NCRR Commuter Rail Ridership & Market Study

Summary Report

May 2010

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CONTENTS

1 INTRODUCTION 1

2 BACKGROUND 1

3 CHARACTERISTICS OF THE REGION 2

4 THE RIDERSHIP STUDY 5

The SDG Model 5

Scenarios modeled 13

5 RESULTS 16

SDG Model results 16

The Aggregate Rail Ridership Forecasting (ARRF) Model 21

6 CONCLUSIONS 23

FIGURES

Figure 1.1 Study corridor map 1

Figure 3.1 2000 Census journey-to-work flows in the region 3

Figure 3.2 2009-2022 population growth of main study area counties 4

Figure 3.3 2009-2022 employment growth of main study area counties 5

Figure 4.1 Model composition and coverage 6

Figure 4.2 Current and planned Triangle area bus service 9

Figure 4.3 Current and planned Piedmont Triad area bus service 9

Figure 4.4 Stated preference survey coverage 11

Figure 4.5 Base scenario commuter rail configuration 14

Figure 4.6 Base scenario commuter rail fare structure 15

Figure 5.1 Base scenario comparison (40-minute peak headways for all years) 16

Figure 5.2 Daily station boardings, 2017 and 2022 base scenarios 17

Figure 5.3 2017 scenario comparison 18

Figure 5.4 2022 scenario comparison 20

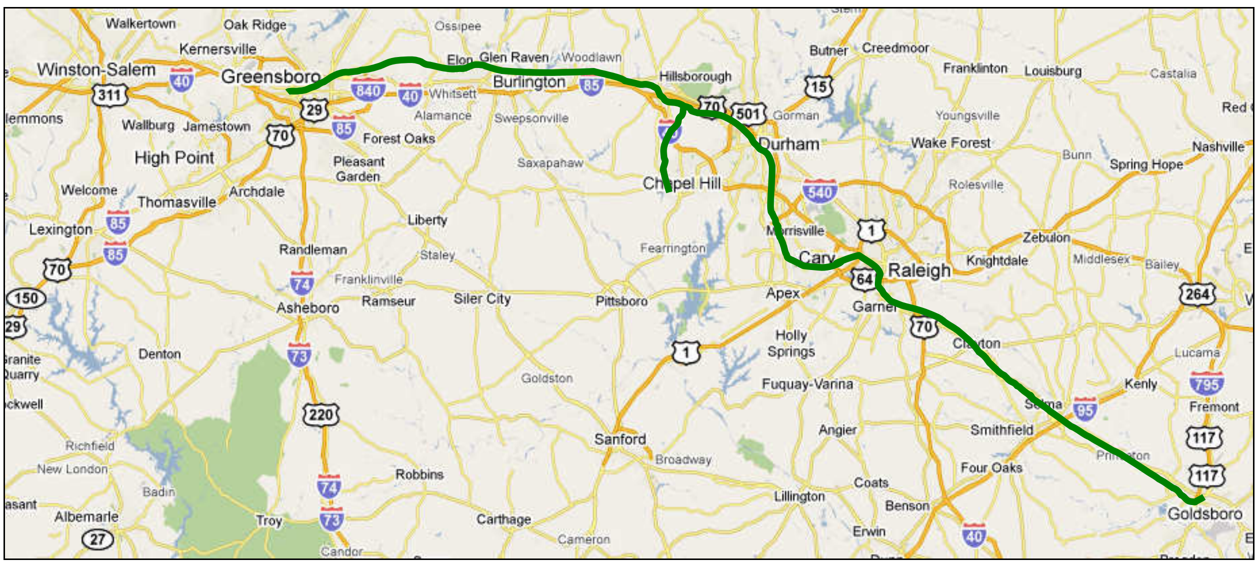
TABLES

Table 3.1 2009 population and employment of main study area counties 4
Table 4.1 Implied values of time from the SDG mode choice diversion models ($2009) 12
Table 4.2 Study area wage rates 13
Table 5.1 Summary of base scenario results 16
Table 5.2 2017 sensitivity analysis results 18
Table 5.3 2022 sensitivity analysis results 19
Table 5.4 Top twenty US commuter rail systems by ridership 21
Table 5.5 ARRF Model estimated total daily commuter rail ridership 22
Table 5.6 Comparison of SDG Model total daily commuter rail ridership estimates with ARRF Model estimates 23

1 Introduction

The North Carolina Railroad Company (NCRR) retained Steer Davies Gleave[1] to perform a ridership and revenue forecasting study of potential commuter rail service on a portion of the rail corridor that it owns. The NCRR corridor stretches 317 miles from Charlotte to Morehead City, serving many of the major population and employment centers in North Carolina. The scope of the ridership study included the 143-mile section of the NCRR-owned corridor between Greensboro and Goldsboro (which includes Burlington, Mebane, Hillsborough, Durham, Raleigh, Garner, Clayton, Selma, and Princeton), and the Norfolk Southern-controlled line from Durham to Chapel Hill/Carrboro. The study corridor, which is shown in Figure 1.1 below, is the section of the NCRR corridor east of the heavier north-south freight main line, and is the same segment for which NCRR conducted a commuter rail capacity study in 2008. Note that commuter rail service west of Greensboro was not included in the scope of this study, because Piedmont Area Regional Transit (PART) has conducted studies to evaluate commuter rail service in the area west of the NCRR corridor.

FIGURE 1.1 STUDY CORRIDOR MAP



2 Background

Currently, the full NCRR corridor is maintained and used for freight service by Norfolk Southern (NS) under an exclusive trackage rights agreement. Norfolk Southern operates approximately 70 freight trains per day on the corridor. In addition, four Amtrak passenger routes—the Carolinian, the Crescent, the Piedmont, and the Silver Star—utilize part of the NCRR corridor. The Carolinian and Piedmont use the Selma-Charlotte portion of the corridor, the Crescent uses the Greensboro-Charlotte portion, and the Silver Star uses the Selma-Cary portion. Each of these routes is served by one daily train in each

[1] In January 2009, Steer Davies Gleave established its US headquarters in Boston by acquiring the transportation planning group of Charles River Associates in a friendly transaction.

direction. Two additional Amtrak trains providing mid-day service between Raleigh and Charlotte will begin operating on June 5, 2010, increasing the state-sponsored Amtrak service to six daily trains between the state's two largest cities.

NCRR's agreement with NS allows the operation of commuter rail service on shared track with freight and Amtrak trains as long as the commuter rail operation does not interfere with NS freight operations. There has been considerable interest from state and local authorities and local communities in using the NCRR corridor for passenger rail. This interest in passenger rail prompted NCRR to undertake a Shared Corridor Commuter Rail Capacity Study for the Greensboro to Goldsboro section.[2] NCRR commissioned this study to determine the infrastructure improvements that would be required in this corridor to accommodate new commuter rail operations along with existing freight and Amtrak operations. The Shared Corridor Capacity Study recommended that a ridership forecasting study be conducted as a next step to assess potential demand for commuter rail service in the NCRR corridor. The present study has been undertaken as a result of that recommendation.

It should be noted that the Shared Corridor Capacity Study only estimated the capital costs of the improvements required to implement commuter rail service. The study did not consider operating, maintenance, or other major rehabilitation costs that would be incurred during the life cycle of the commuter rail system.

3 Characteristics of the region

A number of unique characteristics of the study area merit special consideration in this ridership and revenue forecasting study. First, neither the Piedmont Triad area (between Greensboro, High Point and Winston-Salem) nor the Triangle area (between Raleigh, Durham, Cary and Chapel Hill) has a single dominant central business district. (Note that both Winston-Salem and High Point are outside the scope of this ridership study.) Instead, there are multiple major employment centers, including the CBDs of Greensboro, High Point, and Winston-Salem for the Triad, and the CBDs of Raleigh, Durham, and Cary, as well as the Research Triangle Park for the Triangle.

The study area also contains large individual employers in the education, health, and research industries, including Duke University and Medical Center, the University of North Carolina-Chapel Hill, IBM, North Carolina State University, the Moses H. Cone Health System, UNC Healthcare, and GlaxoSmithKline.

