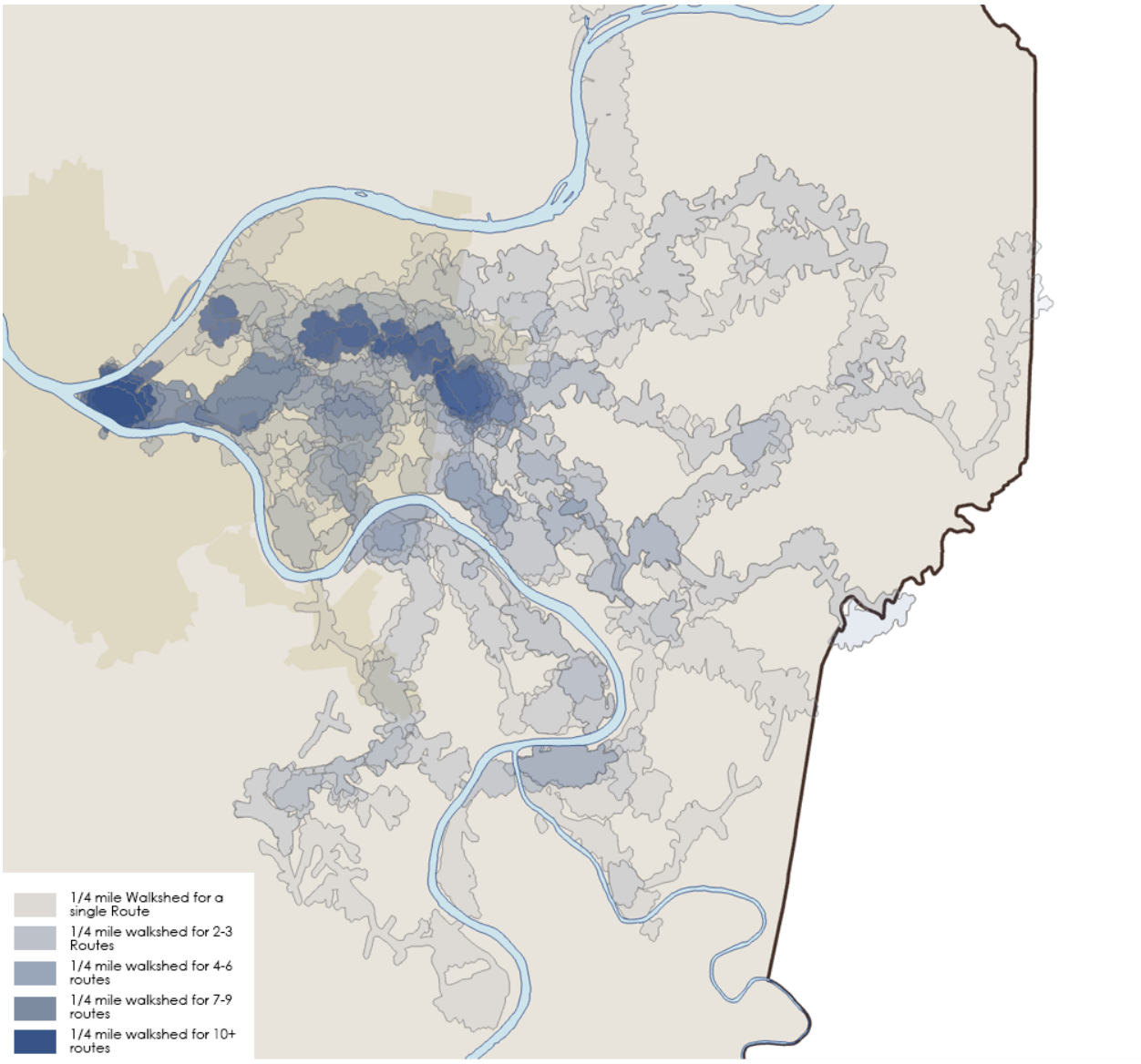
Figure 7. Map of Allegheny County with both study's Interest Areas outlined and labeled.

Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/.

Figure 8. Map of Allegheny County depicting all Municipalities in the County and individual neighborhoods within Pittsburgh.

Boundary shapes for county, city, municipalities, neighborhoods, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/.

Figure 9. A map depicting overlapping ¼-mile walksheds of all transit routes within the study area. The darker the coloration, the more transit routes serve that area.



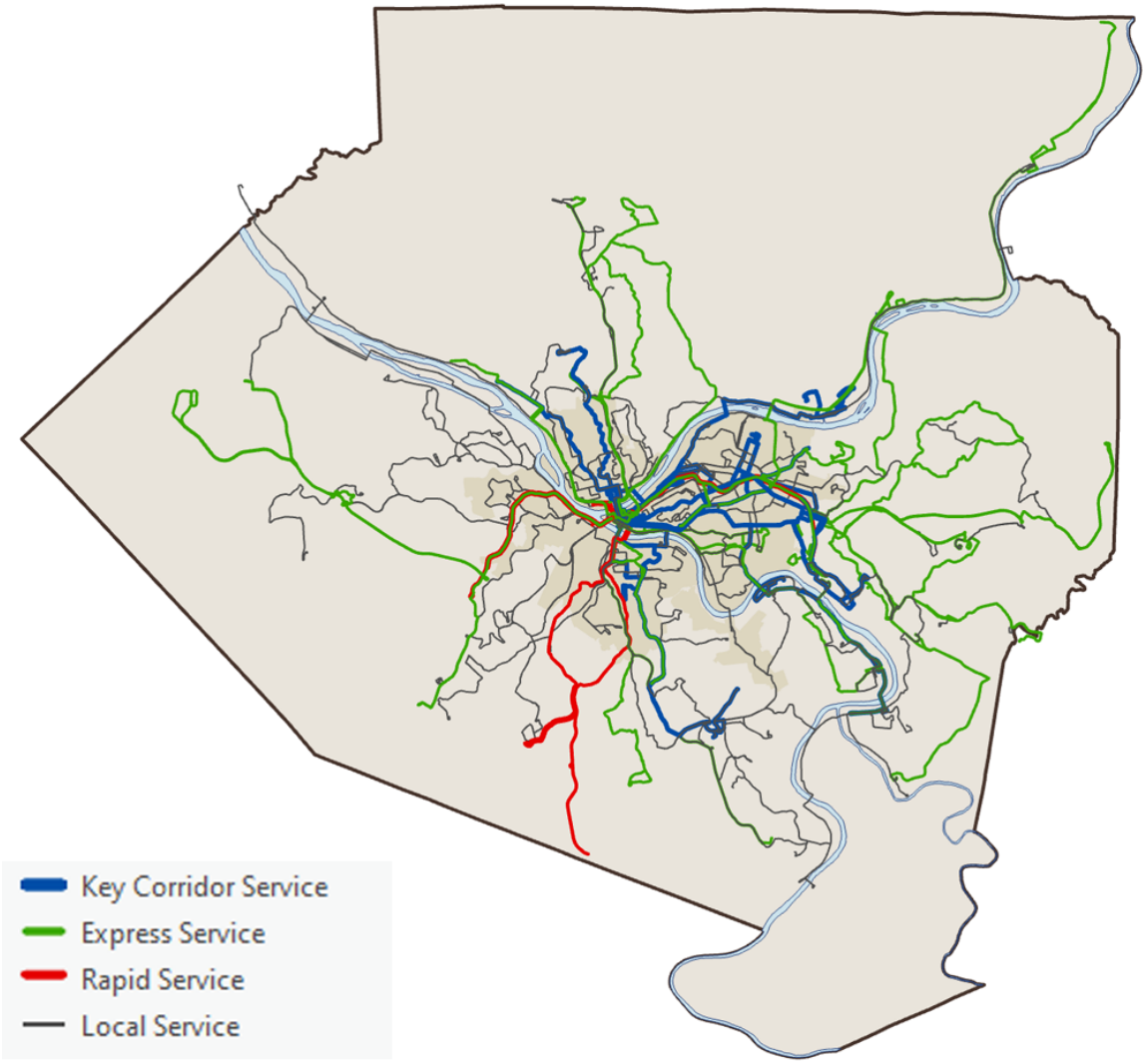
Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Walksheds generated with use of Esri, HERE< Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Figure 10. Map of Allegheny County showing the outlines for all 2014-2018 ACS Census Block Groups.

Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Census Block Groups generated from data available at the Western Pennsylvania Regional Data Center http://www.wprdc.org/.

Analysis was done for all of these defined areas, however the main focus (and majority of efforts) was centered in the eastern suburbs connected to and extending beyond the Martin Luther King Jr East Busway. The East Busway connects the Central Business District of Pittsburgh to a number of vital neighborhoods including Oakland, East Liberty, Homestead, Wilkinsburg, and Swissvale, and represents one of the existing rapid bus route corridors within Pittsburgh. Additional rapid transit routes within the PAAC system include the West Busway connection between Carnegie and adjacent to downtown Pittsburgh, the North Hills HOV/bus facility, the South Busway, and the three light rail routes that predominantly connect downtown Pittsburgh to the communities in the hills south of Pittsburgh. The other 96 transit routes that make up the PAAC transit system include two inclined planes and 94 surface street bus routes with varying lengths and stop frequencies. (see figure 11)

Figure 11. Map of Allegheny County showing all PAAC Routes with colors to indicate the type of service offered on each line.



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Transit routes generated from data available at the Port Authority of Allegheny County https://www.portauthority.org/business-center/developer-resources/.

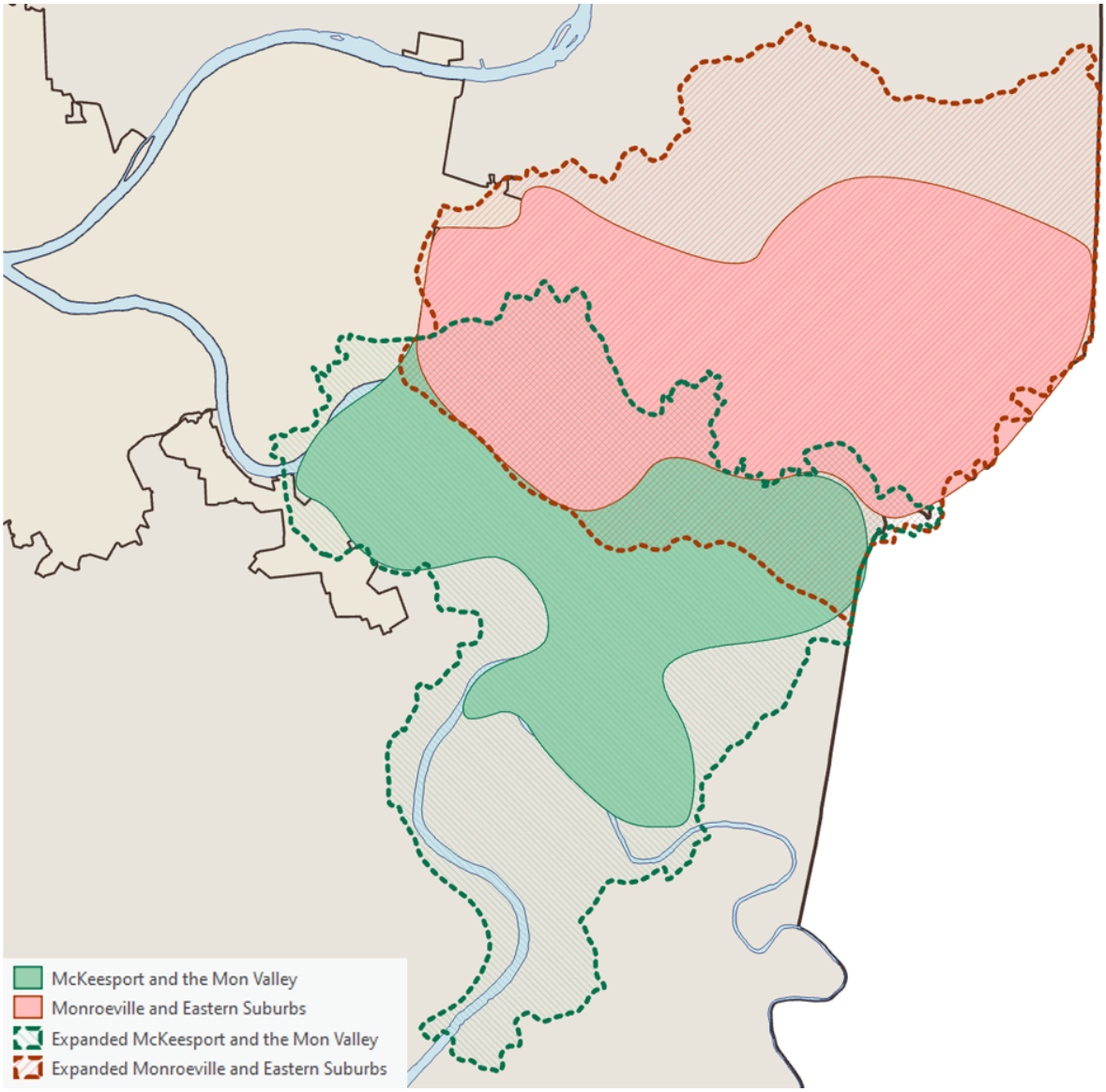
Mon Valley Analysis Breakdown

Interest Areas

The Beyond the Busway Survey by PPT identified two specific interest areas to focus on. These two interest areas initially were simple, rounded areas identified in the survey to facilitate the interactive aspect of the online survey, but did not appear to follow existing bus routes, established road networks, or community boundaries. As such, both interest areas were slightly expanded to better reflect demographic, geographic, and transportation areas of focus. While the expansion of both interest areas did not impact the transit routes being investigated, it did expand the list of possible points of interest beyond what survey respondents were given. However, the

vast majority of final analysis and recommendations fall within the original areas included in the survey and response analysis. (see figure 12)

Figure 12. Map showing original interest areas identified in the PPT survey (solid color) and the expanded interest areas used for analysis (hatched)



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Original Interest Area shapes generated from data made available by CivicMapper https://www.civicmapper.com/.

Communities of Interest

The Allegheny County municipalities below were included in both the McKeesport and Mon Valley interest area and the Monroeville and Eastern Suburbs interest area. Together they constitute the Beyond the Busway interest area and were used for analysis.

Braddock Borough
Braddock Hills Borough
Chalfant Borough
Churchill Borough
Clairton
Dravosburg Borough
Duquesne
East McKeesport Borough
East Pittsburgh Borough
Edgewood Borough
Elizabeth Borough
Elizabeth Township
Forest Hills Borough
Forward Township
Glassport Borough
Homestead Borough
Jefferson Hills Borough
Liberty Borough
Lincoln Borough
McKeesport
Monroeville Municipality
Munhall Borough
North Braddock Borough
North Versailles Township
Penn Hills Municipality
Pitcairn Borough
Plum Borough
Port View Borough
Rankin Borough
Swissvale Borough
Trafford Borough
Turtle Creek Borough
Versailles Borough
Wall Borough
West Elizabeth Borough
West Homestead Borough
West Mifflin Borough
Whitaker Borough
White Oak Borough
Wilkins Township
Wilkinsburg Borough
Wilmerding Borough

Based on the interest areas and responses from the PPT survey, all neighborhoods in the eastern sector of Pittsburgh were considered throughout the analysis. Several neighborhoods emerged from the PPT survey as particularly important to Beyond the Busway interest area riders including:

- Central Business District
- East Hills
- Glen Hazel
- Regent Square
- Squirrel Hill South
- Swisshelm Park
- Western, Central, and North Oakland
- West, South, and North Homewood

Demographic and Socioeconomic Characteristics

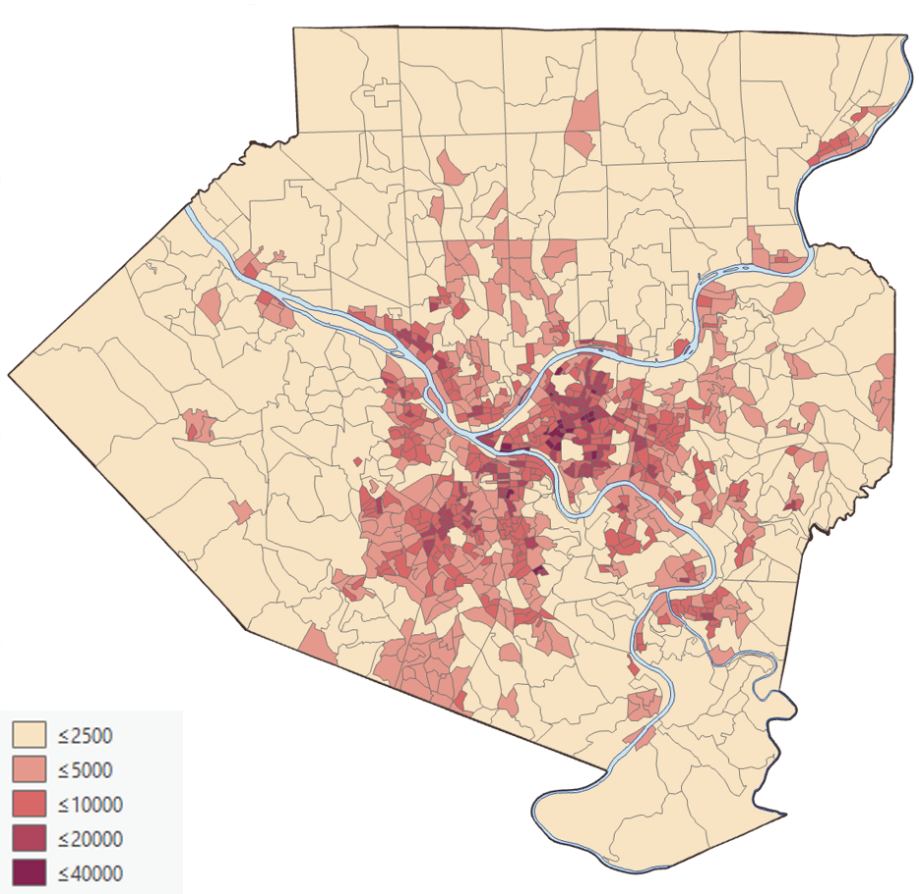
While the PPT survey did highlight some elements of population demographics such as race, employment status, and age, many more elements were looked at to get a better picture for the current and potential transit riders within the study's two interest areas. We used a combination of data provided from the U.S. Census Bureau's American Community Survey (ACS) and data collected and made available through the 2019 Equity Index of Mobility Need report produced by the Port Authority's Planning department. Elements of population and population density, age, education, race/ethnicity, household income, car ownership, and transit usages all went into initial analysis for identifying areas of need and also helped to supplement data for the ridership elasticity model used to predict changes in ridership for all recommendations and conclusions.

Information specific to the ridership prediction model is found under the ***Ridership Methodology Section*** of this report.

Population

As with most major cities, the population is most dense in areas around the Central Business District and then fans out to the secondary communities and cities surrounding the urban core. This is the same with Allegheny County and Pittsburgh. Both Downtown and Oakland serve as epicenters for work, education, and retail with a number of pocketed clusters of dense population throughout the city. Beyond the City of Pittsburgh, population density can be traced along the main rivers and transportation corridors with isolated clusters of very densely populated areas in and around secondary cities and communities. The geographic makeup of Allegheny County, with drastic elevation changes, rivers, and densely forested land forces population into tightly defined pockets with vast areas of minimal population sprawl. As a result, many areas of more dense population have become self-supporting, close-knit communities that also serve as destination nodes throughout the county.

Figure 13. Map showing Number of Persons per Individual Census Block Group

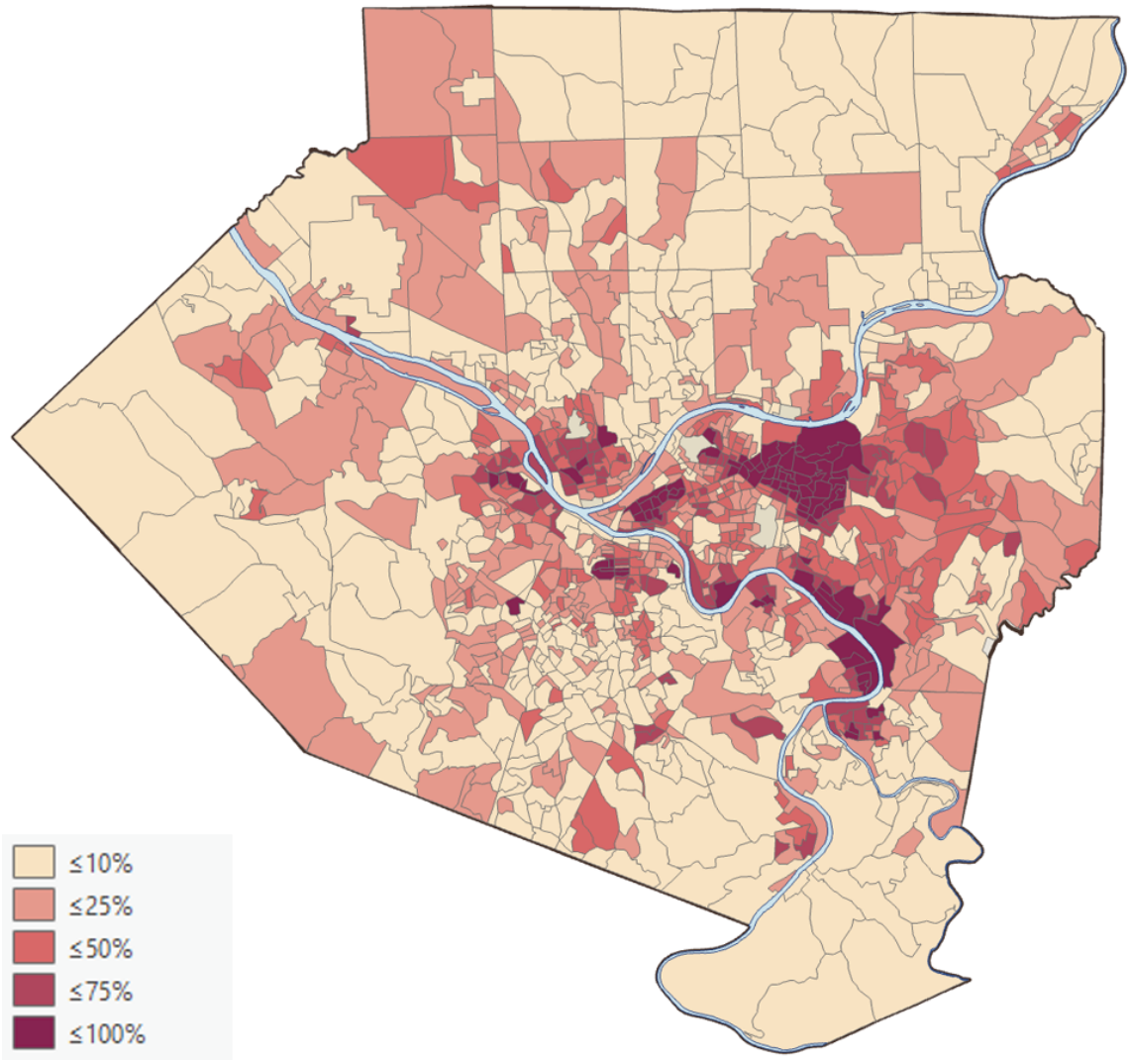


Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

Minority Population

Of the nearly 1.3 million people that live within Allegheny County, roughly 280,000 (approximately 22%) persons identify as a minority, non-white race. This percentage is roughly half the national average of 40.2%, and just slightly below the state average of 24.47%. This relative lack of diverse racial population is further amplified by the clustering of population that is seen across the area. As a result, the City of Pittsburgh and the surround communities represent the vast majority of non-white population for the entire county. Specifically note the highest density of minority populations located to the east of downtown Pittsburgh, along the rivers and falling within the focus of this study.

Figure 14. Map showing Percentage of Non-white Persons per Census Block Group

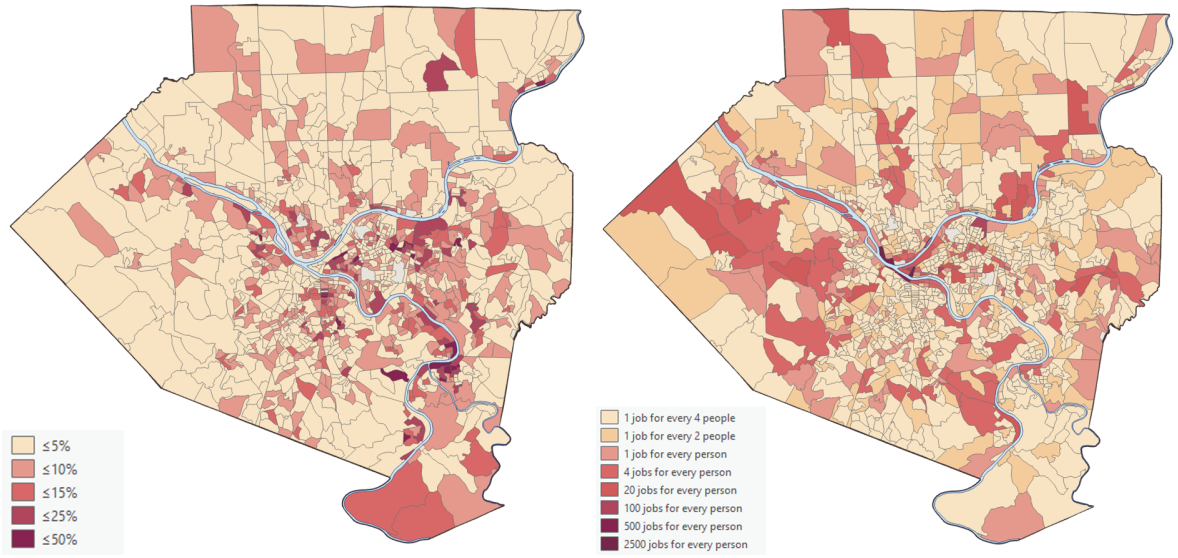


Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

Employment

One burden for using public transit was unemployment according to the PPT survey results. A large number of people travel daily for commutes to and from their employer. Without an employer to travel to and no income, public transit use becomes less vital. As with most of the country, pre-COVID19 unemployment has seen a steady decline following spikes immediately following the Great Recession of 2008/09. Unemployment across the county is reasonably low and on track with state and national averages. However when looking at the number of jobs vs population for any given area, one can see that employment does not align with locations for employment – meaning more and more people must rely on commuting outside their immediate community to remain employed.

Figure 15. Maps showing Unemployment Rate (left) and Jobs per Person (right) for each Census Block Group

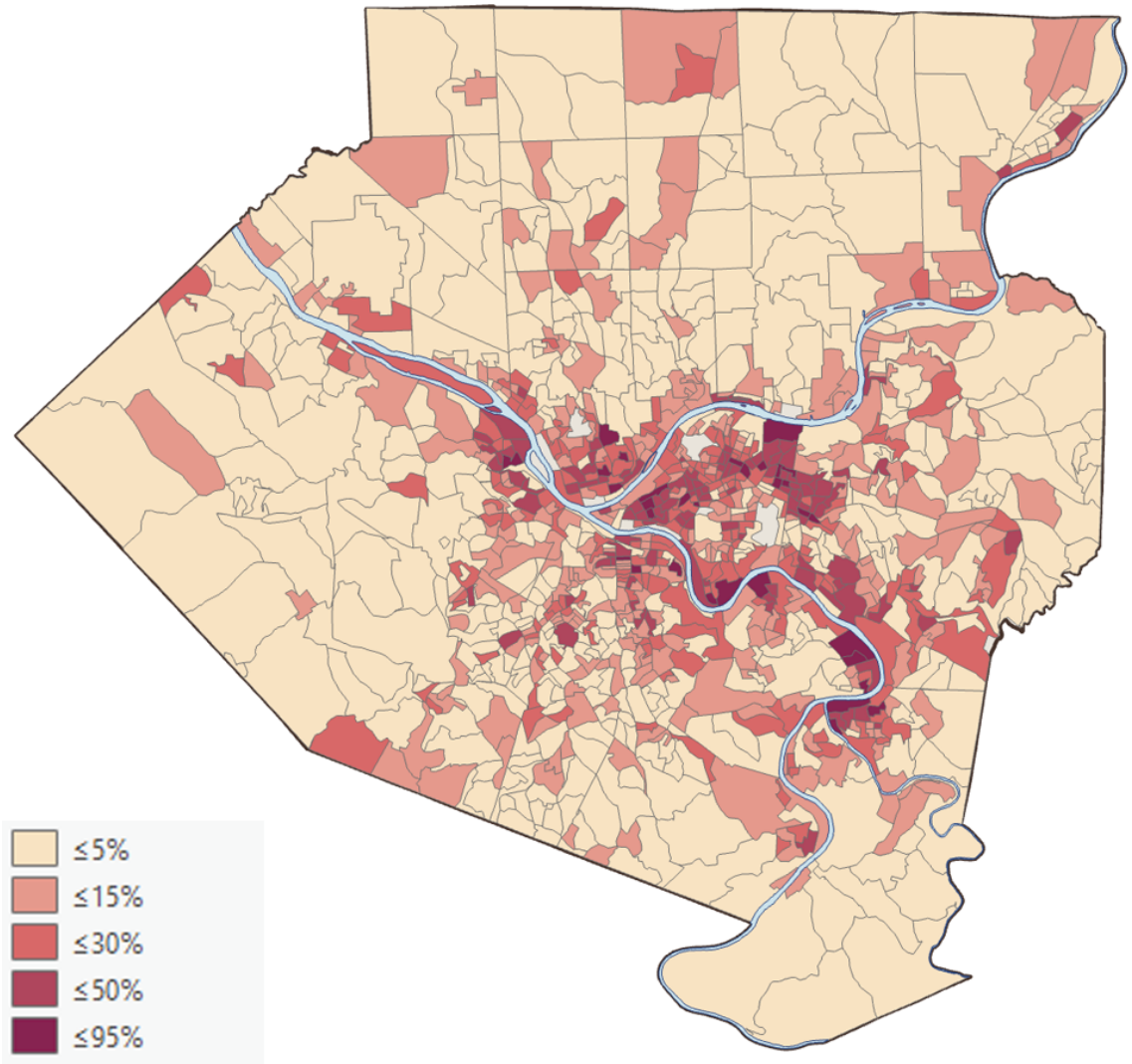


Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

Car Ownership

The locations of jobs (Downtown, North, West, and South of the main rivers) compared to locations of minorities and population clusters (City of Pittsburgh and eastern suburbs) highlights the need for transportation methods in and out of the study area. With the winding nature of roads and transit routes, bus trips from the suburbs into Pittsburgh can take upwards of 30-60 minutes. As such, there is a strong reliance for automobile transit. Census data for car ownership however illustrates the need for public transit to fill the gap between transit need and access to personal vehicles.

