Spring 5-1-2019

Data-informed recommendations for fixed-route public transit in the Greater Susquehanna Valley

Elise Covert

Zachary Feit

Megan Fournier

Alexandra Koumas

Data-informed recommendations for fixed-route public transit in the Greater Susquehanna Valley

Elise Covert, Zachary Feit, Megan Fournier, Alexandra Koumas

May 1, 2019

1 Abstract

Greater Susquehanna Valley United Way (GSVUW) aims to propose a fixed-route bus system across a mostly rural five-county region (Columbia, Montour, Northumberland, Snyder, and Union counties) in Central Pennsylvania to be operated by River Valley Transit (RVT). Regional needs assessments demonstrate a critical lack of public transit, the implementation of which can increase access to medical care and facilitate workforce development. With input from GSVUW and other stakeholders, this paper aims to provide data-informed recommendations for a bus route, bus stops, and time tables that optimize potential ridership and accessibility. Data from the American Community Survey, a United States Census household survey, and from Rabbit Transit, a local ride request service, are employed to quantify and visualize the distribution of potential demand for public transit within the region. Recommendations produced by such analyses will be used by GSVUW to apply for a Pennsylvania Department of Transportation feasibility grant to pilot the fixed route bus system.

2 Introduction

In rural areas of Central Pennsylvania, there is a critical lack of public transportation. Transportation in the Greater Susquehanna Valley, a largely rural region, depends on vehicle ownership and ride share services almost exclusively. Regional service agencies have expressed a need to connect residents with local employers spread across the region. A 2018 transportation access survey - conducted by Greater Susquehanna Valley United Way (GSVUW) in partnership with Bucknell University - of 68 employers and human service agencies reported that access to jobs and healthcare are the two areas most affected by the lack of accessible transportation. Further, the survey claims that there are 29,000 potential public transportation clients within the five-county region of the Greater Susquehanna Valley [2]. GSVUW also identified a number of regional healthcare and human service providers who, due to the present lack of public transit available to their clients, must send staff members to those clients' homes, creating extra demands on time and transportation costs. Ameliorating this issue would allow businesses to more effectively and efficiently serve more clients. Access to, and accessibility of, public transportation networks leads to economic growth and enhanced quality of life, as well as decreased impacts on the environment [3]. The ability to use public transit for reliable transportation to and from work can help break a cycle of welfare dependency, as well, allowing people to build better lives [6].

In this rural region, one solution will not satisfy all needs. Solving the region's transportation problems requires a comprehensive, multilevel strategy that connects people and organizations to enhance existing options. The main transportation option is a local ride share service, which is an expensive option, especially for a regular commute to work or travel to a weekly doctor's appointment, for example. In order to supplement this service and provide access to residents who cannot access or afford ride share, a team of local governments and organizations in the Greater Susquehanna Valley formed the Pennsylvania Transportation Coalition with the aim of implementing fixed-route bus service in a five-county region of Central Pennsylvania. The region of interest includes Union, Columbia, Northumberland, Montour, and Snyder counties. The project team identified workforce development as their primary goal, with access to medical care being a natural, and clearly desirable, side effect. In rural areas such as the study region, health care providers and facilities are often sparsely distributed [5]. Accessibility of these providers via public transportation can lead to significant improvements in quality of life.

The coalition aims to propose a grant to the Pennsylvania Department of Transportation (PennDOT) in order to secure funding to pilot this fixed-route bus system for a period of three years. The grant proposal requires a quantification of need, including potential ridership figures, and a thoughtful plan for routing, stops, and time tables. Each of these components can be bolstered by mathematical and statistical analyses. The goal of this paper is to explore the available and relevant sources of data in order to provide data-informed recommendations for fixed-route transportation to our industry partners.

Naturally, the task of creating fixed-route public transportation in the Greater Susquehanna Valley presents some notable challenges. First, because the five-county region is largely rural, the population of potential riders is highly scattered. Low population density in rural areas makes the task of establishing an effective public transportation network difficult [6]. Most potential clients live in very rural areas that a reasonable bus route will not be able to service directly. Further, along the route, we will need to balance stopping at enough locations to make the bus useful with limiting the time of the route such that it is not excessively long and thus undesirable. Studies show that utilization of public transit, in general, is higher if origin-destination travel times are lower [3]. In this case, we look to balance access to public transit, meaning residents' proximity to service and its cost, with accessibility of public transit, which refers to the suitability of the system to move clients in a reasonable amount of time [3].

Another challenge is that individual level data are almost impossible to attain. For example, we cannot obtain a breakdown from each major regional employer of where their employees commute from; not only would that data be difficult to collect, but it would be unwieldy to manage, analyze, and interpret. Further, there undoubtedly exists potential demand, or demand that has not been explicitly expressed but that would be present when public transit is accessible [8]. Therefore, we will need to develop a method of inference based on responses from employers in conversation at meetings and in input collected through surveys and supported by data sources providing contextual information. Our data-informed recommendations will address a more generalized picture of the need for public transit in the target region.

With these challenges in mind, a look at the public transportation literature suggests certain paths to take in order to produce the desired recommendations. A fixed-route bus system similar to the one that we desire to implement in our five-county target region was implemented in 2017 in neighboring Clinton County. Clinton County and PennDOT published a Feasibility Study for their bus service which offers some guidelines for analysis [4]. First, it suggests the possibility of running two different routes - one during peak commuting hours, based on shift times for major regional employers, and another during the day in between commuting times. Next, mapping regional ride shares was identified as a method of distinguishing where high potential for ridership exists [4]. High use of ride share service can indicate a lack of access to a vehicle full-time, which naturally lends itself to high likelihood of use of public transit. Another strategy to quantify propensity for transit use is with a transit propensity index. Clinton County selected demographic variables that have been shown to be significant predictors of ridership propensity by identifying populations who are more likely to take advantage of public transportation. They then combined these variables to create a numerical index of propensity of using public transportation.

A similar statistical method was employed in a study of public transportation in Atlanta, Georgia [8]. The author of this study employs past ridership data in a regression model to identify significant predictors of ridership per stop. While we cannot implement his model directly because we do not have ridership data from an existing route, we can still consider his variables as potential predictors of ridership in our area. Once the route is piloted and ridership data become available, the author's need index can help us to identify areas with high need but low coverage that could be targets of expanded service [8]. It is important to note, though, that the author's study targeted an urban area, whereas our region of interest is largely rural. Therefore, we have reason to be skeptical that the variables may predict ridership differently given our radically different context.