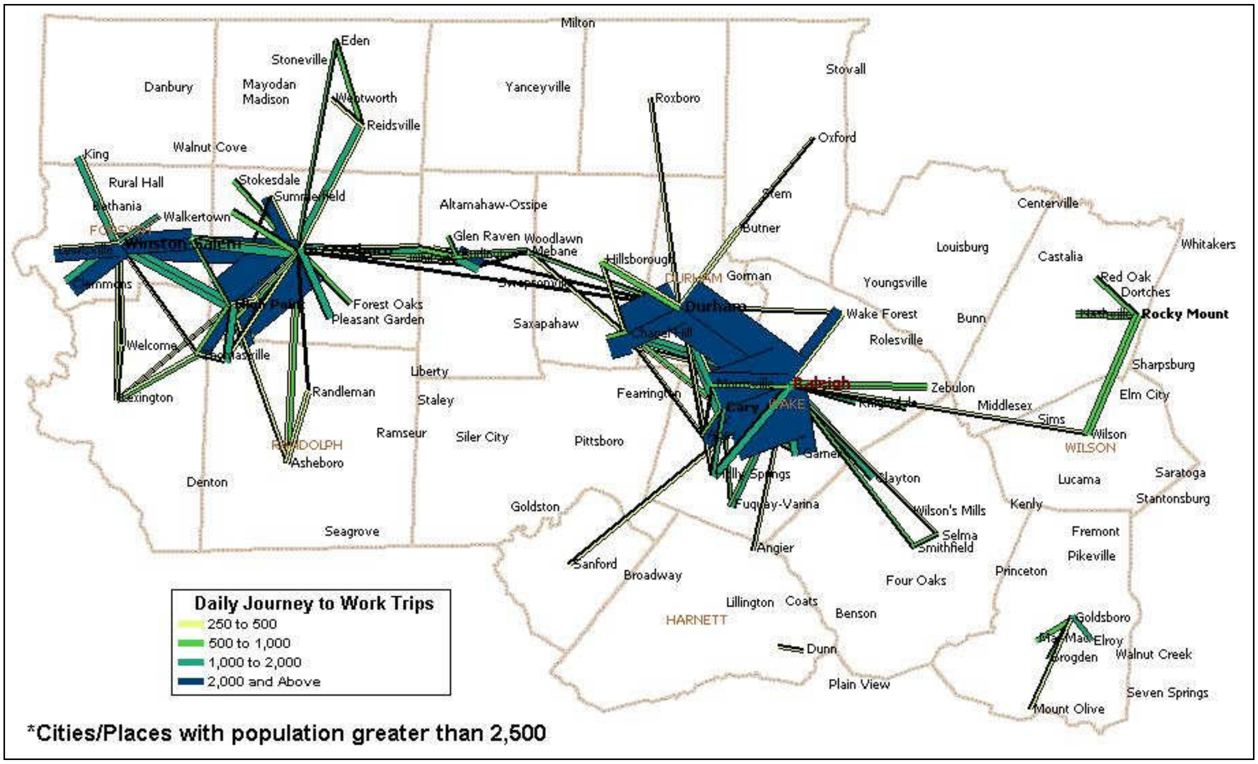
Another characteristic of the region is the presence of many colleges and universities, including North Carolina State University in Raleigh, University of North Carolina at Chapel Hill, University of North Carolina at Greensboro, Duke University in Durham, North Carolina A&T State University in Greensboro, and Elon University. Accordingly, students traveling to area universities merit special consideration. Seymour Johnson Air Force Base in Goldsboro, where approximately 5,200 active duty and reserve personnel are stationed, also requires careful treatment in the study.

Figure 3.1 shows the journey-to-work flows between study area cities/places having a population greater than 2,500; these data come from the 2000 Census Transportation Planning Package (CTPP). It

[2] Shared Corridor Commuter Rail Capacity Study, 2008, HNTB Final Report for North Carolina Railroad Company

is evident from Figure 3.1 that the majority of the commuting trips are concentrated in the Triangle and Piedmont Triad areas. The Triangle and Triad areas have the most extensive bus networks in the region at present, and these are expected to expand in the coming years. Figure 3.1 also indicates that most commuting trips are of relatively short distance. This combination of competition from bus services and short commuter trip lengths may somewhat lessen the attractiveness of the potential commuter rail system within the two most heavily commuted portions of the study corridor.

FIGURE 3.1 2000 CENSUS JOURNEY-TO-WORK FLOWS IN THE REGION



Source: 2000 Census CTPP data

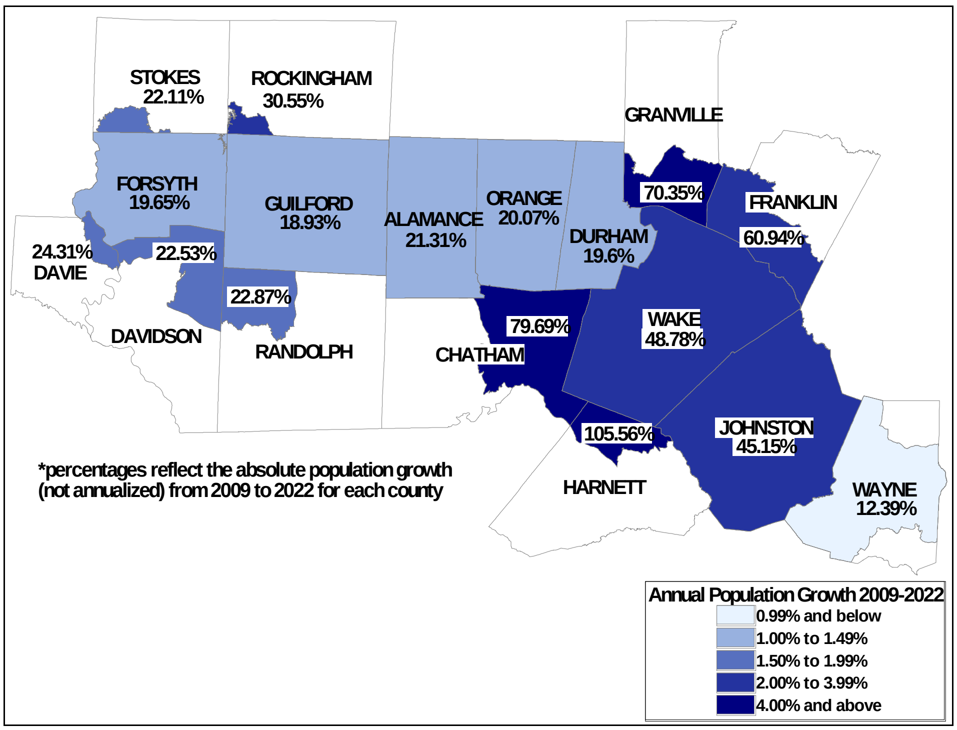
The study area—particularly the Triangle—is expected to experience rapid population and employment growth over the next several years, as shown in Table 3.1, Figure 3.2, and Figure 3.3 below. It has experienced a steady increase in highway congestion in the recent past, and the Texas Transportation Institute currently ranks Raleigh-Durham as the 35th most congested metro area in the US with 35 hours annual highway delay per traveler.

TABLE 3.1 2009 POPULATION AND EMPLOYMENT OF MAIN STUDY AREA COUNTIES

County	Population	Employment
Forsyth	351,230	206,822
Guilford	490,241	308,001
Alamance	150,377	67,959
Orange	139,103	60,172
Durham	265,715	190,622
Wake	906,777	481,240
Johnston	172,746	49,006
Wayne	94,302	50,103

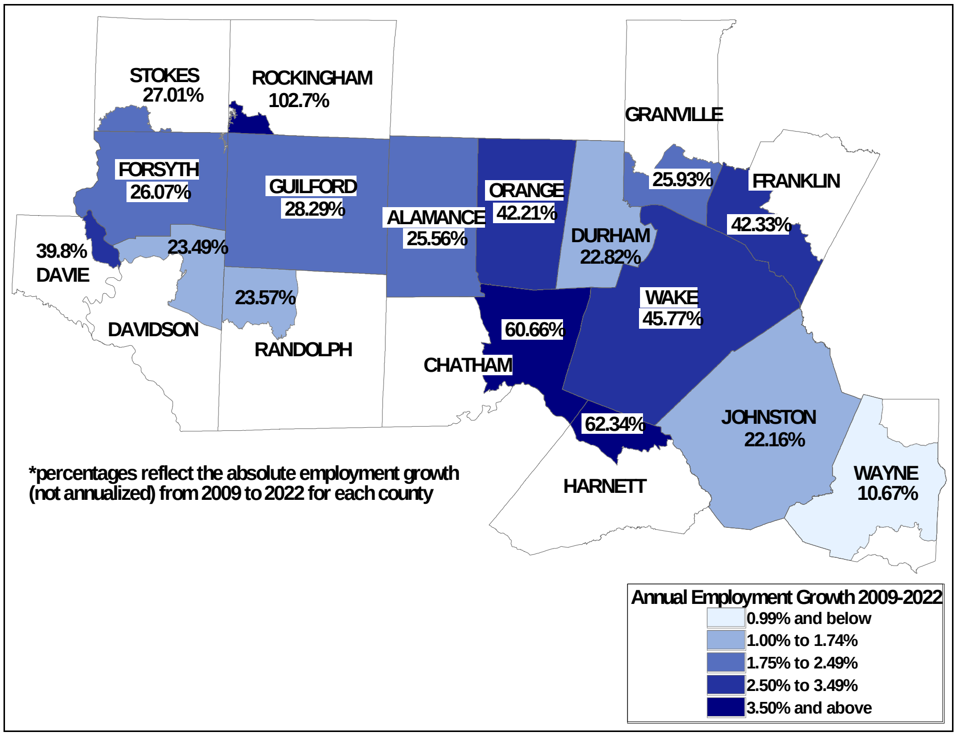
Source: infoUSA as used in the TRM and PTRM models

FIGURE 3.2 2009-2022 POPULATION GROWTH OF MAIN STUDY AREA COUNTIES



Source: infoUSA as used in the TRM and PTRM models

FIGURE 3.3 2009-2022 EMPLOYMENT GROWTH OF MAIN STUDY AREA COUNTIES



Source: infoUSA as used in the TRM and PTRM models

4 The ridership study

This ridership study follows the recommendation of the Shared Corridor Capacity Study by examining in greater detail the potential passenger demand for commuter rail service within the Greensboro to Goldsboro portion of the NCRR corridor. The key focus of the present study is to derive the ridership and revenue implications of the recommendations presented in the Shared Corridor Capacity Study, and to assess the viability of commuter rail service along various segments of the NCRR corridor from a ridership perspective. In terms of analytical rigor, the study is intended to fall between a sketch planning exercise and an investment-grade forecast.

