APPENDIX A

Frederick-Shady Grove Ridership and Revenue Study and Sensitivity Analysis Memo

Frederick-Shady Grove Ridership and Revenue Study
Executive Summary

This report documents the assumptions, methodologies, and results of a study to develop **feasibility-level ridership forecasts** for the proposed monorail service between Frederick and Shady Grove. Ridership analysis was performed using the recently adopted regional model Version 2.3.75 and the FTA's STOPS model using key assumptions for the proposed monorail service. These inputs reflect an ambitious design and service concept which includes low run times and high operation speeds, frequent service, competitive fares, and free parking. Specifically, the following scenarios and assumptions were evaluated:

- The base frequency used was comparable to Metrorail, the higher frequency assumed service much better than Metrorail, and the lower frequency was comparable to Metrorail for peak and slightly worse for off-peak periods.
- The fares were assumed to be comparable to Metrorail, with no premium price applied.
- Parking facilities were assumed to be available and free of charge at every station.
- Run time inputs of 31 minutes for the 27-mile route were used reflecting an average operating speed of 56 miles per hour (mph) and a top design speed of 70 mph. Following the conclusion of this study, CS was informed that run time should be 42 minutes based on a top design speed of 65 mph after correcting an error inadvertently made. A 2045 model run for the higher frequency Metro-like scenario and the updated travel time showed a 13 percent reduction in ridership in comparison to the ridership forecast for the 31 minute run time.

The recently adopted regional model Version 2.3.75 was applied using the latest planning assumptions including land uses and proposed transportation improvements in the fiscally Constrained Long Range Plan. The monorail is a new mode in this region, and its attractiveness has not been tested in a large regional system in the US. The initial design concept assumed that the monorail has an attractiveness similar to or better than the Metrorail currently operating in the Washington region, leading to a Metro-like scenario for ridership forecasting. Since Metrorail has seen its ridership decline over recent years, we accounted for uncertainty by testing a scenario that assumed less attractive LRT-like attributes.

STOPS, the FTA sponsored ridership forecasting tool, was also used to develop a reference forecast and provide a reasonableness check for ridership forecasts for the proposed project. For the horizon year 2045, the STOPS ridership forecast was approximately fourteen percent lower than the prediction under the Metro-like scenario using the regional model Version 2.3.75.

Average daily ridership forecasts were grown to annual ridership forecasts for purposes of estimating revenue. A ramp-up period of three years was assumed starting with the 2025 opening year. Annual revenue estimates were developed in constant dollars by scenario and by year and assumed an average fare of five dollars.

The ridership forecasts described in this report provide a feasibility analysis and represent the first step of a tiered ridership forecasting process. A Level-2 study was planned to overcome the limitations of this study which relied heavily on third-party data sources and high-level assumptions about transit level of service. A Level-2 study will refine the inputs, assumptions, and methodology used for the proposed monorail service to illuminate and quantify a range of potential forecast uncertainties.

The High Road Foundation Projects

Frederick-Shady Grove Ridership and Revenue Study

final

report

prepared for

The High Road Foundation, Inc.

prepared by

Cambridge Systematics, Inc.

March 15, 2019

final report

The High Road Foundation Projects

Frederick-Shady Grove Ridership and Revenue Study

prepared for

The High Road Foundation, Inc.

prepared by

Cambridge Systematics, Inc.
3 Bethesda Metro Center, Suite 1200
Bethesda, MD 20814

date

March 15, 2019

Table of Contents

List of Tables

List of Figures

1.0 Introduction

The proposed High Road Foundation Monorail Projects are a new privately developed and funded transit system intended to enhance mobility, improve regional connectivity, and bolster Montgomery County's competitiveness in the greater Washington, D.C. region. The long term project vision is of a monorail network providing an attractive alternative to automobile-based vehicle travel.

This report is focused on discussion of the effort and results from developing a feasibility ridership forecast for the Frederick-Shady Grove segment of the subject projects. The remainder of this Section 1.0 describes the Frederick-Shady Grove project. Section 2.0 discusses the ridership forecasting methodology used for this phase of work. Section 3.0 provides discussion of the ridership forecasting using the regional model, including the model inputs, model validation, and forecasting results in ridership and revenue under different scenarios. Section 4.0 summarizes a reference forecast using the STOPS model, including model configuration, calibration, validation, and forecasting under different scenarios. Finally, Section 5.0 presents a summary of the forecasted project ridership and revenue under this phase of work.

1.1 Alignment and Stations

The project studied in this report is the proposed Frederick-Shady Grove segment of The High Road Foundation projects. It is a 27-mile corridor connecting a Frederick station near the existing Frederick MARC station to a Shady Grove station adjacent to the Shady Grove Metrorail station in Montgomery County, Maryland, largely following the alignment of the I-270 (see Figure 1.1).

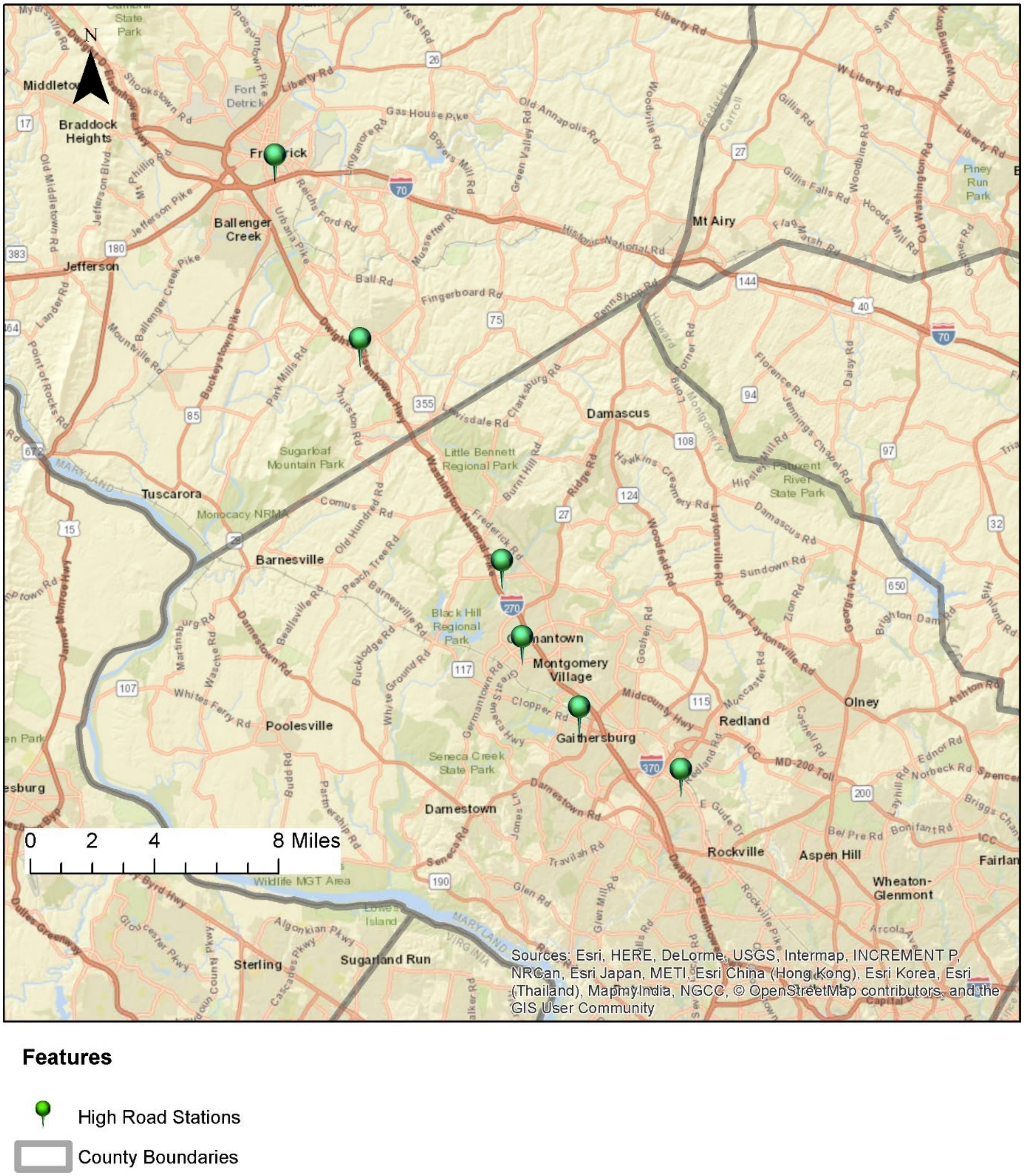
As shown in Figure 1.1, the proposed monorail service will include six stations, as follows:

- Shady Grove
- Metropolitan Grove
- Germantown
- COMSAT
- Urbana
- Frederick

Each station will be highly visible and branded for easy recognition by transit users. These stations and their surroundings, including nearby Metro and MARC stations, are shown in detail in Appendix A.

The Frederick-Shady Grove project is located within Frederick County and Montgomery County, Maryland and primarily serves a commuter travel market. It provides transit service to new and existing centers of commerce, residential, and educational development in the corridor, including Metropolitan Grove and the adjacent Life Science centers, Germantown, COMSAT, and Urbana. These developments have been planned and constructed as transit-oriented mixed-use developments. The monorail will provide direct connections with transit services into the District of Columbia and other regional destinations by way of the MARC Brunswick Line at Metropolitan Grove and the Metrorail Red Line at Shady Grove.

Figure 1.1 Proposed Project Station Locations



Source: The High Road Foundation, Inc.

1.2 Service Frequency and Span of Service

Service on the project will be scheduled at regular intervals for predictability. Three sets of service assumptions were tested:

- base frequency of service which would be the same as the Metrorail: every 6 minutes during peak periods, every 12 minutes midday and evening, and every 15 minutes during late night times;
- higher frequency of service which would increase the frequency to 3-minute headways for peak periods and 10-minute headways for midday and evening periods; and
- lower frequency of service which would be the same as the base frequency, except for 15 minute headways for midday and evening periods.

On weekends, the monorail would operate at a 10 minute interval throughout the day. Table 1-1 summarizes the service frequency and span of service on the monorail system.

Table 1.1 Hours of Operation and Frequency of Service

Day of Week and Time of Day	High Service Frequency (minutes)	Base Service Frequency (minutes)	Low Service Frequency (minutes)
Weekday			
AM Peak (5:00 AM - 9:30 AM)	3	6	6
Mid Day (9:30 AM - 3:00 PM)	10	12	15
PM Peak (3:00 PM - 7:00 PM)	3	6	6
Evening (7:00 PM - 10:00 PM)	10	12	15
Late Night (10:00 PM - 12:30 AM)	15	15	15

Source: Adapted from The High Road Foundation, Inc. Service begins with Metrorail service; ends 30 minutes after Metrorail close.

1.3 Travel Time and Service Quality

The proposed High Road Foundation Monorail Project for Frederick to Shady Grove is positioned to provide high-quality service in an experience that provides passenger comfort. The BYD Skyrail vehicle has been used as the prototype for planning. BYD Skyrail is a sleek, lightweight train with vehicles running on electric power and on raised guideways, giving passengers easy boarding, comfortable seating, and a memorable view of their surroundings as they glide past the traffic below.

Innova Technologies, a consultant to The High Road Foundation, developed estimates of station-to-station travel times using station-to-station guideway distances and performance characteristics for the Skyrail vehicle set. Specifically, the travel time estimates were based on the top design speeds (up to 70 miles per hour), service acceleration and deceleration rates, and station dwell times.

The resulting one-way estimated travel time on the monorail from Frederick to Shady Grove would be approximately 31 minutes including 30 seconds dwell time at each station, based on achieving top speeds of up to 70 miles per hour between stations. Table 1.2 summarizes the station-to-station travel times. Times in the table include station dwell time.

Table 1.2 Estimated Station-to-Station Travel Times

Station A	Station B	Travel Time (Minutes)
Frederick	Urbana	8.28
Urbana	COMSAT	8.52
COMSAT	Germantown	4.87
Germantown	Metropolitan Grove	4.71
Metropolitan Grove	Shady Grove	4.48

Source: Innova Technologies

1.4 Fare Assumptions

The fares for the proposed High Road Foundation Monorail Project for Frederick to Shady Grove may be arranged through a combination of direct farebox and subscription-based pass payment methods. Overall, the service is intended to present as priced compatibly and competitively with public transit services in the area. Accordingly, no premium price was applied in developing the ridership forecasts for the service for the base cases, while a sensitivity test with respect to fare was conducted to evaluate the responses to a fare increase. Put simply, it can be viewed as being priced equivalent to Metrorail service for comparable trips for purposes of ridership forecasting.

2.0 Ridership Forecasting Methodology

Ridership analysis for this project was performed using the recently adopted regional model and the Federal Transit Administration's Simplified Trips-on-Project Software (STOPS).

The regional travel demand model used in this project is the Metropolitan Washington Council of Governments/National Capital Region Transportation Planning Board (TPB) model Version 2.3.75, which was recently adopted and used in the Air Quality Conformity Determination of the 2018 Financially Constrained Long Rang Transportation Plan (Visualize 2045) and FY 2019-2024 Transportation Improvement Program (TIP), reflecting the latest regional planning assumptions.

Version 2.3.75 is a sophisticated, conventional trip-based travel demand model with six major components:

- Demographic models with market stratifications by four household income groups, four household size groups, and four vehicle availability groups;
- Trip generation models for five personal trip purposes, a commercial vehicle trip purpose, and two truck trip types;
- Trip distribution model with doubly-constrained gravity model formulation with a composite impedance of transit and highway travel times;
- Mode choice model with nested logit structure for five trip purposes and two time periods;
- Time of day model with four time periods – AM peak, midday, PM peak, and night time/early morning; and
- Traffic assignment with six user classes and equilibrium assignment methodology.

The mode choice model estimates demand for usage of motorized modes, including low-occupancy vehicles with one or two occupants (LOV), high-occupancy vehicles with three or more occupants (HOV), commuter rail passengers, heavy rail passengers, bus passengers, and bus-to-rail passengers.

For this study, the model performance was further reviewed and validated for the study area. Model validation included review and refinements of highway and transit networks and comparisons of assignment results with the observed transit ridership in the study corridor.

STOPS is used in this study to develop a reference forecast for the proposed Monorail. STOPS comprises a series of programs designed to estimate transit ridership using a streamlined set of procedures. STOPS is similar in structure to regional models and includes many of the same computations of transit level-of-service and market share features found in travel demand model sets. STOPS builds upon existing data for most aspects of the forecasting process and produces all of the reporting needed by project sponsors to review ridership forecasts in detail and to support applications to the FTA Small Starts and New Starts capital grant programs. STOPS internal models have been calibrated and validated against a national collection of over 30 fixed-guideway projects and systems, reflecting streetcar, bus rapid transit, light rail, heavy rail, and commuter rail modes.

STOPS provides ridership estimates using readily available input datasets and a nationwide set of fixed-guideway rider surveys. STOPS takes as input Census Transportation Planning Products (CTPP) and Census Data, General Transit Feed Standard (GTFS) transit scheduling files, observed transit counts on the existing system, travel times and distances from the applicable regional travel demand model, base and forecast year demographic and employment data, and a Transportation Analysis Zone (TAZ) shapefile.

For the proposed High Road Foundation Monorail Project for Frederick to Shady Grove, a STOPS instance was first calibrated to local conditions based on the most recent observed transit data. It then was used to generate ridership forecasts for the build options under consideration. The approach focused on performing analysis for “current” conditions first and then addressing required horizon year forecasting. In addition to producing results in the format endorsed by FTA, STOPS produced:

- Average weekday boardings by station;
- Forecast trips on the monorail by trip purpose, household auto-ownership, and production-end access mode; and
- Changes in Personal Miles of Travel (PMT).

The travel demand modeling component of this study consisted of the following elements:

- Development and analysis of the existing (2017) No Build alternative;
- Development and analysis of the existing (2017) Build alternative;
- Development and analysis of the opening year (2025) Build analysis; and
- Development and analysis of a future (2045) Build alternative.

3.0 Ridership Forecasting Using the MWCOG/TPB Model

This chapter documents the ridership forecasting using the MWCOG/TPB model, including the model inputs, assumptions, base year model validation, ridership forecasting under different scenarios, annualization of ridership and revenue, and the sensitivity of ridership with respect to fares.

3.1 COG Model Inputs

Two major inputs to the model include: 1) the transportation network that represents the long range plan Visualize 2045 and FY 2019-2024 TIP, 2) land use -- MWCOG Round 9.1 Cooperative Forecasts.