3 Methods

3.1 Data Collection

Three main types of data were collected for use in producing recommendations for the proposed public transit system: data providing information about the route, data providing information about potential ridership in the area, and data providing information about contextual variables (e.g. demographics) in the study area.

3.1.1 Route Information

The bulk of initial data used in the fixed route analyses was provided by the Susquehanna Economic Development Association Coalition of Governments (SEDA-COG), a regional council of governments that primarily functions as a multi-county development agency in Central Pennsylvania. SEDA-COG acts as both a service provider and a link between resources to meet local economic and community needs.

SEDA-COG provided us with data files including a proposed fixed route and eight proposed timed stops, along with lists of critical facilities, major employers, medical facilities, and subsidized housing complexes in the five-county target region. Each of these data sets could be accessed in tabular form or in spatial form, meaning that they could be entered into mapping software for visualization.

GSVUW worked with RVT, the bus company who will provide operational support, Geisinger Medical Center, a key financial sponsor of the initiative, and local governments to generate a proposed fixed bus route and eight proposed timed stops, which will be described in further detail. This route and the timed stops are set. Based on financial feasibility and the capacity of RVT, between two and six buses will be available to operate the route.

RVT has a bus depot located in Williamsport, PA, at the northern extreme of the route; therefore, all buses will begin and end the operational day at this location. The route has three spokes that meet centrally at Geisinger Medical Center in Danville, Montour County, PA. The first spoke will run from Williamsport to Geisinger Medical Center, including stops at Williamsport Trade and Transit Center, Allenwood Penitentiary, and Evangelical Community Hospital. The second spoke of the route will travel from Geisinger Medical Center to Berwick, including stops at Buckhorn Plaza and Berwick Hospital Center. The final leg of the route runs from Geisinger to Selinsgrove, with stops at Sunbury Community Hospital and Susquehanna University. Geisinger, then, serves as a logical and natural hub location for all three legs of the route, so that someone in Selinsgrove, for example, could travel to Berwick through the hub if they so desired. Table 1 lists the eight original timed stops proposed by SEDA-COG. Figure 1 maps the proposed route and the eight original timed stops.

Stop Name	Town	Route
Trade & Transit Center	Williamsport	Williamsport to Geisinger
Allenwood	Allenwood	Williamsport to Geisinger
Evangelical Community Hospital	Lewisburg	Williamsport to Geisinger
Geisinger Medical Center	Danville	Hub
Buckhorn Plaza	Bloomsburg	Geisinger to Berwick
Berwick Community Hospital	Berwick	Geisinger to Berwick
Sunbury Community Hospital	Sunbury	Geisinger to Selinsgrove
Susquehanna University	Selinsgrove	Geisinger to Selinsgrove

Table 1. Original proposed timed stops, divided by the spoke of the route on which they are located.

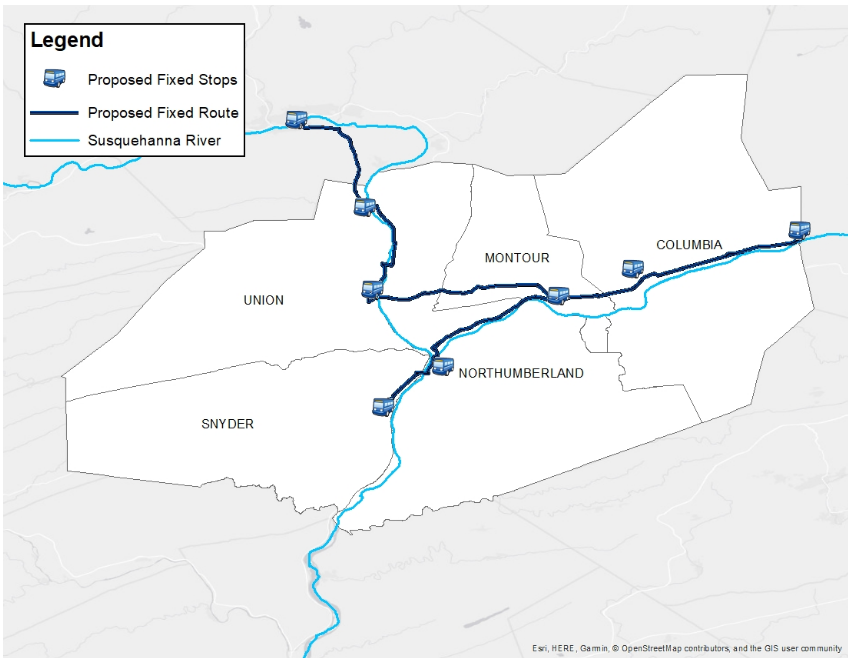

Figure 1. Map of the fixed route and original eight timed stops provided by the client.

3.1.2 Ridership Information

Rabbit Transit (RT), a regional shared ride service where clients specify a pick-up and drop-off location for their trip, was selected as a data source that would assist in identifying pockets of transportation need in the target study area. RT provided a data set including 218,553 pairs of pick-up and drop-off requests from the entire year of 2018 with unique X-Y coordinates for each pick-up and drop-off location.

3.1.3 Contextual Information

The American Community Survey (ACS), a U.S. Census nationally-representative household survey, was identified as a useful data source to provide contextual demographic information about our potential rider population in the five-county area [7]. ACS is a source of detailed population information and housing information on a nationwide scale, whose variables could serve as plausible predictors of public transit use in the study area.

Commuter Flow Characteristics Subset

To gain a better understanding of the flow of workers commuting within the region of interest, we examined Commuter Flow Characteristics data from ACS. The subset included information about where people live, work, and what mode of transport they use for commuting. We note that while ACS is meant to be nationally-representative, we treat commuting estimates for the region of interest with caution. Because the region is largely rural and sparsely populated, the margins of error associated with the commuting estimates were relatively high, in many cases. Therefore, although we are skeptical of using the data to provide precise information about numbers of commuters, we feel confident in using this data set to draw more general conclusions about directionality of commuter flow in the study area, as well as the county connections with relatively high volumes of commuters.