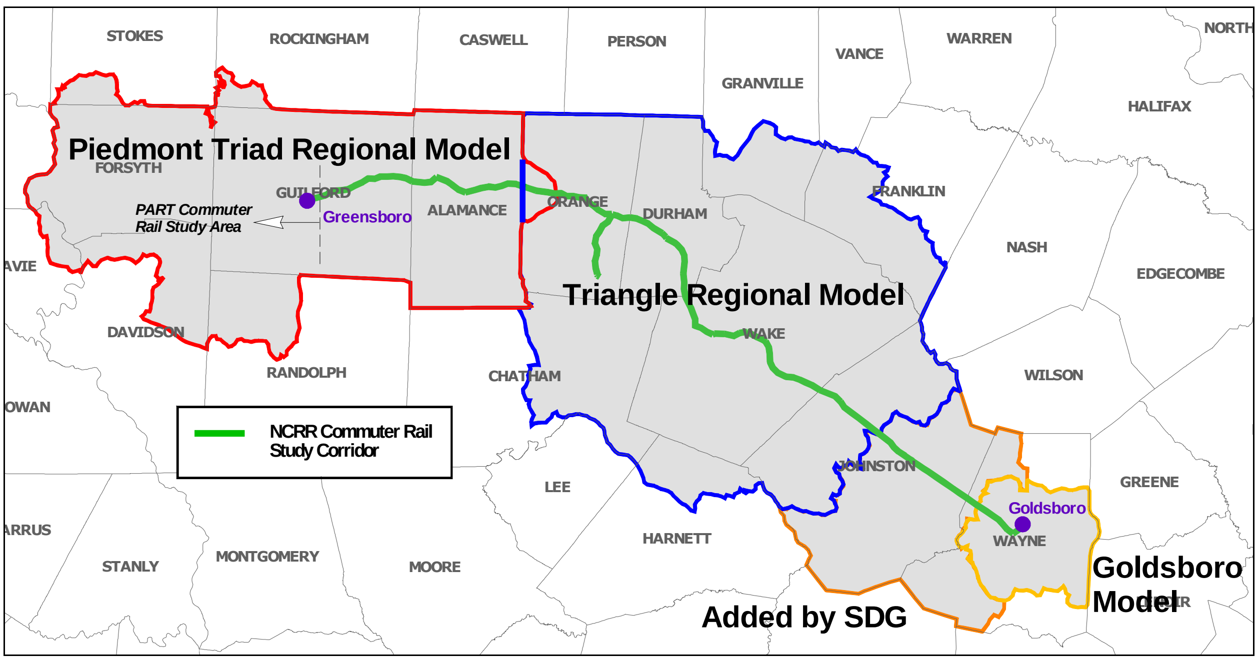
Forecasts were developed for three future model years chosen by NCRR—2012, 2017, and 2022—and a base year, 2009. The forecasts were based on the operating characteristics recommended in the Shared Corridor Capacity Study. The sensitivity of ridership with respect to commuter rail fare, service frequency, and population and employment growth was also examined.

The SDG Model

There are three existing travel demand forecasting model systems that each cover a portion of the study area: the Triangle Regional Model (TRM), the Piedmont Triad Regional Model (PTRM), and the Goldsboro Travel Demand Model (GTDM). Each model is the responsibility of the respective area's metropolitan planning organization (MPO). However, none of the models covers the entire Greensboro-Goldsboro corridor, so it was necessary to create a new regional model for this study. There is also a portion of the study corridor between the southeast edge of the TRM and the western edge of the GTDM that is not covered by any of the existing models.

Since all three of the existing forecasting model systems are TransCAD-based four-step urban travel demand models, we chose to take advantage of the MPOs' efforts in developing and validating models that accurately represent their local travel patterns. Accordingly, we combined the three models to form the core of our corridor-wide travel demand model system, and supplemented the combined models with data for the area between the southeastern edge of the TRM and the western edge of the GTDM. Figure 4.1 below shows the coverage of each of the existing models in addition to the area filled in by SDG. Note that while our model does take into account travel patterns in the Winston-Salem and High Point areas, it does not include commuter rail service west of Greensboro, as it is outside the scope of this study.

FIGURE 4.1 MODEL COMPOSITION AND COVERAGE



Model preparation

Since the TRM covers the majority of the large population and employment centers in the study area, we chose to base our corridor forecasting model on the general model structure of the TRM, and modify the inputs for the PTRM and GTDM to conform to the TRM inputs. The models have different ways of treating many inputs, and incorporate different assumptions and procedures. When combining the models, it was necessary to make decisions regarding the conversion of attributes between model systems to resolve these differences. The key model components combined included the following:

- Traffic analysis zones (TAZs): Travel demand models typically divide a study area into traffic analysis zones (TAZs), which are relatively small geographic areas that have uniform characteristics and represent locations where trips begin or end. The final SDG corridor model includes more than 4,300 TAZs, which is a very large number for a model of this type. This high level of detail causes the model to be very computationally intensive.

- Highway network: Each segment of each road in the corridor (with the exception of small local streets) is represented as a link in a highway network. Model network links are described by attributes such as facility type, free-flow speed, congested speed, traffic signal density, etc. The highway network is used in the model for the assignment of auto trips. Buses also travel over highway links, and passengers accessing public transit via park-and-ride or kiss-and-ride must first travel from their origin to their boarding stop over the highway network.
- Transit route systems: Each transit route and its associated stops are represented in a route system. Each route has attributes which include mode, fare, peak period headway, and others. The transit route system is used in the assignment of public transit trips.
- Socioeconomic data: The travel behavior of individuals in each TAZ is predicted based on the socioeconomic characteristics of the TAZ. To this end, the model includes a table with a number of socioeconomic attributes for each TAZ, including population, employment by category, mean income, and others.
- Other inputs: The model includes numerous other input files that provide details on very specific aspects of the region's transportation system, such as timed transit transfer locations, TAZs where universities are located, and counts of external-external trips (trips passing through, but not beginning or ending in the model area). For each of these inputs, we converted similar files from the PTRM and GTDM to the TRM format, while adding the appropriate information for the SDG-added area. In cases where the PTRM and GTDM do not include similar files, we created the appropriate files using various data sources.

Some of the major challenges faced in model combination were:

- Expansion of the model computer programs to allow significantly more TAZs: A number of the programs executed in the model runstream were designed to allow a maximum of 2,500 TAZs. Since these programs were compiled using software that is no longer commercially available, it was a challenge to obtain the tools necessary to modify the appropriate portions of code and recompile the programs.
- Differences in model base years: The base year of the TRM is 2005, while the base year of the PTRM is 2009, and the base year of the GTDM is 2003. In order to achieve a consistent base year of 2009, we had to interpolate all socioeconomic data between the TRM and GTDM base years, and the next available model years for the respective models. It was also necessary to incorporate any modifications to the highway network and transit route systems that took place between the TRM and GTDM base years and 2009.
- Differences in treatment of university students/trips: For Duke, NC State, and UNC Chapel Hill, the TRM uses a fixed distribution of student trips, meaning the input files dictate how many students travel from each home-end TAZ to each university-end TAZ for university trips. The PTRM uses fixed distribution for university trips to Greensboro University, High Point University, Salem College, and UNC-Greensboro, but uses a different method to do so. As a result, we modified the PTRM university trip distribution input files while maintaining the existing data to be consistent with the treatment of TRM university trips.
- Conversion of external-external trips to internal-external trips: Many of the external-external trips (trips that pass through, but do not begin or end in the model area) in the

three existing models are no longer external-external trips in the combined model. To account for this, it was necessary to re-estimate the external trip matrix by matching endpoints of external trips between each pair of models. This allowed us to estimate how many trips would remain in the external-external category, and how many would correspond to each external zone.