Significant transportation projects in the study area include the following:

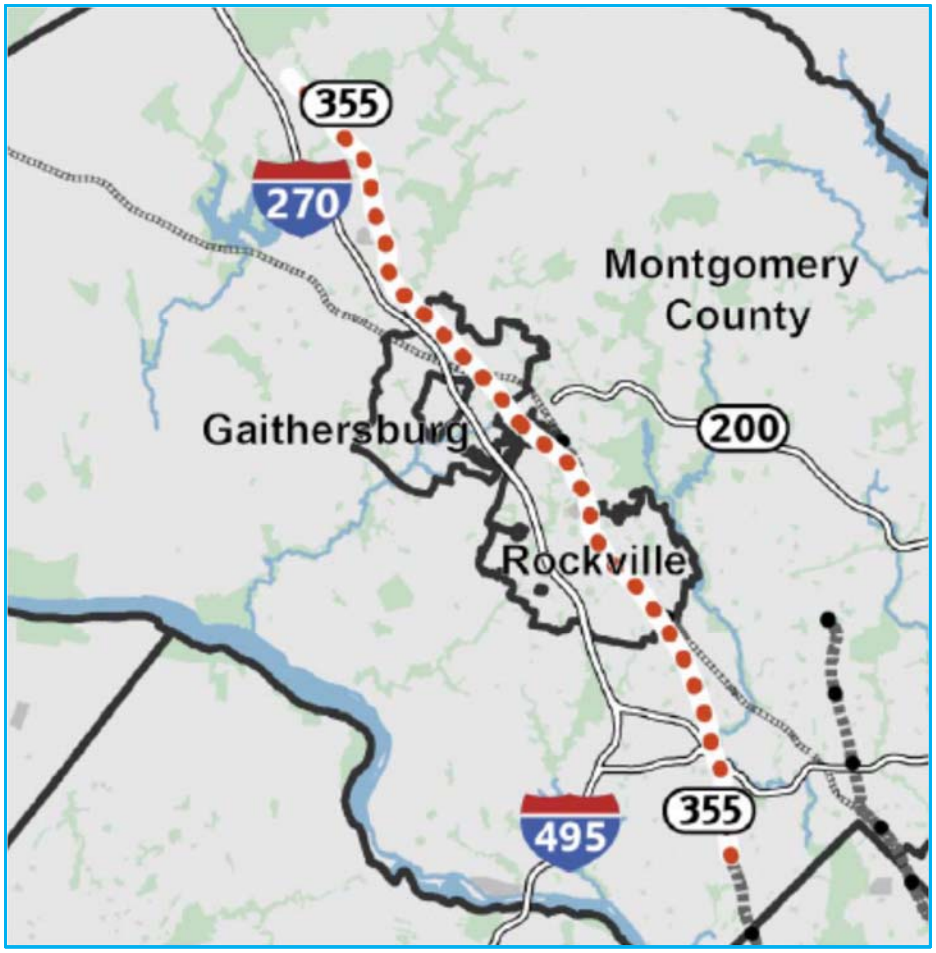
- I-270 Traffic Relief Plan, construct 4 managed lanes, 2025 ($4.0B)
- I-95/I-495 Traffic Relief Plan, construct 4 managed lanes, 2025 ($4.2B)
- Corridor Cities Transitway BRT - from Shady Grove to COMSAT, 2020 ($545M)
- MD-355 BRT - from Bethesda Metro to Clarksburg, 2040 ($1B)
- North Bethesda Transitway BRT - from Montgomery Mall to White Flint Metro, 2040 ($115M)

Figure 3.1 shows the location of the proposed managed lanes along I-270 in the Maryland Traffic Relief Plan, which will affect the travel choices in the study corridor in 2025 and beyond. Figure 3.2 exhibits the proposed Route 355 BRT that would connect Clarksburg in northern Montgomery County with Bethesda inside the Capital Beltway. Figure 3.3 demonstrates the propose Corridor Cities Transit BRT that runs between Shady Grove and COMSAT. These two proposed BRT services can be used to make connections with the proposed monorail, through Shady Grove, Metropolitan Grove, and COMSAT.

Figure 3.1 Major Highway Projects in the Study Corridor

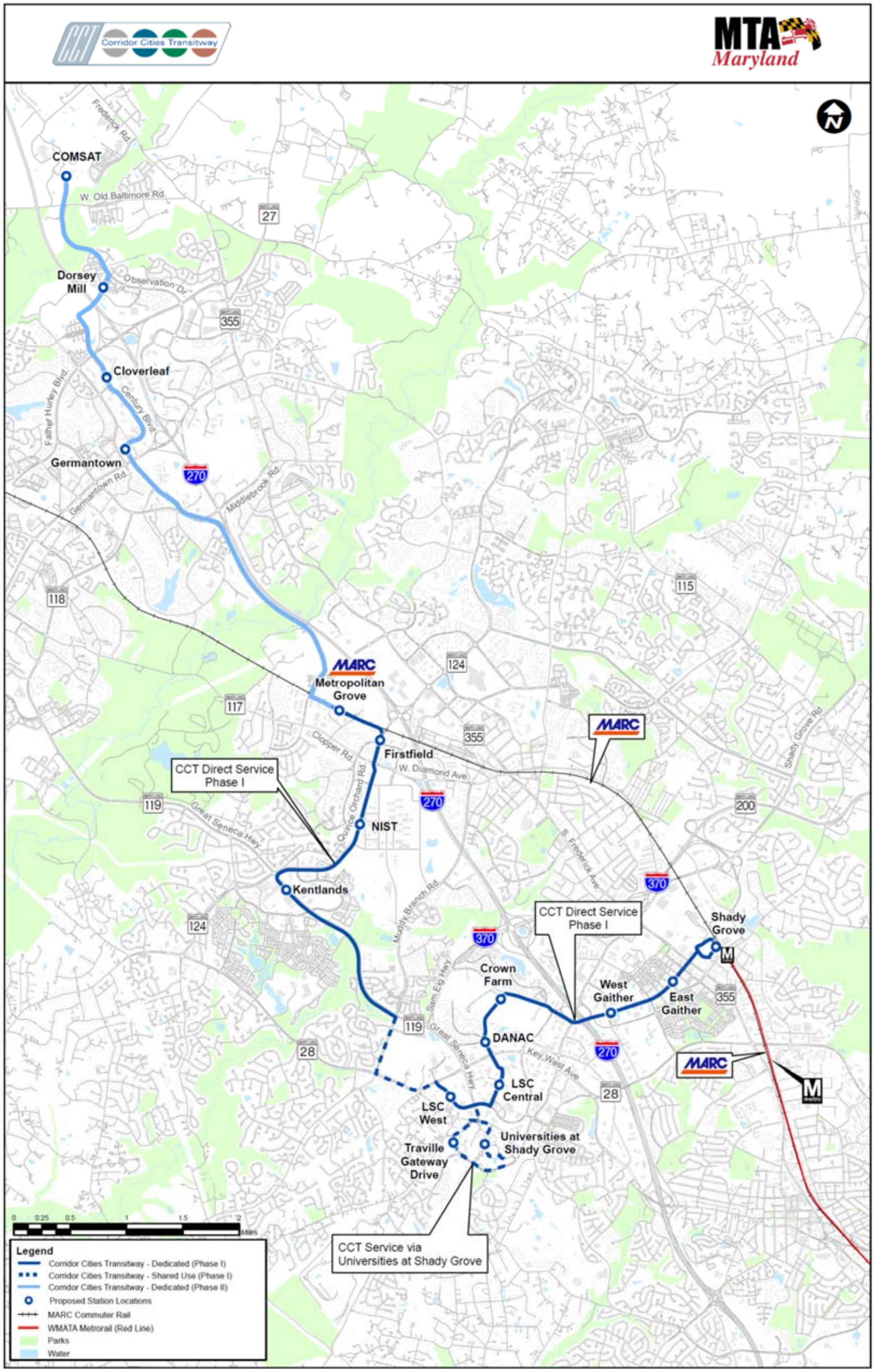
Source: TPB, Visualize 2045.

Figure 3.2 Major Transit Projects in the Study Corridor



Source: TPB, Visualize 2045.

Figure 3.3 Proposed Corridor Cities Transitway

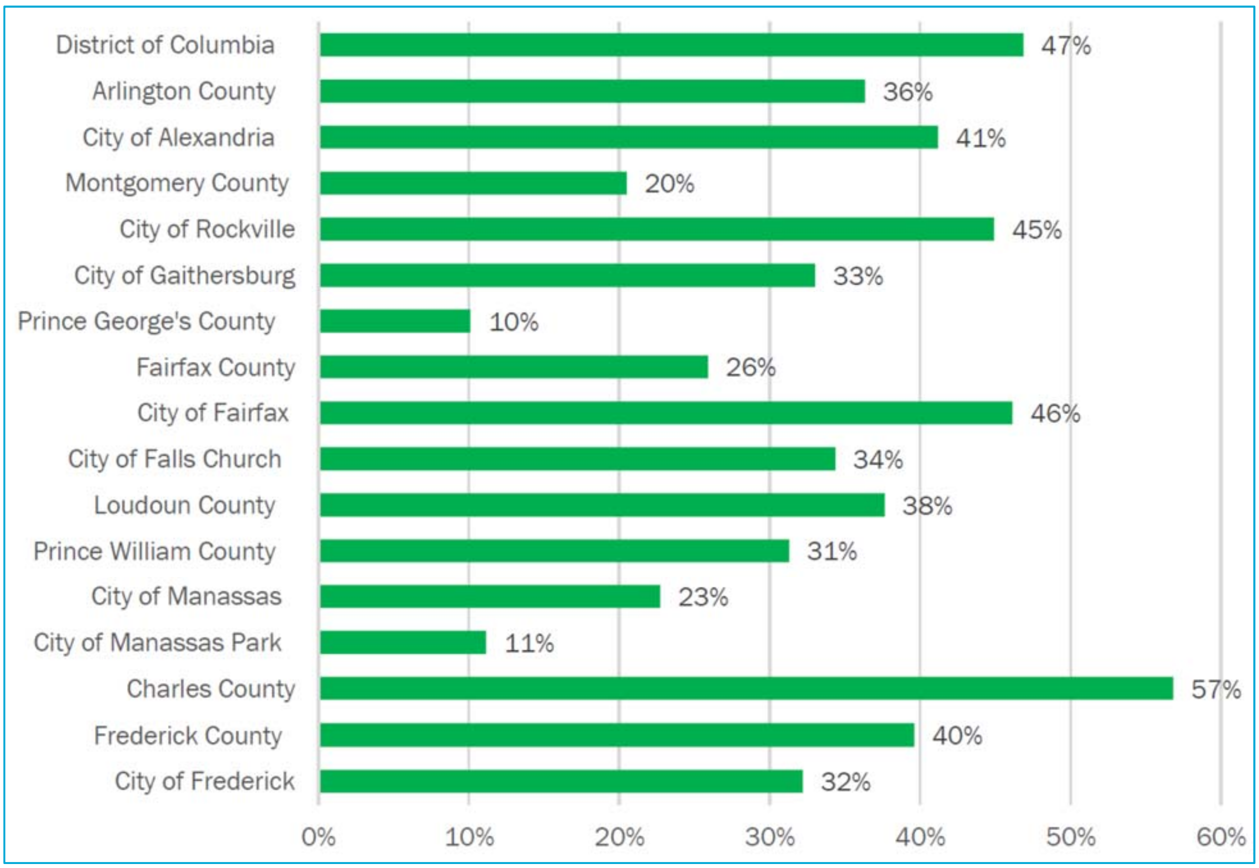


Source: MDOT/MTA

The latest officially adopted land use forecasts in the region, namely Round 9.1 Cooperative Forecasts, were used in this ridership forecasting process. Figures 3.4, 3.5 and 3.6, respectively, show the population, households, and employment growth by jurisdiction between 2015 and 2045. As can be seen, Montgomery County is expected to increase its population by 20 percent and its employment by 30 percent, while Frederick County if forecast to grow its population by 40 percent and employment by 30 percent during the thirty years.

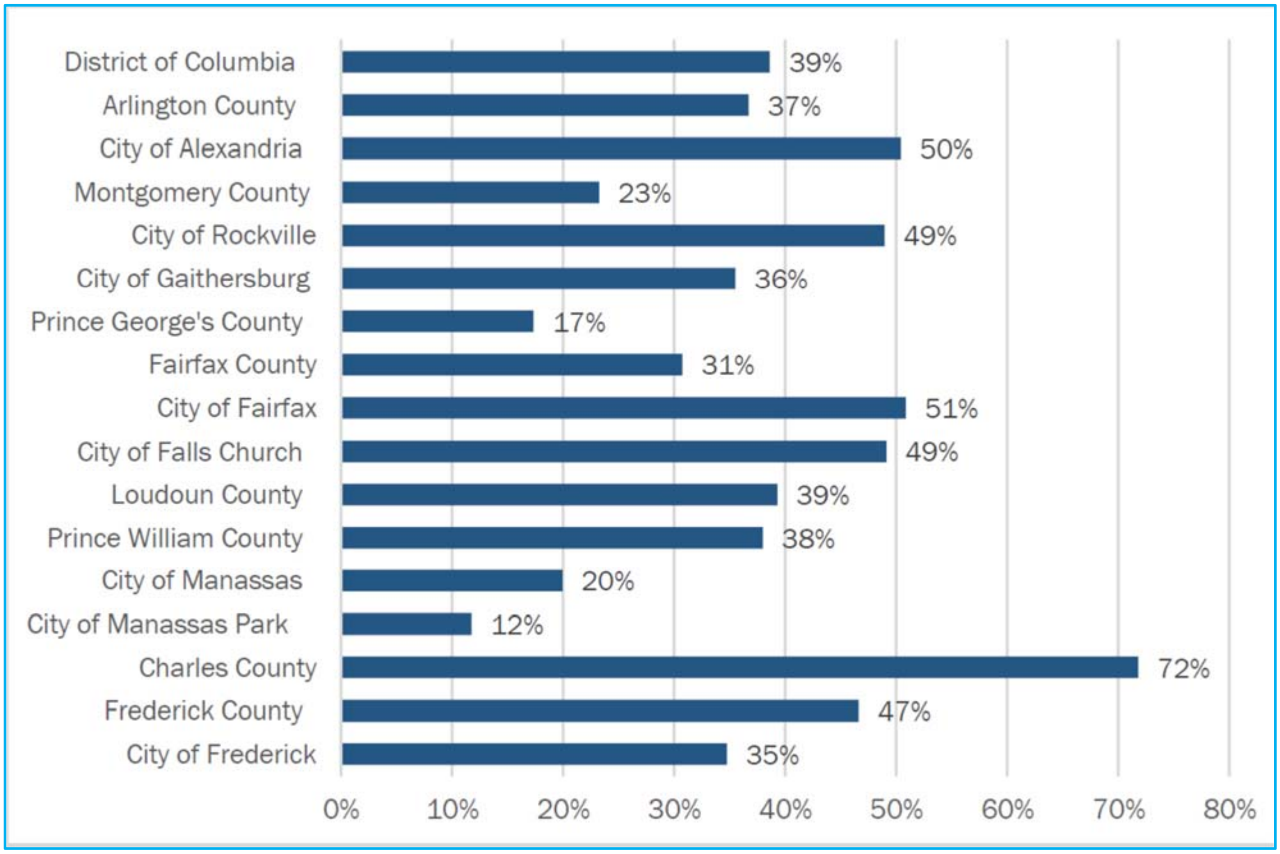
Figures 3.7 and 3.8 highlight the areas in the study corridor that would undergo major changes in population and employment densities, respectively. As can be seen, the areas near the proposed stations are expected to see considerable growth in both population and employment. Appendix B provides information at the Transportation Analysis Zone level for the study area.