Transit Propensity Index Subset

Clinton County, a neighboring county northwest of the study area, employed variables from ACS to construct a Transit Propensity Index by census block group in their county. Variables used in the Clinton County index included the following [4]:

(a) Population density
(b) Seniors as a percent of the total population
(c) Young workers as a percent of the total population
(d) Percent black
(e) Percent Hispanic
(f) Percent of workers without access to a car
(g) Percent of workers with a high school education or less
(h) Immigrants as a percent of the total population
(i) Percent of workers with a disability
(j) Percent of workers with income below the poverty line

ACS data pertaining to each of these variables were pulled from the 2013-2017 American Community Survey 5-Year Estimates on the American FactFinder website, aggregated by census tract [7]. The census tract is the second smallest census grouping and the smallest at which all of the ACS variables of interest were available. We note that percent of workers with a disability was not available at the geographic specificity level we needed, so percent of the total population with a disability was substituted. Additionally, note that the most recent population density statistics were pulled from the ESRI database on ArcGIS online because the U.S. Census only calculates population density in the decennial census.

3.2 Data Analysis

Spatial analysis was done using ArcGIS, a mapping software which provides tools necessary for easy data manipulation, exploratory data analysis, and effective data visualization [1].

3.2.1 Commuter Flow Visualization

The Commuter Flow Characteristics Subset of ACS was pared down to include only variables of interest for the five-county target region. Next, we aggregated the total number of commutes between and within counties of interest across all indicated modes of transportation in order to demonstrate that our route will serve to improve regional workforce development. We also examined the number of people living in one of our five counties of interest and commuting outside of the study area, as well as people living outside of the study region and commuting in for work. To better understand this flow, we compiled these commutes for each of the five counties. We repeated the same process for those commuting into or out of the study region. We utilized this data to generate a visualization displaying commuter flow.

3.2.2 Choosing Stops

Figure 2 shows major employers, medical facilities, subsidized housing complexes, and critical facilities [1] within the five-county target region. We identified the locations within a 0.75-mile buffer of the proposed fixed route as feasibly accessible points of service by the transit system to account for timeliness. We then used the point density analysis tool in ArcGIS to identify pockets along the route with high concentrations of major employers and critical facilities. Along with the input of our client and project stakeholders, we placed additional fixed stops to coincide with the dense clusters identified in our analysis.

3.2.3 Rabbit Transit

Analyzing RT data can provide insight into where potential public transit users are located and their common travel destinations. RT's customers are residents of the target area whose needs are not being sufficiently met by current forms of fixed transportation. We note that exploratory data analysis demonstrated that pick-up and drop-off locations matched up almost one-to-one. This is evidence that RT customers are using the service round trip. Figure 3 maps all unique pick-up and drop-off locations extracted from 2018 RT ride requests. 437,106 rides were concentrated at 5,322 unique locations.

3.2.4 Timing and Directionality

Once we had identified the proposed set of fixed stops to optimize route accessibility and utility, the next step was to determine how to best operate the route logistics. This challenge included ensuring feasibility while maximizing the number of potential riders who could use the bus to commute to work. Concerns to be addressed included determining the number of buses that would service the route, their hours of operation, the time-based construction of the route, and the routing flow of buses that would allow potential riders access to any stop along the route from any other stop.

Time Table Formation

In order to accurately plan the timing of the buses along the proposed fixed route, we created an Excel workbook that allowed us to automatically generate specific timetables based on certain variable inputs; operation start time and adjusted travel time between stops.

The first sheet of the workbook is a list of the departure-arrival pairings for adjacent stops along the route. For each pairing, there is an input cell noting how long a bus takes to travel between the two stops. The travel time between stops was provided to us by RVT based on historical data that takes in to account distance, speed, stop time, and traffic.

The subsequent sheets contain time tables for each of the four buses, starting at their respective stops (one at Williamsport TTC, one at Susquehanna University, and one at the Berwick Hospital Center) and operating the route's fixed rotation. For ease of use, there is an input cell at the top of each sheet that allows a user to input that bus's start time. When that time is changed, all of the times in the table adjust accordingly based on the start time and the amount of minutes between each stop, making for simple updates as the route evolves.

3.2.5 Transit Propensity Index

Once the predictor variables were identified and pulled as described in Section 3.1, a transit propensity index was constructed based on the method outlined in the Clinton County Feasibility Study [4].

[1] Critical facilities comprise local government centers, places of worship, post offices, pharmacies, and the like. The list of critical facilities is a data product provided by SEDA-COG.

Index Calculation

We combined the ten predictors identified in 3.1.3 to calculate a more comprehensive index that can tell us about the likelihood that residents of a given census tract will use public transportation. Census tracts containing prisons were excluded. To calculate the transit propensity index, we first calculate the maximum and minimum values for each of the ten predictor variables. Each variable was then linearly standardized, with the maximum value assigned to an output of 1 and the minimum value assigned to an output of 0. All other values were proportionally interpolated along the rest of the interval. The values of all ten predictors were then summed, such that the sum had a maximum value of 10 and a minimum value of 0. We then apply the same linear standardization procedure to scale the sum from 0 to 1 for the final transit propensity index.

4 Results

4.1 Commuter Flow

Using the commuter flow characteristics data from ACS, we map estimates of commuting volumes within and between the five counties in the study area, as well as volumes of commuters commuting into or out of the five-county region. Each of these aspects is mapped in Figure 4, which illustrates the movement of commuters within the five-county region of interest.

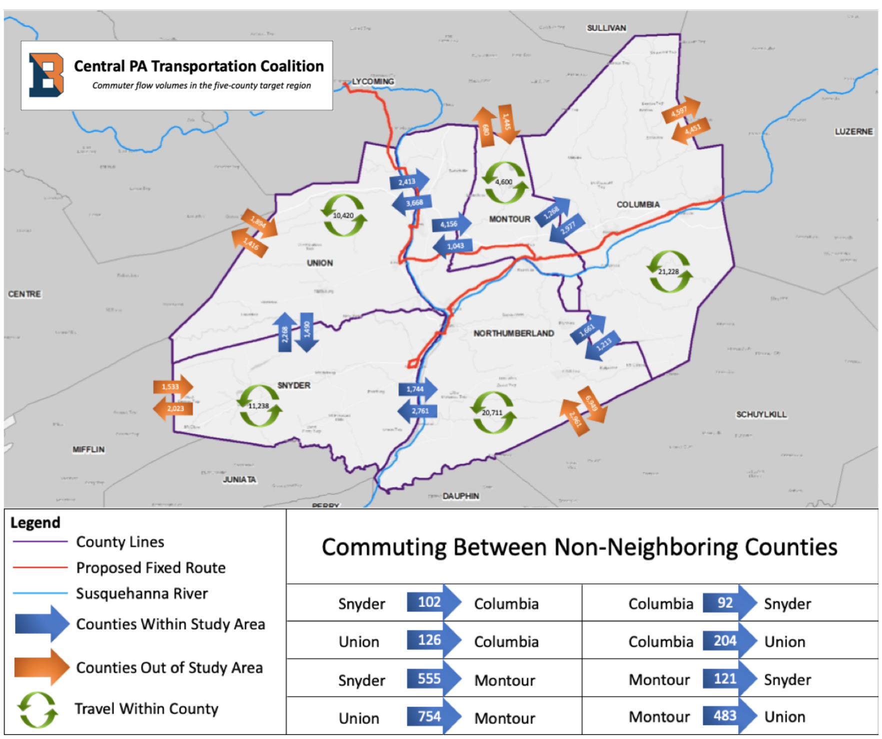

Figure 4. Map illustrating commuter flow volumes in the five-county target region.