Additional input data

Data from the three existing models were used to the maximum extent possible. Since the existing models did not explicitly model 2012, 2017, or 2022, data for these years were computed by interpolating between existing model years. For the portion of the study area not covered by the three existing models, socioeconomic data for each model year were estimated by computing the values from Census data, then growing at a constant rate—also calculated using Census data—to the appropriate future year.

Additional data used to complete input files included route information for current and planned public bus routes from a number of transit operators in the region, as well as traffic counts from the North Carolina Department of Transportation.

In addition to the data used for model inputs, we gathered data on commuting patterns from a number of local institutions, including Duke University, NC State University, UNC-Chapel Hill, Raleigh-Durham International Airport, the Research Triangle Park, the Raleigh Chamber of Commerce, and the Downtown Raleigh Alliance. This information was not explicitly included in the model inputs, but rather was used to check the reasonableness of the travel patterns produced by the model for home-based work trips.

Observations on initial model inputs

In order to understand the differences between the results of the base scenarios, it is important to first be familiar with the major differences between the key input files of the MPO models, which include the following:

- Bus fares are generally higher in the Piedmont Triad area than the Triangle area. Because the differential between bus and commuter rail fares is greater in the Triangle area than in the Triad area, rail will be less attractive relative to bus.
- For both the TRM and PTRM, 2015 was the nearest existing model year to both 2012 and 2017. Since this is the case, 2015 transit route systems for the TRM and PTRM models were used as the transit route system for the respective region in both the 2012 and 2017 combined models. As a result, existing bus service expands modestly between 2009 and 2012, remains the same from 2012 to 2017, and expands significantly between 2017 and 2022. The 2022 transit route system is based on the TRM and PTRM planned transit route systems for 2025. The planned expansion of bus service can be seen for the Triangle area in Figure 4.2 and for the Piedmont Triad area in Figure 4.3 below.

FIGURE 4.2 CURRENT AND PLANNED TRIANGLE AREA BUS SERVICE

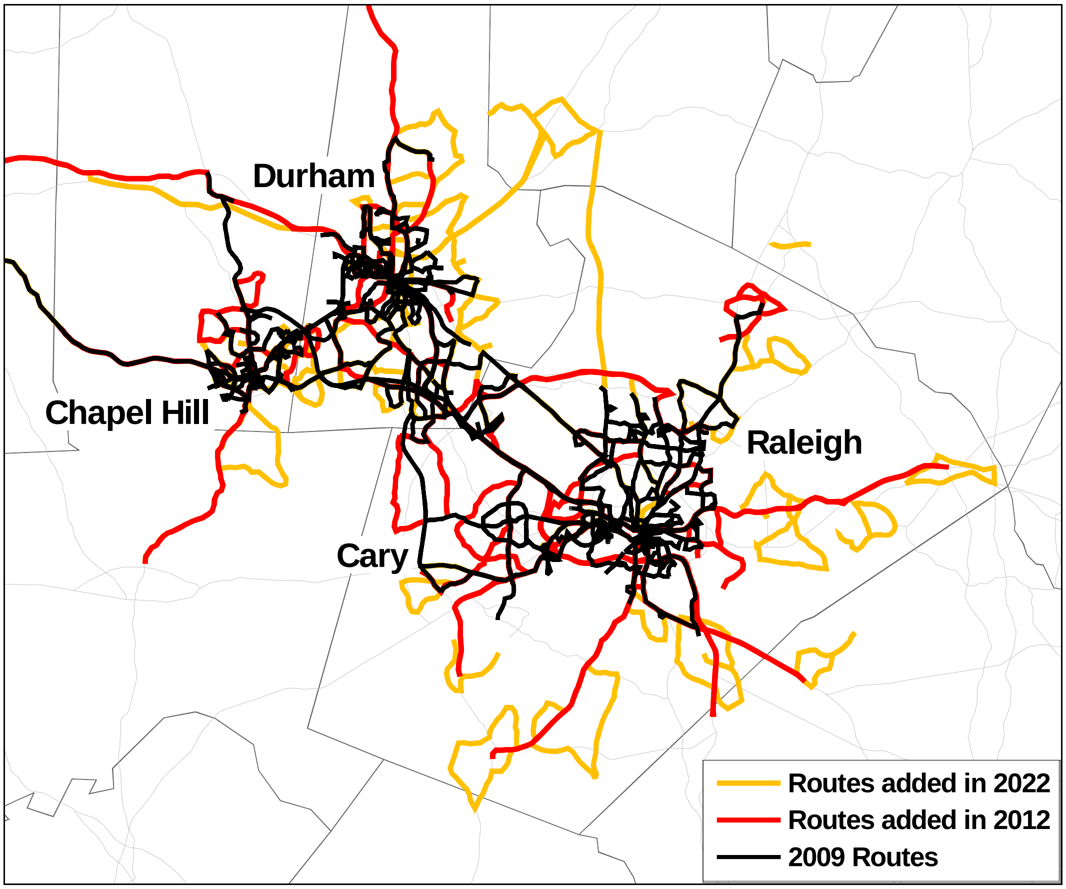
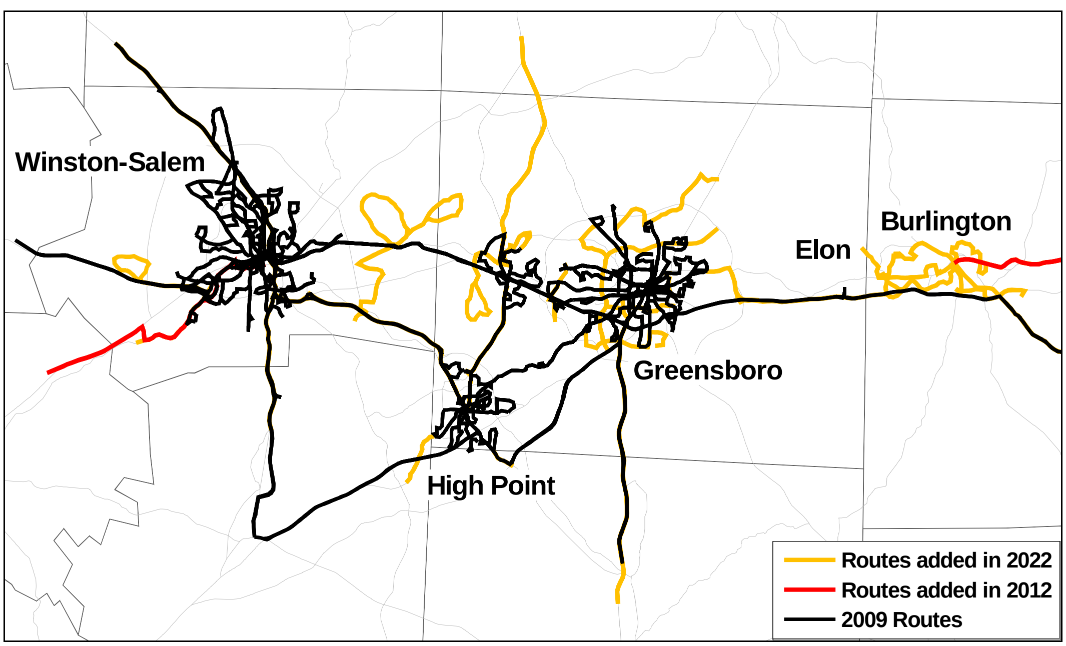


FIGURE 4.3 CURRENT AND PLANNED PIEDMONT TRIAD AREA BUS SERVICE



Note: 2017 bus routes are not shown because they are identical to the 2012 bus routes in the model.

Stated preference survey

None of the three model systems used to develop our combined model system for this study (TRM, PTRM, and GTDM) has a commuter rail option as part of its mode choice component. In order to incorporate the commuter rail mode in the mode choice of local travelers, we had two options: 1) refer to commuter rail mode choice models developed elsewhere, and adapt them as needed to the specific characteristics of the corridor; or 2) perform a travel survey of local residents and use information from the survey to develop new mode choice models that include a commuter rail option. However, mode choice models developed without use of locally-collected survey data (the first option) may be subject to criticism. Other things equal, it is preferable to fit a model to local conditions using local data. We considered using recently conducted surveys in the study area (e.g., the 2006 Transit Survey[3], the 2006 Household Survey[4]), however, these surveys referred to the current transportation system, which does not provide commuter rail service in the study corridor. Consequently, we concluded that it would be worthwhile to design and carry out a new travel survey in the corridor, using the survey results to enhance the mode choice component of our regional model. This approach was preferred by NCRR because of its desire for greater accuracy.