Figure 3.4 Population Growth by Jurisdictions, 2015 to 2045



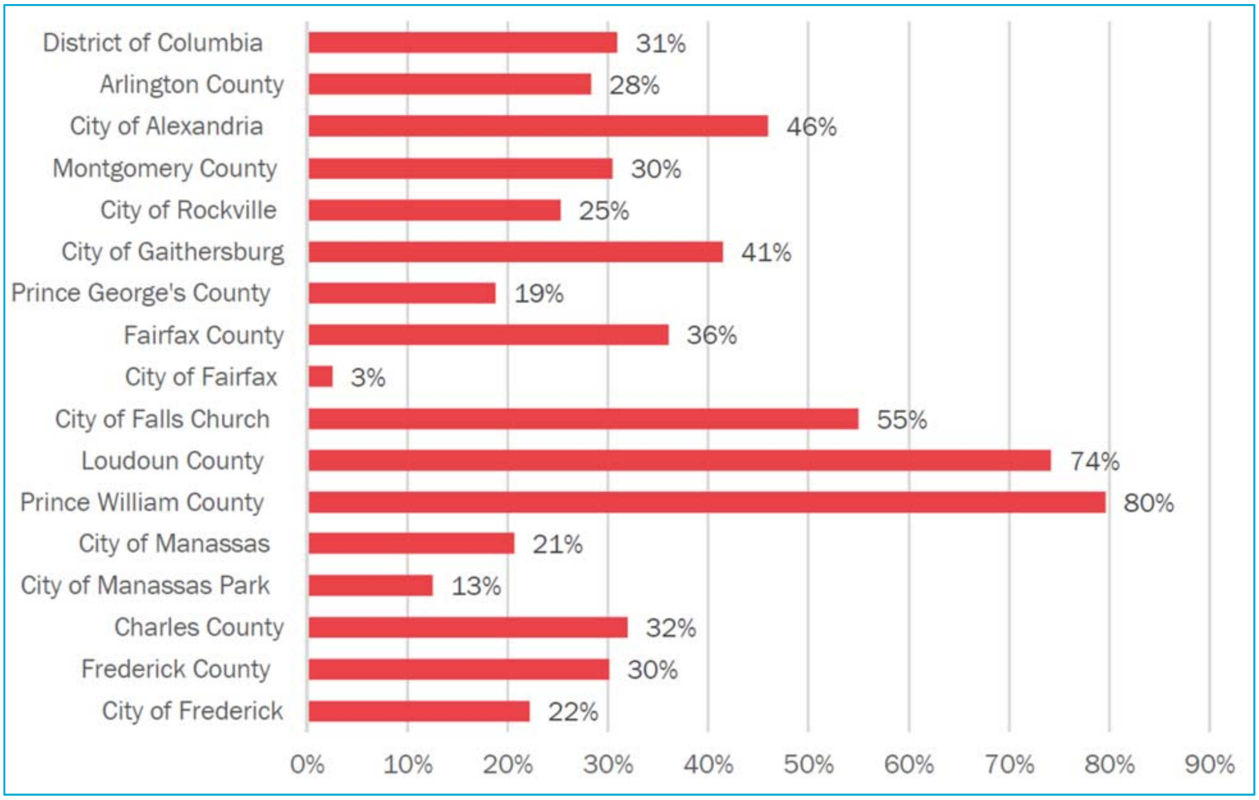
Source: MWCOG. 2018. Growth Trends: Cooperative Forecasting in Metropolitan Washington

Figure 3.5 Households Growth by Jurisdictions, 2015 to 2045



Source: MWCOG. 2018. Growth Trends: Cooperative Forecasting in Metropolitan Washington

Figure 3.6 Employment Growth by Jurisdictions, 2015 to 2045



Source: MWCOG. 2018. Growth Trends: Cooperative Forecasting in Metropolitan Washington

Figure 3.7 Changes in Study Area Population Density, 2015 to 2045

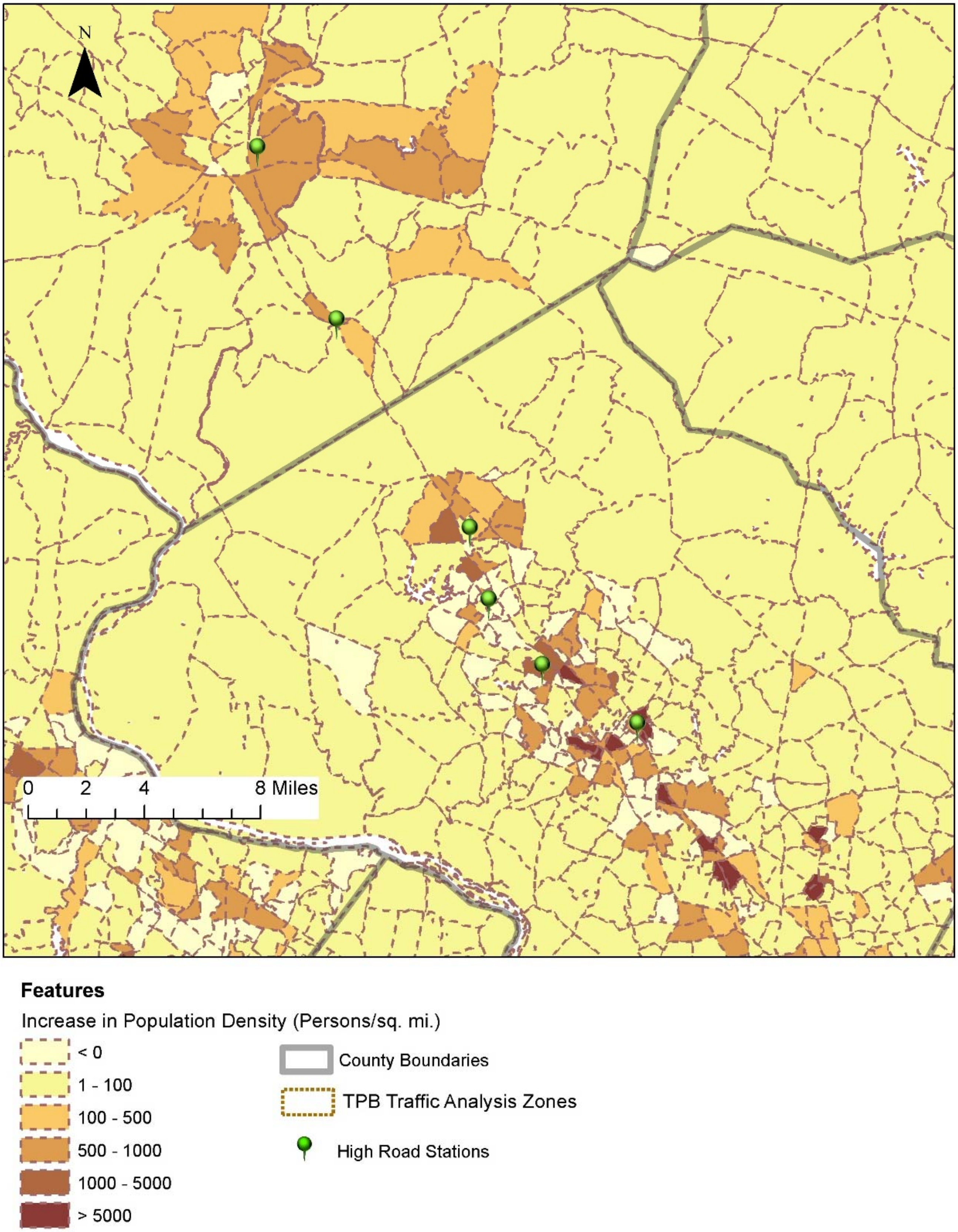
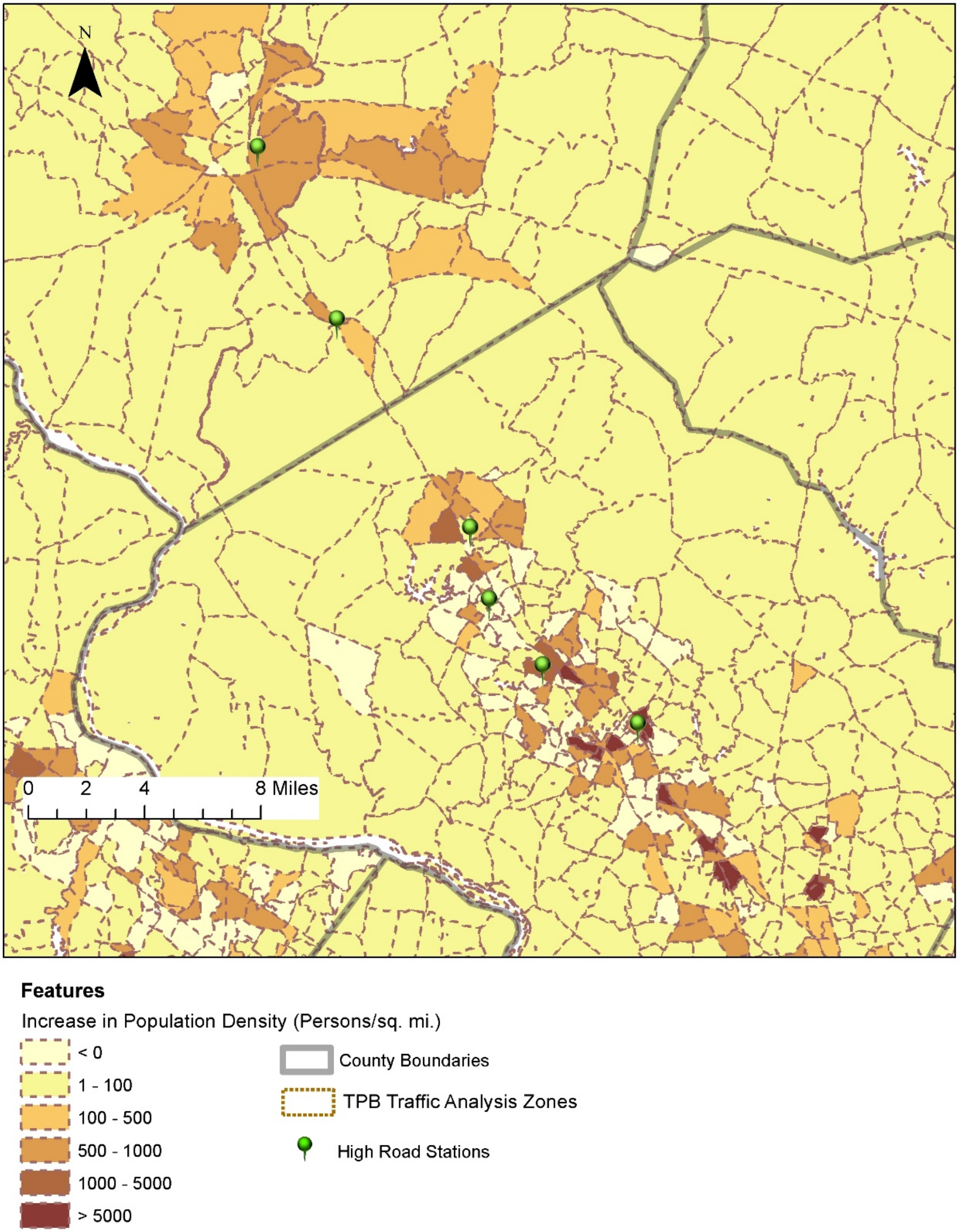


Figure 3.8 Changes in Study Area Employment Density, 2015 to 2045



3.2 Base Year Model and Validation

The MWCOG/TPB model has been regularly calibrated and validated at the regional and jurisdiction level. For this study, the model was further reviewed and validated for the study area. Model validation included:

- Highway network review and refinements based on the existing roadway conditions;
- Transit network coding review and refinements based on published transit schedule and routing information; and
- Comparisons of estimated traffic volumes vs observed traffic counts in the study area.

The study area is currently served by the WMATA Metrorail, MTA MARC, MTA Commuter Bus, and Montgomery County Ride-On Bus. The model estimated ridership is compared with the observed ridership for the Metro Station Shady Grove, MARC stations in the study area, MTA Commuter Bus services, and Montgomery County Ride-On bus services in the study area (Table 3.1). Overall, the model estimates are higher than the observed ridership in the study area. The combined model estimates for Shady Grove Metro station and all MARC stations, which are most relevant to the forecasts for the proposed monorail, are reasonably close to the observed ridership.

Table 3.1 Observed versus Estimated Route Level Boardings

System	Route	Observed	Estimated
WMATA*	Shady Grove	13,308	14,630
MARC**	Metropolitan Grove	290	407
	Washington Grove	300	1
	Gaithersburg	542	835
	Frederick	136	35
MTA***	505/515	1,343	2,491
	204	298	212
RideOn***	43	707	589
	54	1,918	5,040
	55	8,422	7,934
	56	2,168	1,471
	61	2,934	1,728
	63	744	523
	66	173	437
	67	129	205
	70	659	3019
	71	345	437
	74	1,254	3,086
	75	536	832
	76	868	1,371
	78	265	407
	79	300	424
	83	499	810
	90	957	1,239
	97	684	167
	98	477	724
	100	2,306	1,659
Total		**42,562**	**50,713**

Notes: * WMATA observed ridership is for 2014
** MARC observed ridership in 2016
*** MTA and RideOn observed ridership is for FY2015, from MWCOG RTDC database

3.3 Ridership Forecasting

Monorail is a new mode in this region, and its attractiveness has not been revealed as part of a large regional system in the U.S. Currently operating U.S. monorail service has been limited to specialty applications (e.g., Seattle shuttle, Las Vegas tourism). Also, as part of this study, we did not undertake stated preference surveys to explore potential user perceptions of monorail. Instead, for this feasibility study, we explored modeling analogs to the proposed service.

In the Washington, D.C. region and in select other major cities, rail transit services like Metrorail have long been held as representing the transit option that has the most attractive service. Primarily, we are referring to attractive in terms of what are known as “unincluded attributes” – things other than travel time and cost that make up the decision of a user to utilize the mode. Unfortunately, holding Metrorail up as the gold standard of transit today, when it has been suffering from image and reliability problems and losing ridership, may seem out of touch. However, in terms of our forecasting models, when we speak about Metrorail, we are thinking of a repaired, refurbished, clean, and comfortable Metrorail – a mode that has the most possible “points” assigned to its attractiveness.

LRT transit is also viewed as attractive in most applications. However, it does have a reputation, perception, and brand identity that suffer from it being generally a slower mode of travel that may have fewer station and vehicle amenities than Metrorail. In the Washington, D.C. region, LRT is under construction in the form of the Purple Line, and our regional model includes a representation for it which has been vetted through a process with the FTA.

Given that the proposed monorail is seen as having many of the same attractive qualities of the restored Metrorail, we have coded a scenario named “Metro-like,” to assume a mode attractiveness of Metrorail for the monorail in the modeling. To account for potential uncertainty about perceptions of ride quality, comfort, and reliability, we have also coded a lower mode attractiveness scenario named “LRT-like,” where we assume the attractiveness of LRT for monorail in the modeling. We believe this should serve as a lower bound on the forecasts given that we believe the operating characteristics and amenities associated with the proposed monorail will make it more attractive than LRT.

The daily project boardings are tabulated by scenarios and forecast years in Table 3.2, representing steady state ridership without taking into account the ramp-up factors which will be discussed in the next section on annual ridership and revenue. The base year is 2017, the opening year is 2025, and the horizon year is 2045. Three levels of service frequency were tabulated previously in Table 1.1, specifically referred as Higher Service Frequency, Base Service Frequency, and Lower Service Frequency.

As expected, the Higher Service Frequency scenarios generate the highest ridership among the three service frequency levels. The differences between the Base Service Frequency and Lower Service Frequency levels are small, as they have only a small frequency differences in mid-day and evening hours, when the ridership is low. The differences for the Metro-like scenario between the Higher and Base Service Frequency are approximately 3,600 in 2045 and 3,100 in 2025. The Metro-like scenarios have significantly higher ridership forecasts than their comparable LRT-like scenarios, reflecting the higher attractiveness of the Metro-like services. Between the open year 2025 and horizon year 2040, the ridership is forecasted to increase by approximately 40 percent.

The station-level boardings are tabulated for the Metro-like scenarios under three frequency service levels (see Tables 3.3, 3.4, and 3.5). Among the six stations, Shady Grove has the highest ridership estimate, as it serves as a connecting point for the Metro Red Line, the proposed CCT BRT and MD 355 BRT services. Frederick has the second highest ridership, as the terminal station with a larger catchment area. Metropolitan Grove has the connectivity with both MARC and CCT BRT, especially those activity centers such as Life Science Centers.

Table 3.2 Daily Project Boardings by Scenario and Forecast Year

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	37,300	35,100	34,800
LRT-Like	29,500	27,300	27,300
2025			
Metro-Like	39,500	36,400	36,100
LRT-Like	31,600	28,900	28,900
2045			
Metro-Like	55,100	51,500	50,500
LRT-Like	42,800	39,700	39,400

Note: Rounded to 100s

Table 3.3 Daily Project Boardings by Station and Forecast Year (Higher Frequency Metro-Like Scenario)

Station	2017	2025	2045
Shady Grove	18,100	19,000	26,400
Metropolitan Grove	4,400	5,000	5,700
Germantown	3,600	3,800	4,000
COMSAT	1,600	1,700	2,600
Urbana	1,300	1,400	2,000
Frederick	8,300	8,600	14,300
Total	**37,300**	**39,500**	**55,000**

Note: Rounded to 100s

Table 3.4 Daily Project Boardings by Station and Forecast Year (Base Frequency Metro-Like Scenario)

Station	2017	2025	2045
Shady Grove	17,000	17,500	24,700
Metropolitan Grove	3,900	4,400	5,000
Germantown	3,300	3,400	3,600
COMSAT	1,500	1,600	2,300
Urbana	1,300	1,300	1,900
Frederick	8,000	8,200	13,900
Total	**35,000**	**36,400**	**51,400**

Note: Rounded to 100s

Table 3.5 Daily Project Boardings by Station and Forecast Year (Lower Frequency Metro-Like Scenario)

Station	2017	2025	2045
Shady Grove	16,900	17,400	24,300
Metropolitan Grove	3,900	4,300	4,800
Germantown	3,200	3,300	3,500
COMSAT	1,500	1,600	2,300
Urbana	1,300	1,300	1,900
Frederick	8,000	8,200	13,700
Total	**34,800**	**36,100**	**50,500**

Note: Rounded to 100s

3.4 Annualized Ridership and Revenue

The common industry practice for calculating annual gross revenue involves multiplying the average weekday revenue by 250 weekdays per year and applying a holiday/weekend revenue factor to address revenue for 115 holiday/weekend days per year. A common source for the annualization factor is to review the U.S. National Transit Database information for comparable figures. These can be localized based on specific project knowledge of the proposed service levels and ridership potential. It should also be noted, that they can be influenced by the variation of ridership between weekday and weekend levels. That is, a system with very high weekday ridership relative to its weekend ridership will tend to have a lower annualization factor than a system with relatively similar ridership on weekdays as compared with weekends.