4.2 Set of Proposed Stops

Using the map of major employers, medical centers, subsidized housing, and critical facilities in the study area, we made rough estimates of where stops are needed. Figure 5 maps the original proposed timed stops with the additional timed stops placed from our analysis. The set of proposed stops is listed below:

Stop Name	Town	Route
Trade & Transit Center	Williamsport	Williamsport to Geisinger
Allenwood	Allenwood	Williamsport to Geisinger
Watsontown Elementary	Watsontown	Williamsport to Geisinger
Milton	Milton	Williamsport to Geisinger
Lewisburg Walmart	Lewisburg	Williamsport to Geisinger
Evangelical Community Hospital	Lewisburg	Williamsport to Geisinger
Downtown Lewisburg/Bucknell	Lewisburg	Williamsport to Geisinger
Geisinger Medical Center	Danville	Hub
Woodbine	Danville	Geisinger to Berwick
Buckhorn Plaza	Bloomsburg	Geisinger to Berwick
Bloomsburg University and Hospital	Bloomsburg	Geisinger to Berwick
Luzerne County Community College/BIDA	Berwick	Geisinger to Berwick
Berwick Community Hospital	Berwick	Geisinger to Berwick
Sunbury Community Hospital	Sunbury	Geisinger to Selinsgrove
Target Shopping Center	Selinsgrove	Geisinger to Selinsgrove
Susquehanna Valley Mall	Selinsgrove	Geisinger to Selinsgrove
Susquehanna University	Selinsgrove	Geisinger to Selinsgrove
		Blue boxes represent original 8 proposed stops.

Table 2. Full set of proposed timed stops, divided by the spoke of the route on which they are located.

4.3 Rabbit Transit

Mapping RT ride requests using GIS software allowed us to visualize the concentrations of ride requests within the five-county region. We interpret high volumes of ride requests as indicators that there is a need for alternative transportation in that area. Figure 6 displays number of RT ride requests summarized by census block group. Darker shades represent census block groups with a higher demand for Rabbit Transit ride shares.

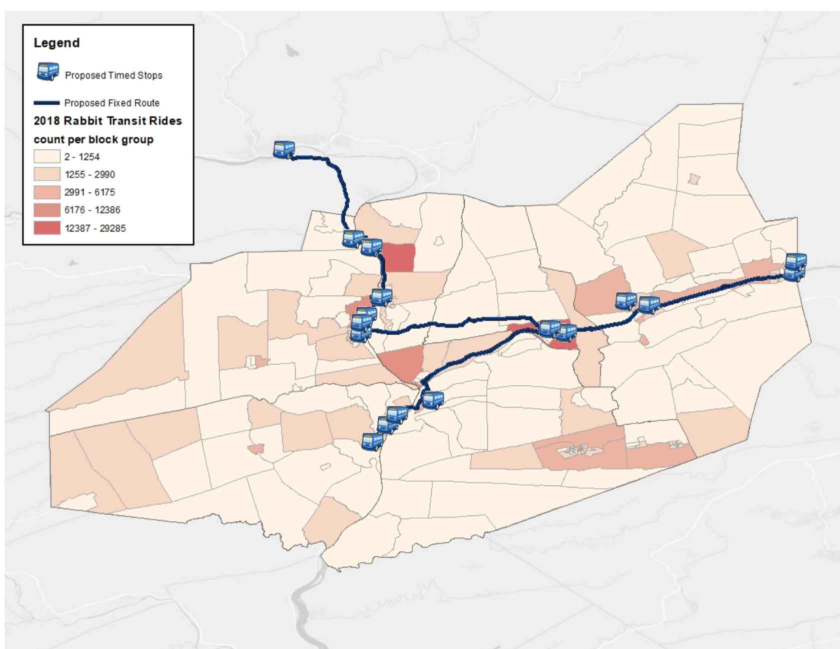

Figure 6. Darker shades represent census block groups with a higher demand for Rabbit Transit rides.

4.4 Timing and Directionality

4.4.1 Route Flow

Analysis suggests that, in terms of workforce development, this route is optimally served by four buses. Two would express from Williamsport directly to the other two route extremes, Berwick and Selinsgrove. The other two would depart from Williamsport at staggered times.

To maximize workforce development, we recommend that RVT deploy buses from each of the route extremes (Williamsport, Berwick, and Selinsgrove) at 5 AM. This construction would allow three of the buses to converge at the Geisinger hub early enough that all potential riders would be able to arrive at their place of work, no matter where it is located on the fixed route, before 9 AM. The Coalition may consider adjusting this in the future, which can be done easily using the automated timetables to account for changes in start time subject to outside factors.

Initial analysis demonstrated that the Williamsport to Geisinger leg was almost twice as long as the other two legs of the route (Berwick to Danville and Selinsgrove to Danville). In the time tables, we extended stop times where necessary to achieve a perfect 2:1:1 ratio. Buses will stop for 15 minutes at Geisinger Medical Center to allow for transfers and build in a buffer period in the inevitable case that buses run behind schedule. Buses will stop at Williamsport TTC for 45 minutes for personnel switches. Each of these factors is built into the 2:1:1 proposed ratio. The movement of the four buses flows as follows:

1. Bus 1 leaves Williamsport and travels directly to Geisinger, servicing stops along the way.
2. Bus 2 departs Williamsport directly for Berwick, traveling the fastest route without servicing any stops. It then services stops along the route as it moves from Berwick to Geisinger.
3. Bus 3 leaves Williamsport and expresses directly to Selinsgrove. It then services stops along the route as it moves from Selinsgrove to Geisinger.
4. Bus 4 departs from Williamsport TTC later, when the other three buses leave Geisinger.