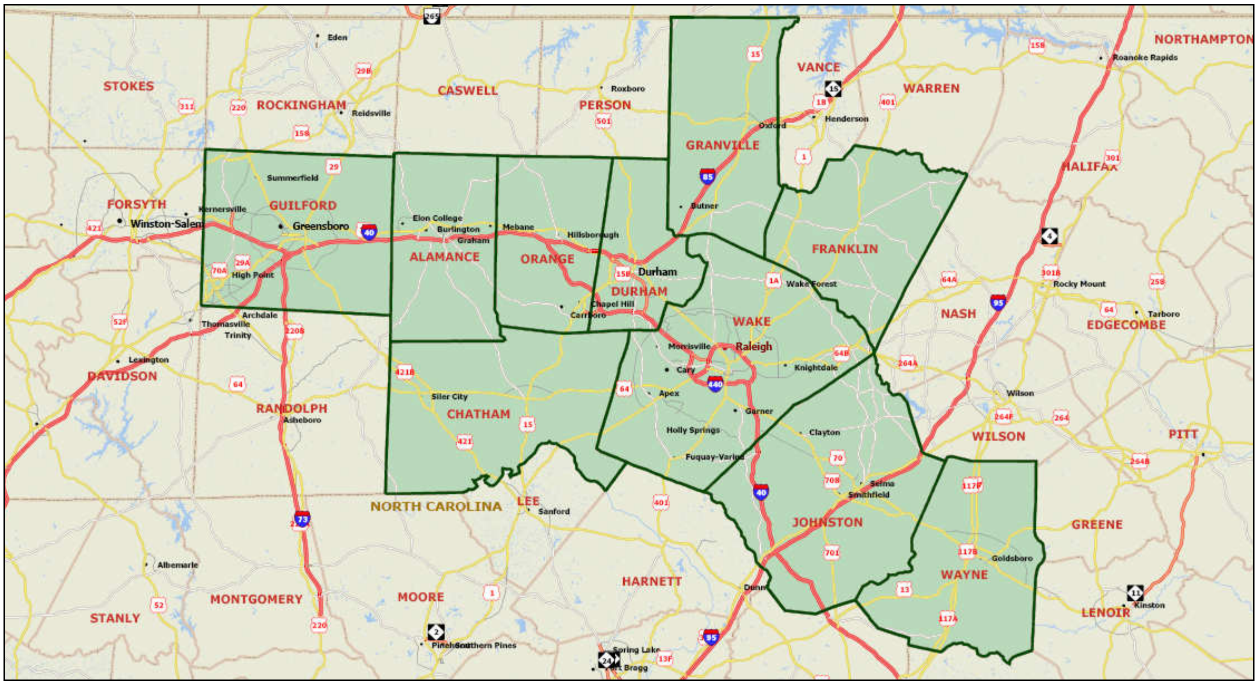
Because commuter rail is not currently available in the corridor, we conducted a stated preference (SP) survey, which presented hypothetical but realistically representative travel options to survey respondents and asked them to indicate which option they prefer. Respondents were also asked about their personal and household characteristics, as well as about their actual travel patterns. In this way, travelers' preferences for commuter rail (in a variety of service options) *versus* other modes were explored and related to their demographic and travel characteristics. While the validity of SP survey results can always be questioned because the questions involve hypothetical rather than actual choices, experience has shown that carefully designed SP surveys can give reliable results that cannot be obtained in any other way.

Our survey was focused on Greensboro-Raleigh-Goldsboro corridor travelers who had made recent private vehicle and bus trips within the shaded area of the corridor as shown in Figure 4.4 below. The respondents were members of a pre-recruited internet-based market research panel of residents maintained by the survey research firm TNS. The TNS panel contains approximately 6,500 members for the 10-counties surveyed.

[3] A region-wide on-board survey of all seven transit providers in the Triangle region of North Carolina.

[4] A Triangle area travel survey of 5,107 households to document demographic and travel behavior characteristics of regional travelers.

FIGURE 4.4 STATED PREFERENCE SURVEY COVERAGE



We targeted about 1,600 complete surveys. Households were screened to ensure that at least one member had recently taken a trip within the shaded area of the corridor, as shown in Figure 4.4 above. The questionnaire was customized for four groups, with each group receiving different choice exercises:

- Bus commuters
- Bus non-commuters
- Auto commuters
- Auto non-commuters

The survey was approximately 12 minutes in length, with about 45 questions, including initial screening questions and the choice exercises. The survey launched on Tuesday, December 1 and closed after ten days on Friday, December 11. We received a total of 1,670 completed surveys, distributed among the four groups as follows:

- Bus commuters: 125
- Bus non-commuters : 40
- Auto commuters: 754
- Auto non-commuters: 751

The full questionnaire was broken into two sections. The first section included questions about a) socioeconomic characteristics of the respondent, b) usual preferences in transportation modes, and c) the characteristics of the respondent's most recent trip by car or bus in the study area. The second section included nine hypothetical trade-off questions in which the respondent was asked to indicate his or her choice between two alternative transportation modes—the respondent's current mode and the hypothetical commuter rail mode—in different trip situations. For each trade-off question, we described an auto or bus trip with characteristics similar to the one that the respondent had reported in the first section of the survey, and a commuter rail trip with characteristics selected to reflect an option that would be competitive with the respondent's original trip. Based on the characteristics of each option, the respondent was prompted to indicate which alternative was preferred for the trip.

Diversion modeling

Information from the survey was then used to estimate statistical relationships expressing the fraction of travelers who will divert from each existing travel mode to the commuter rail mode as a function of the service attributes of each mode and traveler (market segment) characteristics. The diversion model between the current travel mode and commuter rail mode is a two-mode (binary) logit model that compares the attractiveness of commuter rail with the existing mode of travel. The model predicts the fraction of trips expected to divert to commuter rail from the auto and bus modes. We derived separate and independent diversion models for auto and bus. These models consider the travel time, cost, and frequency of each mode being compared, with travel time disaggregated into access, egress, wait, and line-haul components. Modal constants account for all unobserved attributes of the commuter rail mode compared to the other modes. In order to reflect differences (in terms of modal preferences and valuation of modal attributes such as travel times and out-of-pocket cost) in the behavior of travelers for these two purposes, we developed separate diversion models for commuter and non-commuter travel market segments. Unfortunately, the bus traveler sample size was too small to estimate distinct models for each travel purpose.

The estimated coefficients of the diversion models can be converted to equivalent value of time estimates, which are generally used to assess the reasonableness of estimated mode choice models. The value of time is the amount that a traveler would be willing to pay in order to save time, or the amount that would be acceptable as compensation for lost time. Table 4.1 presents the values of time of auto and bus travelers calculated from the estimated mode choice diversion model coefficients for the various components of travel time and travel costs.

TABLE 4.1 IMPLIED VALUES OF TIME FROM THE SDG MODE CHOICE DIVERSION MODELS ($2009)

Value of Time ($/hr) (2009 dollars)	Auto Trip Purpose		Bus Trip Purpose*
	Business	Non-business	Business/Non-business
In-vehicle time	$11.90	$10.90	$9.60
Access/Egress time	$24.10	$23.90	$6.40
Wait time	$24.10	$23.90	$6.40

*Sample size too small for bus travelers to estimate separate models by travel purpose

These values of time bring local corridor specificities into consideration, and are generally consistent with our findings in other rail studies. Values of time calculated this way are often compared to the prevailing wage rates in the local area (e.g., they may be 70% of the hourly wage) for reasonableness checking. Table 4.2 shows wage rates for different areas in the region. The values of time implied by our estimated model coefficients are consistent with the range of wage rates shown in Table 4.2.

TABLE 4.2 STUDY AREA WAGE RATES

Area	Hourly 25th Percentile Wage	Hourly Median Wage (50th Percentile)	Hourly 75th Percentile Wage	Hourly 90th Percentile Wage
Durham	$11.79	$18.11	$29.18	$47.03
Goldsboro	$8.95	$12.67	$18.31	$25.82
Greensboro-High Point	$10.00	$14.49	$21.57	$31.77
Raleigh-Cary	$10.65	$15.64	$24.53	$37.96

Source: Bureau of Labor Statistics, Department of Labor

Scenarios modeled

As the starting point for our modeling efforts, we used the commuter rail configuration recommended in the Shared Corridor Capacity Study, which includes four routes each with 40-minute peak headways. After running the model using this configuration for each of the four model years (2009, 2012, 2017, and 2022), we then examined the sensitivity of ridership and revenue to various commuter rail characteristics. This was done by running additional scenarios where one aspect of the commuter rail system was modified at a time, then comparing the results to those of the base scenario for the given year.