Figure 16. Map showing Percentage of Households Reporting No Vehicle (lease or own)

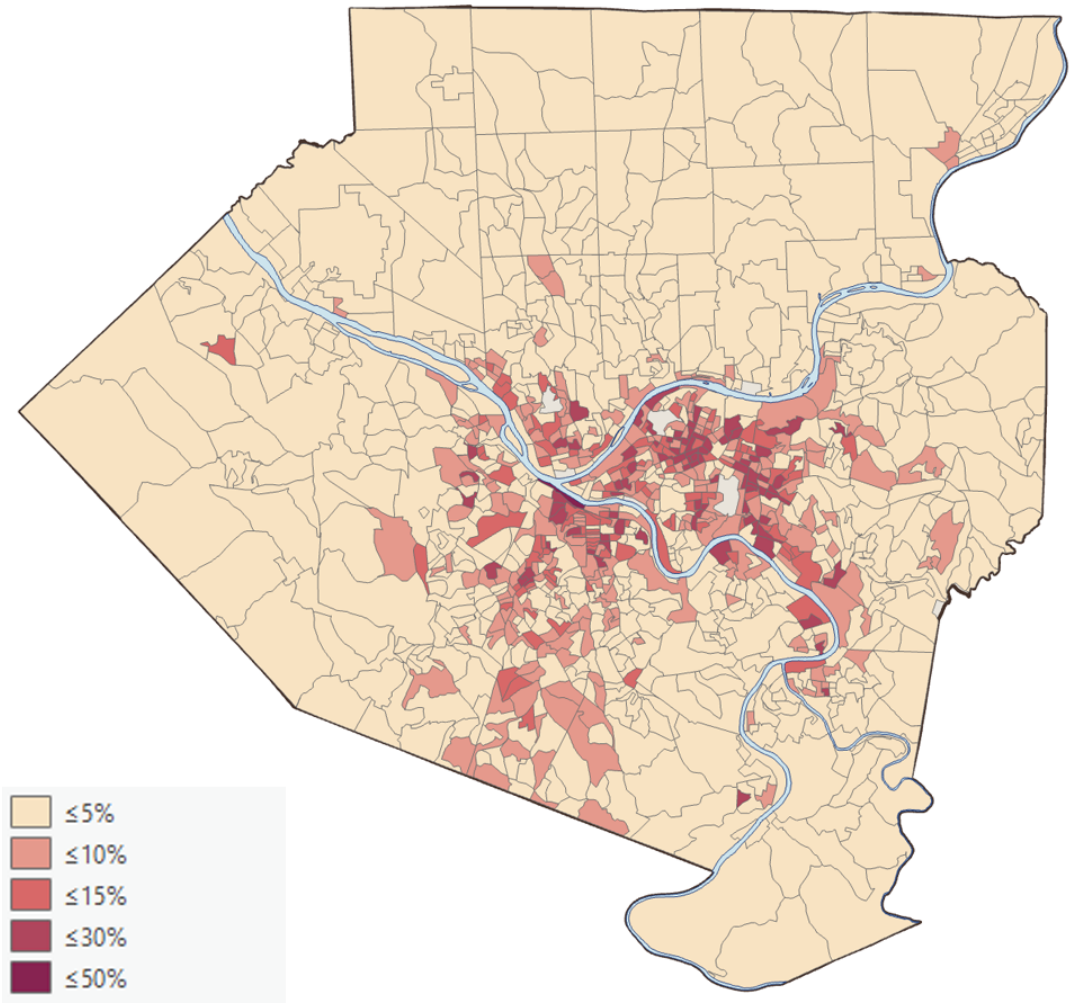


Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

Transit use

A standard assumption is that areas with low jobs and low vehicle ownership would result in higher than normal transit usage. For the most part, this assumption holds true for the city of Pittsburgh and the eastern suburbs. Areas with access to transit routes that are frequent and have useful destinations show higher than average transit usage (9.46% transit usage for work commutes in Allegheny County and 5.6% for the state of Pennsylvania). However, the further one gets away from routes that utilize the East Busway for rapid transit to Oakland and Downtown, the lower the overall use of transit becomes. This is also echoed in a number of the responses in the PPT survey that show high reliance on relevant destinations as a key factor for using public transit.

Figure 17. Map showing Percentage of Individuals in the Workforce that Report Using Transit for Commute

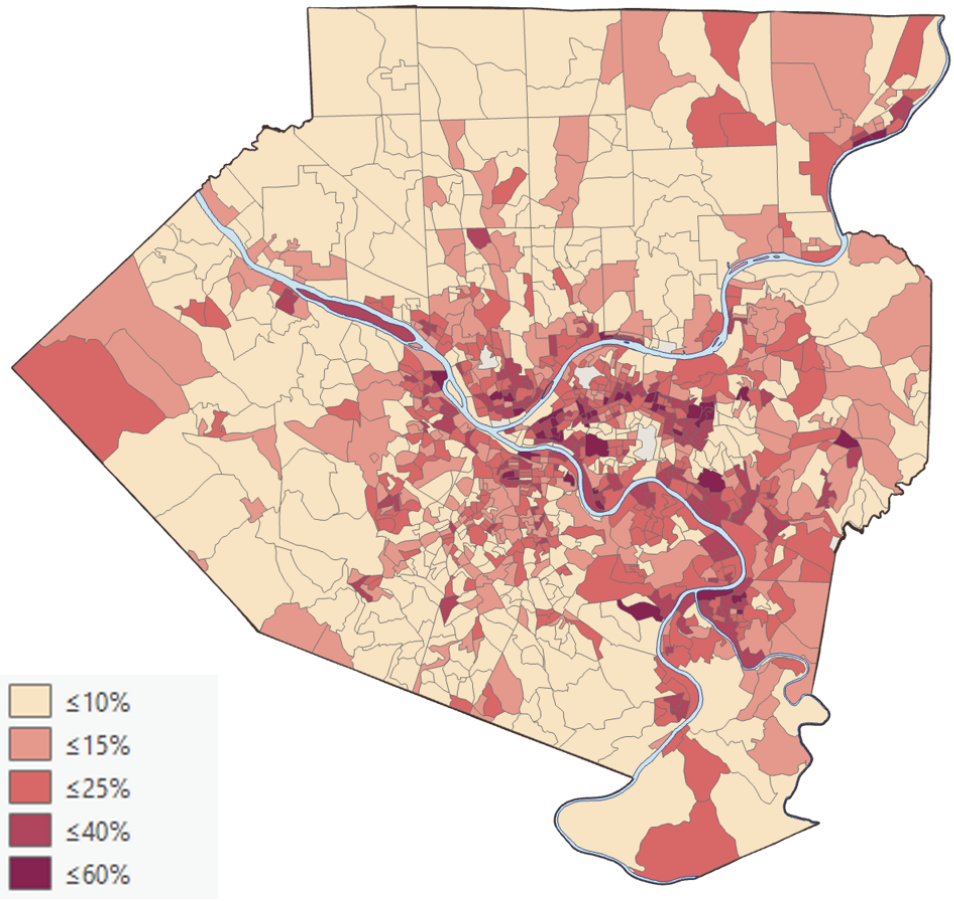


Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

Income/Cost Burden

Other than transit time and proximity to bus routes that address one's need, the other major factor that determines use of transit is its financial burden on the user. The cost to utilize PAAC transit varies depending on use of the pre-paid, Connect Card ($2.50/ride) versus paying cash upon boarding ($2.75/ride). Additionally, the current system model does not offer discounts for transfers on cash fares and each trip is treated as a unique instance for fare collection (transfers with connect card are $1.00 if within three hours of first trip). For an individual who needs to take the bus round trip, five days a week with a single transfer, the cost for transit ranges from $35-55/week. For that same person to work 50 weeks a year, transit costs could range from $1750-$2750 per year. For a person making $35,000 or less (approximately 50% area median income for Allegheny County), transit just for work commutes would account for 5-8% of gross annual income.[26]

Figure 18. Map showing Percentage of Persons Earning less than $35,000 Annually



Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Demographic data from 2014-2018 ACS made available at Social Explorer care of U.S. Census Bureau https://www.socialexplorer.com/

[26]ConnectCard.org - FAQs. Accessed May 19, 2020. http://www.connectcard.org/faqs.aspx#benefits.

2019 Equity Index of Mobility Need

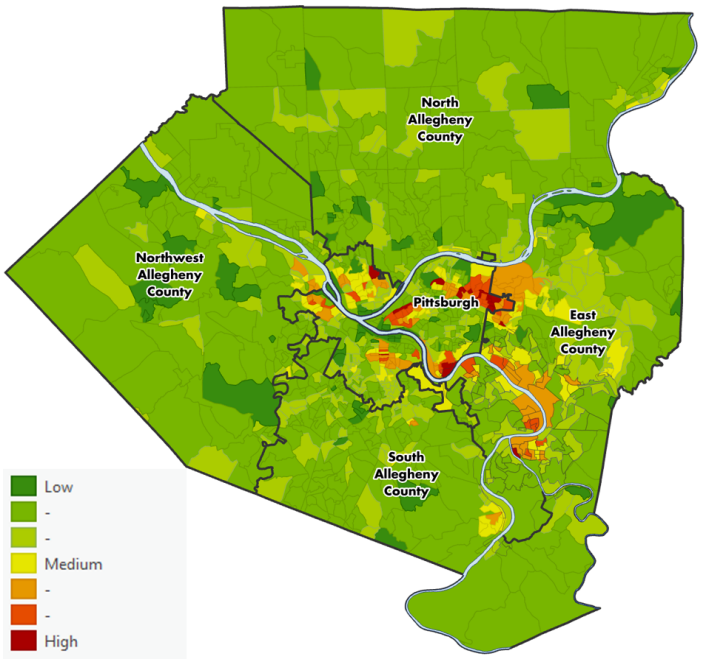
Many similar metrics were used by the PAAC to produce their 2019 Equity Index on Mobility Need report. The report took into account eight major metrics across Allegheny county in order to develop a holistic view of which areas within their system had a higher need for improvements and/or additional service efforts. The areas the report focused on included:

- Number of People with Disabilities
- Number of People Living below Poverty Line
- Locations for Minority Race and Ethnicity Persons
- Households without Vehicles
- Older Adults
- Persons under the Age of 18
- Persons with LImited English Proficiency
- Female Head of Households

While the breakdown of these metrics were done at the census block group level, summing the totals for areas within the different geographic districts, it is clear that the study area for this report has a pressing need for transit access.

- 2nd Lowest Median Income ($50,562)
- 2nd Highest Transit Use (9.3% - higher near busway with drop off in use further east)
- Greatest Inequality for Mobility Access
    - 168 of the top 338 top 25% equity score block groups
    - 50 of 134 top 10% highest need

Figure 19. Map Reconstructed from PAAC 2019 Equity Index of Mobility Need with Study Geographic Districts Outlined.



Boundary shapes for county, census block groups, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Equity ranking data generated from the 2019 Equity Index of Mobility Need report by PAAC https://www.portauthority.org/siteassets/inside-the-pa/transparency/data-and-statistics/paac-2019-equity-index.pdf

Transportation Network

In addition to geographic and demographic information, aspects of the transportation network offer insight into the study area of the report. Specifically, aspects of service times, headways, service areas (walksheds) and transit infrastructure play a large role in the overall efficacy of any transit solution. As the area of study was limited to the two main interest areas, the vast majority of effort and discovery was placed on routes, stops, roads, and points of interest within these designated areas. Furthermore, the nine originally identified corridors of travel from the PPT survey served as the starting point for more in depth analysis.

McKeesport and the Mon Valley

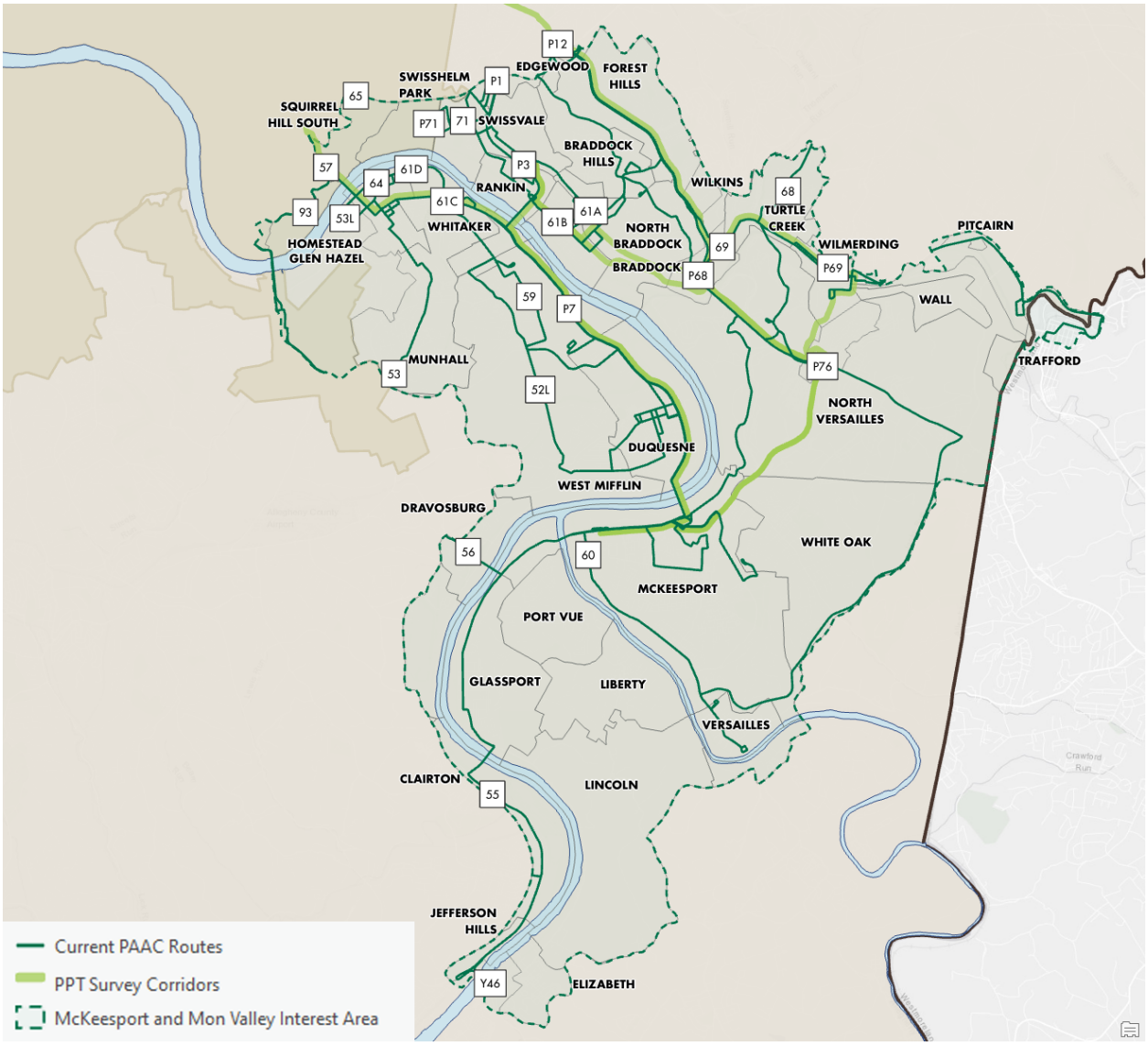
Routes

The McKeesport and Mon Valley Interest area has a few main corridors of service with overlapping and closely woven routes that connect the many smaller communities along the river. Many of the routes have paths that continue onto Oakland and Downtown with the two exceptions - the 59 and 71 are almost completely contained within the interest area and serve as routes that allow for more direct transportation between the communities.

Routes that serve the McKeesport and Mon Valley Interest Area include:

- 52L: Homeville Limited
- 53: Homestead Park
- 53L: Homestead Park Limited
- 55: Glassport
- 56: Lincoln Place
- 57: Hazelwood
- 59: Mon Valley
- 61A: Swissvale
- 61B: Braddock - Swissvale
- 61C: McKeesport - Homestead
- 61D: Murray
- 64: Lawrenceville - Waterfront
- 68: Braddock Hills
- 69: Trafford
- 71: Edgewood Town Center
- 74: Homewood - Squirrel Hill
- 93: Lawrenceville - Oakland - Hazelwood
- P1: East Busway - All Stops
- P12: Holiday park Flyer
- P3: East Busway - Oakland
- P68: Braddock Hills Flyer
- P69: Trafford Flyer
- P7: McKeesport Flyer
- P71: Swissvale Flyer
- P76: Lincoln Highway Flyer
- Y46: Elizabeth Flyer

Figure 20. Map showing PAAC Routes within McKeesport and Mon Valley Interest Area

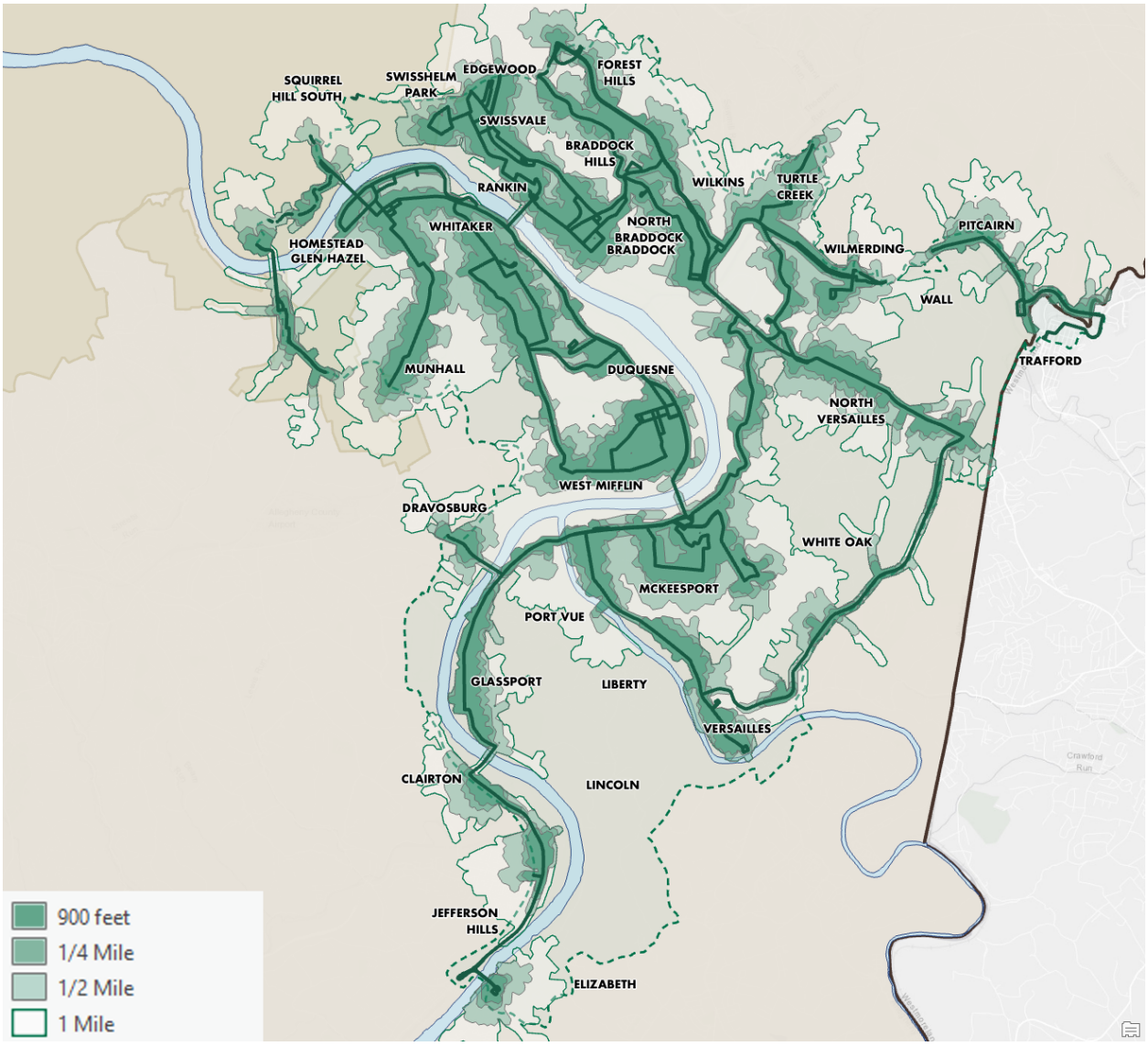


Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Original corridor routes generated from data made available by CivicMapper https://www.civicmapper.com/.

Walkshed

A transit route's relevance to a potential rider is determined by its frequency, speed, destination, and accessibility. With regards to accessibility, one way to determine if a route is relevant to a user is by plotting its walkshed. This is the area in which transit service is accessible by walking or other forms of manual transportation. This area can vary based on geographic features, obstructions along the path, and mobility of the individual. To account for these differences, walkshed distances of 900 feet, ¼ mile, ½ mile, and 1 mile were all looked at. (See figure 21)

Figure 21. Map showing Multiple Distance Walksheds (900 feet, ¼ mile, ½ mile, and 1 mile) for Routes within McKeesport and Mon Valley Interest Area



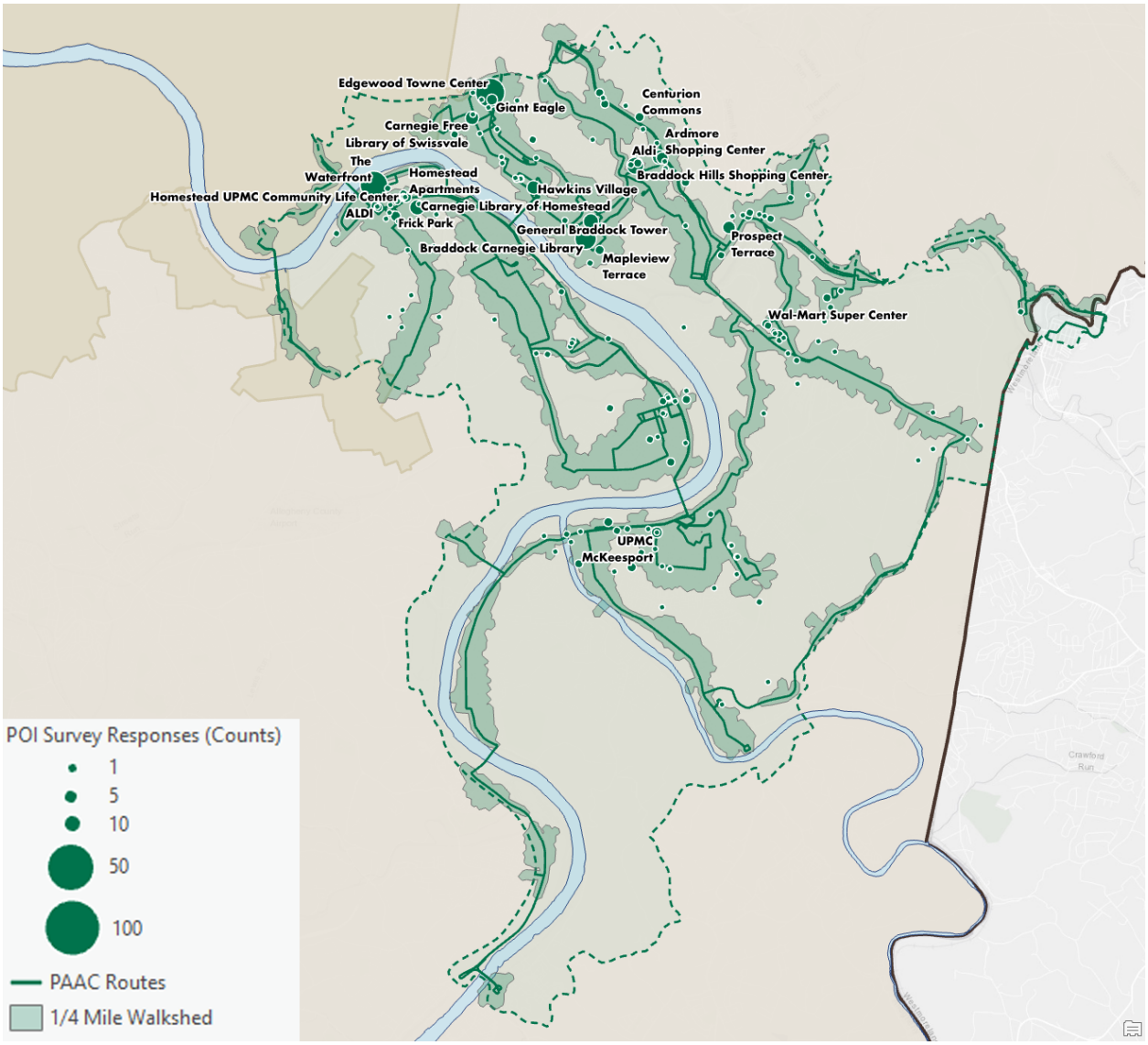
Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Points of Interest

Once a walkshed is calculated, one can map out important origins and destinations for potential riders as a way to determine if an individual route would service that area within an appropriate distance. As the PPT survey specifically asked individuals about places they travel to frequently, these locations served the main points of interest (POI) for which to compare route walksheds. As indicated previously, the survey's predetermined interest areas were smaller than the areas

defined within the study. As such, a number of potential POIs were not recorded by survey respondents. For those that were included, a quick ranking of importance based on frequency of mention within the survey informed the study areas of increased relevancy for potential service improvements. (see figure 22)

Figure 22. Map showing PPT Survey Points of Interest within McKeesport and Mon Valley Interest Area



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Monroeville and the Eastern Suburbs

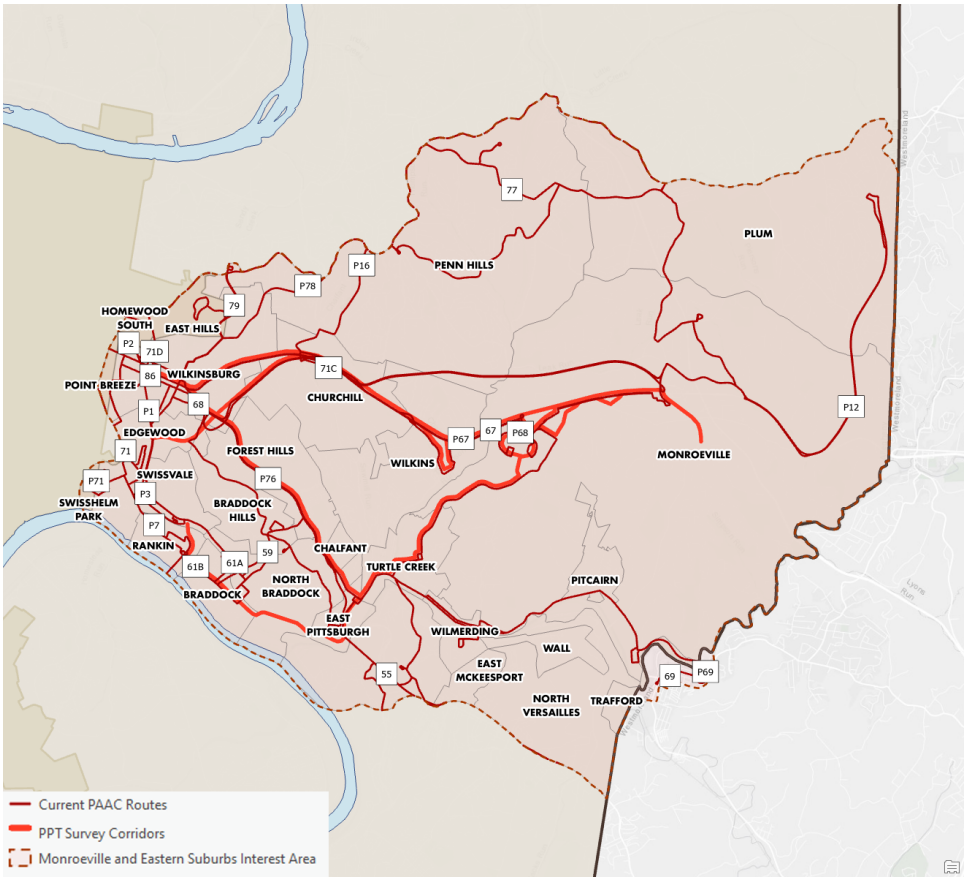
Routes

The Monroeville and Eastern Suburbs Interest Area overlaps with the McKeesport and Mon Valley Interest Area along the northern shore of the Monongahela River and the communities of Swissvale, Rankin, Braddock, East Pittsburgh and North Versailles. Unlike the chain of population clusters along the river, the Monroeville and Eastern Suburbs Interest Area becomes more spread out as one travels further east and north. This is especially true in the northernmost communities of Penn Hills and Plum - two of the areas that ranked with a higher need in the 2019 Mobile Equity Index report.