Bus numbering reflects the ordinal pattern of operation of each spoke: Williamsport to Geisinger, followed by Geisinger to Berwick, followed by Geisinger to Selinsgrove. Each bus will service the entire fixed route rotationally. Following this pattern, whenever there are three buses at Geisinger, there will be one at TTC. For example, departure times are staggered so that Buses 1, 2, and 3 arrive at Geisinger at approximately the same time.

4.4.2 Workforce Accessibility

GSVUW highlighted workforce development as the main concern to be addressed by the transit system. With this in mind, we produced Tables 3-5 to visualize how the route can potentially service users commuting to work in the study region. In each table, the vertical axis lists the timed stops, referencing where a potential rider lives. The horizontal axis indicates the same timed stops, now referencing where a potential rider works. The internal cells show the earliest possible time a rider could get to work from where they live, based on current route time tables. Each table has a target arrival time at work; a green cell implies that the rider can arrive to work by that time, whereas a gray cell indicates that they cannot. For example, if a potential rider lives in Williamsport and works in Bloomsburg, the earliest that they can get to work is 7:33 AM. Note that this cell is gray in Table 3 but green in Tables 4 and 5.

4.5 Transit Propensity Index

Figure 7 illustrates Transit Propensity Index mapped by census tract in the five-county region. Darker shades identify areas where people are more likely to have a need for public transportation. Because the Transit Propensity Index identifies areas with populations in need of public transportation, we also mapped population density to predict where transit is expected to be most productive within the study region. Figure 8 visualizes population density in the study area.

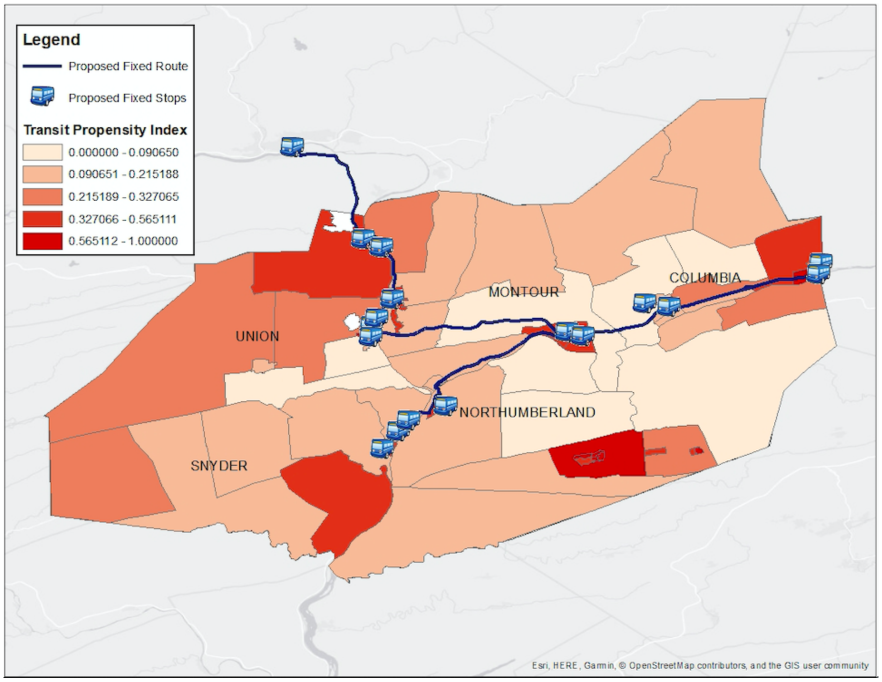

Figure 7. Darker shades represent census tracts with a higher propensity to have residents in need of public transit service.

5 Discussion

5.1 Commuter Flow

We observe two important trends arising from the commuter flow analysis as depicted in Figure 4. First, we see high volumes of the population working in the five-county area outside of their county of residents. For example, the large number of commutes into Montour County supports the route's current design, which employs Geisinger Medical Center in Montour County as an important timed stop and transfer hub. Second, we recognize commuter flow from the five-county region to counties outside of the target study area. This result suggests that we should investigate connections between our cross-county connector and existing fixed-route systems, especially the Clinton County Connector and LATS. Both of these trends reinforce a need for a fixed-route service to enhance regional workforce development, within the five counties and beyond.

5.2 Proposed Stops

The set of 17 proposed timed stops as mapped in Figure 5 allows rider accessibility to many major employers, medical centers, and other critical facilities located along the proposed fixed route. While we acknowledge that the set of fixed timed stops does not encompass all employers and facilities, we note that RVT's operation system will also allow for designated flag-down stops, further increasing accessibility.

5.3 Rabbit Transit Findings

RT visualizations made evident the locations where the need for alternative transportation is greatest and give a sense of the heavy concentration of demand for rides in areas that lay along the fixed route. Figure 3 illustrates high counts of ride requests at locations in and around Danville, for example, which can be accessed by stops at Geisinger and Woodbine.In Figure 6, notice that the darker red mark the highest counts of ride requests, which match where we have proposed timed stops along the fixed route in order to address the ride demand that currently exists through RT.

Further, our fixed route can collaborate with RT in order to construct a comprehensive transportation network in the five-county area. RT is reported to be the second-most frequently used method of alternative transportation in the study area [2]. Considering that RT's system operates under a ride-request model, the hope is that some clients will transition into using public transit for their regular trips, thereby allowing RT to better serve more specialized clientele. Finally, we acknowledge the moderately-concentrated census block groups which are located in the southeast of our five-county area of interest, in the Shamokin-Mount Carmel region. Though our fixed route does not pass through this area, we will keep in mind a potential connection to this area.

5.4 Timing and Directionality

A four bus rotational system best optimizes workforce accessibility. The proposed rotational system allows us to coordinate and connect buses as a continuous system. Geisinger will serve as a transit hub, allowing passengers to easily transfer between route spokes. Also, maintaining proportionality builds in flexibility for adjusting the route in the future. Because all four buses must start and end the day at RVT's garage in Williamsport, we recommend expressing two buses to each extreme (one to Berwick and one to Selinsgrove) to begin the day running towards Geisinger. As shown in Table 5, the system allows everyone to get to work before 9AM, regardless of where they live and work along the route. Additionally, the rotational system is preferable for bus driver shift changes in Williamsport.