Assumptions for all scenarios

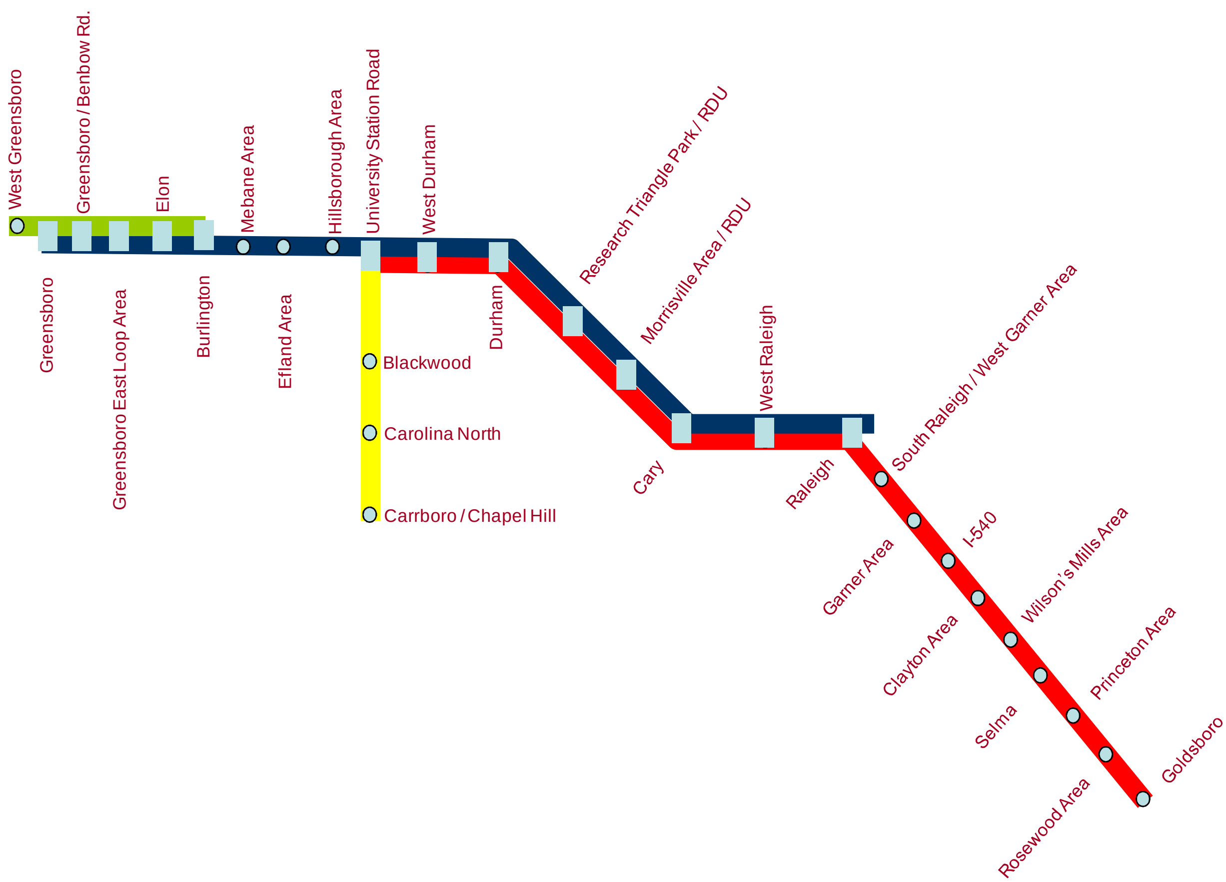
The following assumptions were made in the modeling of all scenarios:

- Commuter rail wait time is equal to one quarter of the commuter rail headway. This reflects the fact that with relatively infrequent public transit service, passengers time their arrivals at stations according to scheduled departure times. By comparison, wait times for bus service are assumed to be one half of the route headway, which reflects passengers arriving randomly without regard to bus departure times.
- Very few travelers will divert from their current travel modes—particularly from auto—to commuter rail for short-distance trips. This limitation is enforced by significantly reducing the commuter rail share of these short trips in the post-processing of the model scenarios. Short commuter rail trips involving a transfer to or from commuter rail to another mode are not limited.
- Transfers between commuter rail routes are free, but transfers between commuter rail and bus service require the passenger to pay the full fare for each service.

Base scenario definition

The preliminary ridership and revenue estimates presented in Section 5 use the common base scenario defined below. All variation in ridership between the scenarios presented is due to changes in population and employment patterns, and changes in the planned highway and bus networks between the different model years. The commuter rail configuration of the SDG base scenario was defined to match the recommended configuration of the Shared Corridor Capacity Study as closely as possible, and includes four lines, as shown in Figure 4.5 below. Stop locations are similar to those used in the Shared Corridor Capacity Study.

FIGURE 4.5 BASE SCENARIO COMMUTER RAIL CONFIGURATION

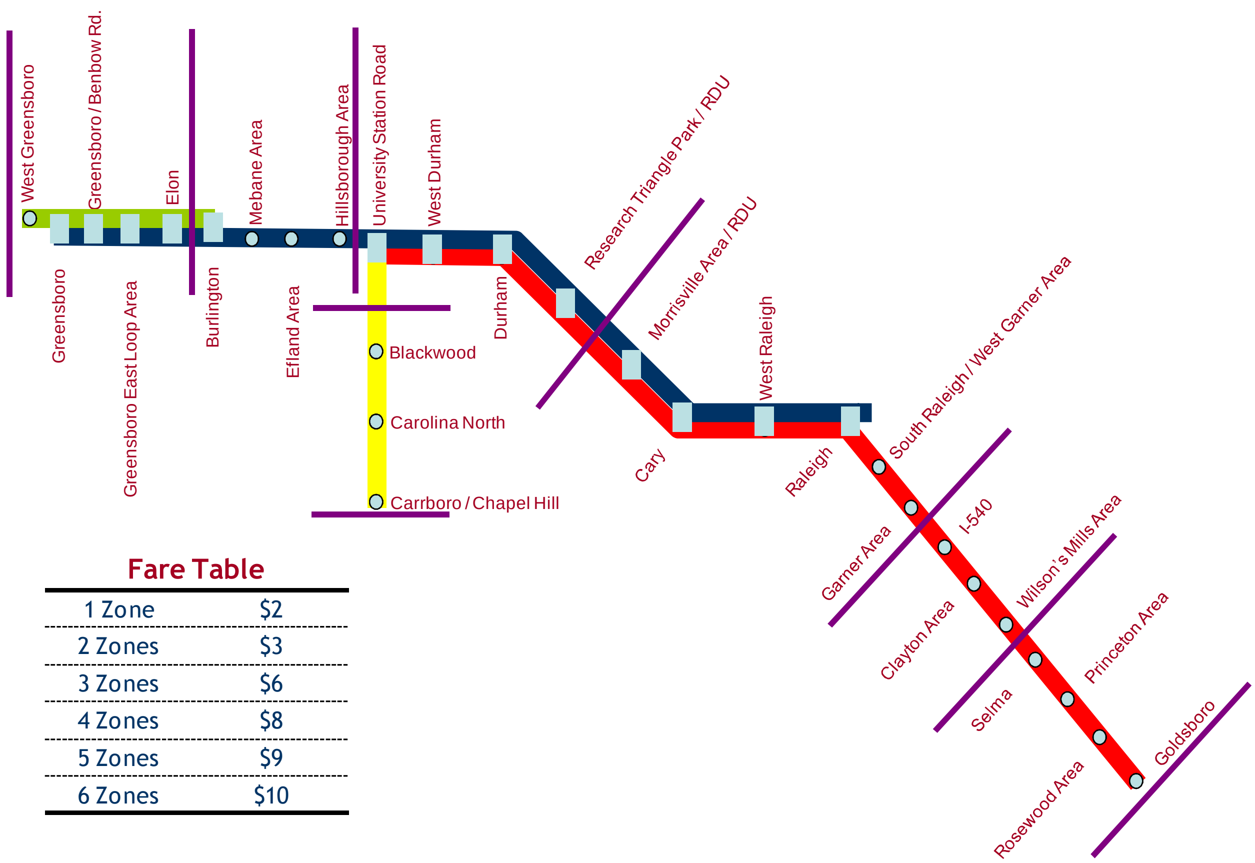


For all years, the base scenario service consists of:

- Trains every 40 minutes during the AM peak period from Burlington to West Greensboro (green), and trains every 40 minutes during the PM peak period from West Greensboro to Burlington. No off-peak trains are run on this route.
- Trains every 40 minutes during the AM peak period from Greensboro to Raleigh (blue), and trains every 40 minutes during the PM peak period from Raleigh to Greensboro. During the off-peak, one train is run in each direction on this route.
- Trains every 40 minutes during the AM peak period from Goldsboro to University Station Road (red), and trains every 40 minutes during the PM peak period from University Station Road to Goldsboro. During the off-peak, one train is run in each direction on this route.
- Trains every 40 minutes during the AM and PM peak periods in each direction between University Station Road and Carrboro/Chapel Hill (yellow). These trains are scheduled to facilitate timed transfers to and from the Greensboro-Raleigh and University Station Road-Goldsboro routes at University Station Road. Two off-peak trains are run in each direction on this route, also scheduled to facilitate timed transfers at University Station Road.