Due to geography and population densities, a number of the routes within this area overlap or serve a similar list of destinations. Routes that serve this interest area include:

- 55: Glassport
- 59: Mon Valley
- 61A: Swissvale
- 61B:Braddock - Swissvale
- 67: Monroeville
- 68: Braddock Hills
- 69: Trafford
- 71: Edgewood Town Center
- 71C: Point Breeze
- 71D: Hamilton
- 77: Penn Hills
- 79: East Hills
- 86: Liberty
- P1: East Busway - All Stops
- P12: Holiday Park Flyer
- P16: Penn Hills Flyer
- P17: Lincoln Park Flyer
- P2: East Busway Short
- P3: East Busway - Oakland
- P67: Monroeville Flyer
- P68: Braddock Hills Flyer
- P69: Trafford Flyer
- P7: McKeesport Flyer
- P71: Swissvale Flyer
- P76: Lincoln Highway Flyer
- P78: Oakmont Flyer

Figure 23. Map showing PAAC Routes within Monroeville and Eastern Suburbs Interest Area

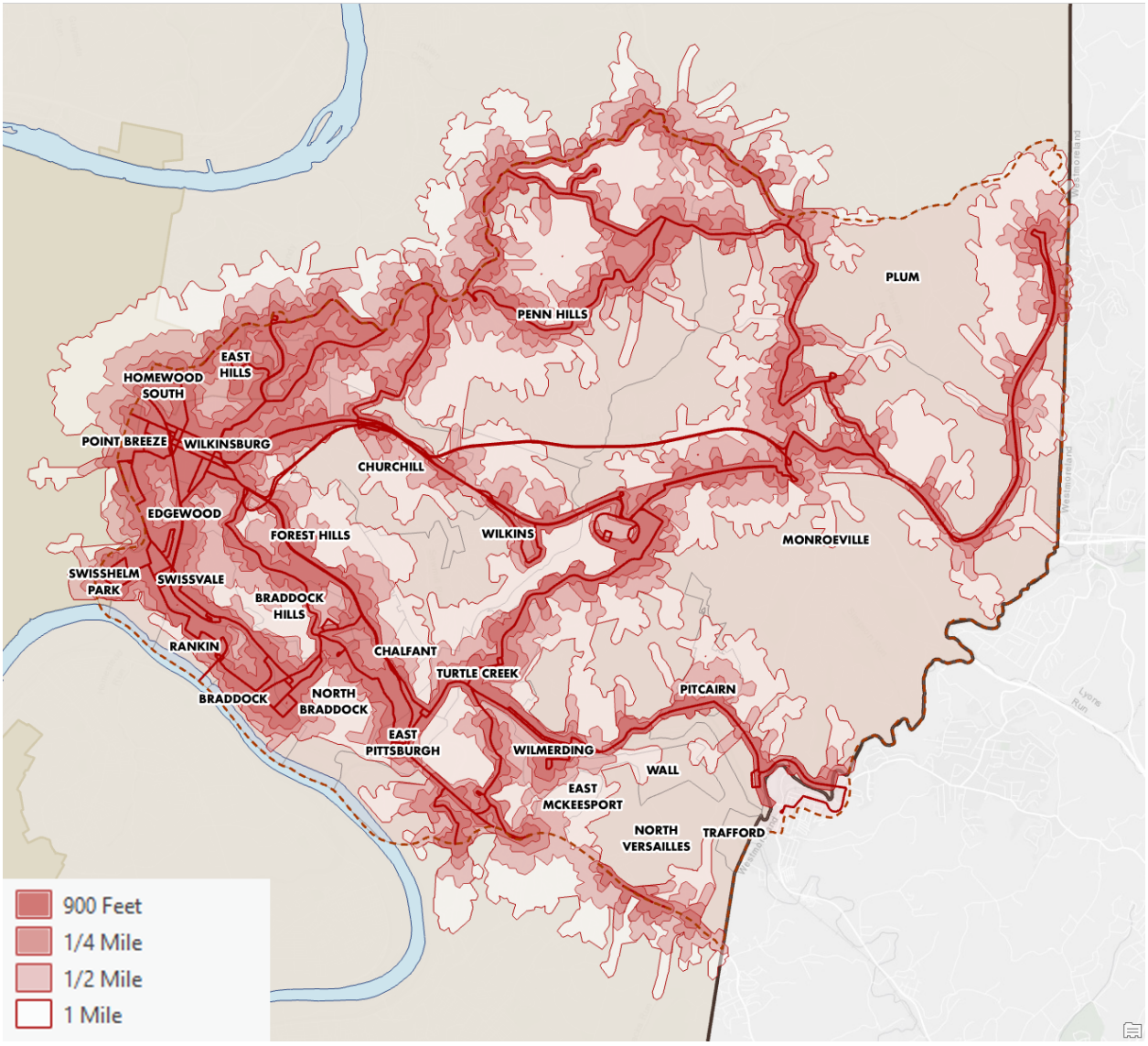


Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Original corridor routes generated from data made available by CivicMapper https://www.civicmapper.com/.

Walkshed

Similar to the walkshed developed for the McKeesport and Mon Valley Interest Area, the routes and stops were analyzed for the Monroeville and Eastern Suburbs using the same breakdowns of 900 feet, ¼ mile, ½ mile, and 1 mile walking distance from each stop. The results highlight the large areas of space not covered by any bus route along the northern and central areas of the interest area. While there is less population in these areas, many of these areas did rank around the middle for need in the 2019 Equity Index for Mobility.

Figure 24. Map showing Multiple Distance Walksheds (900 feet, ¼ mile, ½ mile, and 1 mile) for Routes within Monroeville and Eastern Suburbs Interest Area

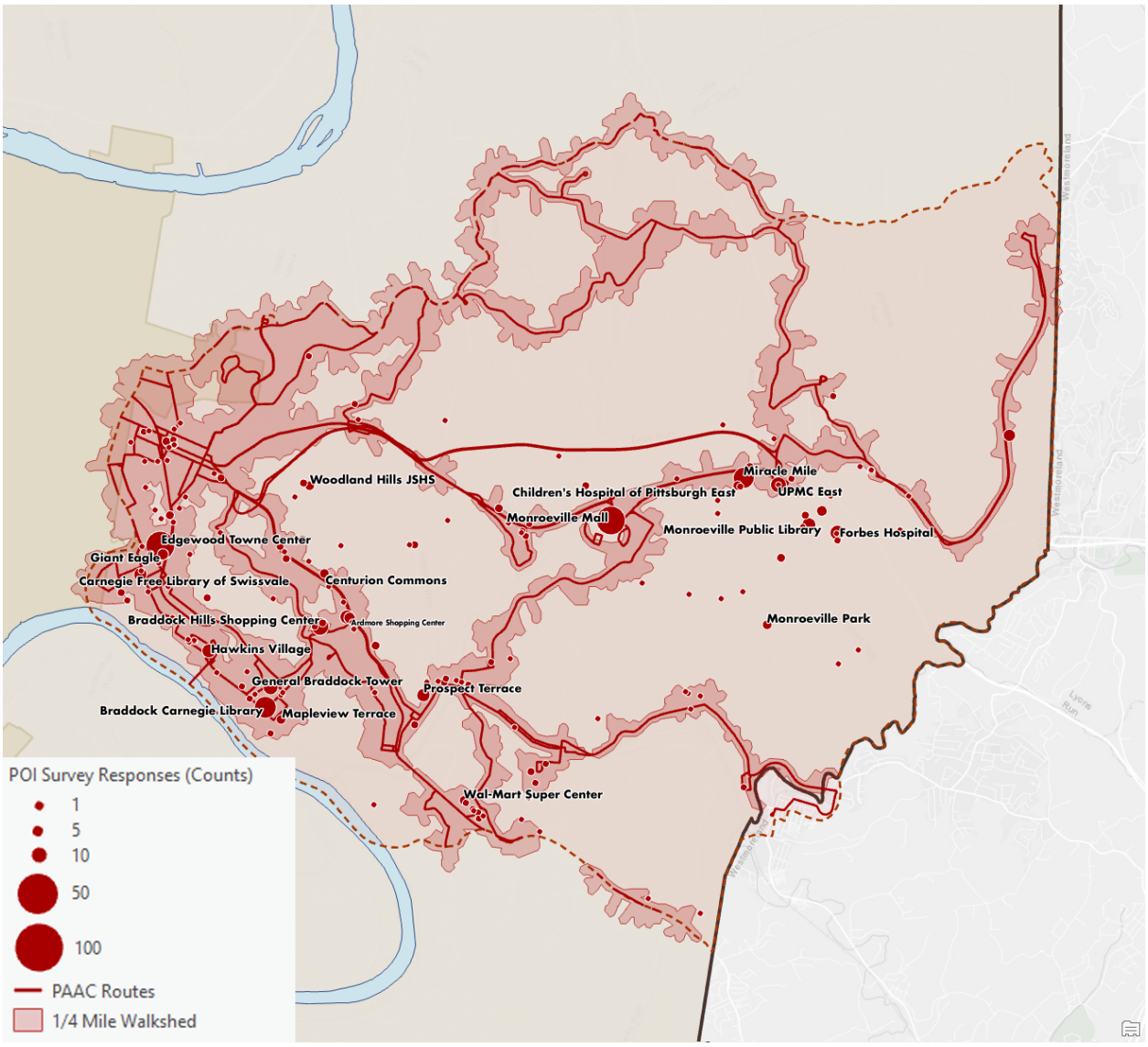


Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Points of Interest

Similar to the McKeesport and Mon Valley Interest Area, a large number of the POIs were centered around the Swissvale, Rankin, and Braddock communities. However a second concentration of highly sought after destinations were also found around the Monroeville Mall and the commercial corridor that extends east to both UPMC East and Forbes Hospital.

Figure 25. Map showing PPT Survey Points of Interest within Monroeville and Eastern Suburbs Interest Area



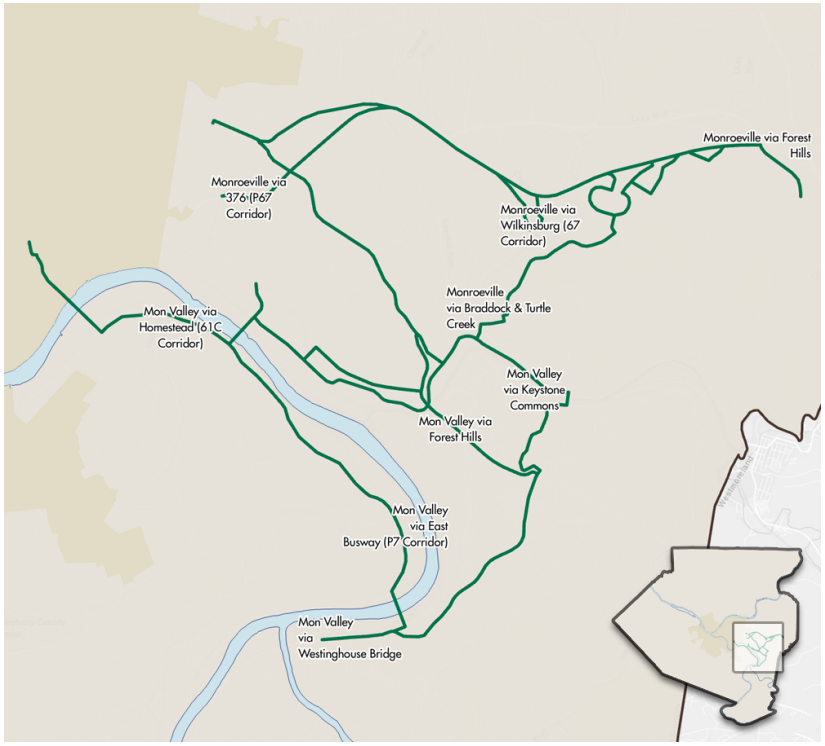
Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Public Outreach: Learnings from the Survey

Pittsburghers For Public Transit (PPT) is a grassroots nonprofit organization of transit riders, workers, and residents who defend and expand public transit. In summer 2019, PPT developed the Beyond the East Busway campaign, one of the nation's first GIS and volunteer-based participatory planning processes. This process involved 15 volunteers collecting over 500 responses from transit and non-transit riders alike. Residents of the Mon Valley and East Suburbs were targeted to take the survey, although it was open to any Allegheny County resident. The goal of the project was to use community generated data to inform transit improvement policy for residents of our interest area.

The survey asked a variety of questions related to transit usage and needs, as well as information about the individual respondents. One of the central questions asked was about which corridor should be prioritized for faster or more dependable service. PPT identified nine different transit corridors that could be targeted for different types of improvements and asked respondents to select the one that would most cater to their community's needs. (see figure 21) Additional relevant information captured includes the area that respondents live in, which routes are already used by correspondents, what areas the respondents are interested in travelling to and from, and why respondents sometimes (or always) use other forms of transportation.

Figure 26. Map of nine corridor routes presented within the PPT survey

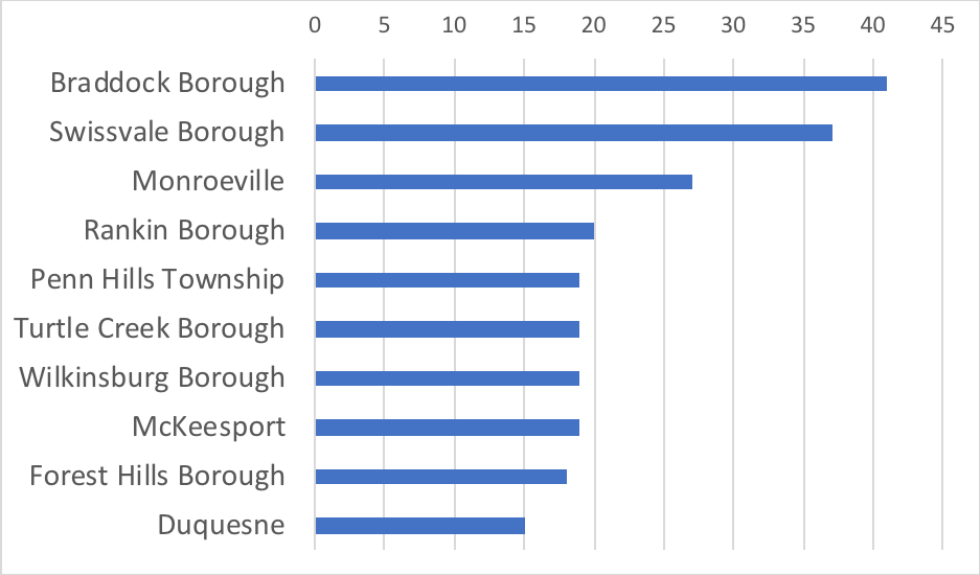


Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Original corridors of interest generated based on data made available by CivicMapper https://www.civicmapper.com/.

Survey Overview

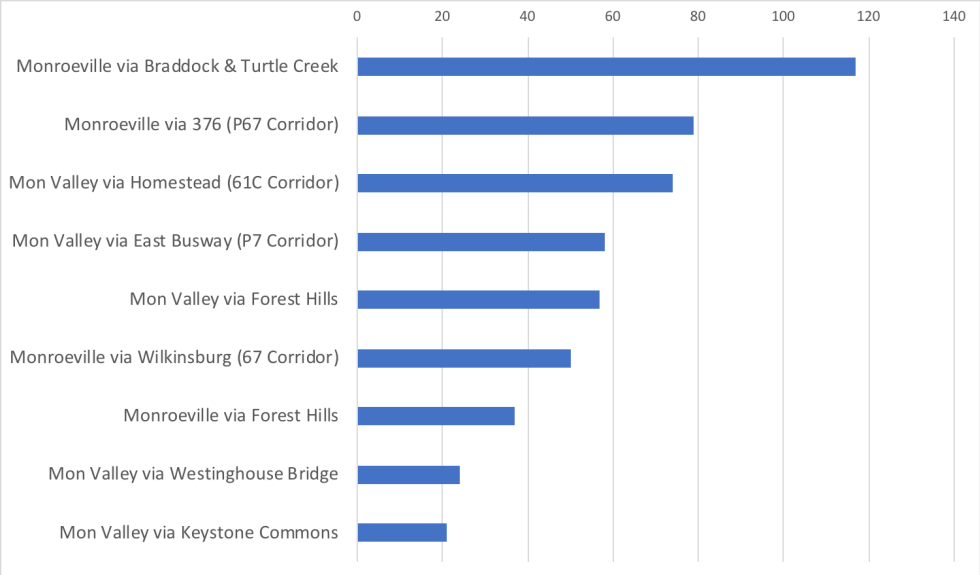
The survey was taken by 518 respondents in total. The majority of responses came in two time periods. The first was right after the survey launched online in June 2019. The second was when PPT began their door knocking efforts in August 2019. We begin our analysis of the survey by looking at simple counts of key fields.

Figure 27. Survey Respondent Locations



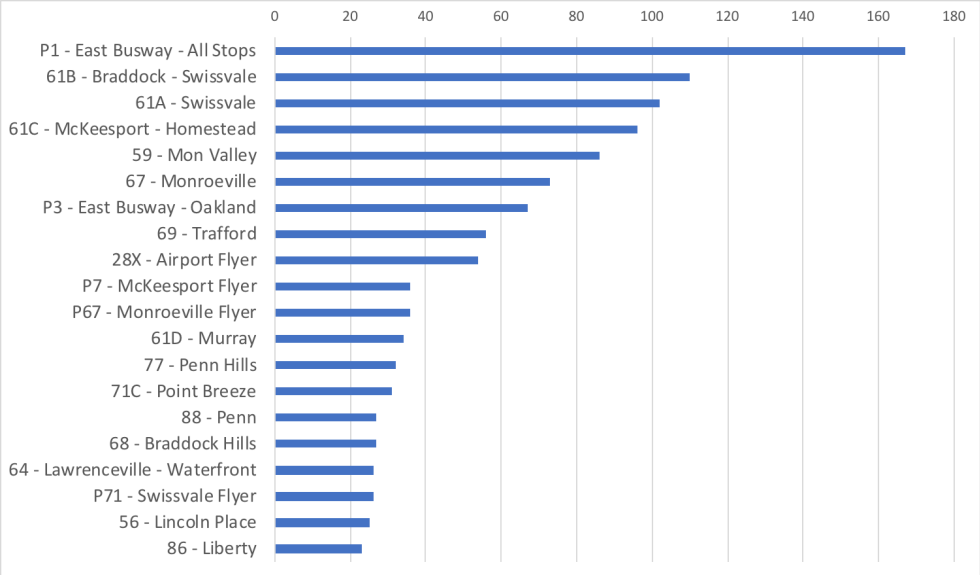
In the figure above, we see the top ten locations survey respondents are from. These ten locations account for about 45% of total respondents and there were about one hundred locations that were identified by respondents. We see that Braddock, Swissvale, and Monroeville are the three most mentioned locations by significant margins and the remaining seven locations were more equal, each in the range of 15-20 respondents.

Figure 28. Survey Respondent Corridors of Interest



The figure above shows corridors in which respondents were most interested in seeing improvements. We see that the Monroeville via Braddock & Turtle Creek Corridor is the most popular by a significant margin of around 20 points more than the second most popular, the Monroeville via 376 (P67 Corridor).

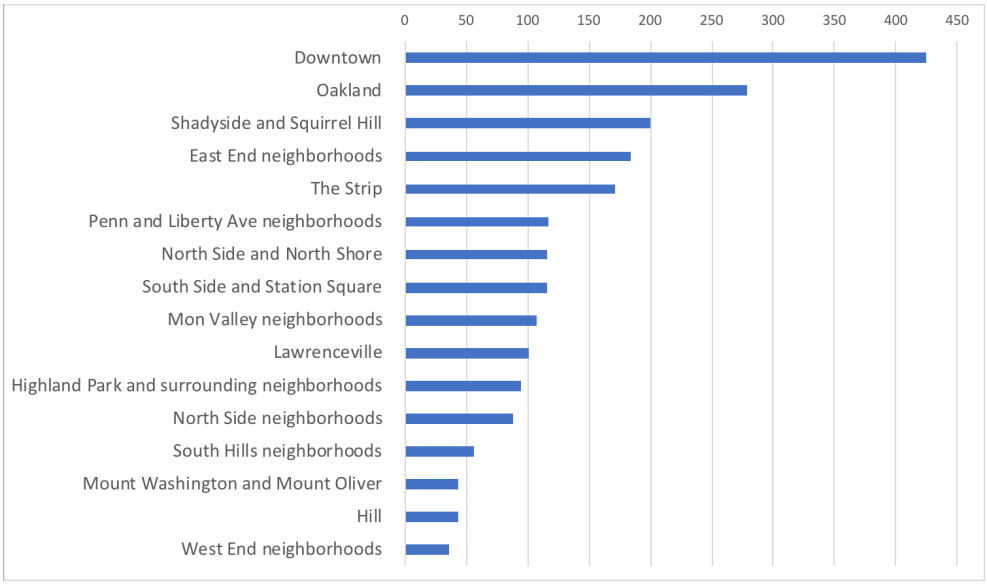
Figure 29. Routes Used by Survey Respondents



The figure above shows the top 20 Port Authority routes that survey respondents already use. There are about one hundred routes that respondents listed as already taking, with a significant drop-off after the 28X. The P1 is the most popular route – a high frequency, high speed line that only traverses the East Busway taking residents from Swissvale to Downtown and vice versa. The 61A, 61B, and 61C are the next three most popular routes to survey respondents, as they are the

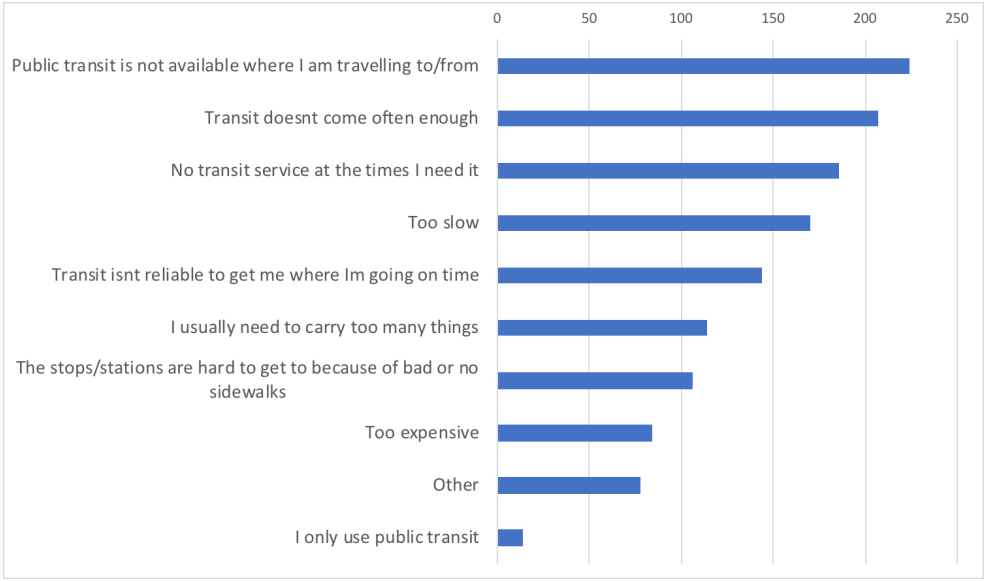
highest frequency and ridership routes in our interest area. The top six routes, as well as the P7 and P68, will be considered for deeper analysis later in this report.

Figure 30. Pittsburgh Neighborhoods of Interest



The figure above shows neighborhoods within Pittsburgh that respondents are most interested in travelling to. Downtown and Oakland, the county's two biggest job centers, are the two highest ranked areas. Frequent, rapid, and reliable transit to these neighborhoods from the Mon Valley and East Suburbs ought to be prioritized to meet rider needs.

Figure 31. Barriers to Transit Use



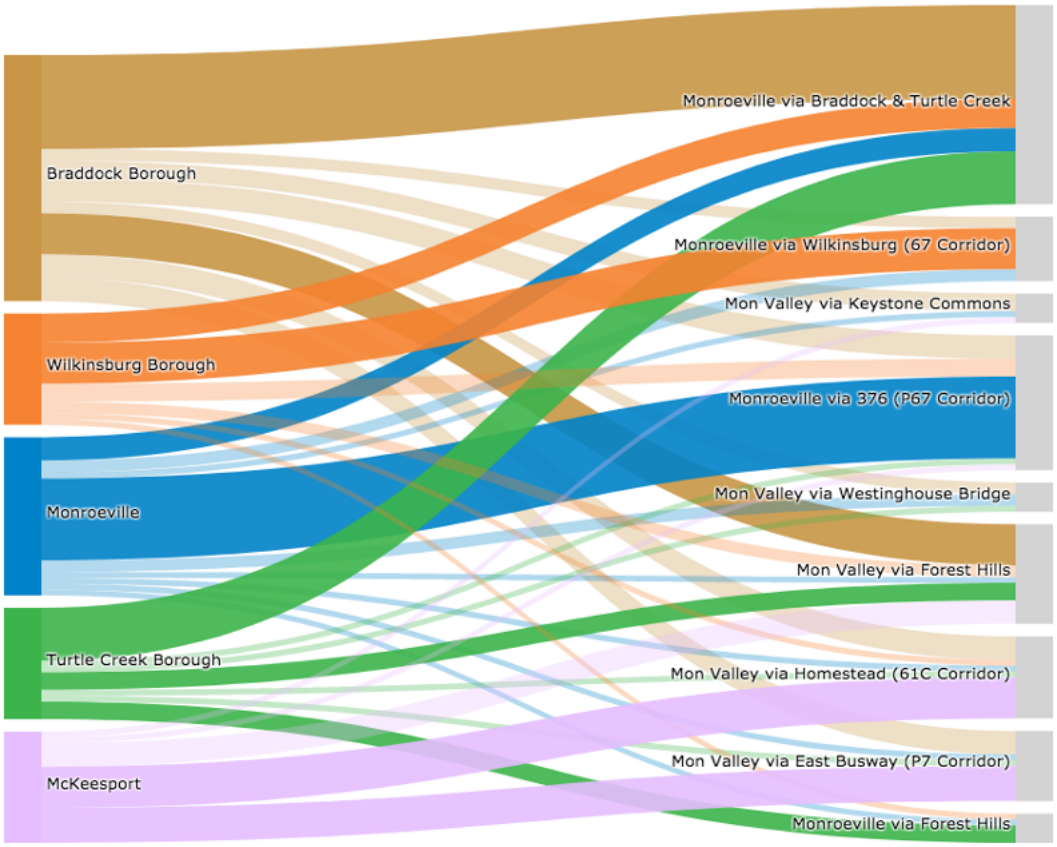
Finally, the figure above shows why respondents use other forms of transportation than Port Authority buses. We see that the most frequent reason is that public transit doesn't go where riders need it to. The next two reasons have to do with bus frequency and service times. The

fourth most frequent reason is that the buses are too slow compared to other modes of transportation available.

Survey Findings - Variable Relationships

To mine deeper insights from the survey data, we wanted to use more complex visualizations to relate different survey fields to one another instead of just looking at responses statically. This was accomplished with Sankey diagrams. Sankey diagrams work by showing the "flow" from one set of nodes to another set of nodes. The size of the nodes represents the total number of elements belonging to the node, while the width of the flow represents the total flow between the nodes. In the case of our survey, the flow represents the number of respondents that answered two questions a certain way.

Figure 32. Survey Origin Communities and Corridors of Interest

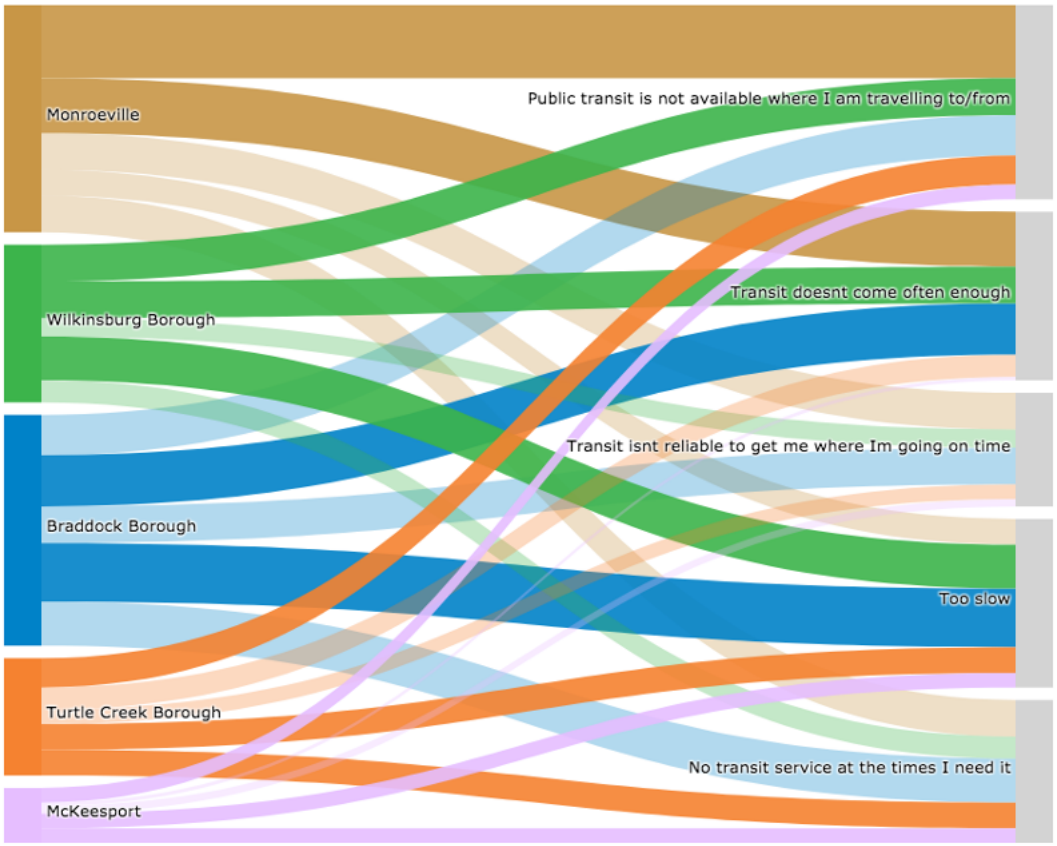


The first Sankey diagram we look at is between respondent location and corridors of interest. For the sake of readability, we only used five origin locations that all had a sufficient number of respondents. These origins comprise a representative geographic sample across our entire area of interest. For each origin node, the top two (or top three in the case of ties) widest flows are shaded a darker color for the sake of readability.

We see that for residents of Braddock, Wilkinsburg, Monroeville and Turtle Creek, improvements to the Monroeville via Braddock & Turtle Creek corridor is highly popular. For residents of

McKeesport, the 61C and P7 Corridors are the most popular. The 67 corridor is popular for Wilkinsburg residents and Monroeville via I-376 is popular for Monroeville residents.

Figure 33. Survey Origin Communities and Barrier to Transit

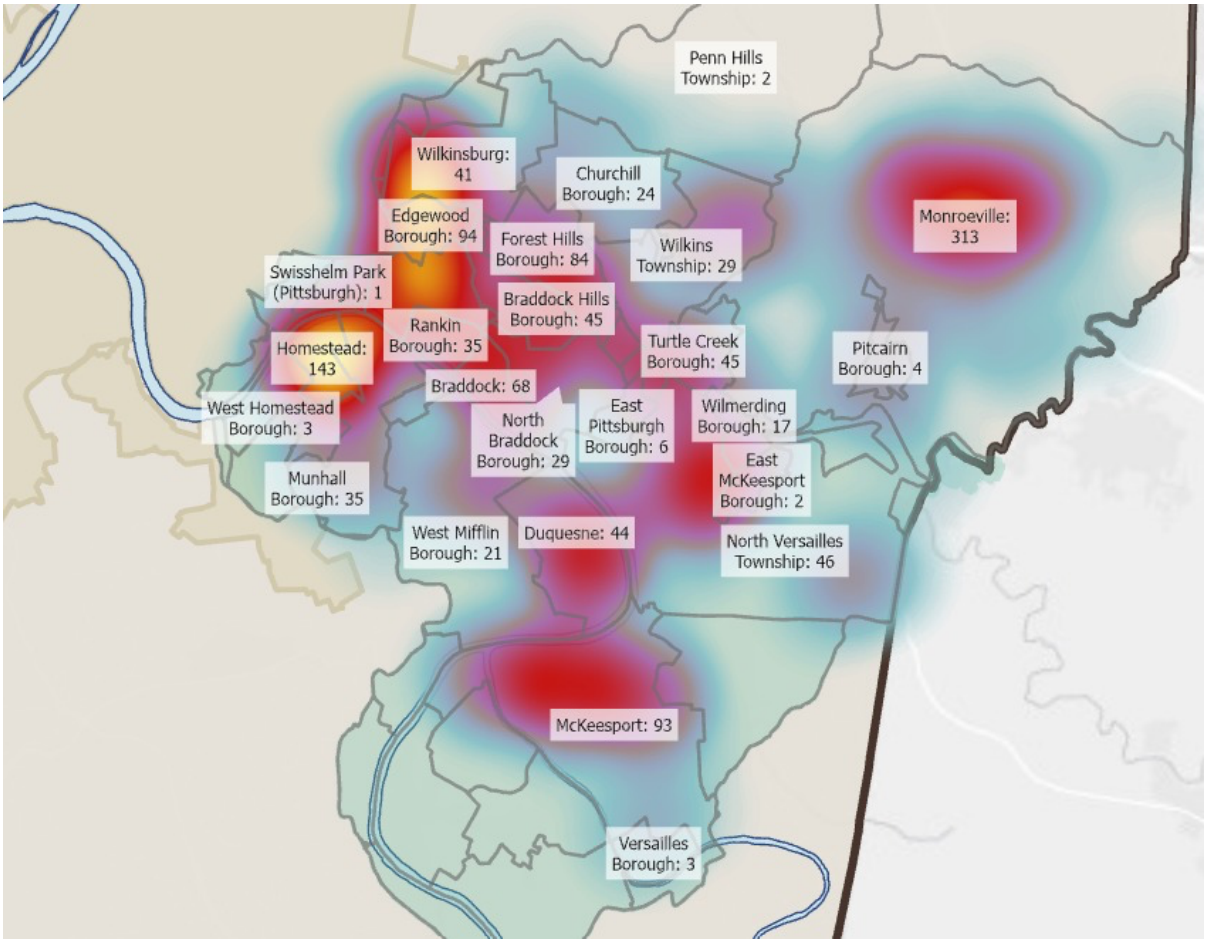


The above figure shows the relationship between respondent locations and barriers to transit. Transit frequency is a significant barrier for many of our interest areas, as is transit coverage. For residents of McKeesport and Turtle Creek, not having service at enough times seems to be an issue. Finally, transit speed is a consistent issue as well.