Table 3.6 presents information from several transit systems in the Metropolitan Washington area for reference. In estimating annualized ridership in the Frederick-Shady Grove study we have considered three sets of annualization factors, the highest being 296, reflecting the regional transit system WMATA's ridership profile where weekend ridership will contribute approximately 40 percent of the ridership that weekday ridership contributes. This figure appears to be in line with the derived annualization factors from other regional services and is the average of the 2013 and 2014 annualization factors derived from WMATA ridership experience. However, the WMATA system and, to a fair extent, the other services listed serve a wide variety of land use conditions and travel markets and also handles a significant volume of transit-dependent customers. The latest 2018 WMATA Metro data were also analyzed to estimate the annualized factor of 286, reflecting the recent reduced levels of weekend travel on Metro.

The third annualization factor we explore is a factor of 271, which is from a recent New Starts project, Durham-Orange LRT in the Triangle region, and which has endured an FTA review of its derivation. The proposed Durham-Orange LRT serves mainly a commuter market and, given this similarity with the proposed monorail, makes it suitable to consider as a reference for developing annual ridership and revenue.

Tables 3.7-3.9 summarize the steady-state annual project boardings by scenarios (Metro-like, LRT-Like, across three frequency levels) and forecast years (2017, 2025, and 2045), using the assumptions of the three annualization factors, respectively. Similarly, Tables 3.10-3.12 shows the steady-state annual project revenues by scenarios (Metro-like/LRT-Like and three frequency levels) and forecast years (2017, 2025, and 2045), using the assumptions of the three annualization factors, respectively.

It is usual for a potential user to take some time to become familiar with new transportation facilities/options, and the demand “ramps up” over the first few years of operations. This behavioral characteristic is not explicitly simulated in travel demand models. The typical revenue model includes ramp-up periods after opening year for each segment/phase in accordance with typical practice (i.e., steady-state ridership will not be fully realized on opening day). Ramp-up periods can vary. In Transit Cooperative Research Program Report 95, Chapter 10, “Traveler Response to Transportation System Changes,” it was reported that ridership growth tends to level off after one to three years. This should be kept in mind, especially, when considering the opening year ridership forecast. An analysis of thirteen urban rail services around the world suggests the use of 79% as a ramp-up factor for the first year, 95% for the second year, and a steady state ridership achieved in the third year. [1]

Table 3.13 shows the annual project revenues with a ramp-up period of three years (79% for the first year and 95% for the second year), in constant dollars, by scenarios and years, using an annualization factor of 271. Similarly, Table 3.14 displays the annual project revenues with a ramp-up period based on the annualization factor of 286.

[1] Neil Douglas. 2003. Patronage Ramp-Up Factors for New Rail Services. https://www.researchgate.net/publication/316788725

Table 3.6 Regional Annualization Factors

Agency	Ratio of Saturday Ridership to Weekday Average	Ratio of Sunday Ridership to Weekday Average	Annualization Factor
WMATA	0.48 0.52 (2015, bus only)	0.32 0.36 (2015, bus only)	294 (2013) 297 (2014) 300 (2015, bus only)
Ride-On	0.53 (2013) 0.55 (2014) 0.57 (2015)	0.39 (2013) 0.41 (2014) 0.28 (2015)	302 (2013) 305 (2014) 306 (2015)
DASH (Alexandria)	0.49 (2013) 0.50 (2014) 0.51 (2015)	0.33 (2013) 0.33 (2014) 0.34 (2015)	298 (2013) 302 (2014) 298 (2015)
ART (Arlington)	0.39 (2013) n/a (2014) 0.39 (2015)	0.22 (2013) n/a (2014) 0.23 (2015)	287 (2013) n/a (2014) 283 (2015, bus only)

Source: National Transit Database 2013, 2014, 2015.

Note: WMATA figures show annualization factors going up as the system seems to lose choice riders. More choice, peak commute riders will tend to lead to a lower annualization factor. The regional services are higher because commuter traffic is limited; there is a higher dependency on transit-dependent populations which are addressing all of their trip needs on transit.

Table 3.7 Annual Project Boardings by Scenarios and Forecast Year (Annualization Factor=271)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	10,109,000	9,499,000	9,420,000
LRT-Like	7,990,000	7,400,000	7,386,000
2025			
Metro-Like	10,705,000	9,854,000	9,784,000
LRT-Like	8,567,000	7,822,000	7,819,000
2045			
Metro-Like	14,924,000	13,959,000	13,677,000
LRT-Like	11,595,000	10,766,000	10,683,000

Note: Rounded to 1,000s. Assuming a steady state.

Table 3.8 Annual Project Boardings by Scenarios and Forecast Year (Annualization Factor=286)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	10,684,000	10,040,000	9,956,000
LRT-Like	8,444,000	7,821,000	7,806,000
2025			
Metro-Like	11,314,000	10,415,000	10,341,000
LRT-Like	9,055,000	8,268,000	8,264,000
2045			
Metro-Like	15,773,000	14,754,000	14,455,000
LRT-Like	12,255,000	11,379,000	11,291,000

Note: Rounded to 1,000s. Assuming a steady state.

Table 3.9 Annual Project Boardings by Scenarios and Forecast Year (Annualization Factor=296)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	11,042,000	10,376,000	10,289,000
LRT-Like	8,727,000	8,083,000	8,067,000
2025			
Metro-Like	11,693,000	10,763,000	10,687,000
LRT-Like	9,358,000	8,544,000	8,540,000
2045			
Metro-Like	16,301,000	15,247,000	14,939,000
LRT-Like	12,665,000	11,759,000	11,669,000

Note: Rounded to 1,000s. Assuming a steady state.

Table 3.10 Annual Project Revenue in Constant Dollars by Scenarios and Forecast Year (Annualization Factor=271)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	50,546,000	47,497,000	47,101,000
LRT-Like	39,948,000	37,001,000	36,929,000
2025			
Metro-Like	53,525,000	49,271,000	48,921,000
LRT-Like	42,837,000	39,112,000	39,093,000
2045			
Metro-Like	74,621,000	69,797,000	68,385,000
LRT-Like	57,975,000	53,830,000	53,415,000

Note: Rounded to 1,000s. Assume $5 Fare. Assuming a steady state.

Table 3.11 Annual Project Revenue in Constant Dollars by Scenarios and Forecast Year (Annualization Factor=286)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	53,422,000	50,200,000	49,781,000
LRT-Like	42,221,000	39,106,000	39,031,000
2025			
Metro-Like	56,571,000	52,074,000	51,705,000
LRT-Like	45,275,000	41,338,000	41,318,000
2045			
Metro-Like	78,867,000	73,769,000	72,277,000
LRT-Like	61,274,000	56,893,000	56,455,000

Note: Rounded to 1,000s. Assume $5 Fare. Assuming a steady state.

Table 3.12 Annual Project Revenue in Constant Dollars by Scenarios and Forecast Year (Annualization Factor=296)

Scenarios\Year	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
2017			
Metro-Like	55,208,000	51,878,000	51,446,000
LRT-Like	43,633,000	40,414,000	40,336,000
2025			
Metro-Like	58,463,000	53,816,000	53,434,000
LRT-Like	46,789,000	42,720,000	42,699,000
2045			
Metro-Like	81,505,000	76,236,000	74,694,000
LRT-Like	63,323,000	58,796,000	58,343,000

Note: Rounded to 1,000s. Assume $5 Fare. Assuming a steady state.

Table 3.13 Annual Project Revenue with a Ramp-Up Period by Scenarios and Forecast Year (in Constant Dollars, Annualization Factor=271)

Scenarios	High Service Frequency	Base Service Frequency	Low Service Frequency
2025			
Metro-Like	42,285,000	38,924,000	38,648,000
LRT-Like	33,841,000	30,899,000	30,884,000
2026			
Metro-Like	51,701,000	47,629,000	47,260,000
LRT-Like	41,316,000	37,755,000	37,723,000
2027			
Metro-Like	55,334,000	51,017,000	50,587,000
LRT-Like	44,153,000	40,381,000	40,333,000
2030			
Metro-Like	58,161,000	53,753,000	53,194,000
LRT-Like	46,203,000	42,363,000	42,266,000
2035			
Metro-Like	63,199,000	58,643,000	57,840,000
LRT-Like	49,834,000	45,885,000	45,697,000
2040			
Metro-Like	68,673,000	63,977,000	62,892,000
LRT-Like	53,751,000	49,699,000	49,405,000
2045			
Metro-Like	74,621,000	69,797,000	68,385,000
LRT-Like	57,975,000	53,830,000	53,415,000

Note: Rounded to 1,000s. Assume $5 Fare.

Table 3.14 Annual Project Revenue with a Ramp-Up Period by Scenarios and Forecast Year (in Constant Dollars, Annualization Factor=286)

Scenarios	High Service Frequency	Base Service Frequency	Low Service Frequency
2025			
Metro-Like	44,691,000	41,139,000	40,847,000
LRT-Like	35,767,000	32,657,000	32,641,000
2026			
Metro-Like	54,643,000	50,339,000	49,949,000
LRT-Like	43,667,000	39,903,000	39,869,000
2027			
Metro-Like	58,482,000	53,920,000	53,466,000
LRT-Like	46,666,000	42,679,000	42,628,000
2030			
Metro-Like	61,471,000	56,811,000	56,221,000
LRT-Like	48,833,000	44,774,000	44,671,000
2035			
Metro-Like	66,795,000	61,980,000	61,131,000
LRT-Like	52,670,000	48,496,000	48,297,000
2040			
Metro-Like	72,581,000	67,618,000	66,471,000
LRT-Like	56,809,000	52,527,000	52,217,000
2045			
Metro-Like	78,867,000	73,769,000	72,277,000
LRT-Like	61,274,000	56,893,000	56,455,000

Note: Rounded to 1,000s. Assume $5 Fare.

3.5 Sensitivity Analysis

The different scenarios conducted in this study show different degrees of ridership sensitivities with respect to service frequency and attractiveness assumptions:

- Considerable sensitivities to the attractiveness assumptions (Metro-like attractiveness vs LRT-like attractiveness)
- Some sensitivities to the peak service frequency
- Low sensitivities to the off-peak service frequency

In addition, model runs were conducted by varying the fare assumptions. With increasing the monorail fare by 20%, the ridership would reduce by 5%, implying an elasticity of -0.25. The well-known Simpson–Curtin rule states that a transit fare increase (decrease) of 10 percent will result in ridership loss (gain) of 3 percent. Generally, heavy rail and Metro ridership tend to have a lower sensitivity to fare changes.

4.0 Ridership Forecasting Using STOPS

This section discusses the key STOPS inputs and the data used for analyzing the proposed High Road Foundation Monorail Project for Frederick to Shady Grove, describes the calibration and validation of the STOPS model in the study area, and summarizes the ridership forecasts results. The STOPS model is used as a reference ridership forecast for the proposed monorail project.

4.1 Model Inputs

4.1.1 Population and Employment

STOPS uses existing population and employment data to factor 2000 CTPP journey-to-work (JTW) data to the existing and horizon years. STOPS does this by applying the 2017 to 2045 growth to the JTW data. Socioeconomic data were obtained from the Metropolitan Washington Council of Governments (MWCOG)/Transportation Planning Board (TPB) for the current year 2017, project opening year 2025 and forecast year 2045. The MWCOG/TPB projections indicate that population in the study area will grow from 7,238,302 in 2017 to approximately 9,123,630 in year 2045, which is approximately a 26 percent increase in 28 years. The same data set also indicates that employment will grow from 4,131,281 in 2017 to 5,454,003 in 2045, which is approximately 32 percent growth.

4.1.2 Transit System Mix of Work and Non-Work Trips

STOPS requires the entry of ratios between current work and non-work trips on the transit system. Users may choose to compute these ratios from current rider-survey data or rely on the average default values in STOPS computed from six metro areas used by the developer to calibrate the STOPS model. For the purposes of this study and in the absence of recent on-board surveys, the default STOPS ratios have been used. Table 4.1 presents the ratios used in this study for future reference.

Table 4.1 Modeled Ratios of Trips by Purposes to the Journey-to-Work Flows

Automobile Ownership Class	Parameter	Coefficient
0 Car Households	HBW : JTW Ratio	1.64
1 Car Households	HBW : JTW Ratio	1.43
2+ Car Households	HBW : JTW Ratio	1.54
0 Car Households	HBO : JTW Ratio	6.58
1 Car Households	HBO : JTW Ratio	5.65
2+ Car Households	HBO : JTW Ratio	6.04
0 Car Households	NHB : JTW Ratio	3.45
1 Car Households	NHB : JTW Ratio	3.26
2+ Car Households	NHB : JTW Ratio	3.68

Note: HBO = Home-Based Other Trip Purpose
HBW = Home-Based Work Trip Purpose
NHB = Non-Home-Based Trip Purpose

Source: Data from Metropolitan Washington Council of Governments

4.1.3 Regionwide Transit Boardings

STOPS requires the user to input current year regional weekday transit boardings. MWCOG/TPB projections indicate that unlinked transit trips in Washington Metropolitan Region will grow from 1,424,000 in 2017 to approximately 1,881,000 in year 2045, which is approximately a 32 percent increase in 28 years. The same projections indicate that the number of linked home-based work trips will grow from 834,800 in 2017 to 1,094,700 in year 2045.

4.1.4 Transit Network

STOPS derives transit levels-of-service from existing, open-source timetable information, which bypasses the need to develop detailed transit networks in the modeling environment. STOPS considers zone-to-zone travel markets stratified by household auto-ownership, employs a conventional mode-choice model to predict zone-to-zone transit travel based on zone-to-zone travel characteristics of the transit and roadway networks, and then assigns the trips predicted to use fixed-guideway transit onto the various rail, bus rapid transit and streetcar facilities.

STOPS uses the General Transit Feed Specification (GTFS) format to represent the transit service. The modeling team downloaded the latest GTFS data for WMATA, MARC, and RideOn services. For the purposes of developing existing year demand, the existing year alternative uses these GTFS data sets directly. The project team manually added the monorail service by creating new sets of alternative-specific GTFS files.

4.1.5 Regional Auto Travel Times

STOPS uses current year peak period, zone-to-zone automobile travel times from the regional travel demand forecasting model. The modeling team obtained these “skims” from the 2017 and 2045 year MWCOG version 2.3.75 model, the currently adopted version.

4.1.6 Project Visibility Factor

The project visibility factor is a setting in STOPS that approximates the differentiation of fixed-guideway alternatives and regular bus service within a corridor. The visibility factor ranges from 0.0-1.0, where a number close to 0.0 would reflect a BRT project indistinguishable from local bus and 1.0 would reflect a highly-visible, branded fixed-guideway alternative that operates along exclusive right-of-way. There is a direct correlation between the selected visibility factor and ridership: higher project ridership can be expected with higher visibility factors.

For calibration, the visibility factor should be based on the characteristics of the existing fixed-guideway systems and other methods used to achieve a reasonable share of fixed-guideway trips. The expectation is for visibility factors to remain within an unofficial, but well-known range developed through cumulative STOPS application experience. The STOPS application documented herein used the FTA-recommended system visibility factor of 1.0 for the monorail system.

4.1.7 Station Group Calibration

The team specified the station group calibration approach that is employed when running scenarios in STOPS. STOPS provides six options for specifying group calibration approach. We chose Full Group Calibration approach. This option allows developing factors for each on- and off-stop group combination for the existing scenario, which are then applied to the No Build and Build scenarios depending on the station stops used in each alternative. According to the STOPS documentation, this option is the most appropriate for this type of project, where there is a comprehensive database of rail station ridership and where the assigned station groups do not change between No Build and Build scenarios.

4.2 Calibration of the Existing System

STOPS utilizes data from a variety of sources to represent travel flows and transit supply, bypassing the need to calibrate these challenging model elements. It utilizes relatively conventional procedures for estimating mode shares, and then auto-calibrates these results to match estimated home-to-work transit shares attracted to each zone (from the CTPP), local regional transit boardings (from the regional model or other sources), and station-level (aggregated to groups) ridership data in cities where fixed guideway transit is already present. GTFS files are used to develop zone-to-zone transit, access, and wait times.

A traditional nested logit mode choice model computes the transit shares stratified by access mode (walk, kiss-and-ride, and park-and-ride) and submode (fixed guideway-only, fixed guideway and bus, and bus-only). In addition, modeled station group boardings and observed group boardings are used to derive adjustment factors. STOPS requires the user to define station groups that represent groups of similar stations. STOPS uses these groups for internal calibration. A station group must be defined for both the existing and new stations. The project team developed station groups to calibrate the station level boardings on the WMATA, MARC, RideOn systems and the proposed monorail service.

The station group boarding adjustment factors were applied in STOPS for the No Build scenario. These adjustment factors are based on the calibration using the observed boarding counts at the existing fixed-guideway stops in the region and GTFS schedule data. Since STOPS utilizes census tract geography to develop the forecasts, it is expected that the stop-level estimated boardings may not be as accurate as regional model estimates. STOPS utilized an average boarding adjustment factor of 1.04 to match overall boardings to the observed boardings which is an indication of a good calibration to existing conditions.