5.5 Transit Propensity Index

The Transit Propensity Index is a composite quantitative measure that we believe predicts the likelihood that citizens of the census tract in question will use public transit. Looking at Figure 7, we see that many of the darkly-shaded tracts lie along the proposed fixed route, indicating that the transit system will be accessible to citizens who need it most. It is important to note that the index does not necessarily indicate productivity of public transit. Past feasibility studies point out that population density is one of the best predictors of public transit productivity [4]. Productivity differs from propensity in that public transit might not be efficient if the bus route tried to reach all residents with the highest predicted need. However, Figure 8 demonstrates that the route also hits many of the areas in the target region with high population density.

5.6 LATS Connection

Overarching the entire project is the goal of creating this cross-county fixed route as part of a larger, more comprehensive public transportation plan in the five-county region. As suggested by RT ridership analysis and strongly reinforced by Transit Propensity Index results, we recommend that the client explores a connection with the Lower Anthracite Transportation System (LATS), which serves the Shamokin-Mount Carmel region. Importantly, the Transit Propensity Index demonstrates that the Shamokin-Mount Carmel area has both high population density and high propensity for ridership, indicating severe need and potential for high productivity of public transit. A connection with the transit system in this area will go a long way in expanding access to employers and medical facilities via a cohesive public transportation system in the Greater Susquehanna Valley. The two routes overlap at two stops: the Target Shopping Center in Shamokin Dam and the Susquehanna Valley Mall. The map in Figure 9 illustrates this overlap. However, under current operation, LATS only runs their route to these stops on Saturdays. In order to create a consistent connection between the two bus systems, LATS would likely need to add daily service along their route. Moving forward, the client might also consider connecting the LATS system directly to Geisinger Medical Center, our proposed route's hub.

6 Conclusion

Overall, our data analysis and careful examination of the visualizations produced allowed us to propose a list of timed stops and provide options for timing and directionality that best suit the distribution of need and demand in the Greater Susquehanna Valley. Results and conclusions are presented to the client and various stakeholders as data-supported recommendations for implementing the proposed fixed-route public transit system in the five-county area. Recommendations will be used to inform GSVUW's proposal for a PennDOT grant to fund a three-year pilot period of the system. Once the system is in operation, ridership data will become available for analysis. Future studies can use this data to adapt the route to better meet community needs.

Additionally, a similar methodology can be used to evaluate the potential demand and feasibility of fixed-route public transportation in other rural regions of the United States. Because rural transportation provides a unique set of constraints and challenges, developing this framework for proposing fixed-route public transit has important implications by encouraging other rural regions to consider the implementation of bus systems. We demonstrated a technique for visualizing potential demand for ridership, as well as productivity and predicted need for the transportation system.

Overall, the analyses discussed in this paper demonstrate that implementing fixed-route transportation in the five-county greater Susquehanna Valley region will reach a population in need of access to public transit. Residents of Union, Northumberland, Montour, Columbia, and Snyder counties will have increased access to employment opportunities and medical care, as well as other critical facilities in their communities. Implementation of the system in question, therefore, would significantly increase the quality of life of residents in the five-county region.

7 Acknowledgements

This project was completed in a Solving Industrial Problems course at Bucknell University in conjunction with the PIC Math program. PIC Math is a program of the Mathematical Association of America (MAA) and the Society for Industrial and Applied Mathematics (SIAM). Support is provided by the National Science Foundation (NSF grant DMS-1722275). Work was done in collaboration with GSVUW, RVT, and SEDA-COG under the supervision of Professor Nathan Ryan and GIS Specialist Janine Glathar.

8 Works Cited

References

[1] ESRI 2017. ArcGIS Desktop: Release 10.5.1. Redlands, CA: Environmental Systems Research Institute.

[2] Greater Susquehanna Valley United Way, 2017, Transportation Access Survey. Unpublished Report.

[3] Murray, A. T. (2001). Strategic analysis of public transport coverage. Socio-Economic Planning Sciences, 35(3), 175-188.

[4] Pennsylvania Department of Transportation. (2017). River Valley Transit Clinton County Service Feasibility Study.

[5] Stentzel, U., Piegsa, J., Fredrich, D., Hoffmann, W., & Berg, N. (2016). Accessibility of general practitioners and selected specialist physicians by car and by public transport in a rural region of Germany. BMC health services research, 16(1), 587.

[6] Trouteaud, A. R., & Parker, J. D. (2003). Transporting Welfare Beyond the City: A GIS Methodology to Guide Rural Transit Program Implementation. Public Works Management & Policy, 8(2), 111-120.

[7] U.S. Census Bureau. (2018). *2013-2017 American Community Survey 5-Year Estimates.* Retrieved from https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t.

[8] Yao, X. (2007). Where are public transit needed - Examining potential demand for public transit for commuting trips. Computers, Environment and Urban Systems, 31(5), 535-550.

9 Appendix

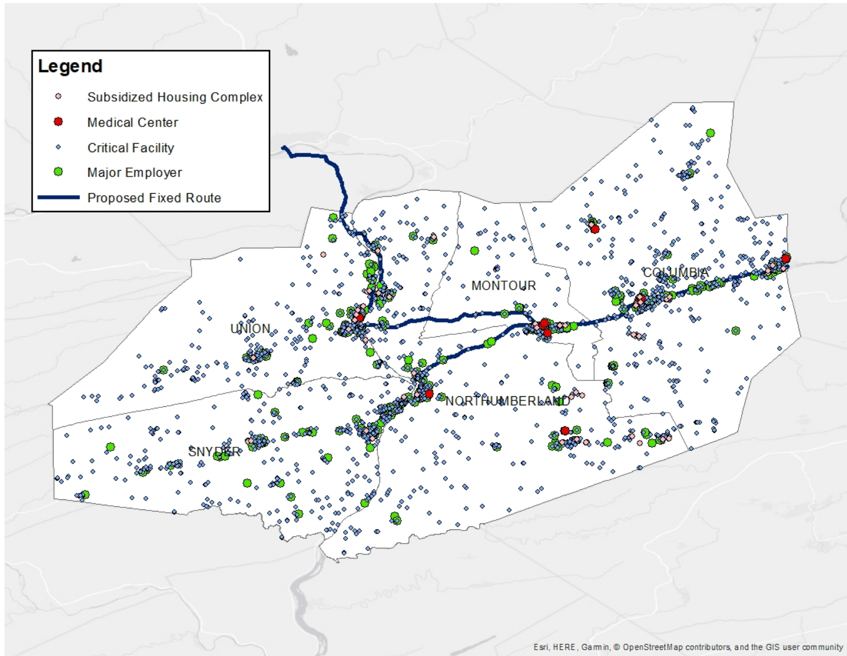

Figure 2. Map of the Critical Facilities, Major Employers, Medical Facilities and Subsidized Housing Complexes provided by SEDA-COG.