Survey Findings - Points of Interest

One particularly useful question asked on the survey had to do with destinations that respondents thought should be better served by public transit. These locations are referred to as "points of interest." Respondents were able to identify the top 5 locations of specific establishments that should be better served by public transit. By comparing these points of interest to current service, we can shape transit improvement recommendations that will improve connectivity in ways that meet community needs.

Figure 34. Beyond the Busway Survey Point of Interest Heat Map

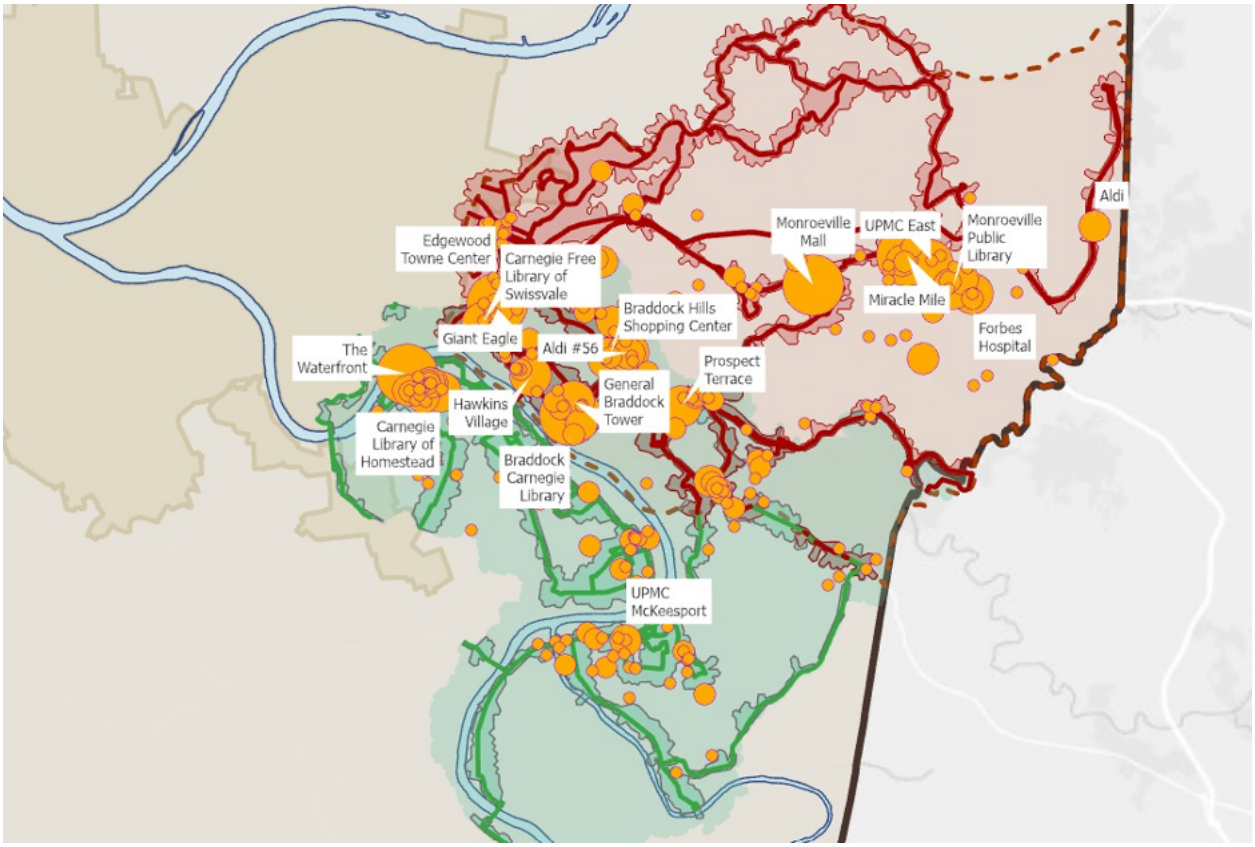


Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/.

The figure above shows a heat map that aggregates respondents' points of interest within our interest area. The closer the color is to orange, the more densely clustered points of interest survey respondents identified within those areas. As we can see, key points of interest-clusters include (by number of clustered respondents):

- Monroeville (313)
- Rankin, Braddock, Braddock Hills, and Forest Hills (193)
- Homestead, West Homestead Borough, Munhall (181)
- Edgewood Borough, Wilkinsburg, Swisshelm Park (136)
- McKeesport (93)
- Duquesne and West Mifflin (65)
- East Pittsburgh, Wilmerding, East McKeesport, North Versailles (71)
- Churchill and Wilkins Township (53)

Figure 35. Beyond the Busway Survey Point of Interest Map



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

In the figure above we see specific points of interest sized by volume of respondent interest. Top categories include shopping centers, medical, housing, and recreational facilities. Some of the most prominent or otherwise interesting ones are labeled. We see that The Waterfront and Monroeville Mall are key destinations within the region. Forbes Hospital in Monroeville is worth attention because it is a prominent location that currently has no service whatsoever. A short-list of key points of interest includes:

- Monroeville Mall
- UPMC East
- Forbes Hospital
- UPMC McKeesport
- Braddock Carnegie Library
- General Braddock Tower Apartments
- Hawkins Village - Allegheny County Housing Authority
- Homestead - Waterfront & Carnegie Library of Homestead
- Prospect Terrace - Allegheny County Housing Authority

- Edgewood Towne Centre

Additional points of interest are existing and planned employment hubs, such as RIDC sites in Duquesne, McKeesport, and Keystone Commons. Future employment generators will include the Carrie Furnace Redevelopment Site,[27] and the recently purchased former Westinghouse facilities in Monroeville[28] and Churchill.[29] Our analyses also included community identified points of interest in the survey, like houses of worship, grocery stores, and child care facilities, among others. Alternatives for analysis in this report were generated to improve connectivity and service time to many of these points.

[27] "Carrie Furnace Redevelopment Site." Carrie Furnace Redevelopment Site | Allegheny County. Accessed May 19, 2020. http://carriefurnacesite.com/.
[28] Carr, Dillon. "Monroeville's Former Westinghouse Site to Be Restored." TribLIVE.com, June 21, 2019. https://triblive.com/local/pittsburgh-allegheny/monroevilles-former-westinghouse-to-be-restored/.
[29] Mackey, Abby. "Potential Amazon Site in Churchill Faces Uncertain Future." TribLIVE.com, March 9, 2020. https://triblive.com/local/pittsburgh-allegheny/potential-amazon-site-in-churchill-faces-uncertain-future/.

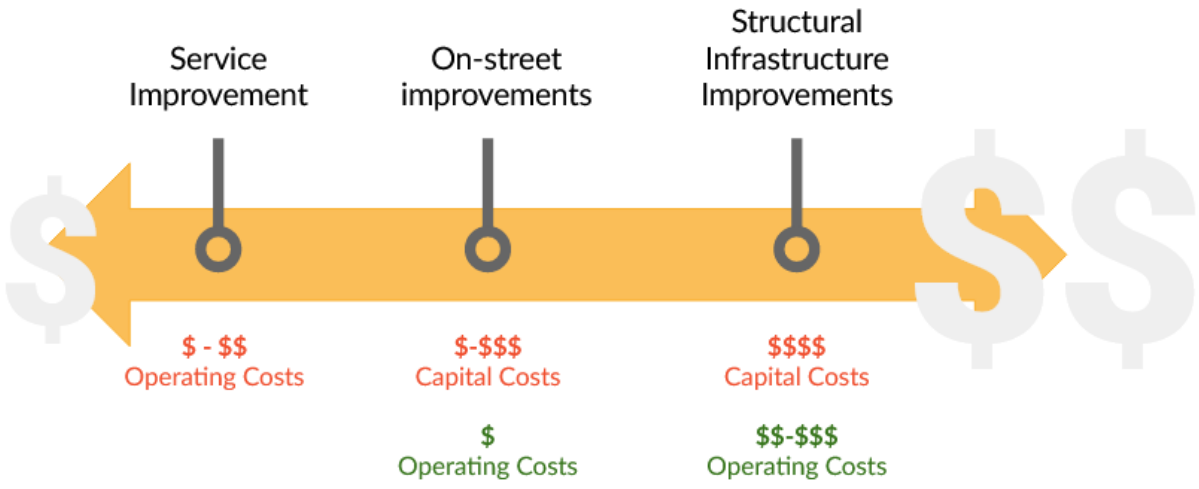
Alternatives Generation

Identifying Long List of Alternatives

Framing of Alternatives

The transit improvement alternatives evaluated within this study have been categorized and ordered as "service changes," "on-street improvements," and "infrastructural improvements." Alternatives were organized in this way to demonstrate the spectrum of costs and benefits derived from increased service within the constraints of the current system. In several cases, capital investments – be it Transit Signal Priority (TSP) or a new Station or Ramp along the East Busway— would result in decreased annual operating costs.

Figure 36. Spectrum of Operating and Capital Costs



Philosophy of Interventions - Diversity of Purpose

As a result of the stakeholder conversations and priorities identified by the PPT Beyond the Busway Survey and Transit Bill of Rights, our alternatives grapple with some of the following philosophical concerns. Transit routes and improvements should have a **Diversity of Purpose**,[30] serving as broad a transit ridership as possible with cost-effective service. As listed below, there are four primary types of routes:[31]

[30] Special thanks to Fred Mergner, former Program Manager of Service Planning & Schedules for the Port Authority for his thoughtful and comprehensive background on historical transit coverage, transit types, and philosophical framings that supported this section of the analysis.

[31] "ANNUAL SERVICE REPORT." Port Authority of Allegheny County, 2018. https://www.portauthority.org/siteassets/services/service-request/2018asr.pdf.

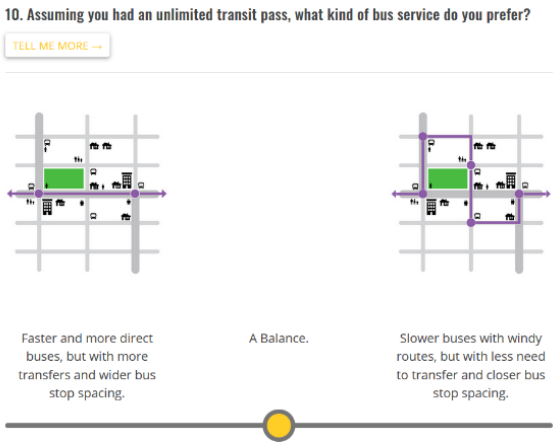
- **Local routes** – or "mainline" routes, emerge from Downtown Pittsburgh and run throughout corridors with high levels of service frequency, span, ridership, and 7-day service.
- **Express routes** – commuter routes that operate primarily during weekday peak hours, though off-peak and weekend service is provided on some express routes. These usually serve the outer section of a route, possibly near a park-and-ride. They may or may not follow the path of a local route that serves a similar area.
- **Crosstown routes** – connect city or suburban neighborhoods, but do not go to the regional hub (Downtown Pittsburgh). Examples are the 55 and 59 in our interest area. Riders on these routes generally do not ride the entire route, but certain legs, which all together comprise a multi-purpose route. For this reason, they are not always direct in terms of bus routings.
- **Feeder routes** – short, limited routes that connect small areas with local or express routes. The 60 in McKeesport is an example. These tend to have low ridership as they aim to connect areas unserved by mainline service.

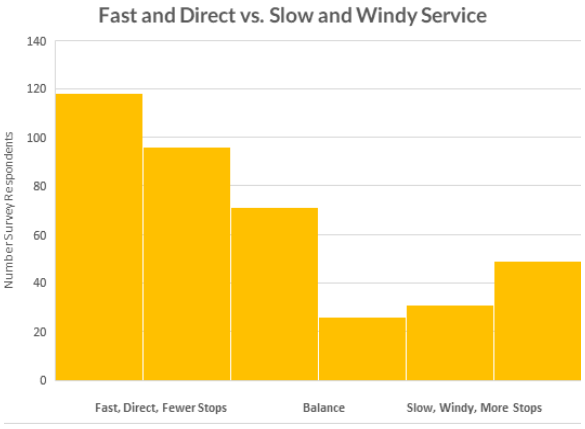
Some routes may serve multiple of these purposes. Given these various kinds of routes, one evaluation metric does not suffice for all of them. We consider local, express, and crosstown routes in this study directly, and acknowledge the need for feeder service, especially in McKeesport. To evaluate these various kinds of routes, we look to some of the trade-offs with speed vs. connectivity, discussed next.

Philosophy of Interventions - Speed vs. Connectivity

One of the questions on the PPT survey asked was, "Assuming you had an unlimited transit pass, what kind of bus service do you prefer?", which included an interactive sliding spectrum from fast, direct service to slower, winding service (see figures 32 and 33) for the question and results). In total, 54% of respondents preferred fast service, 25% preferred a balance, and 16% preferred slow and winding service.

Figure 37. Reyond the Busway Question on Fast Direct vs. Slow Windy Service (left) and Responses to Question (right)





This question is important to our study because the purpose of interventions may justify one side of the spectrum over the other. It does not always make sense to improve speed, at the expense of connectivity. For instance, the goal of extending the P68 to UPMC East and Forbes Hospital is to expand connectivity. This should not impact the trip time from Downtown to Monroeville Mall. While it may decrease headways (as shown in the following analysis), it also significantly increases ridership. In this case, connectivity supersedes the importance of speed. In another example, the purpose of targeting the 61C with Transit Signal Priority (TSP) is to speed it up, which may free up resources to add service in the system. In this case, decreasing speed may indirectly improve connectivity. For each intervention, we take care to denote its purpose and associated metrics.

Preserving Existing System while Avoiding Redundancy

Another goal of generated alternatives is to prevent the reduction or duplication of existing service. The goal is to improve existing service and fill gaps. Duplicating service can cause competition between routes. We acknowledge that PAAC service cuts in 2000, 2009, and 2011 have significantly reduced coverage throughout the Beyond the Busway interest area. Returning service that has been previously cut requires either 1) designing improvements not to compete with existing service or 2) modifying current routes so as to allow for novel service that is not duplicative. A good example is in the "New Braddock Connections" concept, described below. The connections discussed avoid traveling directly on, and thus competing with, the P68 route. Overall, the interventions listed are minimally invasive, attempt to maintain current strong levels of service, and build on the strong skeleton of the existing system.

Alternative Generation

The process of alternative generation involved numerous iterative qualitative and quantitative analyses and discussions with PPT and project stakeholders. The PPT Beyond the Busway Survey first informed key population needs and transit demand of riders in the interest area. These insights were deepened with regional demographic and equity analysis, discussed in the *Defining the Beyond the Busway Interest Area* and *Public Outreach* sections above. Next, Beyond the Busway corridors identified by PPT/CivicMapper in the Beyond the Busway Survey were prioritized by response count, as visualized in the *Public Outreach* section:

1. Monroeville via Braddock & Turtle Creek
2. Monroeville via 376 (P67 Corridor)
3. Mon Valley via Homestead (61C Corridor)
4. Mon Valley via East Busway (P7 Corridor)
5. Mon Valley via Forest Hills
6. Monroeville via Wilkinsburg (67 Corridor)
7. Monroeville via Forest Hills
8. Mon Valley via Westinghouse Bridge
9. Mon Valley via Keystone Commons

These priorities were coupled with intervention possibilities identified through the Transit Cooperative Research Program (TCRP) Bus Rapid Transit Practitioner's Guide (Report 118),[32] CivicMapper and PPT's corridor descriptions from the Beyond the Busway Survey, and conversations with advisory board members (see advisory board listed at the end of report).

From these possibilities, a long-list of alternatives was generated and circulated for feedback to the advisory board and stakeholders listed above. The list was also sent to PAAC staff. After an additional round of conversations with all stakeholders listed and preliminary analyses, the long-list and short-list alternatives below were generated for immediate and future analysis.

Long-List of Alternatives

The combined Long-List of Alternatives identified is shown below. Short-List Alternatives evaluated in this study are highlighted in yellow. Long-list alternatives not evaluated should not be discarded but may be considered in future advocacy and planning efforts. Note that "Scenarios" are mutually exclusive, "Concepts" are independent but non-mutually exclusive, and "Options" may be added onto "Scenarios" or "Concepts" to add additional features to the alternative.

Overall, this long-list of improvements is not final, but intended to serve as conversation-starter for PPT, PAAC, SPC, and other transit stakeholders in the region to discuss community-generated and approved service enhancements.

[32]"Bus Rapid Transit Practitioner's Guide." Transit Cooperative Research Program, 2007. https://nacto.org/wp-content/uploads/2015/04/tcrp118brt_practitioners_kittleson.pdf.

Table 1. Long-list of Alternatives Identified for Study

Long List Alternative Group	All Scenarios (Green: Analyzed and Recommended, Yellow: Analyzed and Needs Further Consideration, Blue: Not Analyzed, Analyze in Future)	Purpose of Alternative
Service Changes		
Hospital Connectors (HC)	Scenario 1) Connect the P68 to UPMC East and Forbes Hospital	Connectivity improvement to UPMC and Forbes Hospitals
	Scenario 2) Connect the 67 to Forbes Hospital a) by alternating trips with CCAC Boyce, or b) by adding Forbes Hospital as a stop along the current trip to CCAC Boyce	
Improvements enabled by the Kenmawr Bridge (KB)	Concept A) Connect the 71 with the Swissvale Station of the East Busway and then extend to the Waterfront, expanding its ridership and access.	Improved Connectivity
	Concept B) Re-route the 59 over the Kenmawr Bridge, shortening the travel time between the Waterfront and Braddock.	Service Time
	Concept C) Reconnect P71 to Swissvale Station East Busway station.	Connectivity for P71 Riders via the busway
	Concept D) P7 – see below for scenarios enabled by Kenmawr Bridge completion	Service Time and Connectivity
P7 Full Day & Weekend Service (P7FD)	Scenario 1) Add off-peak and weekend service to the P7 along its current route	Improve connectivity and travel time for P7 corridor riders all day and on weekends
	Scenario 2) Add off-peak and weekend service to a P7 route that stays completely on the busway during off-peak hours	
	Scenario 3) Add off-peak and weekend service to a P7 route that is completely off the busway during on and off-peak (note: impact to current Edgewood Ave riders during on-peak hours can be addressed with new P-service to those riders, or by constructing edgewood station, not modeled)	
	Cost-Efficiency Option) During off-peak hours, replace every other 61C with a P7 to cover the McKeesport leg and a 61D to cover the Squirrel-Hill, Oakland leg (May be ill-advised due to strong 61C ridership).	Maintain headways while cost-efficiently increasing service
New Braddock Connectors (BC)	New Braddock Route Scenario 1) A new route that travels from the East Busway Swissvale Station in Rankin through Braddock, East Pittsburgh, to North Versailles, and then follows a version of the 2006-era 75B route through Pitcairn into Monroeville. (May start in Waterfront, or elsewhere)	Service time and connectivity improvement from Braddock to

	New Braddock Route Scenario 2) A new route that travels from the East Busway Swissvale Station in Rankin through Braddock, East Pittsburgh, and then up the P68 Route through Turtle Creek before turning on Thompson and traveling up to Monroeville.	Monroeville, also potential to generate 1-transfer trip from McKeesport to Monroeville via Pitcairn
	East Pittsburgh Transfer Hub: By diverting the 61A or 61B from Braddock Hills, and extending the 55 to East Pittsburgh to meet the 59 at Dynamo way (where bus shelters already exist), a new transfer-hub could be generated to connect the 55, 59, 61A/B, 69, P68, P69.	Increased connectivity and transfer opportunities between the 61s, 55, 59
On-Street Improvements		
Transit Signal Priority (TSP)	Scenario 1) Full integration of TSP into ALL traffic signals on routes within the Beyond the Busway interest area.	Improved travel time, O&M, reliability
	Scenario 2) Partial integration of TSP into traffic signals on the 61A, 61B, 61C, 61D routes	Improved travel time, O&M, reliability, cost-effectiveness
	Scenario 3) Priority rank of TSP lights of top congestion within the Beyond the Busway interest area	
Queue Jumps	Queue jumps integrated at all identified candidate locations	Improved travel time, O&M, reliability
Off-board Fare Collection	Off-Board Fare Collection with assumptions: 25% adoption, 50% adoption, and system-wide	Improved travel time, O&M
	Targeted Off-board fare collection based on top locations of need and opportunity	Improved travel time, O&M, reliability, accessibility
Dedicated Bus Lanes	Concept A) Dedicated bus lane in Wilkinsburg, along South Ave, in-bound during AM Peak Hours	Improved travel time, O&M, reliability
	Concept B) Dedicated bus lane in Homestead, along East 8th street, in-bound during AM Peak Hours	
	Concept C) Additional, unidentified candidate sites for dedicated bus lanes	
Structural Infrastructure Changes		
Edgewood Station	Busway Station in Edgewood Towne Centre	Improved connectivity, travel-time, O&M

I-376 Corridor	I-376 Ramp from Busway for rapid Monroeville service (option for inbound shoulder lanes to avoid congestion)	costs
Stops, Stations, and Garages		
Stops	Concept A) Priority list of route stops that should be considered for shelter and accessibility improvements.	For improving accessibility of transfer experience
Stations	Concept B) List of new possible stations. Possible candidate sites discussed through the survey included Monroeville Mall and Waterfront Stations.	
Garages	Concept C) List of possible candidate sites identified for new PAAC Garage locations	Increasing capacity in the PAAC system for expansion

From Long-List to Short-List of Alternatives Analyzed

Due to time and priority constraints, short-list alternatives (in yellow or green above) were selected after further discussions with PPT and the advisory board. The final short-list of alternatives analyzed in depth for this study include the following:

Service changes
- Monroeville extensions to hospital, college (P68, 67 scenarios)
- P7 express service (on and off-busway scenarios)
- 59/71 route potential alterations
- Improved Braddock connections (general rider demand & descriptive)

On-street improvements
- Transit Signal Priority (Entire Beyond the Busway interest area + 61ABCD only)
- Queue Jump (at all identified candidate sites)
- Off-board fare collection (25%, 50%, 100% adoption rates)
- Dedicated Bus lanes (at identified candidate sites)

Infrastructural Improvements
- I-376 Dedicated Bus Ramp (general impact)
- Edgewood Busway Station (general impact)

Each of these will be discussed in the following sections, following an explanation of the methodology. While most will include intense quantitative analysis, qualitative and high-level overviews are shared for the “Improved Braddock Connections” alternative and the “Infrastructural Improvements” section. Long-list alternatives that are not included in this study should still be considered by PPT, PAAC, and SPC, as applicable.

Alternatives Analysis: Methodology

Data

Data for this project were gathered from a wide variety of sources and towards different purposes. The datasets, source, brief descriptions, and the purposes they were put towards are shown in the table below. PAAC, APC, SPC data, and other data data were sourced by public records requests and via requests to those two agencies.

Table 2. Project Data Sources

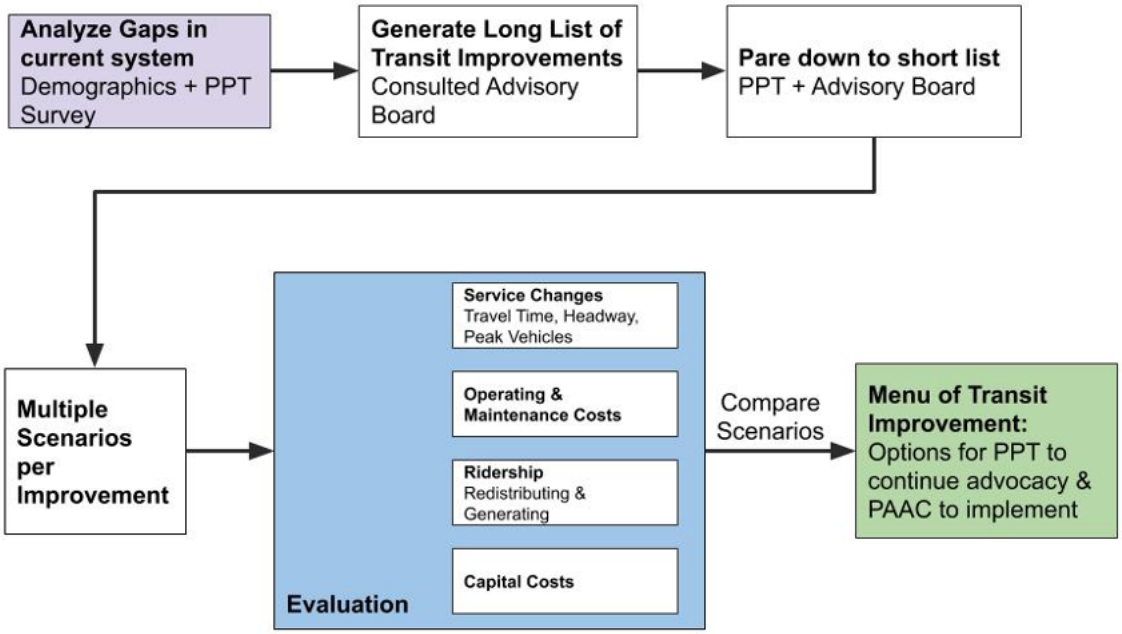
Dataset	Source	Description	Use
Beyond the East Busway Survey[33]	Pittsburghers for Public Transit	Data on respondents' current relationship to public transit, community transit needs, and general community information.	Used to better understand community desires and direct focus on transit improvement alternatives.
Automatic Passenger Counting Data (APC)	Port Authority of Allegheny County	Data automatically collected for every bus at every stop in the PAAC system. Includes time stamps for boarding and alighting.	Baseline route and stop ridership counts.
General Transit Feed Specification (GTFS)[34]	Port Authority of Allegheny County	Granular, stop level data for every scheduled route in the PAAC system. Contains info on trips.	Calculating current route metrics such as trip time, headways, etc. Enables visuals of transit system.
District Trip Estimations	Southwestern Pennsylvania Commission	2020/2045 estimations of all transportation trips between predefined districts within the Pittsburgh MSA, including but not limited to public transit.	Geo-locates travel demand. Estimates location of future travel. Estimating changes in ridership in different improvement scenarios.
PAAC 2018 Budget and Service Report[35]	National Transit Database	Line by line items of PAAC budget, service, and ridership parameters.	Cost allocations for Operations & Maintenance (O&M) models.
Route Vehicle Schedules Overview	Port Authority of Allegheny County	Quarterly sheets issued by PAAC with several summary statistics for all routes in the transit system.	All route Vehicle Revenue Hours (VRH) & Vehicle Revenue Miles (VRM). Used in O&M models.

[33]Beyond the East Busway. Accessed May 19, 2020. https://eastbusway.pittsburghforpublictransit.org/survey/.
[34]"Web Developer Resources." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/business-center/developer-resources/.
[35]"Port Authority of Allegheny County." Federal Transit Administration. United States Department of Transportation, August 28, 2015. https://www.transit.dot.gov/ntd/transit-agency-profiles/port-authority-allegheny-county.

American Community Survey[36]	US Census Bureau	Premier source for detailed population data about the USA.	Understand regional demographic and computing equity scores.

Methodology

Figure 38. Methodology Flow Chart



Above we see a simplified flowchart of the process through which we came to our final recommendations. We began by using the Beyond the Busway survey and other data sources to evaluate public transit needs in the area, worked with our advisory board and PPT to create and then filter our list of improvement alternatives, evaluated multiple scenarios for each improvement, and then finally presented options and analyses of different potential transit improvement outcomes.

Below we give a detailed look at each evaluation category and provide specific methodology for each metric calculated under that category.

[36]US Census Bureau. "American Community Survey (ACS)." The United States Census Bureau, May 11, 2020. https://www.census.gov/programs-surveys/acs.

Terms

Before delving into techniques, we must define a set of terms related to public transit.[37]

Headway - The time interval between buses travelling in the same direction on a particular route.

Peak Headway – Headway during peak hours (commuting hours in morning and afternoon.)

Travel Time - Time it takes for a bus to travel from its origin stop to its terminal stop on a route.

Round Trip - A bus completes a round trip when it has completed both its inbound trip and outbound trip.

One-way Trip – Half of a round trip.

Recovery Period – The time that buses and operators remain inactive after completing a round trip. Enables drivers to make up late time in operating the service. Given as a percent of round-trip time in our models.

Vehicle Revenue Hours (VRH) - Refers to all scheduled time a bus spends serving passengers.

Vehicle Revenue Miles (VRM) – Refers to total miles traversed by a bus while it is scheduled to serve passengers.

Peak Vehicles (PV) - Number of buses a route must be allocated to serve its peak schedule demand. A bus system must have at least as many buses as the sum of its peak vehicles over all routes.