4.3 Model Validation

As part of the validation process, the project team compared STOPS estimated boardings to the existing transit system utilization in the study area. To do this, the team compared the boardings on the Shady Grove Metro station, Metropolitan Grove MARC station, and bus routes that operate in the proposed High Road Foundation Monorail Project for Segment A+B (Frederick-Shady Grove). The STOPS model represents the aggregate corridor ridership well, with a three-percent deviation over the observed boardings for the collection of routes reviewed (approximately 43,734 boardings estimated versus 42,562 boardings observed). At the individual route level, as is typical in transit assignment results, the model exhibited a mix of over- and under-estimation. Overall, the positive and negative deviations balanced out in the corridor. Table 4.2, below, presents the comparison of observed versus calibrated No Build boardings data.

Table 4.2 Observed versus Estimated Route Level Boardings

System	Route	Observed	STOPS Estimated
WMATA*	Shady Grove	13,308	12,270
MARC**	Metropolitan Grove	290	709
	Washington Grove	300	241
	Gaithersburg	542	1,387
	Frederick	136	296
MTA	505/515	1,343	1,822
	204	298	227
RideOn***	43	707	684
	54	1,918	2,088
	55	8,422	5,331
	56	2,168	2,244
	61	2,934	1,805
	63	744	1,555
	66	173	510
	67	129	647
	70	659	644
	71	345	620
	74	1,254	1,700
	75	536	192
	76	868	1,693
	78	265	771
	79	300	955
	83	499	827
	90	957	2,274
	97	684	412
	98	477	373
	100	2,306	1,457
Total		**42,562**	**43,734**

Notes: * WMATA observed ridership is for FY 2015
** MARC observed ridership in 2012-2016
*** RideOn observed ridership is for FY 2015

4.4 Ridership Forecasts

Regular weekday ridership forecasts were developed using STOPS v2.5 for the build project specification for the existing, opening, and horizon years. Tables 4.3-4.5 summarize the steady state weekday monorail ridership forecast by station under three frequency scenarios, based on the STOPS application, for year 2017, opening year 2025, and horizon year 2045. The total ridership estimated for 2017 ranges from approximately 27,700 to 31,000 average weekday trips. Ridership estimated for the steady-state 2025 opening year varies between 29,400 and 32,800 average weekday trips. For the horizon year 2045, average weekday ridership is forecast to be from 43,000 to 47,600 under the three frequency scenarios. The forecasts are generally within the middle of the ridership ranges between Metro-like and LRT-like scenarios that were evaluated using the COG/TPB regional model.

The BYD Skyrail can carry up to 204 passengers (standing and seated) under non-crush conditions per two-car consist. The proposed carrying capacity under the peak-period service level (approximately 20 two-car trains per hour) or 4,000 passengers per hour per direction. The forecasted ridership level appears to be able to be accommodated by the service capacity proposed to be provided.

Table 4.3 Daily Project Boardings by Station under Three Frequency Services (2017)

Station	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
Shady Grove	7,500	6,800	6,800
Metropolitan Grove	2,100	1,900	1,900
Germantown	500	500	500
COMSAT	7,400	7,200	6,500
Urbana	10,400	10,100	9,400
Frederick	3,000	2,600	2,600
Total	**31,000**	**29,100**	**27,700**

Note: Rounded to 100s.

Table 4.4 Daily Project Boardings by Station under Three Frequency Services (2025)

Station	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
Shady Grove	7,800	7,000	7,100
Metropolitan Grove	2,200	2,000	2,000
Germantown	500	500	500
COMSAT	8,000	7,800	7,100
Urbana	11,000	10,700	10,000
Frederick	3,200	2,800	2,800
Total	**32,800**	**30,800**	**29,400**

Note: Rounded to 100s

Table 4.5 Daily Project Boardings by Station under Three Frequency Services (2045)

Station	Higher Service Frequency	Base Service Frequency	Lower Service Frequency
Shady Grove	13,100	12,000	12,000
Metropolitan Grove	3,200	2,900	2,900
Germantown	900	800	800
COMSAT	10,300	9,900	9,100
Urbana	15,700	15,200	14,400
Frederick	4,400	3,800	3,800
Total	**47,600**	**44,600**	**43,000**

Note: Rounded to 100s

As can be seen from Table 4.5, stations with the highest ridership on monorail in 2045 are Shady Grove, Urbana, and COMSAT, accounting for approximately 82 percent of the ridership. Shady Grove is the end of the line station with connectivity to WMATA.

In addition to generating ridership on the monorail itself, the ridership on the corridor transit routes also change. Shady Grove Metro station and Metropolitan Grove MARC station see increases in boardings as a result of implementing the monorail. This effect would provide benefits to overall WMATA, MARC, and RideOn ridership and productivity.

5.0 Findings

This report documents the effort and results from developing a feasibility ridership forecast for the proposed monorail between Frederick and Shady Grove. With six stations, this 27-mile project provides transit service to new and existing centers of commerce, residential, and educational development, including Metropolitan Grove and adjacent Life Science centers, Germantown, COMSAT and Urbana. It also offers enhanced connectivity to the existing transit services such as Metrorail, MARC, and RideOn.

The BYD Skyrail, which is used as the prototype for planning, is a sleek, lightweight train with vehicles running on electric power and on raised guideways, giving passengers easy boarding, comfortable seating, and a memorable view of their surroundings as they glide past the traffic below. The one way estimated travel time on the monorail from Frederick to Shady Grove would be approximately 31 minutes, including 30 seconds dwell time at each station, based on the top design speed of 70 miles per hour. The service frequency is assumed to be comparable to or better than the current Metrorail operation, with three sets of frequency/headways tested in the analysis:

- the base frequency of service will be the same as the Metrorail every 6 minutes during peak periods, every 12 minutes mid-day and evening, and every 15 minutes during late night times
- the higher frequency of service will increase the frequency to 3-minute headway for peak periods and 10-minute headways for mid-day and evening periods
- the lower frequency of service will be the same as the base frequency, except for 15 minute headways for mid-day and evening periods.

The fares are assumed to be comparable to the Metrorail, with a distance-based fare structure and the peak/off-peak fare differentiation.

Ridership analysis for this project was performed using the recently adopted regional model COG Version 2.3.75, with the latest planning assumptions such as the Round 9.1 Cooperative Forecasts for the land uses in the region and proposed transportation improvements in the fiscally Constrained Long Range Plan. The monorail is a new mode in this region, and its attractiveness has not been revealed in a large regional system in the US. However, it is reasonable to anticipate that monorail has an attractiveness similar to or better than the (idealized) Metrorail currently operating in the Washington region, which is a Metro-like scenario for the ridership forecasting. To account for uncertainty, though, a lower-attractiveness scenario was also tested using LRT-like attractiveness. The ridership forecasts were developed for the base year 2017, opening year 2025, and horizon year 2045, with the following findings:

- As expected, the Higher Service Frequency scenarios generate the highest ridership among the three service frequency levels, with small differences between the Base Service Frequency and Lower Service Frequency levels.
- The Metro-like scenarios have significantly higher ridership forecasts than their comparable LRT-like scenarios, reflecting the higher attractiveness of the Metro-like services.
- Between the opening year 2025 and horizon year 2040, the ridership is forecasted to increase by approximately 40 percent, reflecting the socioeconomic growth and transportation conditions in the study area.

- Among the six stations, Shady Grove has the highest ridership estimate, as it serves as a connecting point for the Metro Red Line, the proposed CCT BRT and MD 355 BRT services. Frederick has the second highest ridership, as the terminal station with a larger catchment area.

- With increasing the monorail fare by 20%, the ridership would reduce by 5% under the Metro-like scenarios.

STOPS, the FTA sponsored ridership forecasting tool, was used to develop a reference forecast, so as to ensure a reasonableness in the magnitude of ridership forecasting for the proposed project. For the horizon year 2045, the STOPS forecasted ridership is approximately fourteen percent lower than that predicted under the Metro-like scenario using the COG Version 2.3.75. The lower ridership forecast from STOPS is expected as STOPS used the 2000 Census Transportation Planning Products as the base commuting data and this corridor is a rapid growing corridor with significant growth in the past twenty years and forecasted in the next twenty five years.

Average daily ridership forecasts were grown to annual ridership forecasts for purposes of estimating revenue. A ramp-up period of three years was assumed from the opening year 2025, with 79% for the first year, 95% for the second year, and a steady state ridership achieved in the third year. Annual revenue estimates were developed in constant dollars, by scenarios and years, and assuming an average fare of five dollars. The annualization factors of 271 and 286 were used to cover the potential range of uncertainty related to the shares of weekend market relative to the weekday.

The ridership forecasts have been developed within the context of a tiered ridership forecasting process of which the work described herein is a first step. The forecasts described in this report have been prepared using information available from third-party sources and high-level assumptions. Future work has the potential to refine the forecast inputs, assumptions, methodologies, and results and to illuminate a range of potential forecast uncertainties.

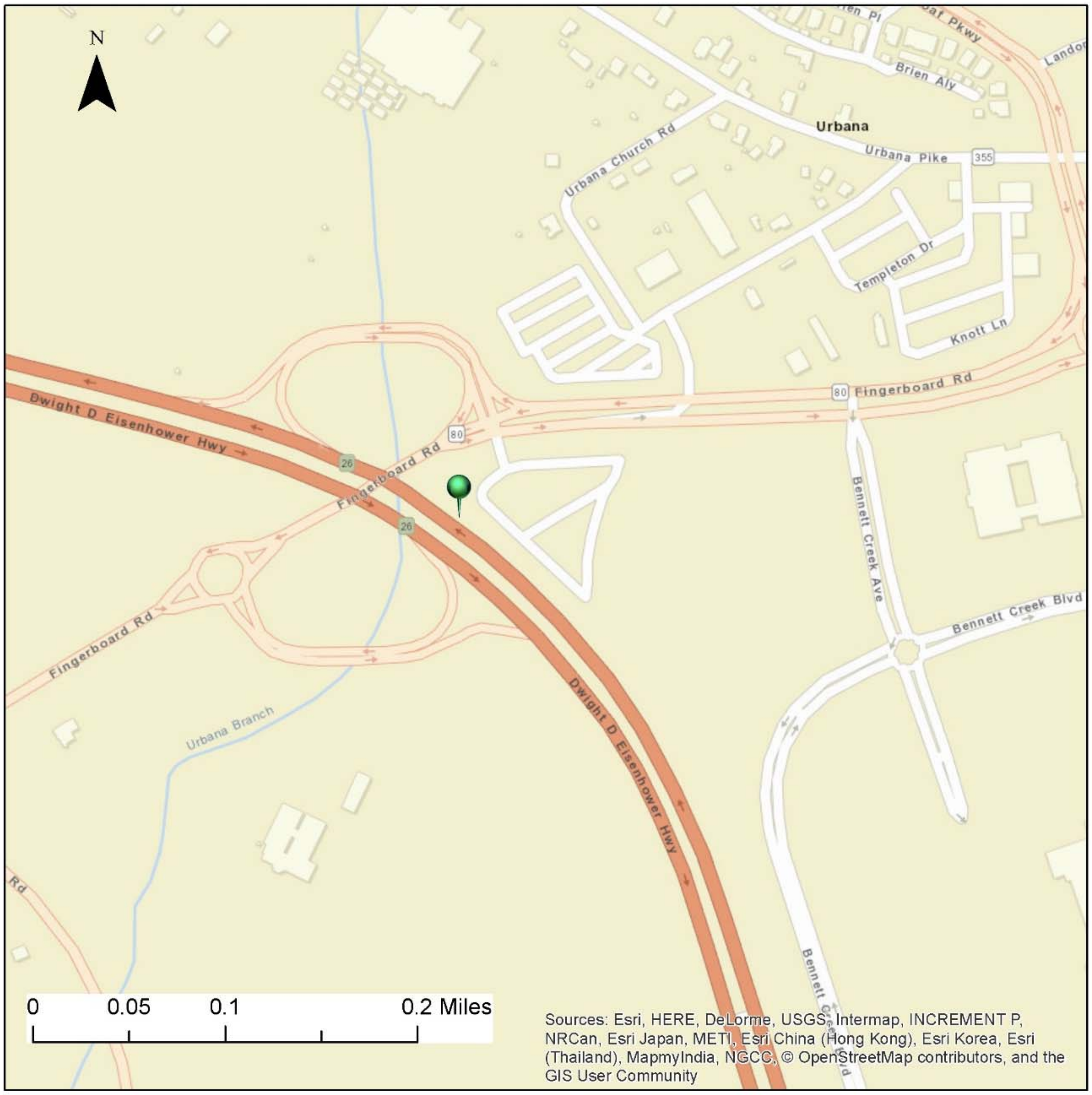
Appendix A. Proposed Monorail Station Locations

Figure A.1 Proposed Monorail Station Location—Frederick

Features

High Road Stations

Figure A.2 Proposed Monorail Station Location—Urbana



Features

High Road Stations

Figure A.3 Proposed Monorail Station Location—COMSAT

Features

High Road Stations

Figure A.4 Proposed Monorail Station Location—Germantown

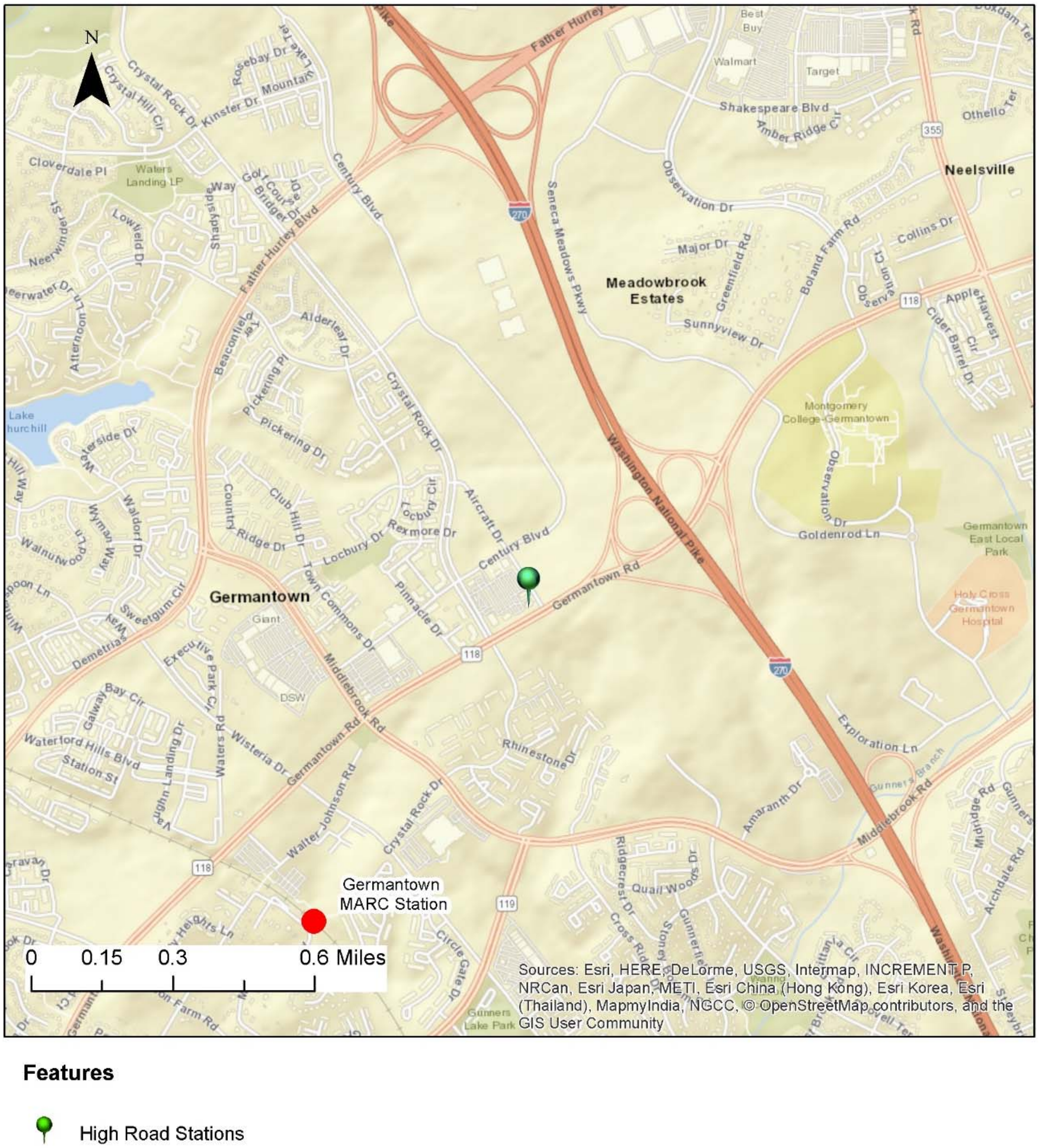
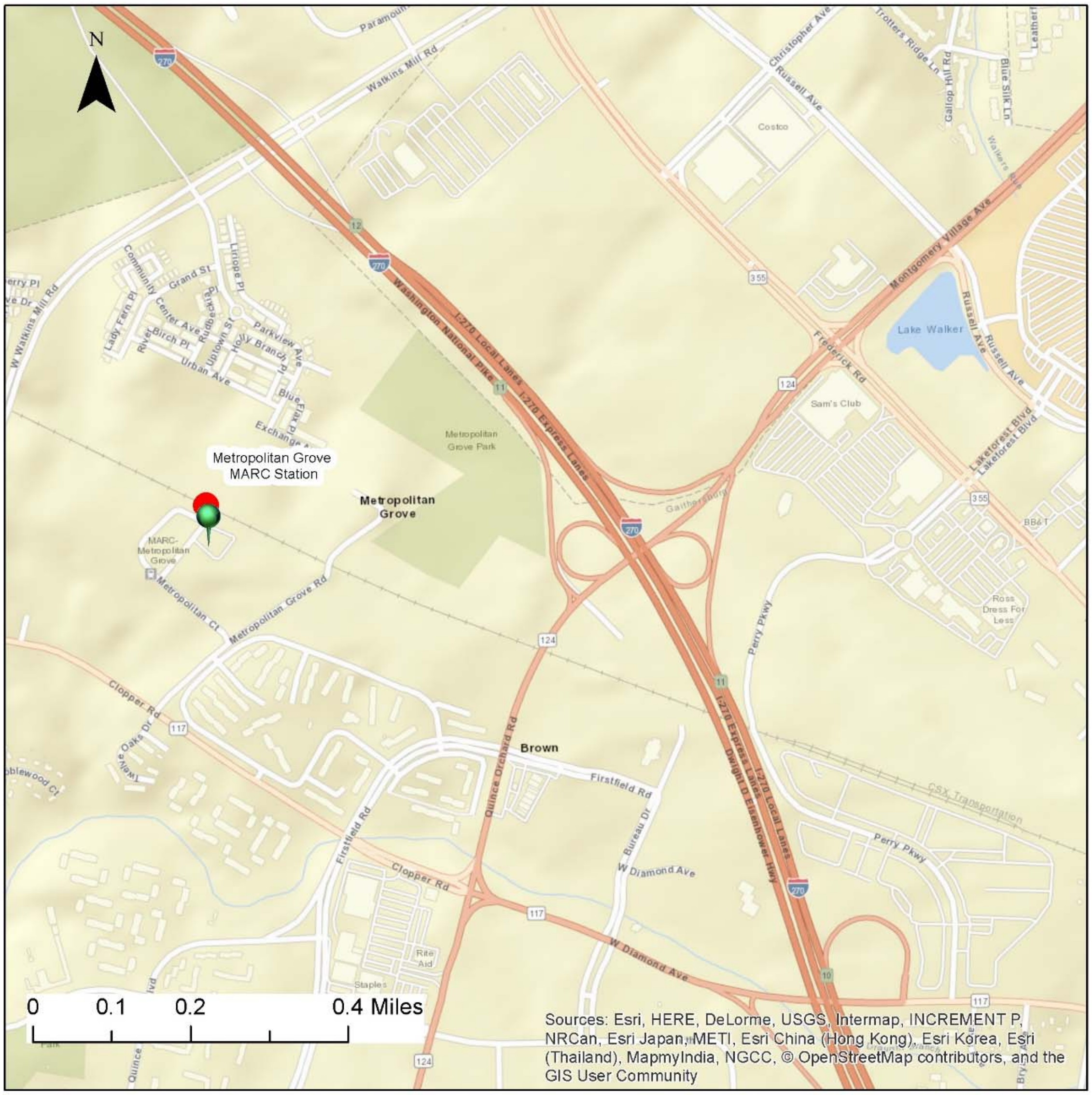