The SDG base scenario commuter rail system uses zone-based fares, which range from $2.00 to $10.00, based on the number of zones traversed. This fare schedule was developed based on a survey of US commuter rail systems' fare policies, with special consideration given to systems having characteristics similar to the potential NCRR commuter rail system.

FIGURE 4.6 BASE SCENARIO COMMUTER RAIL FARE STRUCTURE



Fare Table	
1 Zone	$2
2 Zones	$3
3 Zones	$6
4 Zones	$8
5 Zones	$9
6 Zones	$10

In the figure, purple lines indicate zone boundaries, and zonal fares are based on the total number of zones traversed, including the zones containing the trip's origin and destination stations.

Sensitivity scenarios

For 2017 and 2022, we examined the sensitivity of ridership and revenue to changes in fare, service frequency, and population and employment growth as described below:

- Fare sensitivity: Fares were reduced by 50 percent from the base scenario. All other scenario attributes are identical to the base scenario.
- Service frequency: Peak commuter rail headways were reduced from 40 minutes to 30 minutes for each commuter rail route. Off-peak trains were doubled for each route. All other scenario attributes are identical to the base scenario.
- Population and employment growth: Population and employment were increased by 20 percent uniformly across all zones in the model. All other scenario attributes are identical to the base scenario.

Results of the base scenario runs and the sensitivity analysis are discussed in Section 5.

5 Results

This section summarizes the results of the base scenario runs for the four model years (2009, 2012, 2017, and 2022) as well as the results of the sensitivity scenario runs for 2017 and 2022.

SDG Model results

Table 5.1 shows the total daily and annualized (based on 260 weekdays per year) weekday ridership and gross revenue estimates for the base scenario in 2009, 2012, 2017, and 2022. Similarly,

Figure 5.1 presents the segment-level ridership in each direction for the base scenario in each model year. Ridership for a given segment represents the total number of passengers on trains passing through the segment (defined by the section between two consecutive stations on the commuter rail route). Figure 5.2 shows the daily station boardings for the 2017 and 2022 base scenario runs.

TABLE 5.1 SUMMARY OF BASE SCENARIO RESULTS

Scenario	Daily Ridership	Daily Gross Revenue	Annual Ridership	Annual Gross Revenue
2009 Base Scenario	4,637	$13,169	1.21M	$3.42M
2012 Base Scenario	4,558	$12,331	1.18M	$3.21M
2017 Base Scenario	6,275	$17,652	1.63M	$4.59M
2022 Base Scenario	11,150	$34,669	2.90M	$9.01M

FIGURE 5.1 BASE SCENARIO COMPARISON (40-MINUTE PEAK HEADWAYS FOR ALL YEARS)

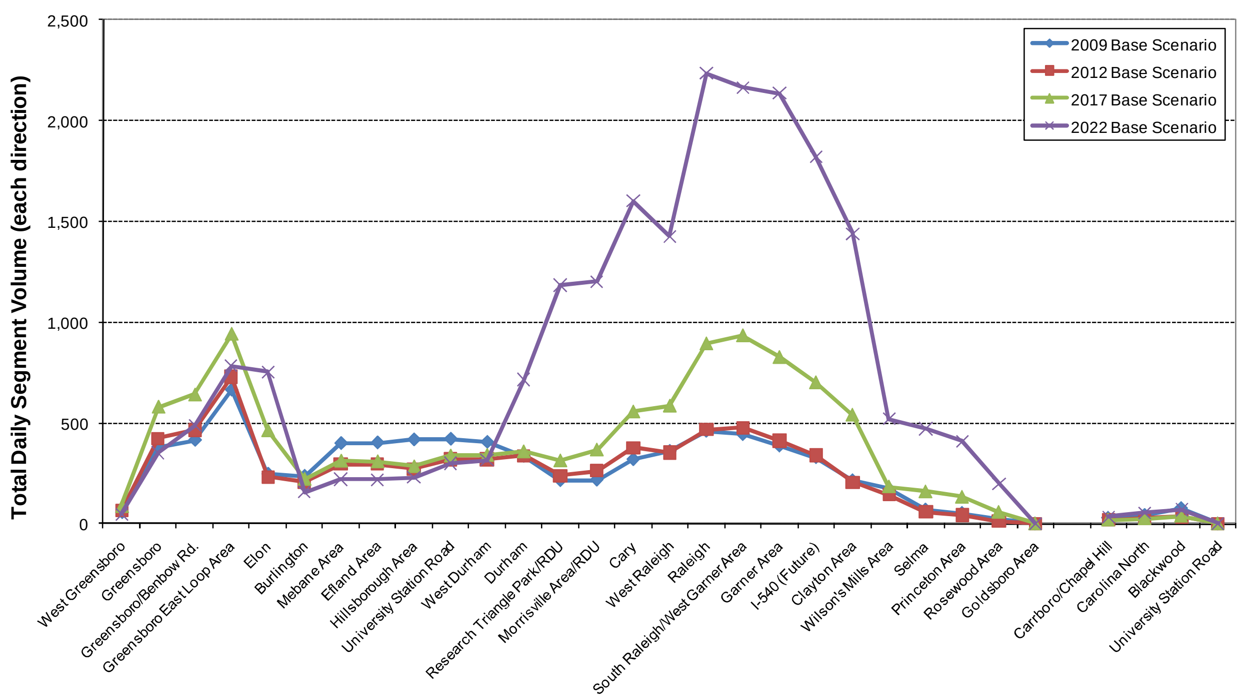


FIGURE 5.2 DAILY STATION BOARDINGS, 2017 AND 2022 BASE SCENARIOS

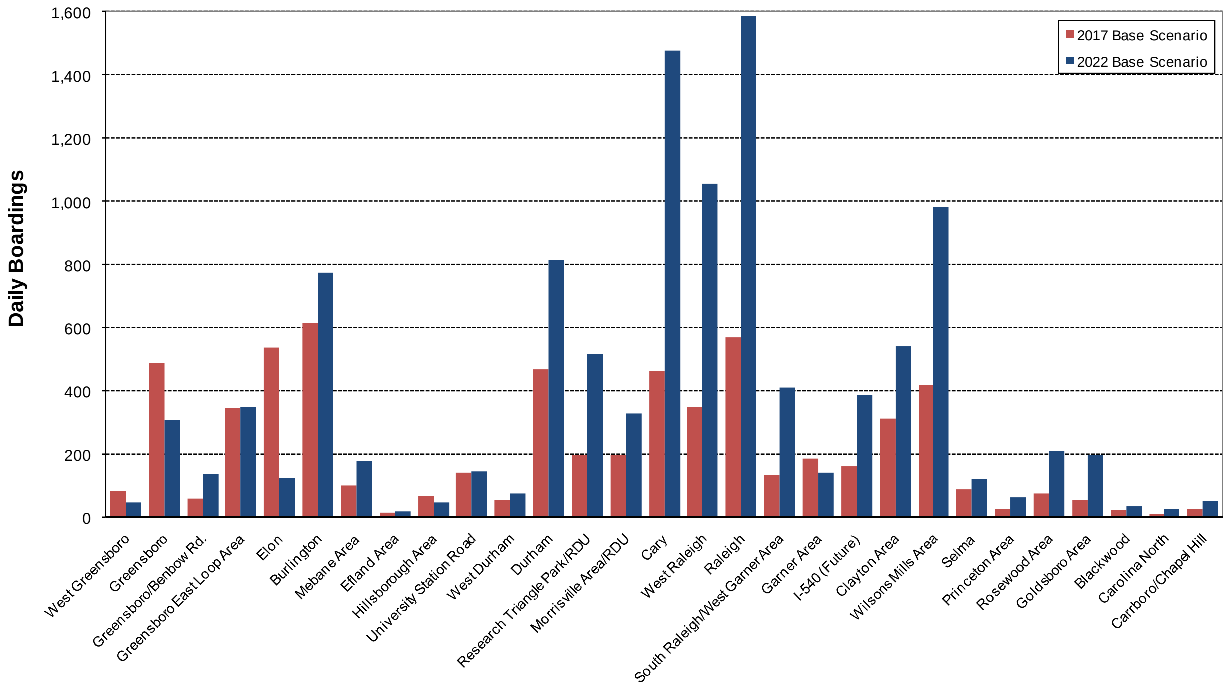


Table 5.1 shows a small decrease in total ridership between 2009 and 2012. This decrease is largely due to the introduction of a bus route from Burlington to Durham in 2012 that captures many riders who would otherwise use commuter rail. This is very clear from

Figure 5.1, where a significant drop in segment-level commuter rail ridership is observed for each of the segments between Burlington and Durham, due to the introduction of the competitive bus service. Similarly, a further drop in ridership between Burlington and Durham is observed in 2022 compared to 2012 and 2017 as a result of an additional bus route that is introduced in that area.