Service Changes

Some of our improvement actions involve changing the physical paths routes take. Depending on the route, we may have explored extending routes to further locations, cutting out parts of routes to have them run faster, or other alterations. Finding ways to reasonably estimate the travel times along altered portions of routes was crucial for dependent models.

$$Travel\ Time_{r,build} = Travel\ Time_{r,no\ build} + \Delta(Travel\ Time_r) \quad (1)$$

Equation 1 gives a general formula for updating travel times on hypothetical route r. The change in travel time term depends on the estimation technique we used.

$$\Delta(Travel\ Time_r) = Travel\ Time_{r',p} \quad (2)$$

[37] "Transit Glossary." AC Transit. Accessed May 19, 2020. http://www.actransit.org/customer/transit-glossary/.

In some cases, the portion of routes that would be altered follow paths that are already followed by other routes. Equation 2 represents the calculation we use in these scenarios. To calculate the change in travel time for route r under the build scenario, we substitute in a portion p of a comparable route r'.

$$\Delta(Travel\ Time_r) = adjustment\ factor * car\ travel\ time(new\ segment_r) \quad (3)$$

In other cases, we are adding new segments to routes that are not already traversed by any other route. Because we have no existing schedule to compare against, we use Google maps to get car travel times along these new segments. Because public transit goes slower than personal vehicles, we increase the travel time by multiplying by an adjustment factor. For our models we use a factor of 1.25. This can be seen in Equation 3.

Operations and Maintenance

Administering bus service to a community involves incurring ongoing variable costs. These ongoing costs are referred to as Operations and Maintenance (O&M) costs. O&M costs are calculated at the route level and can be summed to get the overall system O&M cost.

We divide O&M costs into three buckets: time requirements, distance requirements, and vehicle requirements. The associated route metrics are VRH, VRM, and PV, respectively. Our VRH coefficient estimate came out to $99.71 per revenue hour, VRM coefficient to $1.56 per revenue mile, and $186,102 per PV. The cost allocations can be seen in the appendix.

$$PV_r = \left\lceil \frac{(Peak\ Round\ Trip\ Time_r + Recovery\ Time_r)}{Peak\ Headway_r} \right\rceil \quad (4)$$

VRH and VRM can be taken directly from vehicle schedule overviews, but PV information is not provided. Instead, we use the formula in Equation 4 to estimate peak vehicles allocated to a route *r*.[38] The one sided brackets notate a ceiling function that rounds up to the next nearest integer.

$$O\&M_r = \alpha * VRH_r + B * VRM_r + \gamma * PV_r \quad (5)$$

Equation 5 gives us the equation to estimate route r's associated O&M cost. The coefficient values α, B, and γ are obtained through a cost allocation of expenses in an agency's budget. For instance, operator wages are allocated to VRH while fuel is allocated to VRM.

On-street Improvements

On-street improvements are small scale capital investments made at the street level with the intention of increasing transit speed and decreasing route time.

$$speedup_{r,i} = (speedup\ factor_i) * (\#\ speedup\ input_{r,i}) \quad (6)$$

[38] "Basic Speed/Fleet Size Relationships," n.d. https://www4.uwm.edu/cuts/utp/fleet.pdf.

Equation 6 gives us a simple model for estimating reduction in travel times, or speedups, given implementation of a specific on street improvement. That speedup is equal to the speedup factor of improvement i times the number of speedup inputs corresponding to improvement i on route r. For instance, take transit signal priority (TSP), which reduces the amount of time buses spend at traffic signals. The number of speedup inputs for this improvement along a particular route would be the number of traffic signals along that route.

Table 3. On-street improvement types

On-Street Improvement	Description	Speedup Input
Transit Signal Priority	An operational technology that allows buses to communicate with traffic signals and reduce traffic-signal wait times by holding green lights longer or shortening red lights.	Traffic Signals
Dedicated Bus Lanes	Lanes that separate transit vehicles from the rest of traffic, allowing them to move through congested areas more efficiently.	Miles of bus lane
Queue Jumps	Additional travel lanes or a travel lane segment allocated to buses, usually restricted only to transit vehicles, at traffic signals that give transit vehicles green lights before other vehicles allowing them to jump ahead of other vehicles at intersections.	Number of queue jumps
Off-Board Fare Collection	System for collecting fares before riders board transit vehicles, reducing the delays caused by time spent registering fares.	Reduced riders paying on-board fares

Ridership Estimations

Alterations to routes drive changes in ridership patterns. We use a variety of ridership change projection techniques to project these changes. We will be comparing future-state (the year 2045 as defined by SPC) ridership projections under a variety of scenarios.

$$Future\ Ridership_r = Base\ Riders_r + Attracted\ Riders_r + Shifted\ Riders_r \qquad (7)$$

Equation 7 shows the three components that sum up to future ridership projections per route *r*. Each component has a sub-methodology that is explained below.

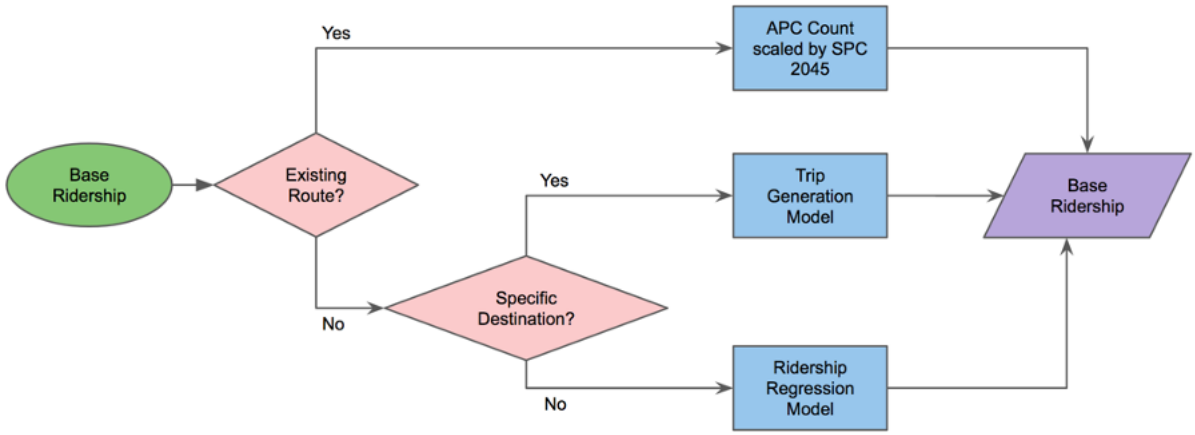
Ridership was estimated at three levels:

1. Determining the "no-build" base ridership
2. Determining ridership increase for new service areas
3. Determining ridership increase due to improved service in areas currently served

Base Ridership

No-build existing route ridership: For base ridership estimates, we take the Port Authority ridership count for 2018 (the last whole year available for ridership) for present day base ridership estimates. The two years of estimates in SPC's data covers 2020 and 2045, that respectively present ridership based on today's, and the 2045-future, population and employment projections. In our scenario analysis however, we account for the future no-build alternative scenario by taking SPC's 2045 estimated percent change in transit trips from 2020, and applying the increase or decrease to the Port Authority ridership count for the route. (Specific future increase factors for a route being analyzed are based on similar corridors of analysis.) In the figure below, that analysis is represented by the "APC Count scaled by SPC 2045" step.

Figure 39. Base Ridership Flowchart



New Service Areas: New service areas provide the greatest challenge for ridership estimation. After a literature review of methods used by planning and transit agencies, it appears that 42% of agencies simply used an estimate based on similar routes. 22% of agencies use transfer data and connecting route information to estimate new ridership, while 17% of agencies use socioeconomic data, 14% use productivity estimates, 11% use a 4-step travel model, 11% use similar geographic estimates, 11% examine land use, 11% use minimum performance standards, and 14% simply would not analyze new ridership levels (granted, agencies in the survey use a mix of these methods so these categories will overlap).[39]

39

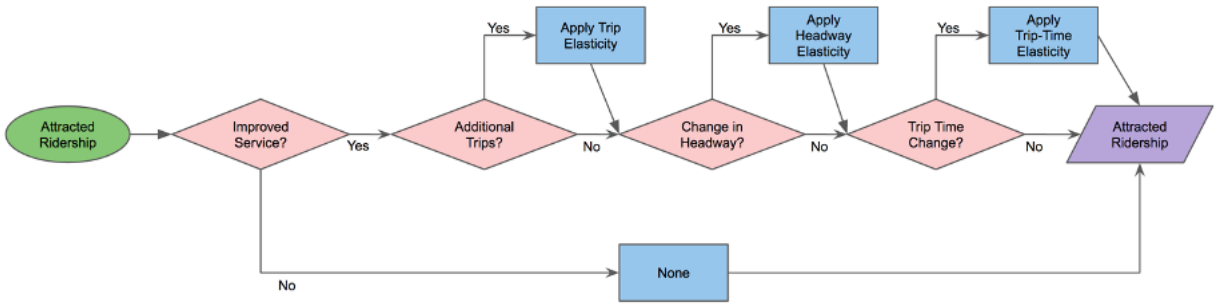
"Fixed-Route Transit Ridership Forecasting and Service Planning Methods" Transit Cooperative Research Program, 2006. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.123.6524&rep=rep1&type=pdf.

In an approach that combines methods using similar routes, socioeconomic data, similar geographic regions, and land use, we model estimated new ridership in a new service area using an elastic-net regression model, with an R^2 of 0.59 (explaining 59% of variance in unseen ridership data) and a Root Mean Squared Error of 500 (this error term applies to the total yearly ridership total by route and provides a confidence interval of 1,000 for our final ridership estimates by route).[40] We estimate based on the demographic characteristics of the route walkshed and the service characteristics of the route what new ridership would be, with separate estimates for weekday and weekend service. A more granular model could be built with more years of ridership data at the stop level along with more granular regional characteristics.

Route extensions: In cases where a route is being extended to a new point of interest, the characteristics of that place of interest are input into a trip generation model that is used instead of a new service area model. Trip generation estimates are determined by previous study multipliers on different headcount estimates by land use type.[41] Once a trip generation total is estimated, the share of transit trips is estimated by applying the transit mode share of the route, weighted by the transit mode share of each district that the route segment traverses.

Attracted Ridership from Improved Service

Figure 40. Attracted Ridership Flowchart



Improved service is estimated relative to existing service. The dimensions of improvement relate to any of the following aspects of service: headway, trip count, travel time or route length. We use a ridership elasticity, which estimates the percentage of additional riders added to the route with 1 percent increase in service.

$$Ridership\ Elasticity = \frac{\%\Delta ridership}{\%\Delta service\ change} \quad (8)$$

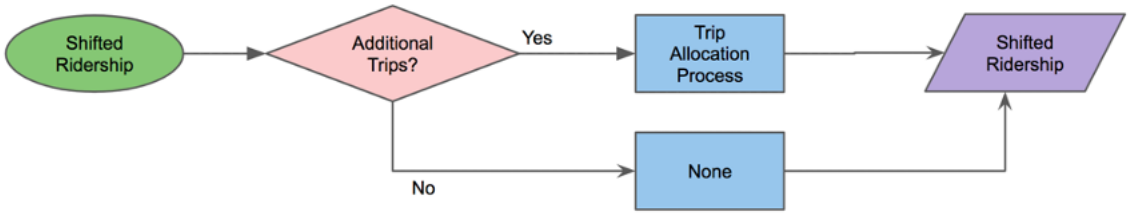
Using case studies both nationally and locally, we apply either a base ridership elasticity rate of (+/-) 0.5, or, when relevant, different off-peak and peak ridership elasticities. For example, given commuting travel behavior, we assume that off-peak and peak ridership elasticity with respect to headway improvements are different and provide estimates for peak weekday ridership vs. all off-peak ridership. On-peak ridership elasticity for travel time savings is -0.29 (a 1% increase in travel time results in a 0.29% decrease in ridership, and vice-versa), while for off-peak, the elasticity is

[40] http://www-stat.wharton.upenn.edu/~stine/stat621/lecture3.621.pdf
[41] https://www.nctr.usf.edu/wp-content/uploads/2011/11/77801.pdf

taken as -0.83. These figures are from the TCRP study of multi-region bus priority demonstrations.[42]

Shifted Ridership

Figure 41. Shifted Ridership Flowchart



Shifting ridership: For any increase in ridership, we additionally determine the ridership increase per route due to ridership shifting away from other routes to the current route, and the ridership increase of brand new transit trips.

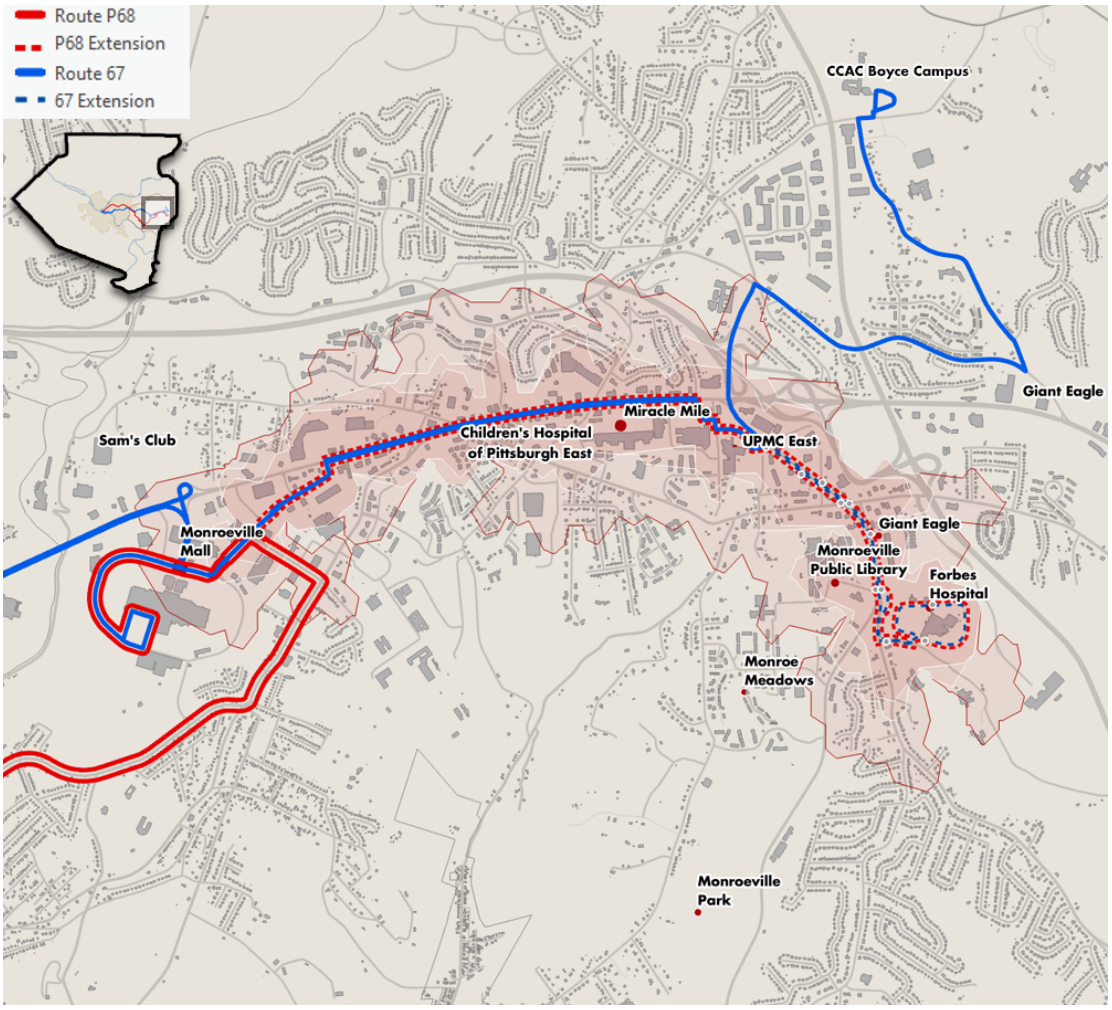
[42] http://onlinepubs.trb.org/Onlinepubs/trr/1981/818/818-003.pdf

Alternatives Analysis: Service Changes

We begin our analysis of transit improvements with service changes. Service changes are defined as actions that only involve alterations to bus routes and schedules. They generally do not require capital investments. For the sake of viewing simplicity, Saturday and Sunday service are bundled together as weekend service despite the fact that the two days typically have different route schedules.

Monroeville Extensions to Hospital

Figure 42. Scenarios for Extending the P68 to UPMC East and Forbes Hospital and 67 to Forbes Hospital en-route to CCAC



Boundary shapes for county, city, buildings, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

In analyzing results of the Beyond the East Busway Survey, we noted that Monroeville was a highly demanded area by survey respondents. Healthcare facilities were the 4th highest requested category of destinations and Forbes Hospital was the 11th most requested destination across all points of interest. There are currently no routes that serve Forbes Hospital, so extending service of one or more routes could better serve communities in need.

The two routes considered are the P68 and the 67. The P68 takes the East Busway to Wilkinsburg, travels east through Turtle Creek, and then ends at the Monroeville Mall. The 67 starts downtown, takes US 22 past Monroeville Mall, up to UPMC East, and ends at the CCAC Boyce Campus. With modest alterations, either or both of these routes could provide service to Forbes Hospital in accordance with the community needs outlined in the survey.

Table 4. Hospital Connectors Scenarios

	P68	**67**
Scenario 0	Ends at Monroeville Mall	To UPMC East & CCAC Boyce
Scenario 1	To UPMC East & Forbes Hospital	No build
Scenario 2	To UPMC East & Forbes Hospital	To UPMC East, Forbes Hospital, & CCAC Boyce
Scenario 3	To UPMC East & Forbes Hospital	To UPMC East, Forbes Hospital, & CCAC Boyce, lengthened headways

The table above summarizes the four scenarios we analyzed and compared. Scenario 0 is current service – the "no build" option. Scenario 1 extends the P68 to Forbes Hospital. Scenario 2 does the same but also has the 67 serve Forbes Hospital, as well as its other current terminal destinations. Finally, Scenario 3 is the same as Scenario 2 but with longer headways on the 67 to reduce the need for an extra vehicle allocated to the 67.

Operations & Maintenance Costs

Figure 43. Hospital Connectors Scenarios O&M Calculations

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Wkdy VRM	1845	2041	2163	2163
Wknd VRM	295	295	327	327
Wkdy VRH	120	128	156	156
Wknd VRH	19	19	26	26
PV	12	13	14	13
Year VRM	510,270	561,230	596,330	596,330
Year VRH	33,215	35,338	43,236	43,236
Total	$ 6,341,112	$ 6,818,429	$ 7,846,747	$ 7,660,645

The figure above gives the O&M breakdown and projections for our four scenarios. Each scenario includes the bundled costs of both the P68 and the 67. We see that Scenario 2 is the most expensive, and that Scenario 1 is the least expensive of the build options.

Figure 44. Hospital Connectors Scenarios Cross-Comparison Chart

		To		
	Cost Delta	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	$ 477,000	$ 1,506,000	$ 1,320,000
	Scenario 1		$ 1,028,000	$ 842,000
	Scenario 2			$ (186,000)

		To		
	% Cost Delta	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	8%	24%	21%
	Scenario 1		15%	12%
	Scenario 2			-2%

The figure above gives one-to-one comparisons of all scenario O&M cost projections. The rows are read as the "from" scenario and columns as the "to" scenario. For instance, the row of the top left cell is Scenario 0 and the column is Scenario 1. This means we are looking at the increase or decrease in O&M cost going from Scenario 0 to Scenario 1.

The first table gives a rounded dollar difference in scenarios. The second gives percent differences. We see that given Scenario 0 as a baseline, Scenario 1 is only an 8 percent increase in costs where the other two scenarios represent much larger 24 and 21 percent increases.

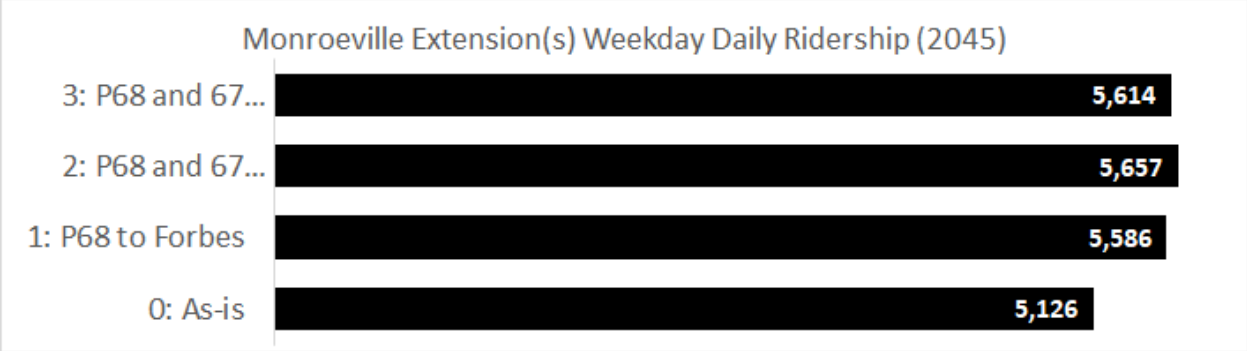
Ridership Projections

Using a trip generation model, we estimated the number of overall hospital trips expected using the number of hospital beds as a driving factor. From there we used an estimate of transit trips based on the transit usage rate of the districts served by P68 and 67 to provide overall estimates of annual ridership in 2045.

Figure 45. Forbes Hospital Ridership Parameters

Forbes Hospital						
291 beds	ITE Trip Rate	Daily Trips (All)	Daily Trips (Transit '20)	Daily Trips (Transit '45)	Annual Trips (Transit '20)	Annual Trips (Transit '45)
Weekday	11.81	3,437	411	460.6	106,915	119,745

Figure 46. Hospital Connectors Ridership Projections



The figure above gives estimates of total weekday daily 2045 ridership in each scenario, with service as-is combining ridership from the P68 and 67 in their current routing. Our No-build scenario (if no service were altered by 2045) shows 5,126 daily weekday trips for routes P68 and 67 combined, with additional scenarios 1-3 showing increases represented in the table below.

Figure 47. Hospital Connectors Ridership Cross-Comparison Chart (Absolute trips upper, percentage lower)

		To		
	Ridership Change	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	461	532	488
	Scenario 1		71	27
	Scenario 2			(44)

		To		
	Ridership % Change	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	9.0%	10.4%	9.5%
	Scenario 1		1.3%	0.5%
	Scenario 2			-0.8%

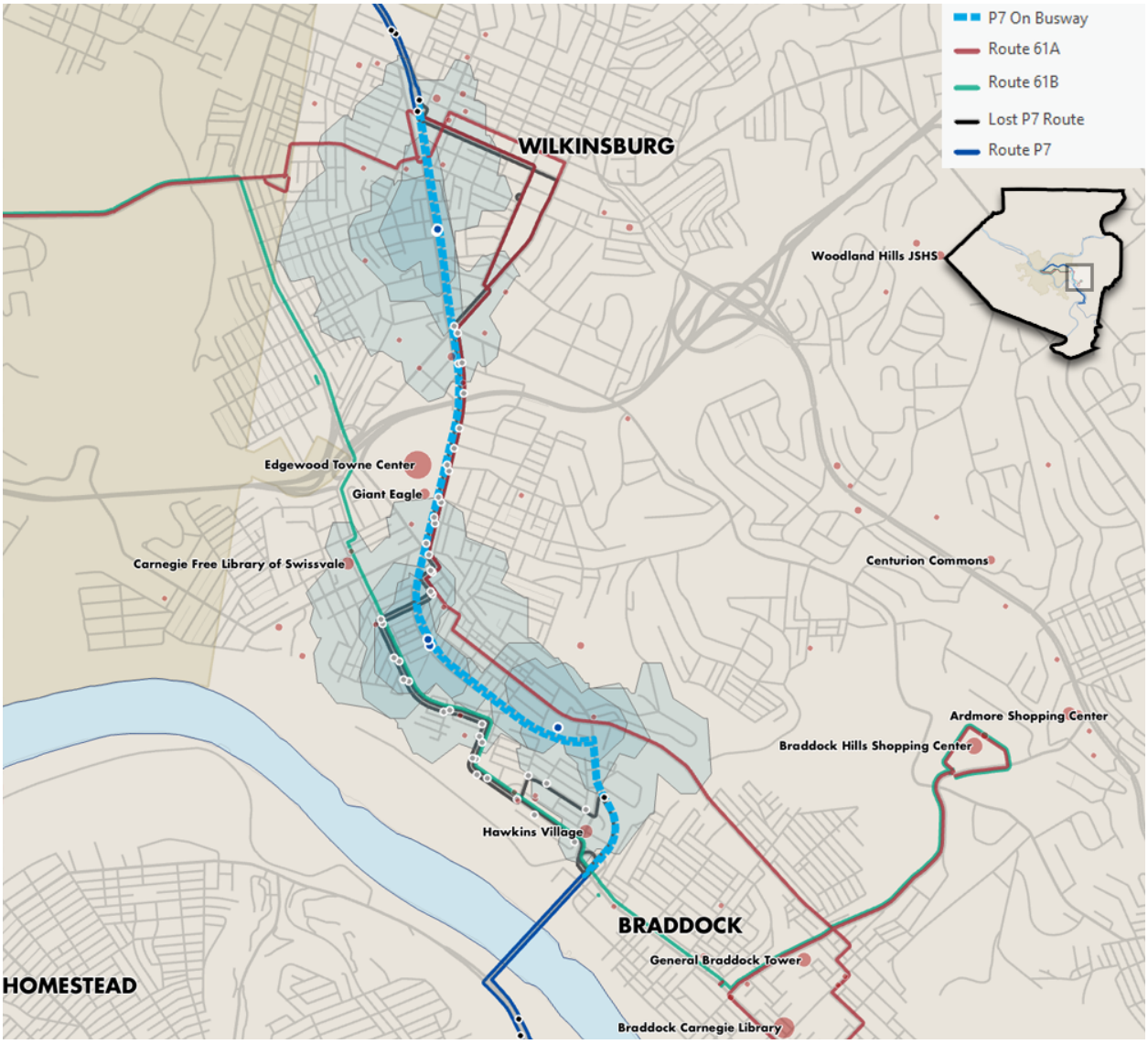
The figures above give one-to-one comparisons of all scenario ridership estimates. All scenarios project increased ridership with the stark exception of Scenario 3. Longer headways are correlated with decreased ridership, as riders prefer frequent service. Given that reality, Scenario 3 looks unappealing from a ridership perspective.

Takeaways

The Beyond the Busway Survey provides strong evidence that service to Forbes Hospital is a community need. Of all scenarios we projected, analyzed, and compared, Scenario 1 comes out most appealing. This is because it represents a modest increase in O&M costs of 8 percent or $477,000 per year and an admirable increase of 460.6 daily weekday trips or 119,745 annual trips over the no build case.

P7 Express + All-day Service

Figure 48. P7 Service Change Scenarios



Boundary shapes for county, city, buildings, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Points of Interest generated based on data made available by CivicMapper https://www.civicmapper.com/. Walksheds generated with use of Esri,

HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool *http://www.arcgis.com*

From our survey results, we see that the two top barriers to public transit use among McKeesport residents are that transit is not available at times residents need it and that transit is too slow. We also see that the P7, along with the 61C, are the two corridors that McKeesport residents are most interested in seeing improvements on. Finally, we know that throughout the entirety of the survey, residents are interested in travelling to Downtown, Oakland, and other east Pittsburgh neighborhoods. Fast and frequent service is a key regional need that could be supplemented by converting the P7 into a route that provided more frequent and/or express service.

(Route 56, which provides relatively fast service between McKeesport and Downtown and also serves Penn State-McKeesport, was not included in the analysis.)

Currently the P7 route connects McKeesport, Duquesne, Braddock and Wilkinsburg up to the busway, with a significant portion of the route meandering along outside the busway in Edgewood before connecting back to the busway at Wilkinsburg station. The P7 also currently only runs during peak weekday hours, with some sparse service during off-peak hours. Extending additional off-peak service and adding weekend service would enable greater connectivity to Mon Valley municipalities, while providing express service to Pittsburgh's eastern neighborhoods and Downtown by moving the route back onto the busway.

Table 5. P7 Service Change Scenarios

	P7
Scenario 0	P7 service to remain Weekday/ Peak service
Scenario 1	Add weekday off-peak and weekend service
Scenario 2	Add weekday off-peak and weekend service Run P7 express by taking busway through Swissvale station, off-peak weekday & weekend only
Scenario 3	Same frequency as Scenario 2 Run P7 express by taking busway through Swissvale station for all trips

The table above gives descriptions of all scenarios we analyzed with regards to this service improvement. Scenario 0 is our current, no-build scenario. Scenario 1 adds more frequent service to the P7 but otherwise preserves the route. Cognizant of potential disruption to riders in Edgewood boarding on the P7's off-busway stops, we analyzed Scenario 2 which added express service only to the new off-peak and weekend service. Scenario 3 gives increased service levels

and has the bus stay on the busway through all hours, effectively removing the Edgewood Avenue stops. (The option of adding a new busway station in Edgewood is discussed later.)

Operations & Maintenance Costs

Below is the summary of costs for each scenario. Currently, the P7 costs an estimated $1.9M to operate.

Figure 49. P7 Service Change Scenarios O&M Projections

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Wkdy VRM	493	935	935	935
Wknd VRM	0	204	204	204
Wkdy VRH	24	46	42	38
Wknd VRH	0	10	10	8
PV	6	6	6	5
Year VRM	128180	264316	264316	264316
Year VRH	6283	12957	11943	10624
Total	$ 1,943,084	$ 2,820,854	$ 2,719,748	$ 2,402,209

What is striking is that scenarios 2 and 3 are comparatively cheaper than scenario 1. This is because running P7 express creates runtime savings that cut down both in terms of Vehicle Revenue Hours as well as the number of Peak Vehicles required.

Figure 50. P7 Service Change Scenarios O&M Cross-Comparison Chart ($)

		To		
	Delta Table	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	$ 878,000	$ 777,000	$ 459,000
	Scenario 1		$ (101,000)	$ (419,000)
	Scenario 2			$ (318,000)

Figure 51. P7 Service Change Scenarios O&M Cross-Comparison Chart (%)

		To		
	% Delta Table	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	45%	40%	24%
	Scenario 1		-4%	-15%
	Scenario 2			-12%

Ridership Projections

In shifting the P7 to the busway, our first concern is the potential inconvenience to riders who currently board the P7 on stops that would be moved onto the busway, which include the include the stops along Edgewood Ave (overlapping with route 61A) and the routes South of Washington St. following Monongahela Ave and Miller Ave (overlapping with routes 59, 71, and 61B) . We focus on the collection of stops along the busway in Edgewood along Edgewood Ave fromMaple to Colombia outside of the walkshed of Roslyn station or Hamnett station. We focus less on the Rankin stops of the P7, as the completion of the Kenmawr bridge would allow the P71 to service the Rankin stops to the busway as it did prior to the bridge construction.