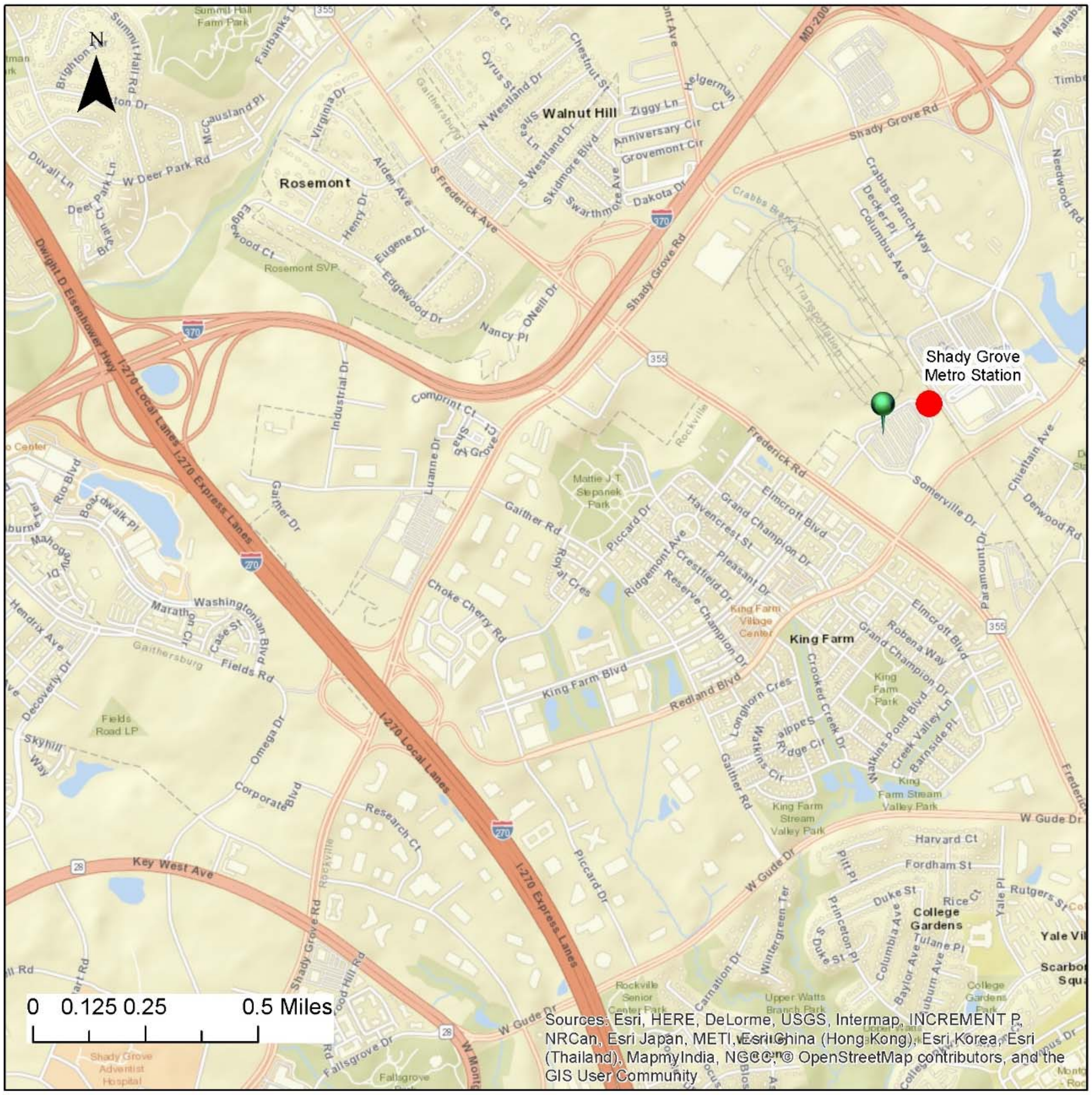
Figure A.5 Proposed Monorail Station Location—Metropolitan Grove



Features

High Road Stations

Figure A.6 Proposed Monorail Station Location—Shady Grove



Features

High Road Stations

Appendix B. Changes in the Study Area Population and Employment by TAZ

This section presents the forecast growth in total population and employment by MWCOG Transportation Analysis Zone (TAZ) geography between years 2017 and 2045 in the study area, as tabulated in Table B.1. The study area includes transportation analysis zones (TAZs) in Fredericka and Montgomery Counties, and TAZ boundary is shown in Figure B.1.

Figure B.1 Transportation Analysis Zones in the Study Area

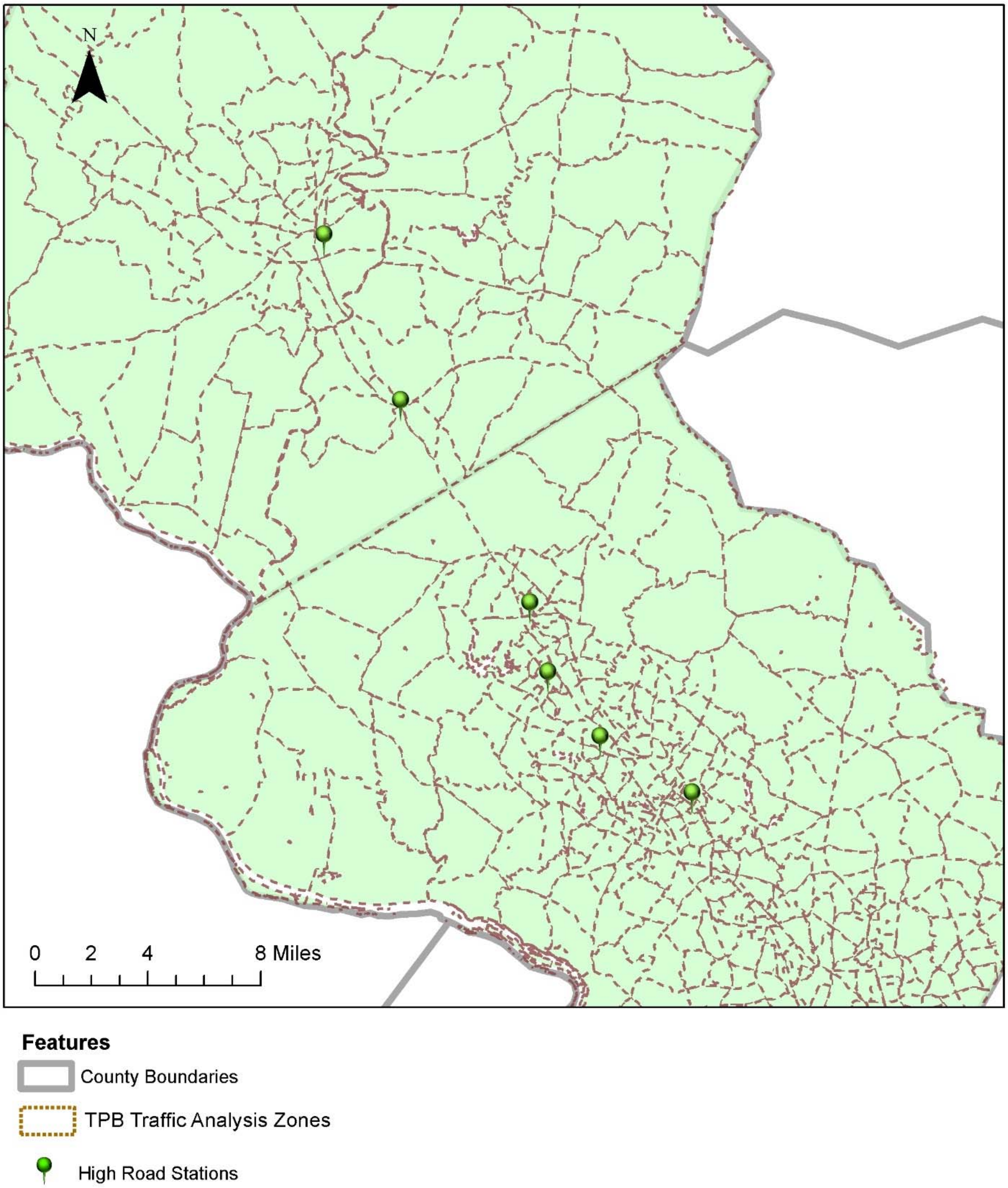


Table B.1 Changes in Total Population and Employment by TAZ in Frederick and Montgomery Counties