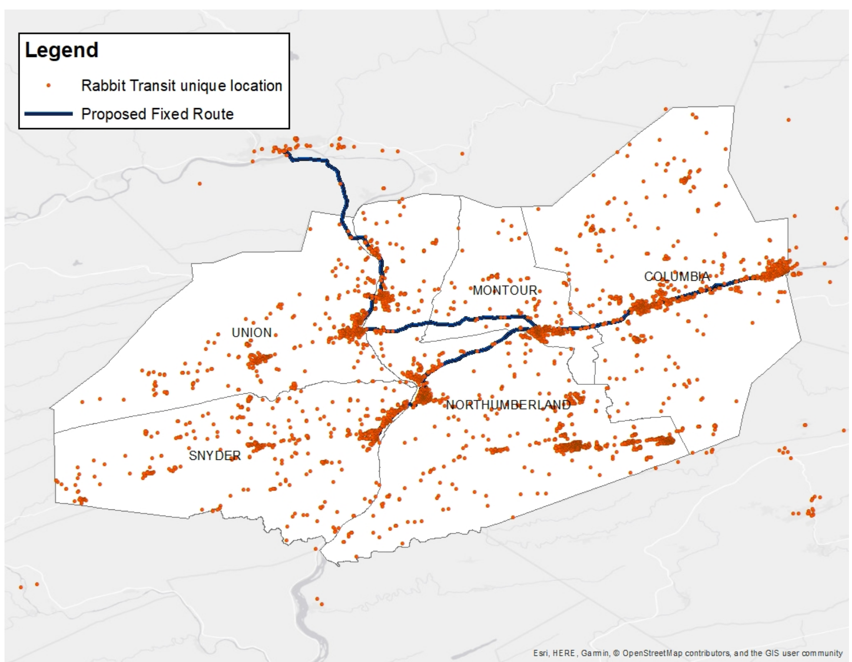

Figure 3. Unique locations extracted from 2018 RT ride requests.

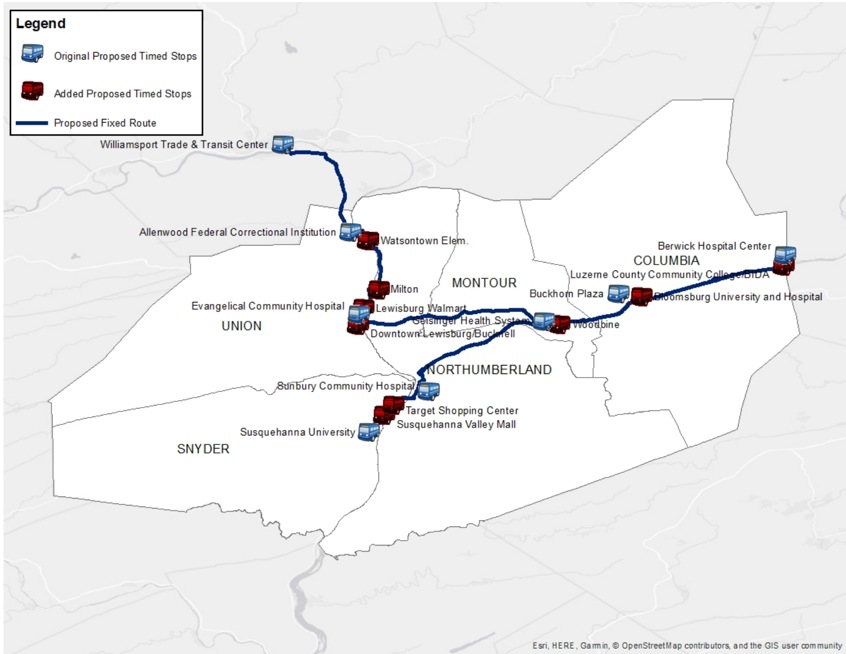

Figure 5. Map of all 17 proposed timed stops.

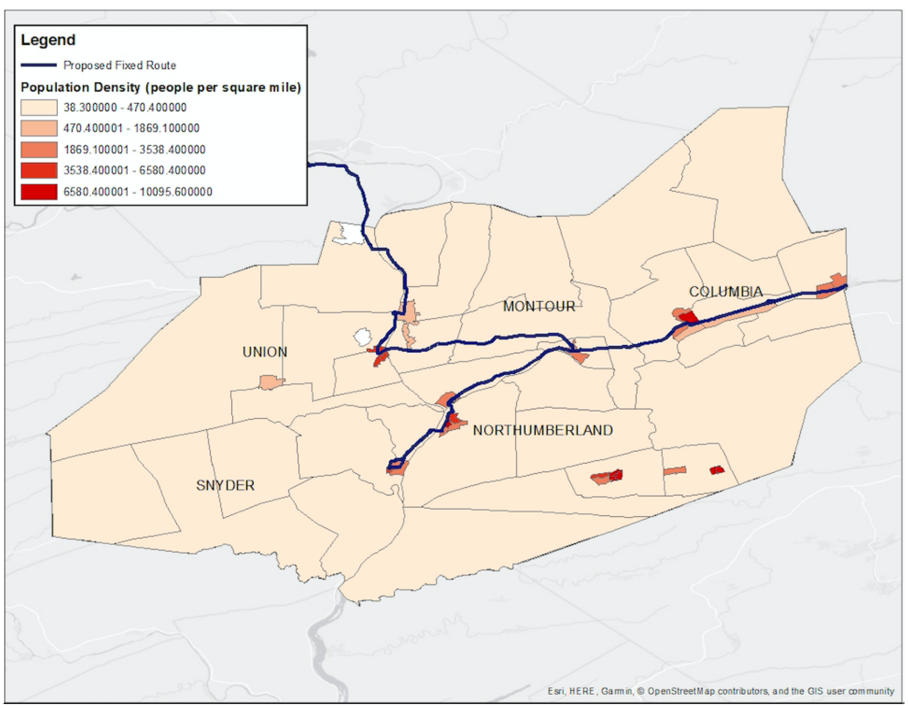

Figure 8. Map illustrating population density, in people per square mile. Darker shades indicate more densely populated census tracts.