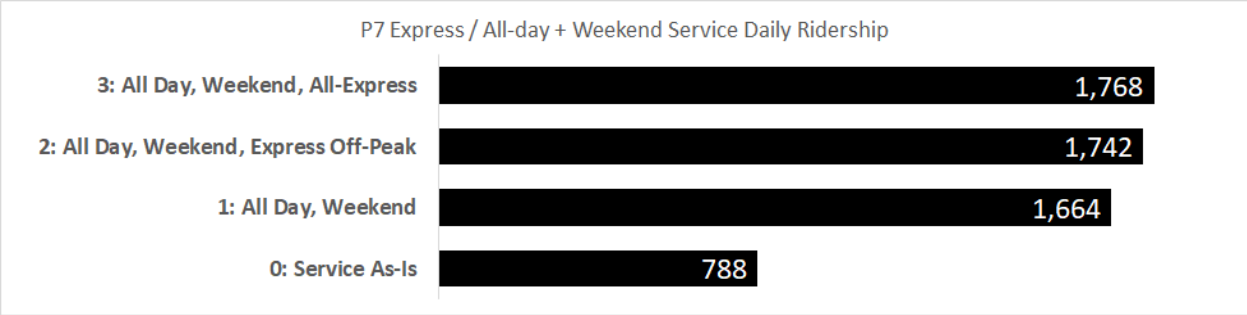
Currently 130 daily boardings occur on the P7 Edgewood Ave. stops according to 2019 Port Authority ridership numbers. Those stops are also served by the 61A. We estimate travel destinations with SPC trip destination estimates, and find that 44 daily trips would be directly impacted, with a need to transfer from the 61A to another route southbound. This loss in ridership is accounted for in Scenario 3, when the P7 is run on the busway entirely.

Figure 52. P7 Service Change Scenarios Potential Ridership Loss from Edgewood Ave Stops

Daily Trip Count from Stop Removal	130
% Trips Going South (not served by 61A)	34%
Loss in Daily Trips	44

Below we have the total daily ridership estimates for each scenario.

Figure 53. P7 Service Change Scenarios Ridership Projections (Annualization factor of 300)



We see that running the P7 all day and weekend, keeping stops as-is (Scenario 1) would boost daily ridership by 875 daily trips to 1,664 daily trips from the No-build (Scenario 0) scenario of 788 daily trips.[43]

If that all-day service were run express, on the busway (Scenario 3), that would result in an estimated 1,491 daily trips, or an additional boost of 104 daily trips from Scenario 1.

[43] *Note:* Scenario 0's annual trips is 236,446. For comparison between weekday only and weekday plus weekend service, we represent daily ridership as 788 averaged over the year with an annualization factor of 300, though the weekday trip count is 916. The increase in weekday trips is still around 748 trips.

Scenario 2 represents service if we were to only run the P7 express on new trips that did not previously exist, avoiding disruption for current riders. However, this could cause significant confusion for P7 riders with alternative routings at different times of day.

We see that the loss in ridership for Edgewood Ave stops means that the ridership increase from Scenario 2 to 3 is minimal (about 25 additional daily trips). This means that determining the best service change for running P7 express should involve significant rider input.

Scenario 2 reprsdfdsfesents service if we were to only run the P7 express on new trips that did not previously exist, avoiding disruption for current riders. However, this could cause signficant confusion for P7 riders. We see that the loss in

Figure 54. P7 Service Change Scenarios Ridership Cross-Comparison Chart (absolute trips)

		To		
	Ridership Diff	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	875	954	980
	Scenario 1		79	104
	Scenario 2			25

Figure 55. P7 Service Change Scenarios Ridership Cross-Comparison Chart (% riders)

		To		
	Ridership % Diff	Scenario 1	Scenario 2	Scenario 3
From	Scenario 0	111.1%	121.1%	124.3%
	Scenario 1		4.7%	6.3%
	Scenario 2			1.5%

New transit trips vs. shifted transit trips: Of the off-peak increase, approximately 78% of daily riders (weekday estimate only) are attributed to shifts from other routes to the P7, with the top routes impacted being the 67 and the P10. There would be significant travel time savings for those shifted riders due to faster or more frequent service.

This means that 22% of the increase in ridership would be projected as new transit trips, converted from the automobile mode.

Takeaways

It's clear that a large ridership boost comes from running the P7 all day and weekend, and providing express service is operationally more cost-effective while providing travel time benefits to riders.

Scenario 3 ends up being most logical from both an operations and ridership perspective. This holds after accounting for disrupted riders who would be shifted to the 61A servicing the same stops, or walk further to the P7's new busway stops if traveling south. Seeing as the P7's current trip schedule runs from 5:23-7:52am and to 2:49-5:54pm, running partial express service would still alter the route for some existing riders and be confusing from a riders' perspective.

Thus, Scenario 3 is recommended, as it requires a modest increase in O&M costs of 8 percent or $459,000 per year while providing 980 additional daily trips (~294,000 additional annual trips)[44] with express service. However, this would first require significant rider input, particularly from existing P7 riders.

Connections to the Waterfront

The Waterfront in Homestead is a major center for retail, entertainment and jobs. It is also the third most requested destination in the Beyond the Busway Survey, giving additional evidence that more connections to the Waterfront would help serve Mon Valley community needs. Currently, the only route servicing Homestead/Waterfront from our interest region is the 59, and there are currently no direct transit connectors between Wilkinsburg and the Waterfront.

According to SPC Cycle 11 projections for 2045,[45] a total of 4,077 trips are expected between the Waterfront and Wilkinsburg districts, with only 3% of those trips via transit - likely again due to the fact that only the 59 services the two regions, with the 59 cutting over from Roslyn.

Figure 56. 2045 Connections to the Waterfront Ridership Trends (SPC Cycle 11 Projections)

	Wilkinsburg to Waterfront	Waterfront to Wilkinsburg	Total Trips
All Trips	6,025	2,129	4,077
Transit Trips (Currently 59 Only)	142	101	122
Transit Modeshare (Currently 59 Only)	2%	5%	3%

The 71 Edgewood Towne Centre route currently runs a limited timetable and route, circulating off the busway from Wilkinsburg station to Roslyn station to Swissvale station. Furthermore, it is one of the more inefficient routes in the system, serving only 90 daily riders at an O&M cost of $19.31 per rider.

As a connecting route, the 71 has the capacity to greatly improve access for the region if it were to connect Wilkinsburg to the Waterfront.

We use the total Wilkinsburg trip count as the trip generation estimate for the Waterfront. The 59 currently runs 38 one-way bus trips a day, which averages about 3.4 transit trips per bus trip, and we apply this rate to the new 71 service frequency to estimate new transit trips for the route.

In order to offset the potential cost of expanding 71 service, we looked into additional scenarios that reduced the runtime of the 59. On such alteration is for the 59 to bypass Rankin, reflecting its pre-Kenmawr bridge routing, with a shorter ride between Braddock and the Waterfront. This also saves about 10 minutes of run-time from the route, which is one of the longest in the system, and provides some operations cost savings. The final scenario doubles 59 route service (still bypassing Rankin) in addition to the extension to the Waterfront.

[44] Accounting for weekend and weekday ridership seperately , or a annulaization factor of 300

[45] https://www.spcregion.org/wp-content/uploads/2020/03/Cycle-11-by-munic-2015-2045.pdf

Table 6. Waterfront Connections with 71 and 59 Scenarios

	71	59
Scenario 0	Runs in off-peak Wilkinsburg to Swissvale	4 hour 30min roundtrip runtime, routes to Rankin
Scenario 1	Extends to the Waterfront Runs all-day and weekend	Bypasses Rankin, saving 20 minutes roundtrip runtime
Scenario 2	Same as Scenario 1	Bypasses Rankin, double the frequency

Operations & Maintenance Costs

The chart below breaks down the different cost scenarios.

Figure 57. Waterfront Connections with 71 and 59 Scenarios O&M Projections

	Scenario 0	Scenario 1	Scenario 2
Wkdy VRM	909	952	1687
Wknd VRM	699	740	1360
Wkdy VRH	93	98	183
Wknd VRH	72	77	149
PV	6	7	12
Year VRM	309,161	324,394	579,969
Year VRH	31,538	33,484	63,202
Total	$ 4,743,557	$ 5,147,425	$ 9,439,814

Figure 58. Waterfront Connections with 71 and 59 Scenarios O&M Cross-Comparison Chart ($)

		To	
	Delta Table	Scenario 1	Scenario 2
From	Scenario 0	$ 403,900	$ 4,696,257
	Scenario 1		$ 4,292,388

Figure 59. Waterfront Connections with 71 and 59 Scenarios O&M Cross-Comparison Chart (%)

		To	
	% Delta Table	Scenario 1	Scenario 2
From	Scenario 0	9%	99%
	Scenario 1		83%

The significant jump in Scenario 2 makes sense, given the cost of doubling service on such an extensive route.

Scenario 1 shows an increase of $675k for the extension of the 71 to The Waterfront. This cost could also be offset by the 59 reroute, savings $271k in costs.

Figure 60. Waterfront Connections with 71 and 59 Scenarios O&M Color-coded ($)

	Scenario 0		Scenario 1	
	59	**71**	**59**	**71**
Wkdy VRM	830	79	735	216
Wknd VRM	699	0	619	121
Wkdy VRH	86	7	79	19
Wknd VRH	72	0	67	11
PV	5	1	5	2
Year VRM	288,595	20,566	255,575	68,819
Year VRH	29,718	1,820	27,517	5,967
Total	$ 4,343,900	$ 399,657	$ 4,072,894	$ 1,074,532
Difference			$ (271,006)	$ 674,875

Ridership Projections

Figure 61. Waterfront Connections with 71 and 59 Scenarios Ridership Projections

In Scenario 1, the estimated increase in daily ridership (offset somewhat by the loss of 59 Rankin ridership) is about 449 daily trips. Scenario 2 likewise shows that though the cost is high, that a significant increase in ridership could come from doubling service on the 59.

Figure 62. Waterfront Connections with 71 and 59 Scenarios Ridership Projections (absolute trips)

		To	
	Ridership Diff	Scenario 1	Scenario 2
From	Scenario 0	449	1,671
	Scenario 1		1,222

Figure 63. Waterfront Connections with 71 and 59 Scenarios O&M Cross-Comparison Chart (% riders)

		To	
	Ridership % Diff	Scenario 1	Scenario 2
From	Scenario 0	21.9%	81.6%
	Scenario 1		48.9%

Takeaways

Extending the 71 to The Waterfront and expanding its service would provide needed Waterfront connections with a boost of 449 daily trips (~164,000 annual trips) at a $403,900 annual cost, if offset by a reroute of the 59.

Monroeville Mall via Braddock & Turtle Creek

Initially, the Monroeville via Braddock & Turtle Creek corridor was flagged as the area of greatest interest. When broken down by origins and destinations of interest from the survey, however, the region-to-region travel did not rank as high. This indicates to us that interest in this corridor is primarily due to the points of interest accessible along the Monroeville via Braddock & Turtle Creek corridor (RIDC Keystone Commons, Monroeville Mall, UPMC East, Forbes Hospital).

However, since it was rated the highest corridor of interest, we made an estimate of costs and ridership. Currently, no direct transit trip serves Braddock, Turtle Creek and Monroeville. To estimate the figures for an entirely new route, we looked at the costs of operating along the corridor for a route departing Swissvale Station off the busway, assuming that this route would run express from downtown along the busway to the station. The route could additionally be a feeder route instead, looping to the busway.

Operations & Maintenance Costs

The costs of running a new route express along the busway onto this new corridor comes to $2,650,000. The cost of running the route only as a feeder route requiring a transfer at Swissvale Station would be $1,429,000. The travel time estimates are based on the current run times for P1 for the express route, and a transit for travel time estimator applied to the rush hour travel time for the extension from Swissvale to Monroeville via Braddock and Turtle creek.

Figure 64.

	Express Route	Feeder Route
Wkdy VRM	587	259
Wknd VRM	195.6	86.4
Wkdy VRH	37	19
Wknd VRH	12	6
PV	7	4
Year VRM	172910	76378
Year VRH	10807	5672
Total	$ 2,650,000	$ 1,429,000

A route running express from downtown would take an estimated 58 minutes one way, while a feeder route to/from Swissvale would take an estimated 32 minutes one way.

Ridership Projections

This route does not follow any existing route paths. In order to estimate new ridership for the segment of the route running from Swissvale to Monroeville via Braddock and Turtle Creek, we applied the regression model that took the walkshed characteristics of the new route, including population, median income, equity score, transit usage, population, and vehicle ownership.

We used an estimate of 36 bus trips a weekday, with 20-minute peak headways and 30-minute off-peak headways (running from 6am to 9pm each day), as well as an estimated 12 bus trips each Saturday and Sunday on 45-minute headways. Our model estimated 1,615 daily trips per weekday and 440 trips per weekend day. This comes to a total of about 465,660 annual trips.

Takeaways

While the ridership projection of 1,615 daily trips is promising, this does not take in account trips shifted from other routes such as the potential P68. This scenario, being a new route, was more sparsely analyzed, and worth further study to determine whether the $1.4M-$2.7M in costs would be justified.

Alternatives Analysis: On-Street Improvements

Overview

The next set of possible improvements examined are various **on-street Improvements** – Transit Signal Priority (TSP), Queue Jumps, Dedicated Bus Lanes, and Off-Board Fare Collection. These on-street Improvements were considered as they require much smaller amounts of capital investment than previous estimates for a busway extension. There are several BRT-style on-street and off-street improvements that are not considered in this study that may still be applicable to the Beyond the Busway interest area.[46] Some of these may be considered for future study and include curb extensions (better pedestrian safety and crossings), transit stations (typical, major, intermodal),[47] and improved amenities and accessibility features at stops.[48]

On-street improvements are considered independently of the Service Changes proposed in the previous section, unless otherwise noted for a combined analysis. For each of the on-street improvements, some brief background on the improvement is given, plus the parameters used for the model, and key findings. The primary metrics of interest are **time saved per one-way trip, projected new riders, and capital costs**. From these metrics, we derive aggregate and cost figures for rider and bus hours saved, as well as projected new riders.

Parameters were sourced from BRT transit research, from the PAAC BRT plan, and from the TCRP BRT Practitioner's Guide. Configurable models are provided separately from this report and are meant to serve as a proof-of-concept for improvement estimation, not as conclusive cost or scheduling prescriptions.

The following videos of various on-street improvements are helpful for better understanding how they look in practice:

- **Boston BRT:** (TSP + Queue Jumps + Dedicated Bus Lanes) https://www.youtube.com/watch?v=oDDPbbw_cag
- **Downtown LA:** Queue Jumps https://www.youtube.com/watch?v=l9QsemSE8Y4
- **Toronto, Canada:** TSP https://www.youtube.com/watch?v=t76X4csl6NY

TSP

According to the PAAC Bus Stop and Street Design Guidelines, 10-20% of bus delays occur at signalized intersections.

Transit Signal Priority is a "smart" traffic signal system in which traffic-signal patterns are optimized to improve bus travel patterns. There are three implementation modes of TSP: Passive,

[46]"Bus Rapid Transit Practitioner's Guide." Transit Cooperative Research Program, 2007. https://nacto.org/wp-content/uploads/2015/04/tcrp118brt_practitioners_kittleson.pdf.
[47]"Station Improvement Program." Port Authority. Accessed May 19, 2020. https://www.portauthority.org/inside-Port-Authority/projects-and-programs/transit-oriented-communities/station-improvement-program/.
[48]"Bus Stop and Street Design Guidelines." Port Authority of Allegheny County, July 18, 2019. https://www.portauthority.org/siteassets/inside-the-pa/surveys-and-reports/bsgfinal.pdf.

Active, and Adaptive.[49] Passive TSP simply refers to pre-programming traffic signals to favor bus schedules and frequency. This type of system does not respond to real-time changes in traffic flows. Passive TSP does not require new equipment. Active TSP is the focus of this study. It is the case in which a bus-based transmitter communicates with a receiver in the traffic signal to modify its phases. Types of Active TSP include:[50]

- **Green Extension** – the approaching bus extends the current green light, which was going to turn red before it arrived
- **Early Green** – red/yellow phases are shortened to generate a green light for the bus
- **Phase Insertion** – a special priority phase is inserted
- **Phase rotation** – the order of signal phases is changed

Finally, Adaptive TSP involves generating traffic conditions that are favorable to ALL vehicles on the road. Adaptive TSP requires that vehicles and the traffic grid be connected to the internet to have full information, relevant to assigning traffic signal phases and timings.[51]

Beyond the Busway TSP Model

Transit Signal Priority and Queue Jumps were modeled for several scenarios impacting the Beyond the Busway region. Note that scenarios are divided by those which include TSP from Downtown to Oakland (Pittsburgh BRT), and those after (east of) Oakland (not included in Pittsburgh BRT):

Beyond the Busway

- TSP on all traffic signals (i.e., signalized intersections) beyond Oakland.
- TSP on traffic signals beyond Oakland, but only on 61ABCD routes.
- TSP on traffic signals beyond Oakland, that are NOT on 61ABCD routes.
- Queue Jumps at selected list of candidate sites

Pittsburgh BRT

- TSP on all traffic signals from Downtown to Oakland (Pittsburgh BRT)
- TSP on all traffic signals including Downtown through Beyond the Busway interest area (Pittsburgh BRT + Beyond the Busway)

The detailed methodology used, summarized in the Methods section, is as follows. For TSP, we calculate using GIS the number of intersections with traffic signals on routes in each of the scenarios listed above. There are 546 total traffic signals on all 37 routes from Downtown through

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[49] Kim, Suhyeon, Minchoul Park, and Kyung Chon. "Bus Signal Priority Strategies for Multi-Directional Bus Routes." *KSCE Journal of Civil Engineering* 16.5 (2012): 855–861. Web. (Proquest)

[50] "Bus Stop and Street Design Guidelines." Port Authority of Allegheny County, July 18, 2019. https://www.portauthority.org/siteassets/inside-the-pa/surveys-and-reports/bsgfinal.pdf.

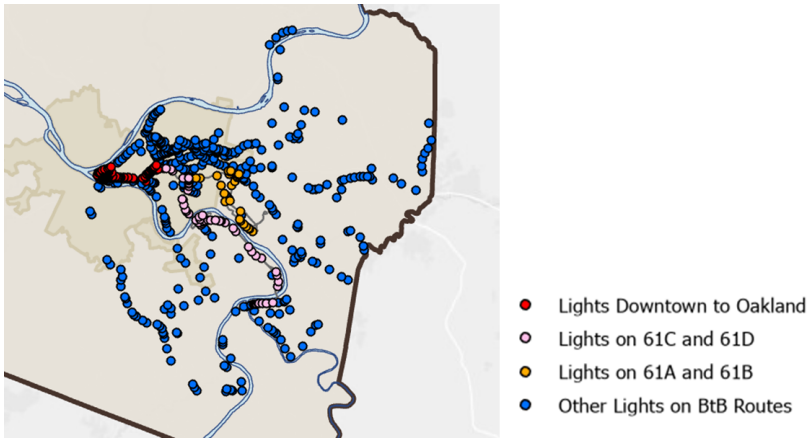
[51] "Transit Signal Priority (TSP)." TransitWiki. Accessed May 19, 2020. https://www.transitwiki.org/TransitWiki/index.php/Transit_signal_priority_(TSP).

the Beyond the Busway interest area. Traffic signals of interest can be viewed on figure 65 and are broken down by scenario in Table 7 below.

Table 7. Traffic Light Counts by Location

Allegheny County	All BtB	All BtB Routes	Downtown to Oakland	Beyond Oakland	61ABCD Past Oakland	61A, 61B Past Oakland	61C, 61D Past Oakland
1477	254	546	99	447	77	34	50

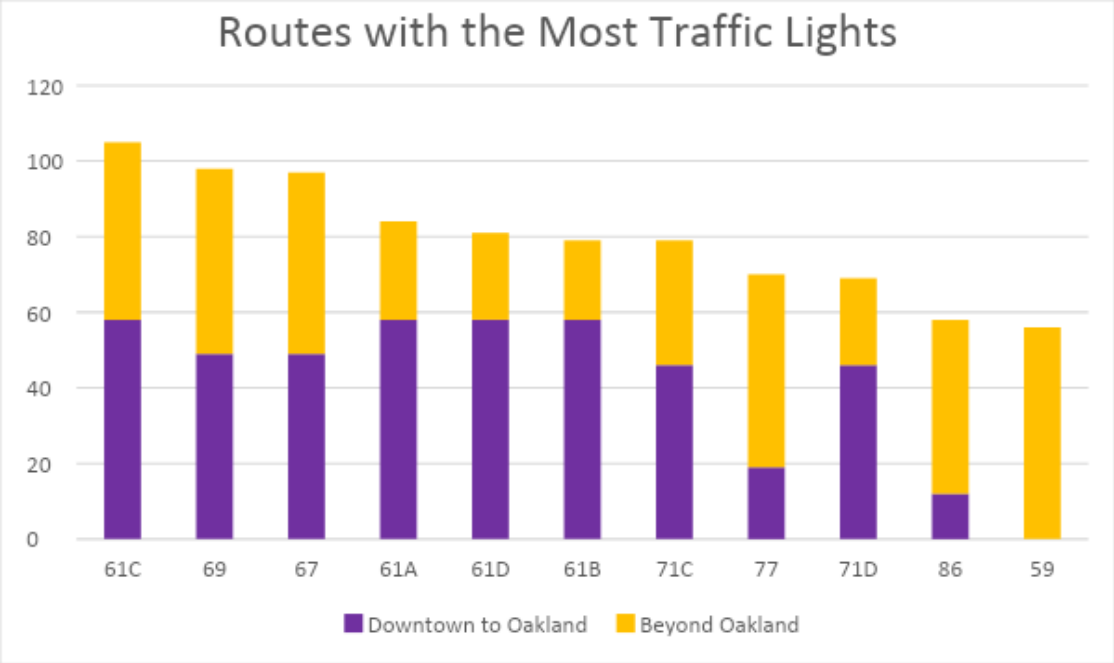
Figure 65. traffic signals on Beyond the Busway Routes



Boundary shapes for county, city, traffic lights, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/.

Note that because routes overlap significantly, the same traffic signal may serve numerous routes. The average number of traffic signals per Beyond the Busway route is 47 – that is, each route intersects with about 9% of all traffic signals within the Beyond the Busway interest area. figure 66 below shows routes with the top number of traffic signals, and thus, top candidates for travel time savings with TSP. Note the large number of traffic signals on the 61A, 61B, 61C, and 61D routes, as well as the 69 and 67. These are all key local routes to the Mon Valley, Monroeville, and Eastern Suburbs region. They will benefit from improved service in the Pittsburgh BRT system and they are prime candidates for further BRT-style improvements.

Figure 66. Traffic Signals on Beyond the Busway Routes by Count



TSP is modeled by calculating time spent at each traffic signal by percentage share of red light. Traffic signals encountered by buses on their routes are assumed to occupy main roads, with 66% of the traffic-signal cycle time. We estimate three scenarios – 10%, 15%, and 25% time-savings for all red-light time, a conservative estimate based on the literature. Implementation of Active TSP has been shown to improve travel times by 10% in Portland, 25% in LA, and 15% in Chicago, on average.[52] The Transit Cooperative Research Program's BRT Practitioner's Guide (TCRP Report 118) suggests TSP improvements of 5 seconds per intersection. While these studies estimate time saved on the entire route, by modeling 10, 15, and 25% savings only for time spent at signals, we take a measured approach. Model parameters used are shown below, in Table 8.

Table 8. Beyond the Busway TSP Model Parameters

Model Parameters	
Signal Cycle Time (s)	60
Main Road Cycle Share (green)	66%
Savings Low Estimate	10%
Savings Medium Estimate	15%
Savings High Estimate	25%

Applying the model to the "All Traffic Signals in the Beyond the Busway" scenario (shown in figure 67), we find that the range of potential peak time savings for the top 15 routes is from between 1-

[52]"Transit Signal Priority (TSP)." TransitWiki. Accessed May 19, 2020. https://www.transitwiki.org/TransitWiki/index.php/Transit_signal_priority_(TSP).

5 minutes, depending on the route. Routes with the highest numbers of signalized intersections benefit the most. In the "All Signals" scenario, the 59, 77, 69, 67, and 61C stand to benefit the most from TSP. To calculate peak ridership increases, we use the peak ridership elasticity figure of -0.5 (there is a 0.5% increase in ridership for every 1% improvement in service time). Using these figures with the 61C as an example, travel time can possibly be improved by 2-4 minutes per trip, with potential ridership increases of between 71 and 175 new riders per day. Other routes such as the 86, 64, 67, 56, and 53L could also experience large increases in ridership.

Figure 67. TSP Time Savings and Improved Ridership for TSP on All Lights Beyond Oakland

TSP ALL Beyond Oakland													
Route Characteristics			Time Savings (min)			Rideship	Improved Peak Time (min)			Improved Peak Riders (daily)		
Route	# Traffic Signals	Time at TSP Signals (min)	Low	Medium	High	Daily	Low	Medium	High	Low	Medium	High
59	56	19	1.90	2.86	4.66	2,142	132	131	130	15	23	37
77	51	17	1.73	2.60	4.25	2,335	77	77	75	26	38	63
69	49	17	1.67	2.50	4.08	1,530	81	80	78	15	23	38
67	48	16	1.63	2.45	4.00	2,146	75	74	73	23	34	56
61C	47	16	1.60	2.40	3.92	6,314	69	68	67	71	107	175
86	46	16	1.56	2.35	3.83	2,937	50	50	48	44	66	108
64	44	15	1.50	2.24	3.67	1,790	50	49	48	26	39	64
55	44	15	1.50	2.24	3.67	1,005	85	84	83	9	13	21
56	41	14	1.39	2.09	3.42	1,700	53	52	50	22	33	54
53L	38	13	1.29	1.94	3.17	1,462	63	63	61	15	22	36

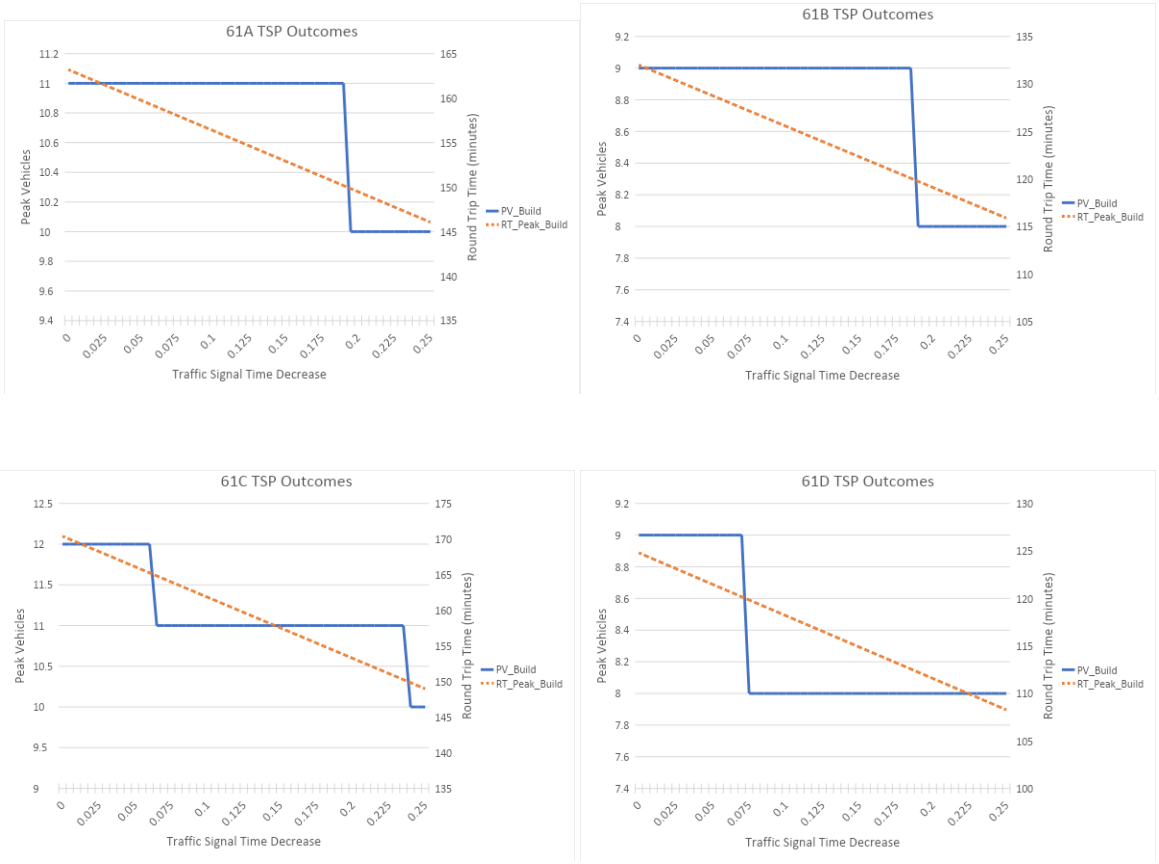
Compare this with the improvements that would abound from integrating TSP only on the 61A, 61B, 61C, 61D lines (shown in figure 68). In this case, the 61C route ranks first in benefits with the same performance metrics stated above. In this scenario, the 59 sees 40% less pronounced time savings with 2.75 minutes saved maximum, as opposed to 4.66 minutes saved in the "All TSP" case. In terms of both time savings and ridership to the 59, 61A, P7, 61D, and 61B all benefit from this implementation.

Figure 68. TSP Time Savings and Improved Ridership for TSP on 61ABCD Lights Beyond Oakland

TSP All 61ABCD Beyond Oakland												
Route Characteristics			Time Savings (min)			Rideship	Improved Peak Time (min)			Improved Peak Riders (daily)		
Route	# Traffic Signals	Time at TSP Signals (min)	Low	Medium	High	Daily	Low	Medium	High	Low	Medium	High
61C	47	16	1.60	2.40	3.92	6,314	69	68	67	71	107	175
59	33	11	1.12	1.68	2.75	2,142	133	133	132	9	13	22
61A	26	9	0.88	1.33	2.17	4,895	67	67	66	32	48	78
P7	25	9	0.85	1.28	2.08	764	50	50	49	6	10	16
61D	23	8	0.78	1.17	1.92	5,451	51	51	50	41	61	100
61B	21	7	0.71	1.07	1.75	4,394	54	54	53	29	43	70
64	18	6	0.61	0.92	1.50	1,790	51	51	50	11	16	26
52L	17	6	0.58	0.87	1.42	429	46	45	45	3	4	7
53L	12	4	0.41	0.61	1.00	1,462	64	64	64	5	7	11
71	10	3	0.34	0.51	0.83	90	30	30	30	1	1	1

While the number of minutes of time saved may be small when measured per bus trip or per intersection, the implications of potentially saving 2-4 minutes per trip on the 61A, 61B, 61C, and 61D impact the entire transit network. See the step-graph figures for the 61A-D on figure 69 below. The x-axis denotes the traffic signal time decrease as a percentage of red-light time, while the y-axis denotes the number of peak vehicles required on that route. We see that at a certain threshold of service time improvement, the speedup of each route means there is a possible reduction in the number of peak vehicles needed to maintain the current headway, by one vehicle. For the 61A and 61B, this threshold is breached at around 20% red-light time saved, which is accomplished in the "High" (25%) savings scenarios above. Both the 61C and 61D can achieve this peak vehicle reduction near the 8% red-light time saved threshold, which is accomplished within the "Low" (10%) scenario above. Further, the 61C has a second possible peak vehicle reduction opportunity if over 23% of time at red lights is reduced.