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
394	141	162	21	15%	41	42	1	2%
395	239	612	373	156%	91	95	4	4%
396	365	475	110	30%	209	214	5	2%
397	1,233	1,375	142	12%	148	158	10	7%
398	111	123	12	11%	106	108	2	2%
399	420	423	3	1%	98	102	4	4%
400	1,346	1,379	33	2%	324	357	33	10%
401	2,368	2,953	585	25%	389	460	71	18%
402	206	226	20	10%	294	346	52	18%
403	4,294	4,315	21	0%	800	836	36	5%
404	369	387	18	5%	36	38	2	6%
405	1,010	1,010	0	0%	127	135	8	6%
406	1,981	1,993	12	1%	542	562	20	4%
407	3,218	3,218	0	0%	596	596	0	0%
408	1,880	1,880	0	0%	0	0	0	0%
409	1,458	1,458	0	0%	153	153	0	0%
410	2,708	2,708	0	0%	951	951	0	0%
411	1,400	1,786	386	28%	2,960	3,293	333	11%
412	184	184	0	0%	1,885	1,898	13	1%
413	4,053	7,774	3,721	92%	2,002	7,370	5,368	268%
414	178	289	111	62%	5	134	129	2580%
415	6,651	6,651	0	0%	407	457	50	12%
416	4,902	5,117	215	4%	253	288	35	14%
417	5,401	5,401	0	0%	631	674	43	7%
418	3,479	3,728	249	7%	332	546	214	64%
419	2,688	2,688	0	0%	443	466	23	5%
420	1,625	1,625	0	0%	254	268	14	6%
421	0	0	0	0%	666	673	7	1%
422	1,502	1,502	0	0%	1,533	1,559	26	2%
423	1,553	1,627	74	5%	1,525	1,722	197	13%
424	453	453	0	0%	22	25	3	14%
425	3,334	3,334	0	0%	192	216	24	13%
426	0	150	150	0%	752	953	201	27%
427	1,916	2,856	940	49%	1,306	1,511	205	16%
428	4,539	4,539	0	0%	347	384	37	11%
429	4,668	4,668	0	0%	160	195	35	22%
430	6,558	6,558	0	0%	1,097	1,385	288	26%
431	8,589	8,751	162	2%	751	817	66	9%
432	164	164	0	0%	46	47	1	2%
433	551	673	122	22%	56	63	7	13%
434	191	499	308	161%	102	79	-23	-23%
435	134	174	40	30%	6	6	0	0%
436	337	1,123	786	233%	59	65	6	10%
437	674	860	186	28%	234	242	8	3%
438	126	241	115	91%	341	343	2	1%
439	491	1,170	679	138%	148	155	7	5%
440	5,811	6,473	662	11%	936	1,128	192	21%
441	350	763	413	118%	118	124	6	5%
442	1,314	1,405	91	7%	182	192	10	5%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
443	1.244	1.920	676	54%	490	690	200	41%
444	1.818	1.962	144	8%	1.015	1.214	199	20%
445	469	496	27	6%	192	198	6	3%
446	18	484	466	2589%	3	220	217	7233%
447	242	287	45	19%	38	38	0	0%
448	807	2.535	1.728	214%	8	19	11	138%
449	207	6.795	6.588	3183%	435	3.788	3.353	771%
450	713	761	48	7%	33	39	6	18%
451	975	2.692	1.717	176%	1.121	1.194	73	7%
452	8.834	9.847	1.013	11%	655	1.271	616	94%
453	1.137	1.607	470	41%	231	573	342	148%
454	502	502	0	0%	35	40	5	14%
455	1.564	1.582	18	1%	146	159	13	9%
456	2.482	2.534	52	2%	337	358	21	6%
457	359	1.254	895	249%	42	48	6	14%
458	5.157	6.676	1.519	29%	362	607	245	68%
459	886	1.074	188	21%	448	459	11	2%
460	829	1.047	218	26%	100	109	9	9%
461	2.246	2.258	12	1%	162	178	16	10%
462	961	967	6	1%	55	62	7	13%
463	2	2	0	0%	0	141	141	0%
464	1.973	4.226	2.253	114%	41	3.364	3.323	8105%
465	2.898	3.449	551	19%	3.097	5.657	2.560	83%
466	1.458	1.581	123	8%	2.104	2.548	444	21%
467	199	199	0	0%	1.848	2.825	977	53%
468	13	13	0	0%	812	1.482	670	83%
469	4	339	335	8375%	1.016	1.026	10	1%
470	0	532	532	0%	835	2.005	1.170	140%
471	218	218	0	0%	2.233	2.843	610	27%
472	1.924	1.962	38	2%	75	103	28	37%
473	3.288	3.288	0	0%	428	454	26	6%
474	1.177	1.325	148	13%	88	94	6	7%
475	5.150	5.159	9	0%	421	460	39	9%
476	3.986	4.037	51	1%	665	811	146	22%
477	2.958	2.991	33	1%	427	451	24	6%
478	3.050	3.050	0	0%	296	320	24	8%
479	4.395	5.331	936	21%	2.076	2.081	5	0%
480	763	2.683	1.920	252%	4.293	7.504	3.211	75%
481	0	0	0	0%	1.312	1.315	3	0%
482	494	3.512	3.018	611%	2.190	2.304	114	5%
483	0	0	0	0%	2.471	2.471	0	0%
484	5.429	5.429	0	0%	654	696	42	6%
485	5.247	5.853	606	12%	2.007	2.090	83	4%
486	4.177	4.389	212	5%	546	581	35	6%
487	5.126	5.187	61	1%	347	385	38	11%
488	3.053	3.053	0	0%	141	163	22	16%
489	4.591	5.138	547	12%	653	693	40	6%
490	5.142	5.471	329	6%	515	557	42	8%
491	6.360	6.360	0	0%	1.344	1.930	586	44%
492	5.256	5.501	245	5%	1.881	2.221	340	18%
493	3.916	4.398	482	12%	589	624	35	6%
494	4.148	4.205	57	1%	709	743	34	5%
495	1.168	1.294	126	11%	523	537	14	3%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
496	1.299	1.315	16	1%	75	84	9	12%
497	10.505	12.141	1.636	16%	2.019	2.791	772	38%
498	1.351	1.618	267	20%	279	407	128	46%
499	8.591	9.975	1.384	16%	4.107	5.078	971	24%
500	2.012	2.105	93	5%	950	974	24	3%
501	997	1.158	161	16%	548	560	12	2%
502	5.796	5.821	25	0%	858	953	95	11%
503	2.854	3.142	288	10%	989	1.222	233	24%
504	6.569	6.811	242	4%	1.268	1.588	320	25%
505	5.806	7.017	1.211	21%	460	507	47	10%
506	259	292	33	13%	44	45	1	2%
507	625	625	0	0%	966	980	14	1%
508	708	741	33	5%	194	203	9	5%
509	5.157	5.184	27	1%	305	343	38	12%
510	268	268	0	0%	5.926	5.986	60	1%
511	6.181	6.303	122	2%	1.027	1.080	53	5%
512	5.030	5.090	60	1%	385	385	0	0%
513	4.843	5.278	435	9%	1.423	2.275	852	60%
514	4.198	4.880	682	16%	2.931	3.073	142	5%
515	2.352	2.667	315	13%	872	920	48	6%
516	901	1.853	952	106%	536	554	18	3%
517	524	526	2	0%	149	155	6	4%
518	735	833	98	13%	1.563	1.699	136	9%
519	0	0	0	0%	991	1.713	722	73%
520	1.203	1.697	494	41%	468	478	10	2%
521	1.048	5.741	4.693	448%	2.752	3.403	651	24%
522	1.948	1.954	6	0%	69	83	14	20%
523	4.077	4.256	179	4%	1.568	1.915	347	22%
524	1.336	1.387	51	4%	159	169	10	6%
525	787	820	33	4%	148	176	28	19%
526	1.445	1.451	6	0%	271	308	37	14%
527	0	672	672	0%	193	582	389	202%
528	1.872	1.872	0	0%	99	99	0	0%
529	3	3	0	0%	873	881	8	1%
530	2.083	2.083	0	0%	3.347	3.394	47	1%
531	224	242	18	8%	2.980	3.106	126	4%
532	125	125	0	0%	7.589	7.589	0	0%
533	3.595	3.620	25	1%	287	316	29	10%
534	491	559	68	14%	77	83	6	8%
535	658	1.029	371	56%	343	357	14	4%
536	3.392	3.521	129	4%	519	704	185	36%
537	4.946	5.051	105	2%	803	857	54	7%
538	1.326	3.064	1.738	131%	1.267	2.339	1.072	85%
539	13.891	13.914	23	0%	2.694	2.894	200	7%
540	15.674	16.293	619	4%	1.403	1.455	52	4%
541	2.841	2.841	0	0%	1.407	1.642	235	17%
542	1.576	1.606	30	2%	230	243	13	6%
543	4.043	4.110	67	2%	625	659	34	5%
544	5.788	8.643	2.855	49%	1.739	2.476	737	42%
545	4.698	4.890	192	4%	670	710	40	6%
546	7.255	7.272	17	0%	484	646	162	33%
547	5.569	5.694	125	2%	988	1.127	139	14%
548	5.675	5.685	10	0%	824	1.144	320	39%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
549	3.546	3.603	57	2%	998	1.033	35	4%
550	2.048	2.129	81	4%	324	362	38	12%
551	653	692	39	6%	25	31	6	24%
552	1.821	2.013	192	11%	51	65	14	27%
553	1.194	6.094	4.900	410%	72	532	460	639%
554	452	603	151	33%	427	455	28	7%
555	923	926	3	0%	53	87	34	64%
556	10.162	10.363	201	2%	576	658	82	14%
557	4.742	4.754	12	0%	500	538	38	8%
558	4.659	4.825	166	4%	1.381	1.393	12	1%
559	1.784	2.582	798	45%	876	905	29	3%
560	2.907	7.007	4.100	141%	4.595	5.149	554	12%
561	874	2.750	1.876	215%	690	892	202	29%
562	2.941	3.039	98	3%	743	799	56	8%
563	4.948	4.981	33	1%	400	438	38	10%
564	3.573	3.676	103	3%	490	520	30	6%
565	3.015	3.107	92	3%	268	289	21	8%
566	7.733	8.530	797	10%	1.195	1.152	-43	-4%
567	3.455	3.515	60	2%	625	653	28	4%
568	1.391	1.465	74	5%	53	61	8	15%
569	2.466	2.466	0	0%	244	264	20	8%
570	4.753	5.661	908	19%	371	410	39	11%
571	3.458	3.534	76	2%	562	734	172	31%
572	1.920	1.995	75	4%	527	547	20	4%
573	5.217	5.326	109	2%	704	746	42	6%
574	4.084	4.174	90	2%	334	391	57	17%
575	4.977	5.018	41	1%	327	362	35	11%
576	5.575	6.000	425	8%	556	600	44	8%
577	6.552	6.881	329	5%	394	444	50	13%
578	1.962	2.094	132	7%	1.062	1.407	345	32%
579	1.468	1.595	127	9%	407	654	247	61%
580	2.623	2.691	68	3%	487	718	231	47%
581	4.230	4.431	201	5%	901	940	39	4%
582	562	765	203	36%	2.281	2.361	80	4%
583	491	497	6	1%	167	173	6	4%
584	19.558	20.944	1.386	7%	2.733	3.014	281	10%
585	4.280	4.629	349	8%	1.267	1.339	72	6%
586	2.432	10.488	8.056	331%	7.172	22.814	15.642	218%
587	9.903	10.043	140	1%	2.433	2.523	90	4%
588	3.973	4.068	95	2%	3.378	3.438	60	2%
589	2.587	2.698	111	4%	251	286	35	14%
590	1.650	1.668	18	1%	391	406	15	4%
591	8.704	11.446	2.742	32%	1.117	2.925	1.808	162%
592	2	2	0	0%	4.957	8.985	4.028	81%
593	1.366	1.453	87	6%	1.672	1.697	25	1%
594	2.756	2.905	149	5%	998	1.053	55	6%
595	3.214	3.406	192	6%	812	844	32	4%
596	4.021	4.047	26	1%	818	864	46	6%
597	3.075	3.117	42	1%	1.198	1.230	32	3%
598	4.427	4.507	80	2%	632	677	45	7%
599	3.172	3.276	104	3%	454	513	59	13%
600	2.070	2.291	221	11%	246	241	-5	-2%
601	1.085	1.091	6	1%	643	747	104	16%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
602	1.875	1.923	48	3%	3.936	3.988	52	1%
603	3.376	3.583	207	6%	1.290	1.327	37	3%
604	988	1.003	15	2%	206	216	10	5%
605	1.829	1.844	15	1%	289	304	15	5%
606	1.899	2.045	146	8%	583	603	20	3%
607	5.296	5.601	305	6%	336	392	56	17%
608	5.720	6.011	291	5%	617	736	119	19%
609	3.985	4.058	73	2%	555	588	33	6%
610	8.194	8.239	45	1%	596	657	61	10%
611	4.799	5.051	252	5%	421	482	61	14%
612	4.872	5.004	132	3%	261	308	47	18%
613	1.676	1.879	203	12%	2.228	2.148	-80	-4%
614	1.896	2.007	111	6%	318	336	18	6%
615	1.014	1.321	307	30%	301	449	148	49%
616	1.756	2.386	630	36%	326	487	161	49%
617	3.617	3.773	156	4%	310	336	26	8%
618	2.615	2.708	93	4%	686	711	25	4%
619	1.996	2.080	84	4%	434	452	18	4%
620	633	639	6	1%	866	926	60	7%
621	2.652	2.782	130	5%	903	929	26	3%
622	4.813	5.099	286	6%	376	455	79	21%
623	3.385	9.559	6.174	182%	5.704	6.416	712	12%
624	5.820	9.174	3.354	58%	11.550	14.027	2.477	21%
625	7.597	11.099	3.502	46%	5.441	7.579	2.138	39%
626	8.455	9.943	1.488	18%	1.274	1.922	648	51%
627	825	851	26	3%	77	84	7	9%
628	2.635	2.942	307	12%	1.661	1.621	-40	-2%
629	2.572	2.698	126	5%	168	187	19	11%
630	819	1.321	502	61%	2.762	2.893	131	5%
631	2.233	3.358	1.125	50%	873	1.247	374	43%
632	2.364	3.542	1.178	50%	533	658	125	23%
633	2.557	3.722	1.165	46%	992	2.117	1.125	113%
634	4.603	4.724	121	3%	700	740	40	6%
635	1.219	1.222	3	0%	500	514	14	3%
636	2.914	2.959	45	2%	539	564	25	5%
637	4.501	6.731	2.230	50%	10.348	10.976	628	6%
638	2.765	2.825	60	2%	363	386	23	6%
639	6.676	8.145	1.469	22%	9.003	10.281	1.278	14%
640	691	706	15	2%	49	55	6	12%
641	1.341	1.369	28	2%	1.705	1.742	37	2%
642	4.670	6.066	1.396	30%	2.136	2.572	436	20%
643	2.109	2.123	14	1%	178	195	17	10%
644	1.448	1.460	12	1%	259	271	12	5%
645	2.884	2.970	86	3%	295	318	23	8%
646	1.811	1.870	59	3%	1.264	1.300	36	3%
647	3.002	3.206	204	7%	443	467	24	5%
648	2.344	2.612	268	11%	516	534	18	3%
649	801	971	170	21%	2.521	2.551	30	1%
650	2.452	2.536	84	3%	657	680	23	4%
651	3.171	3.295	124	4%	1.251	1.286	35	3%
652	3.032	3.142	110	4%	1.190	1.237	47	4%
653	1.967	2.162	195	10%	213	230	17	8%
654	1.568	1.618	50	3%	534	550	16	3%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
655	3.624	4.581	957	26%	482	514	32	7%
656	1.438	1.523	85	6%	543	557	14	3%
657	3.879	4.053	174	4%	1.059	1.096	37	3%
658	1.521	1.556	35	2%	571	589	18	3%
659	2.775	3.058	283	10%	382	405	23	6%
660	4.769	4.939	170	4%	699	738	39	6%
661	2.371	2.436	65	3%	380	401	21	6%
662	4.149	7.164	3.015	73%	21.896	28.415	6.519	30%
663	5.583	9.783	4.200	75%	6.397	6.239	-158	-2%
664	616	851	235	38%	17.695	20.808	3.113	18%
665	5.433	5.559	126	2%	2.311	2.841	530	23%
666	6.048	6.125	77	1%	816	865	49	6%
667	5.727	6.480	753	13%	2.200	2.523	323	15%
668	986	997	11	1%	232	241	9	4%
669	489	568	79	16%	3.527	4.463	936	27%
670	3.992	4.507	515	13%	1.244	1.419	175	14%
671	1.816	2.029	213	12%	151	153	2	1%
672	3.314	3.846	532	16%	1.366	1.401	35	3%
673	4.257	4.711	454	11%	468	519	51	11%
674	1.883	2.218	335	18%	536	559	23	4%
675	3.096	3.253	157	5%	727	845	118	16%
676	1.019	1.070	51	5%	244	255	11	5%
677	1.880	1.925	45	2%	415	431	16	4%
678	1.391	1.391	0	0%	63	71	8	13%
679	4.235	4.704	469	11%	2.057	2.192	135	7%
680	3.208	3.347	139	4%	251	276	25	10%
681	2.003	2.003	0	0%	319	336	17	5%
682	2.999	3.616	617	21%	1.480	1.634	154	10%
683	751	762	11	1%	270	279	9	3%
684	5.746	6.042	296	5%	607	695	88	14%
685	825	889	64	8%	8.385	9.439	1.054	13%
686	2.785	9.118	6.333	227%	9.824	11.973	2.149	22%
687	4.397	14.592	10.195	232%	10.745	19.310	8.565	80%
688	5.384	6.227	843	16%	3.041	3.135	94	3%
689	4.165	4.165	0	0%	2.613	2.730	117	4%
690	2.595	3.637	1.042	40%	5.151	7.312	2.161	42%
691	2.913	9.062	6.149	211%	6.914	10.924	4.010	58%
692	851	2.579	1.728	203%	444	741	297	67%
693	0	590	590	0%	5.538	7.725	2.187	39%
694	5.057	5.057	0	0%	1.091	1.097	6	1%
695	905	1.312	407	45%	4.405	4.405	0	0%
696	1.237	1.644	407	33%	546	555	9	2%
697	5.030	5.030	0	0%	441	449	8	2%
698	0	1.084	1.084	0%	3.051	4.086	1.035	34%
699	2.662	3.018	356	13%	2.498	4.139	1.641	66%
700	3.342	3.395	53	2%	674	703	29	4%
701	2.381	2.488	107	4%	715	739	24	3%
702	679	3.267	2.588	381%	15.460	22.717	7.257	47%
703	2.721	2.721	0	0%	3.810	3.867	57	1%
704	4.941	5.049	108	2%	980	1.023	43	4%
705	4.473	4.598	125	3%	562	795	233	41%
706	4.805	4.858	53	1%	479	517	38	8%
707	5.215	5.469	254	5%	1.224	1.273	49	4%