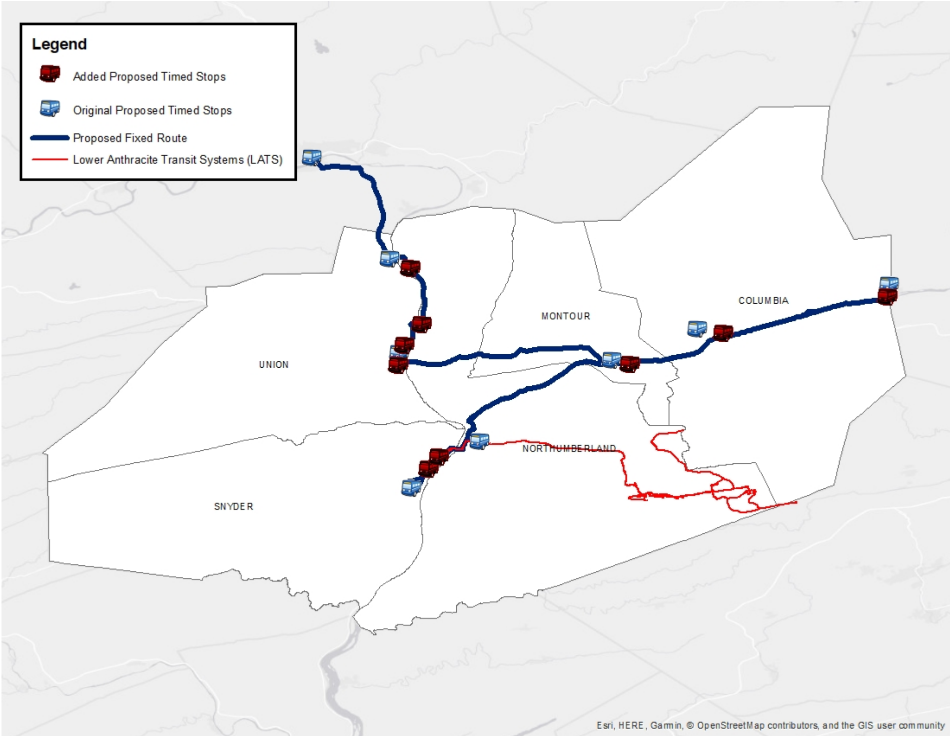

Figure 9. Proposed fixed route with potential LATS connecting route.

Start Time:	5:00 AM	WHERE A POTENTIAL RIDER WORKS													
WHERE A POTENTIAL RIDER LIVES		Williamsport	Allenwood	Watsontown	Milton	Lewisburg	Danville	Woodbine	Buckhorn Plaza	Bloomsburg	Luzerne	Berwick	Sunbury	Shamokin Dam	Selinsgrove	Susquehanna University
	Williamsport	--	5:26 AM	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Allenwood	8:45 AM	--	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Watsontown	8:45 AM	8:20 AM	--	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Milton	8:45 AM	8:20 AM	8:11 AM	--	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Lewisburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	--	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Danville	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	--	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Woodbine	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	--	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Buckhorn Plaza	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	--	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Bloomsburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	--	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Luzerne	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	--	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Berwick	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	5:50 AM	--	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Sunbury	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	--	7:43 AM	7:51 AM	8:00 AM
	Shamokin Dam	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	--	7:51 AM	8:00 AM
	Selinsgrove	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	--	8:00 AM
	Susquehanna University	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	5:57 AM	--

Table 3. Ability of potential riders to get to work by 7:00AM.

Start Time:	5:00 AM	WHERE A POTENTIAL RIDER WORKS													
WHERE A POTENTIAL RIDER LIVES		Williamsport	Allenwood	Watsontown	Milton	Lewisburg	Danville	Woodbine	Buckhorn Plaza	Bloomsburg	Luzerne	Berwick	Sunbury	Shamokin Dam	Selinsgrove	Susquehanna University
	Williamsport	--	5:26 AM	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Allenwood	8:45 AM	--	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Watsontown	8:45 AM	8:20 AM	--	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Milton	8:45 AM	8:20 AM	8:11 AM	--	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Lewisburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	--	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Danville	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	--	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Woodbine	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	--	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Buckhorn Plaza	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	--	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Bloomsburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	--	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Luzerne	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	--	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Berwick	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	5:50 AM	--	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Sunbury	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	--	7:43 AM	7:51 AM	8:00 AM
	Shamokin Dam	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	--	7:51 AM	8:00 AM
	Selinsgrove	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	--	8:00 AM
	Susquehanna University	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	5:57 AM	--

Table 4. Ability of potential riders to get to work by 8:00AM.

Start Time:	5:00 AM	WHERE A POTENTIAL RIDER WORKS													
WHERE A POTENTIAL RIDER LIVES		Williamsport	Allenwood	Watsontown	Milton	Lewisburg	Danville	Woodbine	Buckhorn Plaza	Bloomsburg	Luzerne	Berwick	Sunbury	Shamokin Dam	Selinsgrove	Susquehanna University
	Williamsport	--	5:26 AM	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Allenwood	8:45 AM	--	5:35 AM	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Watsontown	8:45 AM	8:20 AM	--	5:47 AM	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Milton	8:45 AM	8:20 AM	8:11 AM	--	6:04 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Lewisburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	--	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Danville	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	--	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Woodbine	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	--	7:22 AM	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Buckhorn Plaza	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	--	7:33 AM	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Bloomsburg	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	--	7:55 AM	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Luzerne	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	--	8:00 AM	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Berwick	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	6:41 AM	6:24 AM	6:13 AM	5:50 AM	--	7:30 AM	7:43 AM	7:51 AM	8:00 AM
	Sunbury	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	--	7:43 AM	7:51 AM	8:00 AM
	Shamokin Dam	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	--	7:51 AM	8:00 AM
	Selinsgrove	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	--	8:00 AM
	Susquehanna University	8:45 AM	8:20 AM	8:11 AM	7:59 AM	7:46 AM	6:45 AM	7:05 AM	7:22 AM	7:33 AM	7:55 AM	8:00 AM	6:16 AM	6:06 AM	5:57 AM	--

Table 5. Ability of potential riders to get to work by 9:00AM.