Figure 69. Peak Vehicle Reduction Step Diagrams (61A upper left, 61B upper right, 61C lower left, 61D lower right)



These peak vehicle savings can be translated into dollar figures through Operating & Maintenance calculations presented in figure 70, below. Modeling the range from 10% to 25% red light savings on only lights Beyond Oakland (non-Pittsburgh BRT), the 61A and 61B combined stand to save between approximately $88,000-$220,000 annually due to speedup in all cases and peak vehicle reduction in the 25% case. The 61C and 61D stand to save between $140,000-$350,000 annually, with a reduction in peak vehicles in all cases. Combined, O&M savings due to TSP on the 61ABCD could range from $228,000 to $571,000. Considering these findings, the 61s present large potential gains from integration of TSP, especially on the 61C and 61D.

Figure 70. Annual Projected O&M Savings from TSP completely on the 61ABCD routes

	61A	61B	61C	61D	Total
25% Red Light Savings	$ (119,552.16)	$ (100,571.89)	$ (224,399.02)	$ (126,706.48)	$ (571,229.55)
15% Red Light Savings	$ (71,731.29)	$ (60,343.14)	$ (134,639.41)	$ (76,023.89)	$ (342,737.73)
10% Red Light Savings	$ (47,820.86)	$ (40,228.76)	$ (89,759.61)	$ (50,682.59)	$ (228,491.82)

Using the total number of signalized intersections, we can also compare each of the TSP scenarios, on average (figure 71). See that integrating "All TSP" (all 546 traffic signals on all 37 routes) could yield 3-7% average time savings. TSP improvements on the Pittsburgh BRT alone are estimated at 2-4% speedup for all routes. Installing TSP on all 447 signalized intersections in the Beyond the Busway region could produce similar speedup of 2-4% averaged across all routes.

Figure 71. Overall average range of minimum and maximum savings due to TSP by scenario

	TSP Downtown to oakland	TSP Beyond Oakland	61ABCD Beyond Oakland	Non-61ABCD Beyond Oakland	ALL TSP
Low-High Speedup Range Averaged on all routes	2-4%	2-4%	1-2%	1-3%	3-7%

Now, consider the 61ABCD Beyond Oakland option, which could yield 1-2% average time savings across all routes, matched by 1-3% savings in the Non-61ABCD case. The difference between these two Beyond the Busway scenarios is cost. TSP costs are shown in figure 72 for three cost scenarios: low ($30,000/TSP), medium ($280,000/TSP) and high ($500,000/TSP). TCRP estimates that on average, installing TSP can cost $30,000 per traffic signal. However, in the Pittsburgh BRT project, many traffic signals must be outright replaced, which can cost between $250,000-$500,000 per intersection.[53]

It is important to stress that not all traffic signals may need replacement, so in some cases the low-scenario is reasonable. In other cases, an old system may need to be fully replaced, driving up costs. Comparing costs by scenario, we model $27.7M for "TSP Downtown to Oakland" (Pittsburgh BRT) in the medium case, which seems reasonable given the project's $20.7M budget line item.[54] Total costs for "TSP Beyond Oakland" (Beyond the Busway) range from $13M-$224M, depending on the state of current traffic signals. As previous analysis has shown, the "61ABCD Beyond Oakland" scenario is much more cost-effective in achieving much of the TSP gains for a fraction of the price, with a capital cost range of $2.3M-$39M. Meanwhile implementing TSP on "Non-61ABCD" routes would come with a larger price tag.

Figure 72. Range of costs for TSP by scenario

	TSP Downtown to oakland	TSP Beyond Oakland	61ABCD Beyond Oakland	Non-61ABCD Beyond Oakland	ALL TSP
Traffic Lights	99.00	447.00	77.00	370.00	546.00
Low Cost/Unit	$ 30,000.00	$ 30,000.00	$ 30,000.00	$ 30,000.00	$ 30,000.00
Med Cost/Unit	$ 280,000.00	$ 280,000.00	$ 280,000.00	$ 280,000.00	$ 280,000.00
High Cost/Unit	$ 500,000.00	$ 500,000.00	$ 500,000.00	$ 500,000.00	$ 500,000.00
Low Cost	$ 2,970,000.00	$ 13,410,000.00	$ 2,310,000.00	$ 11,100,000.00	$ 16,380,000.00
Med Cost	$ 27,720,000.00	$ 125,160,000.00	$ 21,560,000.00	$ 103,600,000.00	$ 152,880,000.00
High Cost	$ 49,500,000.00	$ 223,500,000.00	$ 38,500,000.00	$ 185,000,000.00	$ 273,000,000.00

Note again that the projected annual O&M savings of the combined 61C and 61D is up to $350,000. The 61A and 61B could achieve similar savings if TSP is particularly effective. Thus, to some extent, investing in this corridor will begin to help pay for a portion of its capital costs.

Overall, these conclusions about potential costs and benefits warrant a future study of TSP implementation at specific intersections in the Beyond the Busway interest area. While this study stays somewhat general, rather than examining individual TSP locations, several sites did emerge

[53] "Traffic Signals." WSDOT, November 15, 2019. https://www.wsdot.wa.gov/Operations/Traffic/signals.htm.

[54] "Small Starts Application: Financial Plan." Port Authority of Allegheny County, September 2018. https://www.portauthority.org/link/b6c62ce8e59e4a4b8ee6c91dc84528c7.aspx .

as possible candidates in this preliminary analysis and could be used as a basis for future investigation:

Locations of interest for congestion/slowdown:

- Forbes and Braddock
- Edgewood and Braddock
- Braddock and Monongahela
- Hazelwood Ave. at Browns Hill Road/Beechwood Boulevard
- Homestead Grays Bridge and 8th Avenue in Homestead
- Ardmore Boulevard at Brinton Road
- William Penn Highway
- Mosside Boulevard at Northern Pike
- Haymaker Road at Mosside Boulevard

Lastly, it is worth noting that whereas we attributed capital costs of TSP to our study, the long-term trend of all traffic systems will be towards "smart" infrastructure. The findings of this section suggest that given the pilot approach of the Pittsburgh BRT, the Beyond the Busway region is well-positioned to begin integrating this technology in the short-term.

Queue Jumps

Queue Jumps are priority lanes at which buses can bypass ("jump") ahead of traffic ("queue").[55] The Queue Jump can be located in either the right or left-turn lane, and should be long enough for a bus or buses. The lane is then signalized, using TSP to give the bus lane a special phase to move ahead of traffic. Some criteria for Queue Jump candidate sites include intersections with buses that have less than or equal to 15 minute headways, traffic volumes greater than 250 vehicles/hour in the curb lane, poor on-time service, and where infrastructural improvements are feasible and affordable.[56]

[55] "Queue Jump." Wikipedia. Wikimedia Foundation, April 19, 2020. https://en.wikipedia.org/wiki/Queue_jump .

[56] Special thanks to Keith Johnson for the background on TSP and Queue Jumps.

Candidate sites for Queue Jumps were identified at such intersections:

- Forbes and Murray (Outbound)
- Murray at Forward & Pocusset (In and Outbound)
- Ardmore at Yost (In and Outbound)
- Forbes & Braddock (AM Inbound, PM Outbound)

Figure 73. Possible Queue Jump Locations and Impacted Routes

Queue Jump Candidate Sites and Impacted Routes

Forbes and Murray Outbound	Murray Avenue at Forward Avenue/Pocussett	Ardmore at Yost Inbound	Ardmore at Yost Outbound	Braddock and Forbes (AM Inbound, PM Outbound, count as one in either direction at any time)
61A	61C	69	69	61A
61B	61D	P69	P69	61B
61C	93	P79	P79	
61D	64			

Figure 74. Possible Queue Jump Location(s) at Forbes and Braddock

A full list of routes impacted by the possible queue jump locations can be found in figure 73. TCRP estimates queue jumps save 6 seconds of trip time per intersection. To be conservative, we modeled three cases of savings: low (2 seconds), medium (4 seconds), and high (6 seconds) of savings. Overall, given the small number of queue jumps, the impact is relatively negligible compared to TSP. At most, the 61C or 61D could be sped up by 0.3 minutes. As we saw with TSP, small service improvements can still dramatically reduce annual costs. However, we find overall that more queue jump locations would need to be identified, and combined with TSP and other improvements to truly make an impact.

Figure 75. Breakdown of time savings with Queue Jump implementation

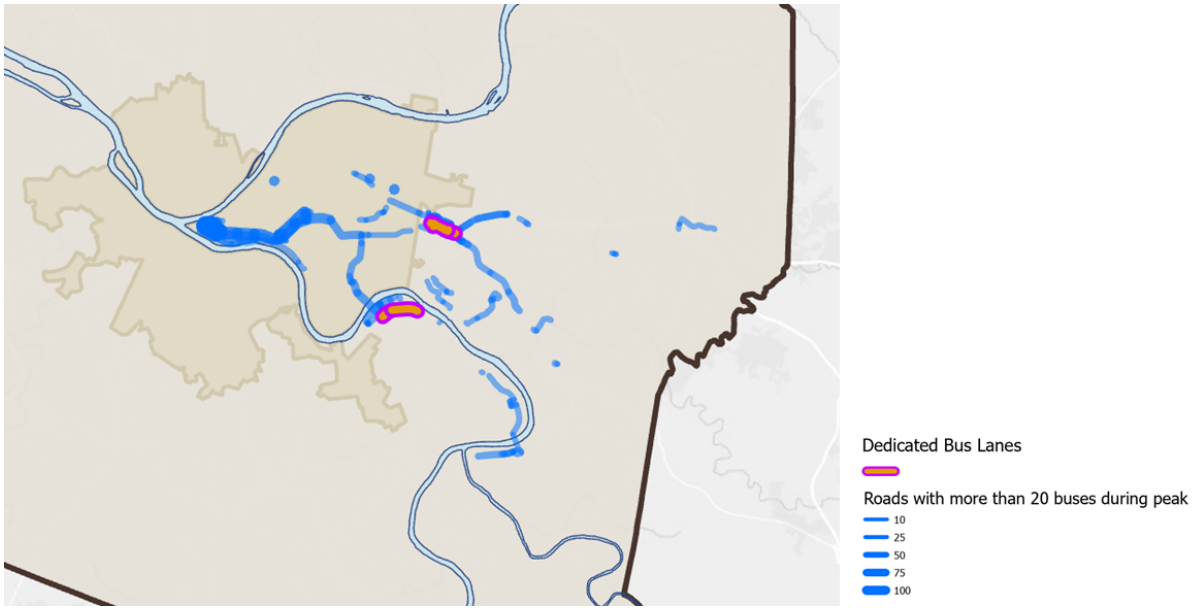
Route Info		Time Savings (min)		
Route	# Queue Jumps	Low	Med	High
61C	3	0.10	0.20	0.30
61D	3	0.10	0.20	0.30
64	2	0.07	0.13	0.20
69	2	0.07	0.13	0.20
93	2	0.07	0.13	0.20
61A	2	0.07	0.13	0.20
61B	2	0.07	0.13	0.20
P69	2	0.07	0.13	0.20

Dedicated Bus Lanes

As mentioned in the BRT section, a key aspect of the Pittsburgh BRT will be dedicated bus lanes, which allow buses to travel at the City speed limit of 25MPH. According to TCRP's BRT Practitioner's Guide, the primary conditions needed to justify and benefit from dedicated bus lanes include: "1) a sufficient frequency of buses, 2) traffic congestion along the roadway, 3) suitable street geometry, and 4) community willingness to enforce the regulations."

To identify possible candidate sites for bus lanes, we used ArcGIS to search every route within the Beyond the Busway interest area for routes with at least 20 peak vehicles at a given time. See below for the full map of possible candidate sites. (Note: an alternative parameter to use for this would be directional bus trips per hour.) All identified candidate sites are shown in figure 76.

Figure 76. Candidate Sites for Dedicated Bus Lanes



Boundary shapes for county, city, roads and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Route shapes generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/.

We then consulted with our advisory board to identify areas that meet conditions 2) and 3) above. Two primary sites emerged: South Ave in Wilkinsburg during AM Peak Inbound service and East 8th Avenue in Homestead during AM Peak Inbound service. To model speedup, we applied the following formula:

Miles traveled on dedicated lane x (1/Current MPH - 1/ New MPH)

From TCRP parameters, we estimated capital costs at $100,000 per mile, which could include right-of-way, design, utilities, paving, sidewalk rebuilding, etc. However, with the sites identified, these costs might be limited to re-striping and signage, so it is a reasonable estimate. Projected costs for both locations are shown in the table below.

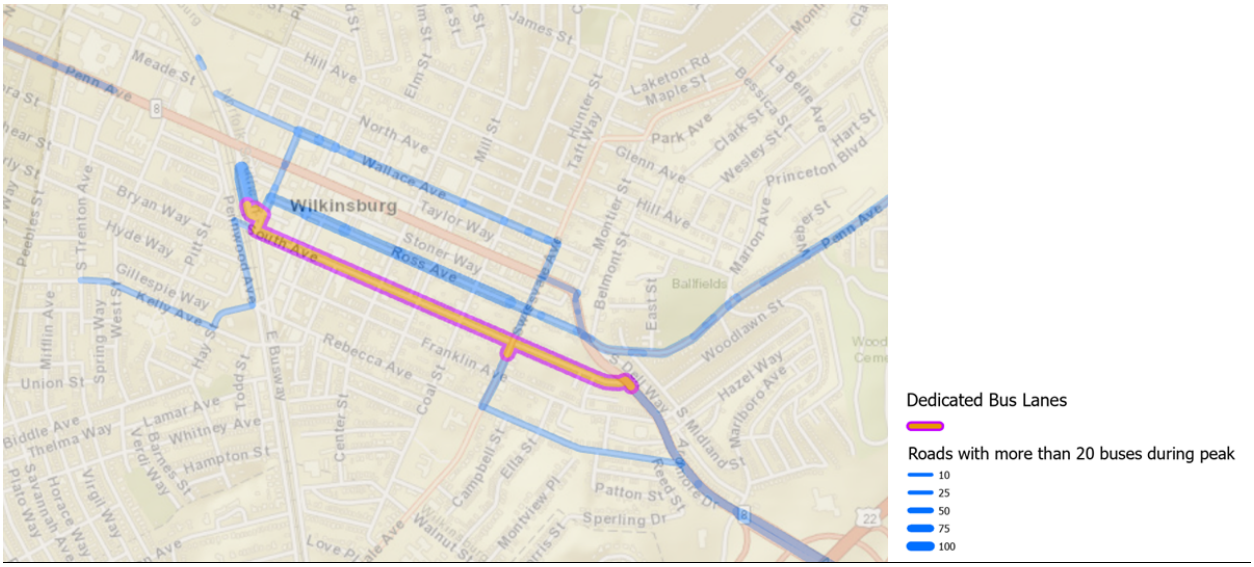
Figure 77. Cost estimates for dedicated bus lanes on South Ave in Wilkinsburg and East 8th in Homestead

	South Ave	East 8th
Total Miles	1.29	0.50
Cost/Mile	$ 100,000.00	$ 100,000.00
Total Cost	$ 129,215.95	$ 50,000.00

For speedup conditions, three project speeds were modeled for both South Ave in Wilkinsburg and East 8th Ave. in Homestead: 15MPH, 20MPH, and 25MPH (city speed limit). The middle case is presented here, for each affected route by the given bus lane.

South Ave in Wilkinsburg:

Figure 78. Dedicated bus lane rendering on South Ave. in Wilkinsburg



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Many buses currently use Wilkinsburg either to access the MLK Jr. East Busway, or to head east towards the Mon Valley or Monroeville. Buses currently use Wallace inbound (1-way), Ross outbound (1-way), and South Ave (2-way) to bypass congestion on Penn Ave. and Ardmore Boulevard. This can create congestion on South Ave, which may be improved by a possible dedicated bus lane (shown in figure 78). The maximum length of the lane was modeled as 1.29 miles, which is along the P68 leg of the road. A dedicated lane may justify minor modification of routes to maximize distance traveled in the lane. Time savings by route are shown in figure 79, below.

Figure 79. Potential Time Savings from Dedicated Bus Lane on South Ave. In Wilkinsburg

Route Characteristics		Time Savings (min)		
Route	Miles of Road	Low	Medium	High
P68	1.29	1.29	2.58	3.36
P7	1.00	1.00	1.99	2.59
P69	0.82	0.82	1.63	2.12
P76	0.80	0.80	1.60	2.07
61A	0.59	0.59	1.18	1.53
69	0.29	0.29	0.58	0.76

East 8th Ave. in Homestead

A dedicated bus lane was also modeled on East 8th Ave. in Homestead, for 0.5 miles, inbound during AM peak hours. Future studies would need to estimate the exact length of a potential lane, as East 8th extends up to 1.2 miles (shown in figure 80). Assuming a 0.5 mile lane, time savings may be as high as 0.8 minutes on each the 52L, 53, and 61C (figure 81).

Figure 80. Rendering of possible dedicated bus lane on East 8th in Homestead

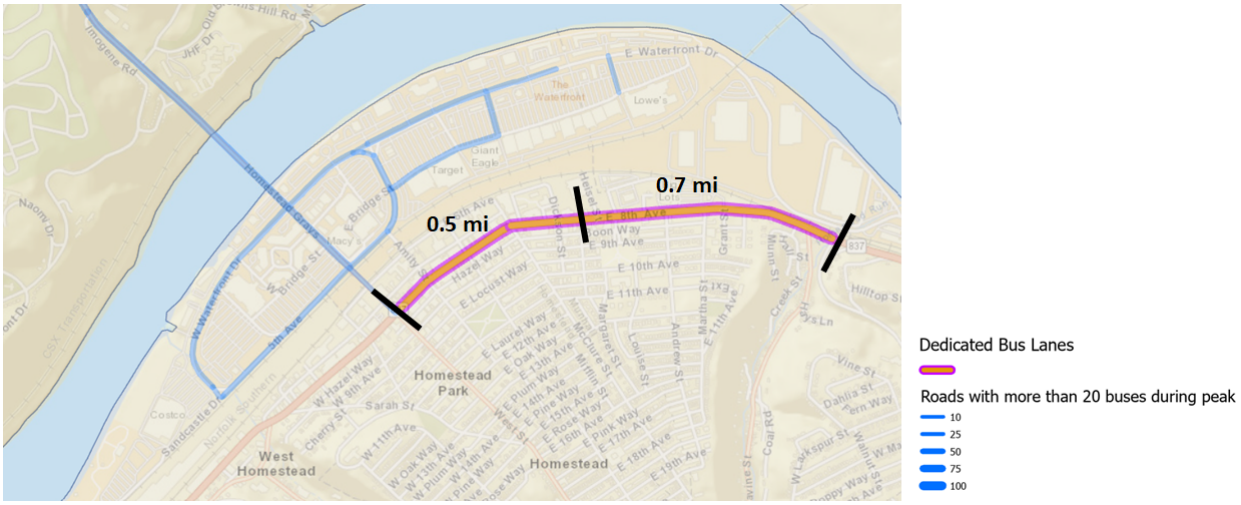

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Figure 81. Potential Time Savings from Dedicated Bus Lane on East 8th Ave. in Homestead

Route Characteristics		Time Savings (min)		
Route	Miles of Road	Low	Medium	High
53	0.50	0.0	0.5	0.8
52L	0.50	0.0	0.5	0.8
61C	0.50	0.0	0.5	0.8

Overall, dedicated bus lanes in both Wilkinsburg and Homestead have the possibility to speed up trips by up to 2.5 minutes and 0.5 minutes, respectively. Further, at under $40,000 per minute saved in Wilkinsburg and under $62,500 per minute saved in Homestead, these are cost-effective measures. These preliminary estimates should warrant future feasibility and cost studies, as well as identification of other dedicated bus lane candidates.

Off-Board Fare Collection

The Pittsburgh BRT will include an off-board fare collection system in which riders purchase a ticket, load a connect card, or load credit to a new app (in development) before boarding. PAAC does not currently have a system in place for off-board fare collection, but it will not have a paid zone at stations, due to pedestrian right-of-way issues. Ticket vending machines will be purchased and cost about $60,000 each.

In the off-board fare collection system, cash will no longer be paid on the vehicle. PAAC states that cash riders take 15 seconds to board the bus, while ConnectCard or the new app takes 2 seconds per rider. Thus, the potential time savings for moving more routes to off-board fare collection can be modeled as a function of the percentage of cash-paying riders, the average number of riders per trip, and the percentage of cash-riders who are projected to convert to non-cash payment. We model the potential speedup with the following equation, for three scenarios of % Riders switching from cash: 25%, 50%, and 100%.

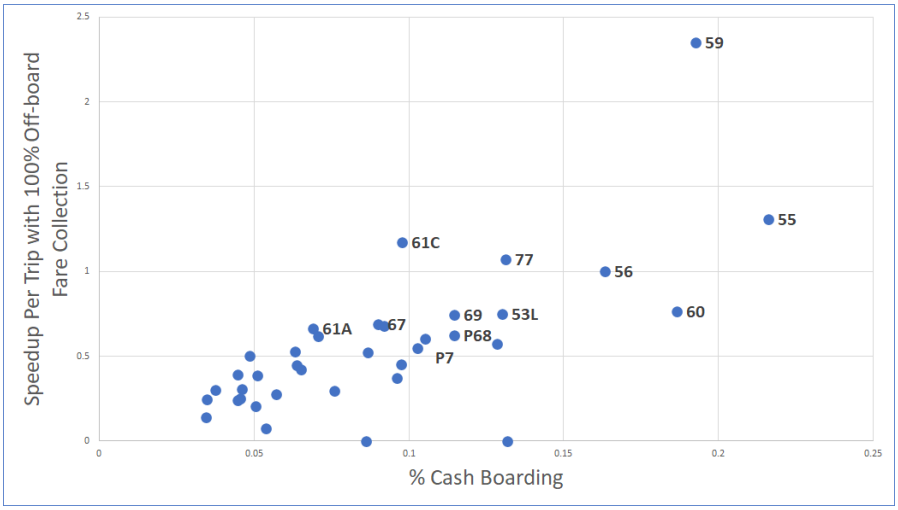
% Cash Users * Avg. Daily 1-Way Riders per Trip * % Riders switching from cash

Results for routes with the greatest benefit of off-board fare collection are shown in figure 82 below. Routes with highest potential for speedup due to off-board fare collection include the 59 (2.35 minutes maximum savings) and 55 (1.3 minutes maximum savings) for their high percentage of cash users, and the 61C (1.2 minutes maximum) for its large number of riders per trip. The scatterplot in figure 83 also shows this relationship, as routes with large time savings either have high ridership, percentage cash users, or both.

Figure 82. Potential time savings for various off-board fare collection adoption rates, based on average daily riders and % cash users.

Route Characteristics			Time Savings (min)		
Route	% Cash Users	Avg. Daily Riders 1-Way	Low	Medium	High
59	19%	56	0.59	1.18	2.35
55	22%	28	0.33	0.65	1.31
61C	10%	55	0.29	0.59	1.17
77	13%	38	0.27	0.54	1.07
56	16%	28	0.25	0.50	1.00
60	19%	19	0.19	0.38	0.76
53L	13%	27	0.19	0.37	0.75
69	11%	30	0.19	0.37	0.74
67	9%	35	0.17	0.34	0.69
86	9%	34	0.17	0.34	0.68
61A	7%	45	0.17	0.33	0.67
P68	11%	25	0.16	0.31	0.62
P1	7%	40	0.15	0.31	0.62
P7	11%	26	0.15	0.30	0.60

Figure 83. Scatterplot of Speedup per trip with 100% off-board fare collection vs. % Cash Boarding.



Aggregated among all 37 routes, the average maximum off-board time savings per rider is 0.63 minutes. This equates to over 300,000 rider-hours and over 8,000 vehicle hours saved annually.

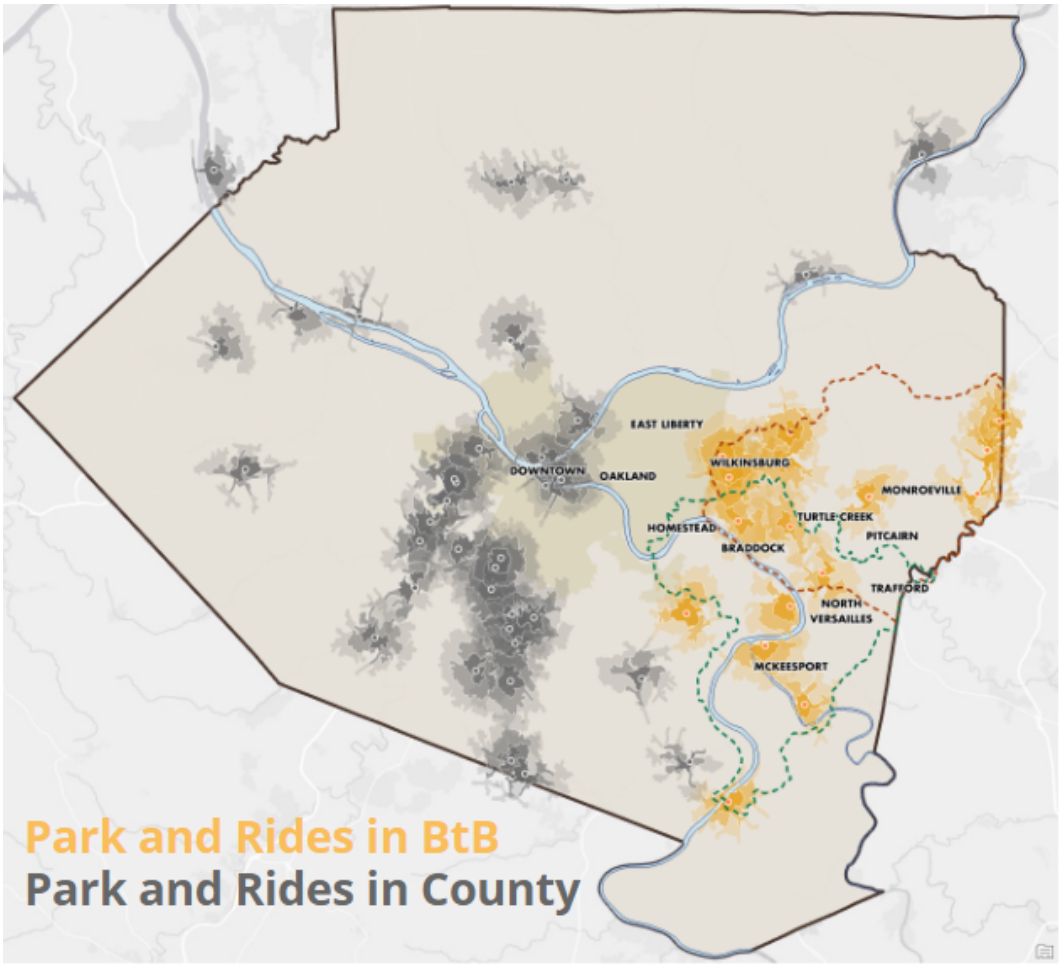
One challenge in implementing off-board fare collection is facilitating a transition for current cash-paying riders. While this study does not go in-depth with estimating optimal processes or locations for ticket sales, it is worth considering a few assumptions for purposes of cost estimation and stimulating future work on possible locations.

Presently, there are 13 park-and-ride locations within, or within the walkshed of the Beyond the Busway interest area (figure 84). Additionally, there are 20 PAAC fare purchase locations (both PAAC and non-PAAC) within the region (figure 85). Lastly, note that of 26,671 average daily stop boardings in the interest area, 7,163 (27%) are covered by the top 25 most frequently on-boarded at stops.

We assume 25 new fare collection systems as an upper-bound cost to cover much of the Beyond the Busway region with off-board ticket sales. At a price of $60,000, we estimate $1.5M to help

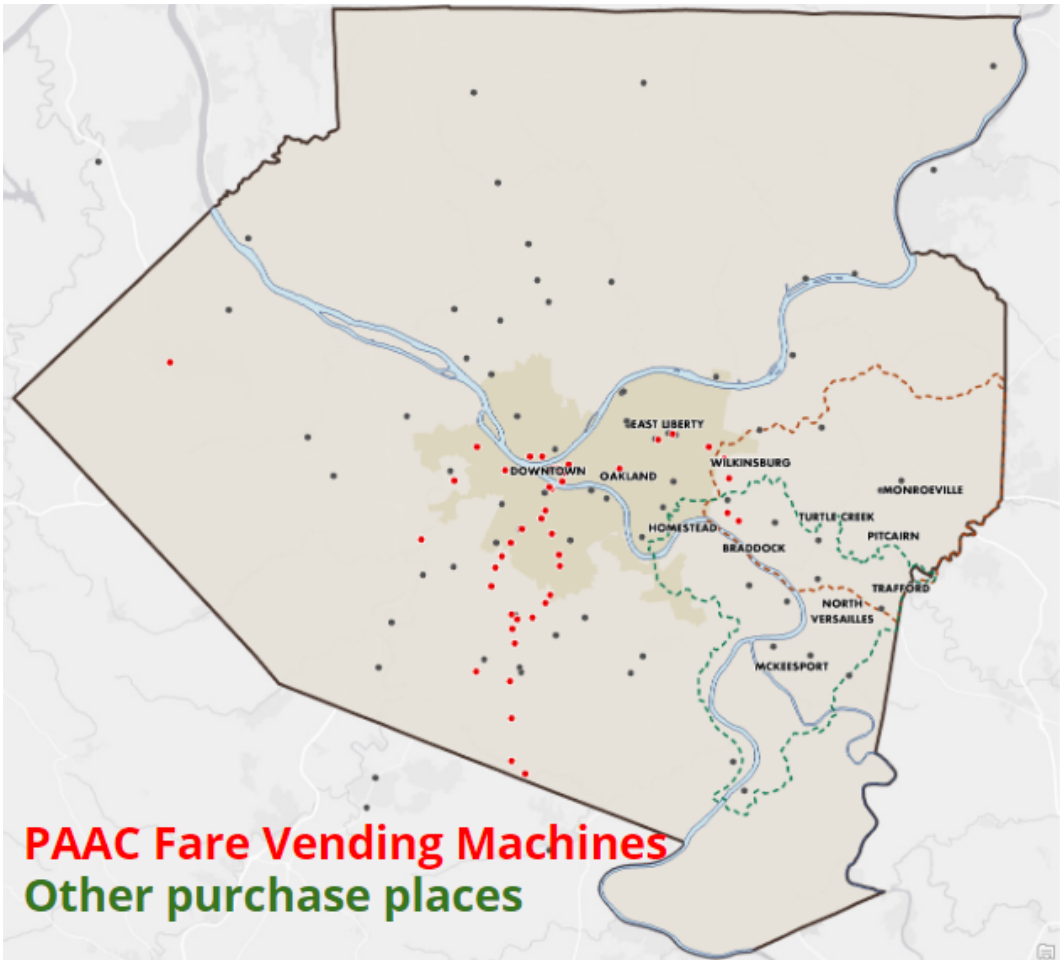
implement off-board fare collection system-wide. It is possible that the number of systems needed is fewer, or slightly more. Truly understanding the needs of riders in purchasing tickets in person or using the in-development app would take another study.