	Total Population				Total Employment			
TAZ	**2017**	**2045**	**Change**	**% Change**	**2017**	**2045**	**Change**	**% Change**
708	2.766	2.771	5	0%	220	242	22	10%
709	1.774	1.983	209	12%	254	270	16	6%
710	3.452	3.452	0	0%	237	237	0	0%
711	3.009	3.929	920	31%	1.624	1.846	222	14%
712	2.049	2.049	0	0%	644	646	2	0%
713	4.775	4.775	0	0%	1.372	1.420	48	3%
714	944	1.351	407	43%	4.210	5.569	1.359	32%
715	2.456	3.865	1.409	57%	644	647	3	0%
716	784	784	0	0%	565	948	383	68%
717	3.658	8.180	4.522	124%	11.172	15.152	3.980	36%
718	1.794	1.794	0	0%	1.675	1.743	68	4%
719	2.639	3.351	712	27%	3.540	3.910	370	10%
720	1.580	1.735	155	10%	109	109	0	0%
721	1.827	1.827	0	0%	424	932	508	120%
722	0	406	406	0%	10.819	12.092	1.273	12%
723	1.796	1.796	0	0%	203	203	0	0%
724	3.137	4.069	932	30%	2.124	3.899	1.775	84%
725	3.956	4.117	161	4%	1.405	1.653	248	18%
726	1.596	1.626	30	2%	80	92	12	15%
727	1.773	2.362	589	33%	1.990	2.702	712	36%
728	91	91	0	0%	6.294	7.694	1.400	22%
729	0	0	0	0%	4.980	6.857	1.877	38%
730	136	136	0	0%	554	560	6	1%
731	2.189	3.092	903	41%	1.923	2.532	609	32%
732	2.628	5.878	3.250	124%	650	1.009	359	55%
733	537	1.988	1.451	270%	1.903	1.938	35	2%
734	2.447	6.516	4.069	166%	4.283	5.428	1.145	27%
735	126	721	595	472%	4.757	6.152	1.395	29%
736	3.085	3.085	0	0%	547	547	0	0%
737	10	10	0	0%	524	530	6	1%
738	168	168	0	0%	841	841	0	0%
739	0	0	0	0%	3.474	3.579	105	3%
740	1.284	1.290	6	0%	2.288	2.288	0	0%
741	603	1.125	522	87%	5.862	9.607	3.745	64%
742	2.447	2.447	0	0%	139	158	19	14%
743	5.376	6.519	1.143	21%	1.724	1.838	114	7%
744	152	152	0	0%	1.217	1.217	0	0%
745	2.936	2.939	3	0%	207	228	21	10%
746	5	11	6	120%	2.875	2.905	30	1%
747	6.097	6.097	0	0%	602	602	0	0%
748	1.956	1.956	0	0%	256	256	0	0%
749	1.649	1.649	0	0%	2.832	6.400	3.568	126%
750	7.207	10.656	3.449	48%	4.581	4.710	129	3%
751	2.611	2.611	0	0%	8	8	0	0%
752	1.377	1.377	0	0%	0	0	0	0%
753	2	2	0	0%	308	5.530	5.222	1695%
754	140	212	72	51%	1.088	1.099	11	1%
755	8.026	8.074	48	1%	989	1.108	119	12%
756	1.229	1.241	12	1%	92	100	8	9%
757	3.024	3.027	3	0%	375	398	23	6%
758	2.658	2.682	24	1%	484	506	22	5%
759	5.098	5.163	65	1%	908	952	44	5%
760	741	810	69	9%	105	112	7	7%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
761	1.296	1.397	101	8%	224	235	11	5%
762	1.021	1.024	3	0%	112	122	10	9%
763	3.315	3.336	21	1%	229	253	24	10%
764	1.482	1.610	128	9%	198	210	12	6%
765	1.432	1.522	90	6%	799	815	16	2%
766	1.285	1.491	206	16%	321	352	31	10%
767	1.830	2.107	277	15%	318	334	16	5%
768	1.754	1.958	204	12%	700	720	20	3%
769	2.899	3.073	174	6%	302	324	22	7%
2820	7.695	11.590	3.895	51%	1.203	1.530	327	27%
2821	618	762	144	23%	37	48	11	30%
2822	469	586	117	25%	14	20	6	43%
2823	1.089	1.171	82	8%	73	94	21	29%
2824	1.079	1.231	152	14%	268	343	75	28%
2825	1.441	1.547	106	7%	94	120	26	28%
2826	3.609	3.906	297	8%	700	890	190	27%
2827	601	681	80	13%	34	45	11	32%
2828	648	725	77	12%	107	134	27	25%
2829	3.696	3.801	105	3%	344	436	92	27%
2830	1.465	1.633	168	11%	259	329	70	27%
2831	703	766	63	9%	138	176	38	28%
2832	937	1.008	71	8%	66	83	17	26%
2833	1.497	1.673	176	12%	543	691	148	27%
2834	996	1.215	219	22%	29	35	6	21%
2835	883	1.076	193	22%	138	176	38	28%
2836	1.080	1.244	164	15%	165	208	43	26%
2837	4.238	6.360	2.122	50%	1.164	1.344	180	15%
2838	6.791	7.920	1.129	17%	1.140	1.367	227	20%
2839	370	1.108	738	199%	27	33	6	22%
2840	6.980	7.790	810	12%	516	618	102	20%
2841	4.168	5.418	1.250	30%	1.002	1.201	199	20%
2842	3.596	3.624	28	1%	1.262	1.504	242	19%
2843	3.601	7.915	4.314	120%	598	728	130	22%
2844	1.246	1.812	566	45%	87	109	22	25%
2845	1.669	1.856	187	11%	249	318	69	28%
2846	944	1.062	118	13%	72	93	21	29%
2847	1.283	1.435	152	12%	195	249	54	28%
2848	304	346	42	14%	289	369	80	28%
2849	2.040	2.168	128	6%	199	253	54	27%
2850	1.154	1.331	177	15%	276	351	75	27%
2851	120	156	36	30%	250	260	10	4%
2852	2.863	3.559	696	24%	942	1.197	255	27%
2853	653	1.155	502	77%	151	194	43	28%
2854	2.515	2.836	321	13%	458	582	124	27%
2855	1.303	1.449	146	11%	156	199	43	28%
2856	1.370	1.792	422	31%	321	407	86	27%
2857	1.803	2.295	492	27%	193	247	54	28%
2858	25	35	10	40%	50	61	11	22%
2859	501	547	46	9%	527	670	143	27%
2860	1.360	1.397	37	3%	559	711	152	27%
2861	227	503	276	122%	73	94	21	29%
2862	371	400	29	8%	21	27	6	29%
2863	580	626	46	8%	61	78	17	28%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
2864	935	952	17	2%	309	395	86	28%
2865	3.273	3.897	624	19%	2.059	2.621	562	27%
2866	973	1.082	109	11%	186	236	50	27%
2867	1.876	2.006	130	7%	672	856	184	27%
2868	1.170	1.381	211	18%	931	1.184	253	27%
2869	2.109	2.339	230	11%	279	354	75	27%
2870	120	147	27	23%	140	178	38	27%
2871	972	1.079	107	11%	88	110	22	25%
2872	769	869	100	13%	51	66	15	29%
2873	514	958	444	86%	32	42	10	31%
2874	1.602	1.623	21	1%	93	119	26	28%
2875	1.476	1.520	44	3%	70	91	21	30%
2876	1.020	1.585	565	55%	174	222	48	28%
2877	734	787	53	7%	129	166	37	29%
2878	5.169	6.396	1.227	24%	551	701	150	27%
2879	4.334	4.814	480	11%	1.263	1.608	345	27%
2880	608	712	104	17%	994	1.194	200	20%
2881	866	1.027	161	19%	118	150	32	27%
2882	631	896	265	42%	113	145	32	28%
2883	1.488	4.953	3.465	233%	79	100	21	27%
2884	1.982	4.237	2.255	114%	74	95	21	28%
2885	979	3.102	2.123	217%	37	48	11	30%
2886	1.422	1.459	37	3%	337	428	91	27%
2887	1.044	1.166	122	12%	429	547	118	28%
2888	961	1.346	385	40%	89	113	24	27%
2889	1.173	1.229	56	5%	138	176	38	28%
2890	1.735	1.905	170	10%	136	174	38	28%
2891	868	913	45	5%	263	335	72	27%
2892	333	433	100	30%	34	45	11	32%
2893	642	790	148	23%	80	102	22	28%
2894	1.276	1.435	159	12%	95	121	26	27%
2895	5.149	5.182	33	1%	1.144	1.457	313	27%
2896	4.038	4.964	926	23%	361	459	98	27%
2897	805	1.300	495	61%	270	345	75	28%
2898	1.168	1.276	108	9%	128	163	35	27%
2899	403	1.673	1.270	315%	335	2.375	2.040	609%
2900	193	381	188	97%	343	435	92	27%
2901	463	1.286	823	178%	1.393	3.925	2.532	182%
2902	283	544	261	92%	1.587	1.784	197	12%
2903	943	1.067	124	13%	159	202	43	27%
2904	5.079	5.447	368	7%	2.502	3.183	681	27%
2905	1.264	3.087	1.823	144%	116	148	32	28%
2906	409	2.834	2.425	593%	181	230	49	27%
2907	220	306	86	39%	10	10	0	0%
2908	145	217	72	50%	264	550	286	108%
2909	7.335	16.637	9.302	127%	665	846	181	27%
2910	1.728	2.090	362	21%	114	146	32	28%
2911	11.312	13.275	1.963	17%	1.146	1.459	313	27%
2912	282	524	242	86%	33	43	10	30%
2913	1.773	3.393	1.620	91%	244	310	66	27%
2914	660	5.939	5.279	800%	4.181	5.003	822	20%
2915	1.724	2.461	737	43%	497	633	136	27%
2916	4.410	8.381	3.971	90%	349	435	86	25%

	Total Population				Total Employment			
TAZ	2017	2045	Change	% Change	2017	2045	Change	% Change
2917	1.756	5.364	3.608	205%	6.167	7.391	1.224	20%
2918	5.251	5.861	610	12%	1.521	1.822	301	20%
2919	2.892	3.587	695	24%	95	116	21	22%
2920	3.258	4.887	1.629	50%	595	731	136	23%
2921	1.935	2.014	79	4%	3.285	3.936	651	20%
2922	1.317	1.317	0	0%	9.206	11.282	2.076	23%
2923	3.274	3.384	110	3%	1.123	1.345	222	20%
2924	911	1.194	283	31%	1.309	1.568	259	20%
2925	2.060	3.034	974	47%	659	789	130	20%
2926	2.693	2.769	76	3%	6.950	8.462	1.512	22%
2927	1.133	1.406	273	24%	877	1.051	174	20%
2928	1.995	2.050	55	3%	3.451	4.135	684	20%
2929	3.315	3.396	81	2%	3867	4635	768	20%
2930	5.439	5.951	512	9%	936	1.122	186	20%
2931	8.046	8.274	228	3%	1.937	2.321	384	20%
2932	0	0	0	0%	428	513	85	20%
2933	8.862	10.210	1.348	15%	1.188	1.499	311	26%
2934	4.351	4.595	244	6%	1.569	1.879	310	20%
2935	78	2.208	2.130	2731%	9.045	11.040	1.995	22%
2936	2.245	2.272	27	1%	9.700	12.648	2.948	30%
2937	5.741	8.743	3.002	52%	2.460	2.897	437	18%
2938	3.247	4.073	826	25%	488	622	134	27%
2939	1.435	4.249	2.814	196%	888	2.031	1.143	129%
2940	1.260	1.937	677	54%	731	931	200	27%
2941	1.036	1.214	178	17%	167	211	44	26%
2942	2.535	2.754	219	9%	788	886	98	12%
2943	860	1.256	396	46%	2.132	2.476	344	16%
2944	205	303	98	48%	119	151	32	27%
2945	757	782	25	3%	388	495	107	28%
2946	86	97	11	13%	11	15	4	36%
2947	95	122	27	28%	181	230	49	27%
2948	2.033	2.338	305	15%	311	397	86	28%
2949	1.489	1.685	196	13%	326	414	88	27%
Total	1.284.958	1.567.483	282.525	22%	643.493	824.279	180.786	28%

Source: MWCOG. Round 9.1 Cooperative Forecasts.

Memorandum

TO: Robert Eisinger, The High Road Foundation

FROM: Feng Liu, Cambridge Systematics, Inc.

DATE: November 5, 2019

RE: Results from a 2045 Model Run for the Higher Frequency Metro-Like Scenario

---

This memorandum provides a brief summary of the results from a 2045 model run for the higher frequency Metro-like scenario. During the Frederick-Shady Grove Ridership and Revenue Study, which ended on March 15, 2019, the run time inputs of 31 minutes for the 27-mile route were used reflecting an average operating speed of 56 miles per hour (mph) and a top design speed of 70 mph. Following the conclusion of this study, CS was informed that run times should range from 40 to 46 minutes varying based on the assumed top design speeds ranging from 50 to 80 mph, and these revised run times were estimated after correcting an error inadvertently made during the previous speed and run time calculation. Per your request, we conducted a 2045 model run for the higher frequency Metro-like scenario, using a run time of 42 minutes under a top design speed of 65 mph, to demonstrate the sensitivity of ridership to the run time assumption. The impacts of run time on the other scenarios were not tested and may differ from this scenario.

Average Weekday Ridership – the ridership forecasted in this sensitivity run shows a reduction of average weekday ridership by approximately 13%, from originally 55,000 to 47,800 boardings.

Ridership by Stations – Daily projected boardings by station are tabulated in Table 1, which also shows comparison of the results from the 42 minute run time scenario with those from the original run that assumed a 31-minute run time. The stations of Shady Grove, Frederick and COMSAT show higher impacts than the other stations.

Table 1. Sensitivity of Daily Project Boardings by Station (Higher Frequency Metro-Like Scenario)

Station	2045 (Run Time of 31 minutes)	2045 (Run Time of 42 minutes)	Difference
Shady Grove	26,400	22,900	-3,500
Metropolitan Grove	5,700	5,100	-600
Germantown	4,000	3,600	-400
COMSAT	2,600	2,000	-600
Urbana	2,000	1,800	-200
Frederick	14,300	12,400	-1,900
Total	**55,000**	**47,800**	-7,200

Note: Rounded to 100s

3 Bethesda Metro Center, Suite 1200
Bethesda, MD 20814
tel 301-347-9100 www.camsys.com **fax** 301-347-9101

Memorandum

TO: Michelle Martin (MDOT)

FROM: Feng Liu, Ph.D.

DATE: Original January 28, 2020; Updated February 24,2020

RE: Monorail Ridership Forecast and Impacts: Sensitivity Analysis

---

This memorandum provides a summary of the latest analyses and results for the Monorail between Frederick and Shady Grove proposed by the High Road Foundation, in support of MDOT for its feasibility study of the proposed Monorail. The objective of this analysis is to evaluate the sensitivity of ridership to more moderate level-of-service assumptions and the impacts relative to the no-build conditions.

Assumptions and Inputs

This analysis started with what had been documented in the Frederick-Shady Grove Ridership and Revenue Study conducted in 2019, which included three sets of service assumptions:

- Base Frequency was comparable to Metrorail (pre-2019 schedule), 6-minute headways for peak periods and 12-minute headways for midday and evening periods
- Higher Frequency assumed service more aggressive than Metrorail, with 3-minute headways for peak periods and 10-minute headways for midday and evening periods
- Lower Frequency was comparable to Metrorail for peak (pre-2019 schedule) and slightly less for off-peak periods.

This analysis uses the Base Frequency assumptions for the proposed Monorail. The differences in service assumptions include:

- Average operating speed is assumed to be 35 mph, which is consistent with an average speed based on the current Red Line operations and also close to the average speed with a maximum design speed of 50 mph for the proposed Monorail, in comparison with an average operating speed of 56 miles per hour (mph) in the initial study
- Parking cost is assumed to be charged at all stations (with parking rates assumed to be the same as that for Shady Grove--$5.2 per day for peak and $1 per day for off-peak), in comparison with the original assumption of parking being available and free of charge at every station (except for Shady Grove).

3 Bethesda Metro Center, Suite 1200
Bethesda, MD 20814
tel 301-347-9100 www.camsys.com **fax** 301-347-9101

Therefore, the results from this analysis reflect the effects of both speed and parking cost changes.

Results and Findings

The 2045 model with changed assumptions for speed and run time and parking costs was run, and the results were analyzed in comparison with the previous runs and the no-build conditions.

Average Weekday Ridership – the ridership forecasted in this sensitivity run shows a reduction of average weekday ridership by approximately 32%, from originally 51,400 to 34,800 boardings.

Ridership by Stations – Daily projected boardings by station are tabulated in Table 1, which shows comparison of the results from the latest run scenario with those from the original Base Frequency run. The stations of Shady Grove, Frederick and Metropolitan Grove show higher impacts than the other stations.

Table 1. Sensitivity of Daily Project Boardings by Station (Base Frequency Metro-Like Scenario)

Station	2045 (original Base Frequency)	2045 (Latest Sensitivity Run)	Difference	% Difference
Shady Grove	24,700	16,600	-8,100	-33%
Metropolitan Grove	5,000	2,000	-3,000	-60%
Germantown	3,600	2,700	-900	-25%
COMSAT	2,300	1,500	-800	-35%
Urbana	1,900	1,600	-300	-16%
Frederick	13,900	10,400	-3,500	-25%
Total	**51,400**	**34,800**	-16,600	-32%

Note: Rounded to 100s

Changes of Transit Boardings (Build vs No Build) – Daily projected boardings for major transit routes in the study area are tabulated in Table 2, which shows comparison of the results from the latest run scenario with those from the 2045 No Build scenario. As can be seen from the table, competing routes are expected to experience declines in daily boardings, especially MARC Brunswick Line, commuter bus MT 505/515, MD355 BRT, and RO 100. CCT BRT would see a slight increase in daily boardings as the transfers from the proposed Monorail to the CCT BRT would outnumber the replacement of CCT BRT trips by the proposed Monorail trips.

Table 2. Projected Changes in Daily Boardings for Major Transit Routes in the Study Area

Routes	2045 (original base Run)	2045 (Latest Sensitivity Run)	2045 No Build	Difference (Latest vs NB)	% Difference (Latest vs NB)
CCT BRT	16,700	16,800	16,100	700	4%
MD355 BRT	36,600	37,100	38,700	-1,600	-4%
N Bethesda BRT	4,300	4,200	4,100	100	2%
MT505/515	100	100	2,700	-2,600	-96%
RO70	900	1,400	1,800	-400	-22%
RO100	0	0	1,800	-1,800	-100%
MARC Brunswick	7,400	7,700	11,100	-3,400	-31%
Metro Red Line	528,400	524,300	512,100	12,200	2%

Note: Rounded to 100s

Changes of Daily Trips (Build vs No Build) – Regional trips were compared between the Build (latest sensitivity run) and No-Build scenarios, and the results are summarized in Table 3. The regional transit trips are forecasted to increase by nearly 10,000 in the Build scenario, in comparison with the No-Build scenario. These represent new transit trips, as a result of the proposed the Monorail. On the other hand, the auto person trips will decline by roughly 13,000, and vehicle trips will decrease by approximately 10,000 vehicle trips.

Table 3. Projected Changes in Daily Trips between Build and No Build

Routes	2045 (Latest Sensitivity Run)	2045 No Build	Difference	% Difference
Regional Transit Person Trips	1,623,300	1,613,800	9,500	0.6%
Regional Auto Person Trios	22,449,600	22,462,100	-12,500	-0.1%
Regional Total Person Trips	24,072,800	24,075,900	-3,100	0.0%
Regional Auto Vehicle Trips	15,737,800	15,748,100	-10,300	-0.1%

Note: Rounded to 100s

The auto vehicle trip reductions are spread in the study area, with a small decrease in traffic volume on major roadways. For example, the southbound traffic on I-270 in the AM peak period would decrease by roughly 350 at the segment north of the Inter-County Connector and by approximately 500 south of Frederick City.