Figure 84. Park and Rides in the Beyond the Busway Interest Area shown in gold, outside the Interest Area shown in Gray



Boundary shapes for county, city, and rivers created from available data at Allegheny County GIS Open Data http://openac-alcogis.opendata.arcgis.com/. Park and Ride locations generated from data made available by Port Authority of Alleghneny County https://www.portauthority.org/business-center/developer-resources/. Walksheds generated with use of Esri, HERE, Garman, OpenStreetMap contributors, and the GIS user community via the Network Analysis tool http://www.arcgis.com

Figure 85. PAAC Fare Vending Machine sites shown in red, other purchase places shown in green



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Aggregating On-Street Improvement Results

Capital costs, annual benefits, and cost per annual benefits are shown in figure 86 below. Cases shown for TSP and dedicated bus lanes are the "medium" savings projections, with off-board fare collection shown at the upper-bound of 100% non-cash trips. Capital costs for TSP are modeled at the "medium" $280,000 case, as a conservative estimate.

For an apples-to-apples comparison, the Pittsburgh BRT offers the most efficient impact, potentially saving 13,221 annual bus-hours at the cost of $2,097 per annual bus/hour saved. "TSP Beyond Oakland" offers the next largest impact in terms of rider and bus hours, but is over double the cost per bus hour than the TSP on 61ABCD lines scenario, which offers relatively efficient gains at $4,286 per bus hour saved. This is nearly double the cost-efficiency of the Pittsburgh BRT, but half that of the "TSP Beyond Oakland" scenario.

The bulk of TSP costs in the Beyond the Busway region would be on non-61ABCD lines. Off-board fare collection offers a promising opportunity for aggregate time savings in the system, distributed

amongst all routes. Dedicated bus lanes offer the overall greatest benefit for their cost at $258.38 per bus hour saved per year. However, with only two locations considered, dedicated lanes offer only 10-20% of the total possible benefits, relative to all other interventions. Queue jumps are not shown, as they should be bundled with TSP.

Figure 86. Overall costs and benefits for TSP scenarios modeled in the "Medium" case and off-board fare collection modeled in the 100% adoption case. Dedicated bus lanes and queue jumps not shown due to lower relative aggregate impact, however efficient they are.

	TSP Downtown to oakland	TSP Beyond Oakland	TSP 61ABCD Beyond Oakland	All Non-61ABCD Beyond Oakland	Only Off-Board Fare Collection
Units	99	447	77	370	25
Cost/Unit	$280,000	$280,000	$280,000	$280,000	$60,000
Total Cost	$27,720,000	$ 125,160,000.00	$ 21,560,000.00	$ 103,600,000.00	$ 1,500,000.00
Yearly Rider Hours	516,275.01	463,709.71	198,869.06	264,840.65	216,800.33
Yearly Bus Hours	13,221.99	13,498.46	5,030.84	8,467.62	5,805.37
Yearly New Riders	176,708.73	226,172.13	54,468.14	171,703.99	112,009.31
$/Rider Hour Saved/year	$ 53.69	$ 269.91	$ 108.41	$ 391.18	$ 6.92
$/Bus Hour Saved/year	$ 2,096.51	$ 9,272.17	$ 4,285.56	$ 12,234.85	$ 258.38
$/New Rider	$ 156.87	$ 553.38	$ 395.83	$ 603.36	$ 13.39

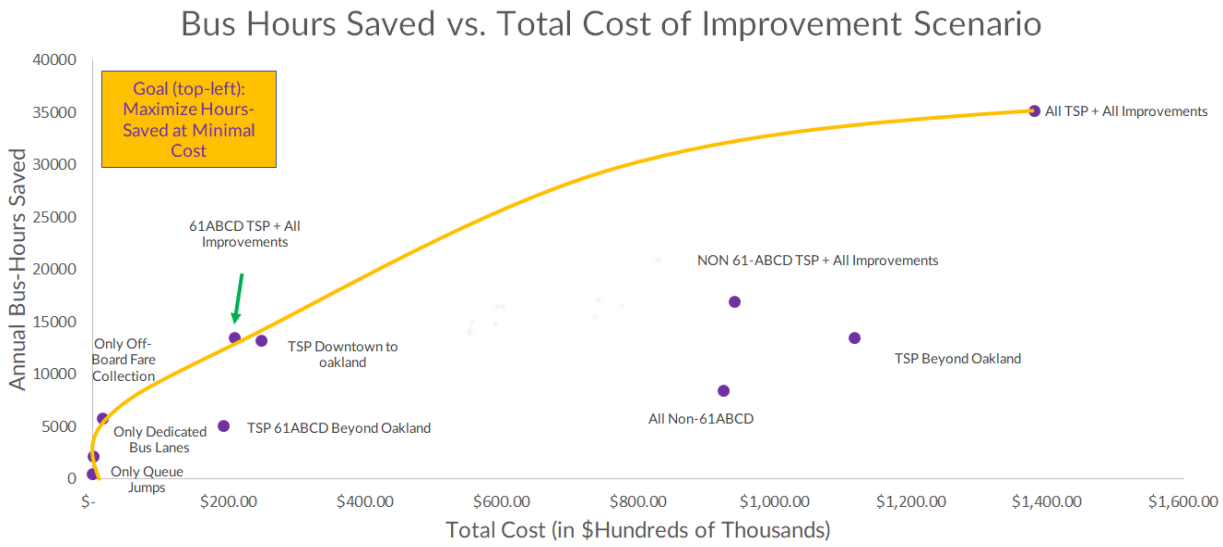
The three combined improvement scenarios considered are: 1) "All TSP + All Improvements" to the Beyond the Busway interest area; 2) "TSP on the 61ABCD + All Improvements," lines only and all improvements elsewhere; and 3) "Non 61ABCD TSP + All Improvements." All improvements after TSP include queue jumps, off-board fare collection, and dedicated bus lanes. These combined improvement scenarios are shown in figure 87.

Implementing scenario 1) results in massive benefits, with up 1.25M rider hours saved and 35,173 bus hours saved, and drawing in up to 2,000 new riders per day. This is also the costliest option, on the order of up to $154M in capital costs. Combined improvements along the 61-ABCD lines again show the biggest bang for their buck – achieving over 35% of the gains of the All TSP scenario for 22% of the cost, at a medium estimate of $23M. Again, the Non-61ABCD shows itself to be the more expensive, but the more impactful intervention, in aggregate, than the 61ABCD combination. See the efficiency graph in figure 88 for further proof that implementing TSP on the 61A, 61B, 61C, 61D coupled with all other improvements yields the largest impact for the lowest cost.

Figure 87. Overall costs and benefits when modeling three scenarios of TSP plus ALL other improvements: queue jumps, dedicated bus lanes, and off-board fare collection.

	All TSP + All Improvements	61ABCD TSP + All Improvements	NON 61-ABCD TSP + All Improvements
Total Cost	$ 154,559,215.95	$ 23,239,215.95	$ 105,279,215.95
Yearly Rider Hours	1,267,536.82	486,421.16	552,392.75
Yearly Bus Hours	35,173.58	13,483.97	16,920.74
Yearly New Riders	571,863.20	223,450.47	340,686.32
$/Rider Hour Saved/year	$ 121.94	$ 47.78	$ 190.59
$/Bus Hour Saved/year	$ 4,394.19	$ 1,723.47	$ 6,221.90
$/New Rider	$ 270.27	$ 104.00	$ 309.02

Figure 88. Efficiency Frontier Mapped to All Improvements



Another way to consider the aggregate improvements is at the route level. When combining on-street and service improvements, the routes that benefit the most in absolute terms are the 61C, 59, and P7, three core routes to the Beyond the Busway interest area. In figure 89 below, the 61C is shown to save up to 7.2 minutes per trip when factoring TSP from downtown through the beyond the busway area, off-board fare collection, and queue jumps, with TSP contributing the largest share. On-street improvements to the 59 are shown in figure 90, with a plurality of savings coming from off-board fare collection, followed by TSP along the 61A-D routes. Lastly, in figure 91, the potential service time improvement of the P7 staying on the busway is added to the on-street improvement time savings for a total of nearly 12 minutes in time savings from the current route. Note that the lion's share – 9 minutes—is from the busway service change, while TSP may contribute almost 2.5 more minutes in time savings.

Figure 89. Medium-Case Aggregate Time Savings for All Improvements Applied to Route 61C

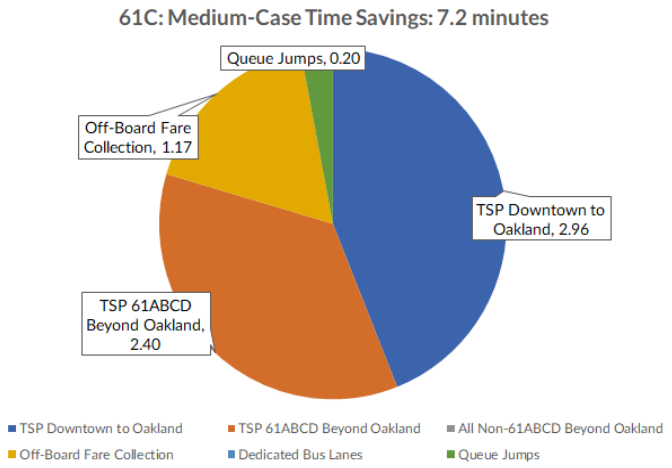


Figure 90. Aggregate Travel Time Savings of On-Street Improvements on Route 59

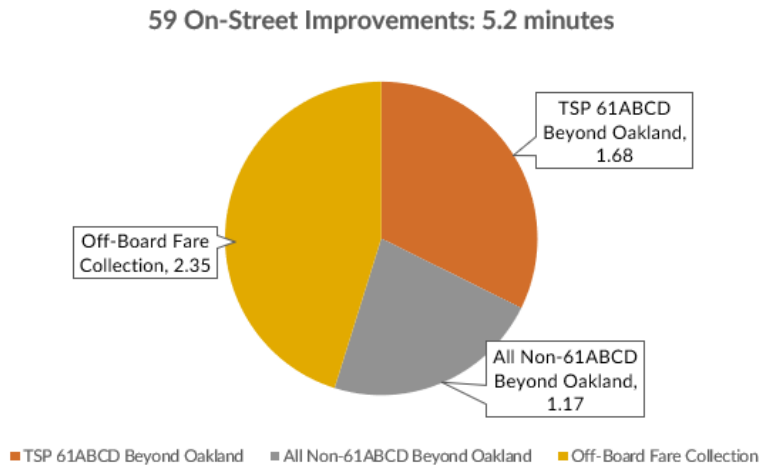
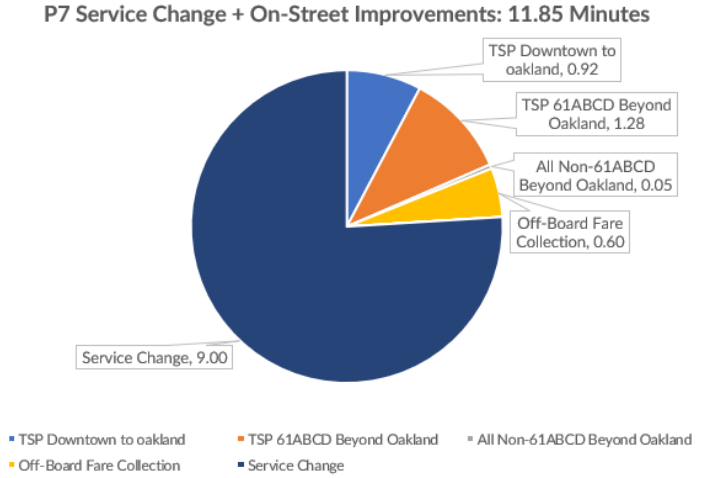


Figure 91. Aggregate Travel Time Savings of P7 Service Change and On-Street Improvements



It is important to note that whereas we attributed capital costs of TSP to our study, the long-term trend of all traffic systems will be towards "smart" infrastructure, so it can be argued that TSP capability will be available as a matter of course a few years down the line. The findings of this section suggest that given the pilot approach of the Pittsburgh BRT, the Beyond the Busway region is well-positioned to begin integrating this technology in the short-term in a way that prepares the region for future growth and technology deployment.

Alternative Analysis: Infrastructural Improvements

Through our analyses we have identified two key, considerably more long-ranged Infrastructural Improvements that could be transformative for the transit system and its delivery in the Beyond the Busway region. Considerably more analysis and development would be required to assess the cost, planning, and engineering of these projects. However, preliminary analysis included in this report highlights the significant upside of these structural improvements.

I-376 Dedicated Bus Ramps

Construction of new ramps from the East Busway after Wilkinsburg along Edgewood Ave. to/from I-376 would allow for the re-routing of the P67, P12, and P16 for faster service to and from Monroeville and the Mon Valley. This was originally intended for the East Busway in the early 1980's but was dropped with the termination of the original busway at Wilkinsburg. Today, with daily Parkway traffic jams as far back as Churchill, such ramps would need to be accompanied by parkway bus lanes (potentially using the shoulder as is done in Minneapolis and elsewhere) between the new ramps and Churchill.

One of the three outbound lanes would be converted to a dedicated bus lane, while a larger infrastructure investment would be required to support inbound traffic as the two lanes and minimal shoulder space in both directions would need to be expanded. The inbound alignment challenge is furthered by the stretch of I-376 being elevated with potential right of way (ROW) constraints. Though we would expect this project to cost in the upper tens of millions, this investment is far below the cost of the proposed busway extension.

Though estimating the cost of this structural infrastructure development is out of the scope of this project, initial service and travel time models indicated significant potential time and O&M savings. Estimated travel times to Monroeville from Downtown Pittsburgh are expected to reduce by 10 to 30 minutes. When incorporating these savings, estimated travel times from the following points of interest in the region are as follows: ~12min. from Wilkinsburg, ~19min. from Churchill, ~30min. from Monroeville Mall, and ~40min. from Forbes Hospital, in total travel time.

Edgewood Busway Station

The Edgewood Busway Station along the existing MLK Jr. Busway would be a rather significant station. It would require a new pedestrian bridge to cross over the busway and existing railroad

tracks. The inbound platform, because of the limited width of the ROW next to the railroad tracks, would have to be built underneath Edgewood Ave. to some extent. Additionally, we anticipate this station would abut the bus lanes, foregoing the bypass lanes at other East Busway stations.

This could impact the flow of buses at peak hours, but not significantly. This location has many fewer buses than the "maximum load point" of the busway, which is located west of Wilkinsburg, and therefore an "on-line" station is more appropriate at the Edgewood location of the proposed new station. Modeling suggests improved service and ridership outcomes on the P7, P71, and 71 routes in particular, with general additional impacts on all other routes using the busway. One particular benefit is that if the station were added, the P7 could stay along the length of the busway while still serving the residents of Edgewood.

Given the existing ROW along the route, the construction of this station is expected to cost far less than a new station on an extended busway. Preliminary research suggests the station could cost around $5M. Furthermore, this project allows for unique financing through transit-oriented development opportunities in and around Edgewood Towne Centre.

Findings, Recommendations and Next Steps

Summary of Findings

Overall, we find that there are numerous effective, efficient, and equitable alternatives within and associated with those called for by PPT's Beyond the Busway initiative. Working with community members to identify desired service changes, on-street improvements, and infrastructural improvements will both maximize the investment and extend the reach of the Pittsburgh BRT, while widely improving service to many thousands of residents in the Mon Valley, Monroeville, and Eastern Suburbs.

A summary table of our key findings can be found on the following page. Overall takeaways are also synthesized below:

Service Changes

Community-supported service changes have the opportunity to increase connectivity and decrease travel time in the most cost-efficient way possible. Some examples are listed below.

- Extending the P68 to UPMC East and Forbes Hospital has the potential to expand transit access to Forbes Hospital, currently unreachable from within the PAAC system. O&M costs would increase, but so would ridership with up to 461 additional daily weekday trips.
- Adding off-peak and weekend service on the P7, while re-routing entirely on the busway could result in faster, more frequent service, while increasing ridership, for modest O&M cost increases
- Extending the 71 to the Waterfront may greatly expand access to the Waterfront for riders from Wilkinsburg through Edgewood, with similar increases in O&M cost to the previous two changes.
- A Monroeville route via Braddock and Turtle Creek has the potential for significant ridership boost, but more analysis is needed to determine how it complements existing service, whether the route should run express or as a feeder, and whether the costs are justified.

On-Street Improvements

- *Transit Signal Priority (TSP)* may provide significant benefits to travel time and O&M costs. Implementing TSP on the 61A, 61B, 61C, and 61D may be particularly cost-efficient, with full emphasis on the 61C. Queue Jumps should be considered as a sub-component of larger emphases on TSP.
- *Dedicated Bus Lanes* provide a highly cost-effective opportunity to speed up ridership. South Ave. in Wilkinsburg and East 8th Ave. in Homestead are among two candidate sites that should be further explored.

- *Off-Board Fare Collection* would provide distributed benefits that impact the entire PAAC system. Further analysis and community engagement should inform methods to maximally deploy this type of system, in line with PPT #FairFares guiding principles.
- *Combining Improvements* further solidifies the gains of any improvement individually, and should be considered to maximize cost-efficiency of investments.

Infrastructure Improvements

- Edgewood Busway Station should be considered for increasing transit oriented development opportunities in the Beyond the Busway interest area, while promoting more effective utilization of the existing busway and adjacent routes. Additionally, if the recommendation of moving the P7 route to the Busway is accepted, building this station would address potential ridership loss to and from Edgewood.
- I-376 Dedicated Bus Lanes would mark a significant step toward resolving structural issues in the delivery of PAAC service to the Beyond the Busway interest area, and providing BRT-like service on important routes by minimizing the impact of a significant peak traffic congestion point on average travel times.

Table 9. Summary of Findings

Top Alternative	Service Benefit	O&M Cost/Savings	Projected New Riders	Capital Cost
P68 Extension to Hospitals - Scenario 1	Transit access to Forbes hospital (previously unserved)	$477,000 in additional O&M costs	461 additional weekday daily trips or 120k additional annual weekday trips	N/A
P7 Express on Busway - Scenario 3	Faster, more frequent service	$459,000 in additional O&M costs	980 additional daily trips, or 294k additional annual weekday and weekend trips	N/A
71/59 - Scenario 1	Transit connection between Wilkinsburg and the Waterfront (previously unserved)	$403,900 in additional O&M costs	449 additional daily trips, or 164k additional annual weekday and weekend trips	N/A
Monroeville via Braddock & Turtle Creek - Feeder Route	Transit connection from Braddock to RIDC, Monroeville Mall (previously unserved)	$1,429,000 in additional O&M costs	~1615 weekday daily trips, ~440 weekend daily trips, or 465k annual trips	N/A
61ABCD TSP	1-2% savings on all routes, up to 4 minutes on 61C	Up to $500,000 saved on 61ABCD, not including other routes	241-590 daily weekday or 72,300- 177,700 annual trips	Low: $2M Medium: $20M High: $40M
Dedicated Bus Lane on South Ave, Wilkinsburg	1-3 minutes speedup on impacted routes	Future Study	Future Study	$130,000
Dedicated Bus Lane on East 8th Ave., Homestead	1 minute speedup on impacted routes	Future Study	Future Study	$50,000
System-wide Off-Board Fare Collection	0.63 minutes average savings on ALL routes	Over 5,000 annual bus-hours saved	112,009 new riders due to speedup	Variable, but potentially $1.5M for 25 ticket locations
Edgewood Towne Centre Station	Increased utilization of the busway	Future Study	Future Study	$5M+ with TOD/TRID Benefits
I-376 Bus Ramp	Significantly Decreased Travel Time	Future Study	Future Study	Future Study
East Busway Extension	Significantly Decreased Travel Time	Increased efficiency of routes	4,091 new daily or 1,227,300 annual trips	$371M (2016 dollars)

to East Pittsburgh)[57]				
East Busway Extension to Monroeville Mall	42 minutes Downtown to Monroeville Mall	Increased efficiency of routes	4,900 new daily Or 1,470,000 annual trips	$476M (2016 dollars)

Further Recommended Analysis

Several lines of future work have emerged from this study including, but not limited to:

Feasibility and deployment analysis for on-street improvements

- Top TSP locations by congestion, cost
- Dedicated bus lanes on South Ave in Wilkinsburg
- Extending Off-Board Fare Collection to maximize adoption and access for riders of varying levels of need

Feasibility analysis of Beyond the Busway-relevant infrastructure projects

- Edgewood Towne Centre Station
- I-376 Dedicated Bus Ramps

Equity analysis of the post Covid-19 service plans

- Who is impacted, who and how many riders receive better or worse service (ridership, O&M, service metrics, equity analysis)
- PPT Survey 2.0 to capture rider's perspectives on such issues

Deployment Recommendations by Stakeholder

None of these improvements should be taken at face-value. Deployment recommendations are listed by stakeholders below to ensure maximum engagement from the grassroots (riders) to the grasstops (county leadership).

Pittsburghers for Public Transit

PPT should work with its members to interpret the results of this study, which will inform the next phase of their advocacy campaign. PPT should consider a blend of service and capital improvements, including some combination of those listed here or elsewhere identified. Beyond sharing the report, opportunities for rider engagement include through town halls and alternative evaluation training.

[57] "Martin Luther King Jr. East Busway Extension Feasibility Study." Port Authority of Allegheny County, May 2017. http://wyep.org/files/wesa/files/EastBuswayExt_FeasStudy_05302017.pdf.

Port Authority of Allegheny County / Southwestern PA Commission

PAAC and SPC should commission future studies on the implementation of BRT-style service in the Beyond the Busway interest area, using this report as a foundation. These results may also be informative to long-range planning efforts by both organizations. Additionally, the SPC should consider integrating the study's findings with their current draft 2022-2024 TIP, performing their own analysis or integrating analysis and numbers from this study.

Regional Leadership

Regional leaders should prepare to secure funding through local, state, federal sources to finance plans supported by PPT and analyzed by PAAC/SPC. Some possible funding opportunities are listed below.

Funding Opportunities

The proposals analyzed in the Beyond the East Busway report should be eligible for a range of regional improvement plans. Transit funding sources are available at the federal, regional, and local level.

Federal level

Highway Funding: The proposal for I-376's dedicated bus ramps could qualify for federal funding under the National Highway System (NHS).

Congestion Mitigation and Air Quality Improvement (CMAQ) - A program administered via the FHWA, this programs funds programs that reduce emissions. Transit and public transportation projects are eligible for this funding allocation.

Federal Reimbursements for Coronavirus-related loss in passenger revenue: As a part of the USDOT's program for transit agencies suffering lost revenue during the current covid-19 pandemic, $141 million is being provided to PAAC administered through the SPC in recovery funding.[58]

State Level

PennDOT Statewide Transportation Set-Aside Program:[59] This program awards between $50,000 to $1,000,000 for project construction costs. The project must be discussed together with the sponsor's regional metropolitan planning organization and its implementation must be discussed with PennDOT. This funding would be most appropriate for facility upgrades such as new station and shelter proposals outlined above.

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[58] Blazina, Ed. "Beleaguered Port Authority Eligible for up to $141 Million in Reimbursements Due to COVID-19 Losses." Gazette. Pittsburgh Post-Gazette, April 3, 2020. https://www.post-gazette.com/news/transportation/2020/04/03/Port-Authority-federal-reimbursemenbt-COVID-19-141-75-million/stories/202004030185.

[59] "Transportation Alternatives Set-Aside." Pennsylvania Department of Transportation. Accessed May 19, 2020. https://www.penndot.gov/ProjectAndPrograms/Planning/Pages/Transportation%20Alternatives%20Set-Aside%20-%20Surface%20Trans.%20Block%20Grant%20Program.aspx

Green Light-Go: Pennsylvania's Municipal Signal Partnership Program:[60] This program provides state funds for traffic signal upgrades along critical corridors and state highways. This would be most applicable to the TSP upgrades proposed in the Beyond the East Busway report as the municipalities in our interest region are maintaining older street infrastructure and signalling systems, yet fall outside of the current Pittsburgh BRT zone.

Pennsylvania Infrastructure Bank: The Pennsylvania Infrastructure Bank provides flexible financing for projects that include transit projects. Local Project Sponsors, including municipalities, authorities, corporations and development agencies are eligible for loans through the PIB if their project is eligible for other transportation funds.

A note on Act 89: One of PPT's joint campaigns involves advocating for state renewal of Act 89, which funds the Act 44 mandate for transit and infrastructure funding in Pennsylvania via the Pennsylvania Turnpike Commission. This funding remains critical to regional upgrades and to providing funding resources for the plans recommended in this report.

Regional Level

SPC's Regional Traffic Signal Program: This program, implemented by SPC, has the benefit of assisting municipalities with traffic signal upgrades, but also with implementing Transit Signal Priority. The municipalities in our region, as noted above, are in need of separate eligible funds to bear the cost of infrastructure upgrade.[61]

Next Steps

By integrating the Beyond the East Busway proposals into ongoing long range and medium-range transportation planning efforts on the Mon Valley, the transportation improvement projects listed would be eligible for a range of funding and implementation support. SPC's next draft study should include recommendations from this report, and PAAC should advocate for TSP implementations in the Mon Valley, Monroeville and Eastern Suburb regions that would add the marginal run-time benefits needed to decrease overall operations costs in peak vehicles.

This study did not go into depth on the impact of development and land use, though the PAAC/SPC long range Transit Vision study alluded to regional development trends, which would in the long term incur further sparse land development, higher municipal costs in services, and poor mobility of access, especially to residents who have limited mobility options..[62] An additional impact study of increasing transit availability from the proposals generated from this study could demonstrate the benefits to more transit-oriented, dense development for the region. This is also in keeping with recent SPC long-range transportation and development plans.

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[60] "PennDOT: Traffic Signal Portal." PennDOT|Traffic Signal Portal. Accessed May 19, 2020. http://www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/FUNDGLG.html

[61] "Transportation: Operations & Safety Committee: Regional Traffic Signal Program (Southwestern Pennsylvania Commission)." Visit PowerSmart. Accessed May 19, 2020. http://spctiptracker.org/trans_ops_traff.shtml .

[62] "A Regional Strategic Vision for Public Transportation Serving Southwestern Pennsylvania." SPC, March 2006. https://www.spcregion.org/wp-content/uploads/2019/09/TransitVision_FullReport.pdf.

This study, finally, provides a menu of options for PPT to provide its members for feedback and for mobilizing further advocacy campaigns. PPT has served as a conduit for community voices in the Mon Valley, Monroeville and Eastern Suburbs, with the Beyond the East Busway campaign a clear need and desire for improved transit access in the region. It is up to municipal leaders to act as local partners in a deployment capacity, with the components of this proposal providing the quantified justifications and formulations for further analysis and future deployment. We hope that this study provides the next needed step in propelling the voice of community into the process of regional development and planning.

Project Advisory Board and Partners

This project could not be completed without the constant support, insights, and commitment to student learning shown by our Project Sponsors, Advisory Board, and Faculty Advisor over the course of the Spring 2020 semester. This brief acknowledgements section does not and cannot capture our team's thanks and appreciation.

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- **Richard Feder,** Adjunct Professor, University of Pittsburgh and CMU

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- **Sue Scanlon,** PPT Coordinating Committee Co-Vice Chair, Port Authority Bus Operator, Member of ATU Local 85, and PPT Cofounder
- **Stan Caldwell,** Executive Director, Traffic21 Institute
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- **Elijah Hughes,** EcoDistricts AP, evolveEA
- **Christian Gass,** VP and COO, Civic Mapper

- **Jess Zimbabwe,** Founder of Plot Strategies, Professor of Urban and Regional Planning, Georgetown University

List of Images

List of Tables

Data & Models Used

Data and models with instructions will be provided directly to project partners for future analysis and testing.

Appendix - National Transit Database Cost Allocations

		NTD Report-Year 2018			
5 Digit NTD ID	30022				
Legacy NTD ID	3022				
Agency Name	Port Authority of Allegheny County	PV	VRH	VRM	Total
Reporter Type	Full Reporter				
Reporting Module	Urban				
Mode	MB				
TOS	DO				
Operating Expense Type	Total				
Operators' Salaries and Wages	$62,697,343		$ 62,697,343		$ 62,697,343
Operators' Paid Absences	$9,236,445				
Other Salaries and Wages	$68,315,452	$ 34,157,726	$ 34,157,726		$ 68,315,452
Other Paid Absences	$5,208,844				
Fringe Benefits	$109,811,204				
Total Fringe Benefits	$124,256,493	$ 62,128,247	$ 62,128,247		$ 124,256,493
Service Costs	$9,870,905	$ 3,290,302	$ 3,290,302	$ 3,290,302	$ 9,870,905
Fuel and Lubricants	$15,500,382			$ 15,500,382	$ 15,500,382
Tires and Tubes	$1,985,914			$ 1,985,914	$ 1,985,914
Other Materials and Supplies	$16,987,964	$ 8,493,982		$ 8,493,982	$ 16,987,964
Utilities	$3,234,868	$ 3,234,868			$ 3,234,868
Casualty and Liability Costs	$2,775,470			$ 2,775,470	$ 2,775,470
Taxes	$0				$ -
PT Funds In Report	$0				$ -
PT Funds Reported Separately	$0				$ -
Miscellaneous Expenses	$2,742,610	$ 914,203	$ 914,203	$ 914,203	$ 2,742,610
Reduced Reporting Waiver - Total OE	$0				$ -
Total Operating Expenses	$308,367,401	$ 112,219,328	$ 163,187,821	$ 32,960,253	$ 308,367,401
Total Operating Expenses (No Funds Reported Separately)	$308,367,401				$ -
ADA Related Expenses	$0				$ -
	Variable to Allocate	603	1,636,544	21,183,003	
	Cost Allocation	$ 186,102	$ 99.71	$ 1.56	
	Bus O&M estimation equation: Annual PAAC O&M = $186,102 * PV + $99.71 * VRH + $1.56 * VRM				