All existing and planned bus routes modeled in this study are based on the TRM, PTRM, and GTDM models' default assumptions that resulted from the long range transportation plans of the respective MPOs. The introduction of the commuter rail option would likely cause a re-evaluation and re-design of the study area's future bus plans. The re-planned bus routes should ideally complement the commuter rail service—more so than those included in our study—as they will be planned with commuter rail in mind. Our ridership estimates are conservative from this perspective.

Figure 5.1 shows that in 2022, there is a large increase in ridership in the Durham to Wilson's Mills portion of the corridor. This is also evident in the significantly higher boarding totals for the corresponding stations, as shown in Figure 5.2. This ridership increase is driven by improved bus service throughout the Triangle area, which takes passengers to and from the commuter rail system; and by increased traffic congestion in the area, which improves the relative attractiveness of commuter rail. Indeed, the coverage of the bus network in the Triangle region improves considerably in 2022 compared to the earlier years (as seen earlier in Figure 4.2). Improved bus service makes commuter rail a viable option for significantly more travelers because they can take a bus between the nearest commuter rail station and their trip origin or destination (an option which may not have been present before 2022). The significantly increased highway congestion in the Durham to Wilson's Mills area makes commuter rail a more attractive option in 2017 and 2022.

The Burlington-Greensboro portion of the corridor experiences an overall decline in ridership from 2017 to 2022 as well as a major shift in ridership patterns, due to the expansion of the Greensboro bus network to include routes that compete with portions of the studied commuter rail system (including Elon-Greensboro and Greensboro East Loop-Greensboro). In 2022, a new bus route between the Greensboro area and Elon is introduced that directly competes with the commuter rail service. A substantial portion of the travelers who would have otherwise taken the commuter rail instead choose bus because the bus is less expensive, commuter rail does not have any notable travel time advantage over bus for passengers traveling between Elon and the Greensboro area, and accessibility of the bus network is considerably higher in the Greensboro area in 2022 due to the introduction of several new bus routes (as seen earlier in Figure 4.3). Moreover, the expansion of the bus network in the Greensboro area in 2022 results in substantial shifts in ridership patterns, making Greensboro/Benbow Road and Greensboro East Loop stations more prominent destinations on the commuter rail route due to the increased bus network connectivity. The reduction in Elon trips and the shift in ridership patterns are evident in the differences between 2017 and 2022 boardings, as shown in Figure 5.2.

TABLE 5.2 2017 SENSITIVITY ANALYSIS RESULTS

Scenario	Daily Ridership	Daily Gross Revenue	Annual Ridership	Annual Gross Revenue
2017 Base Scenario	6,275	$17,652	1.63M	$4.59M
2017 50% Fare Reduction from 2017 Base Scenario	9,335	$14,070	2.43M	$3.66M
2017 Increased Frequency	7,690	$21,533	2.00M	$5.60M
2017 Plus 20% Additional Growth from 2017 Base	7,535	$21,212	1.96M	$5.52M

FIGURE 5.3 2017 SCENARIO COMPARISON

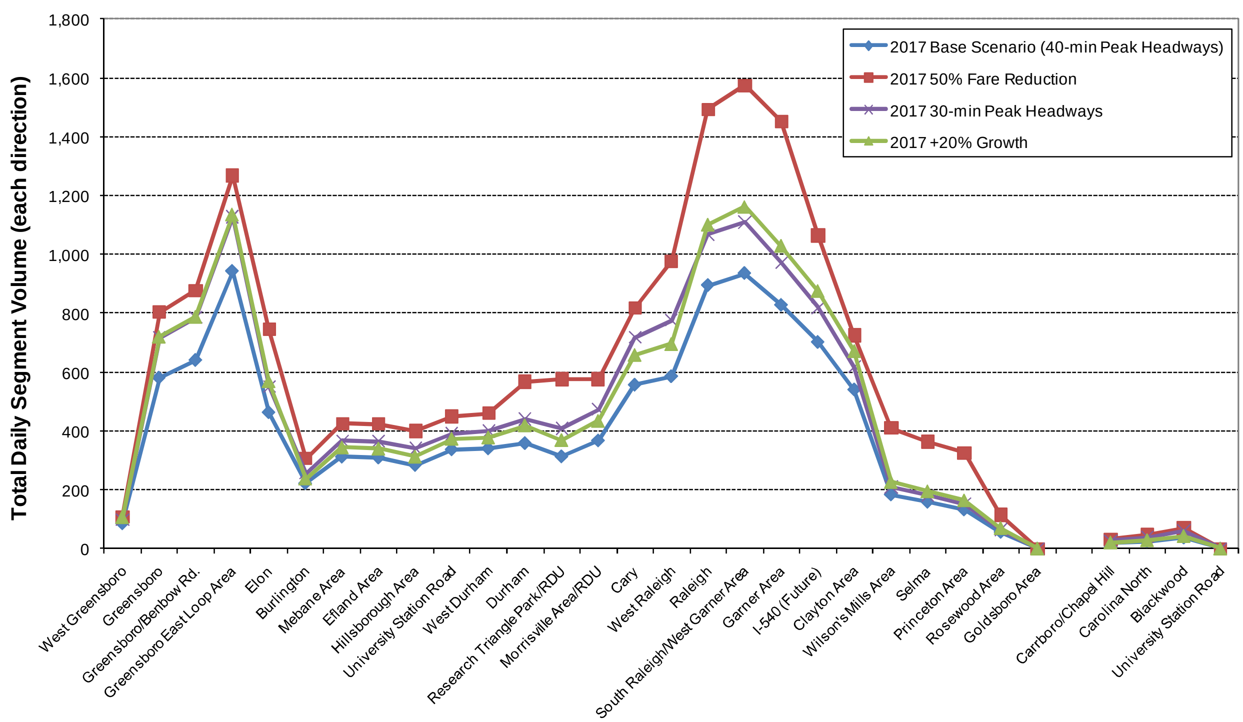


Table 5.2 and

Figure 5.3 show the results of the sensitivity analysis scenarios for 2017, which indicate that:

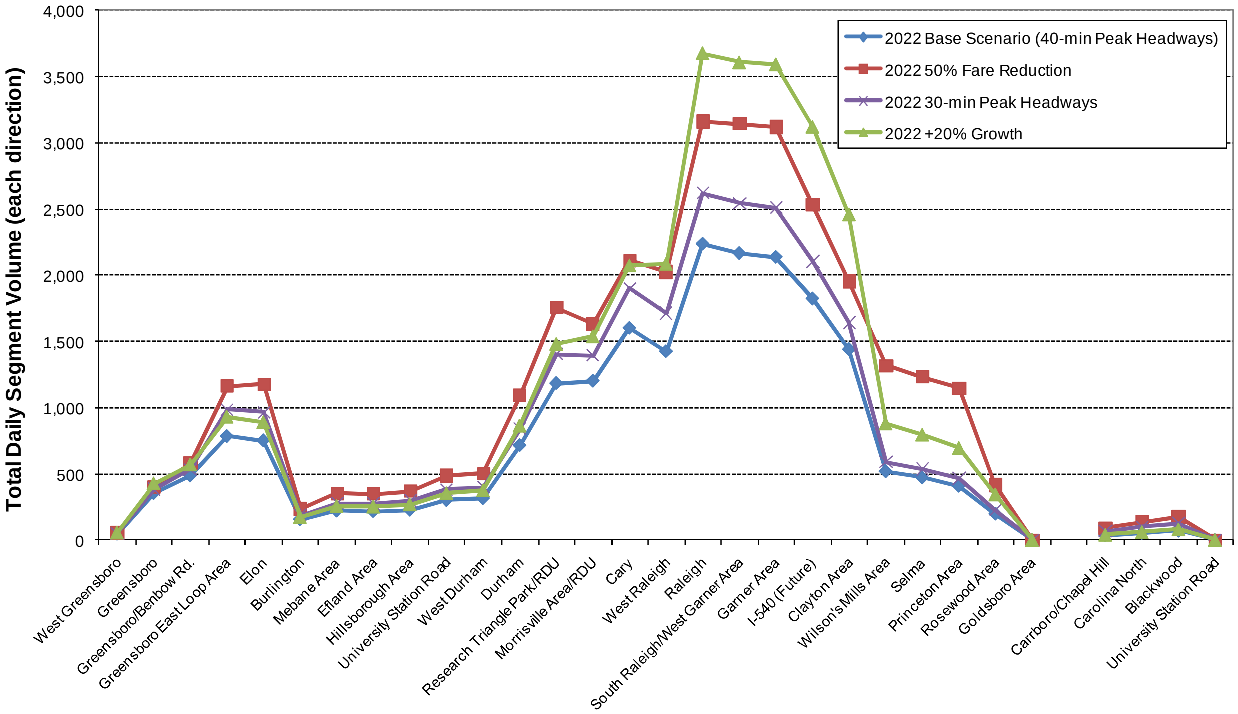
- Ridership is extremely sensitive to reductions in fare. When fares are reduced by 50%, ridership increases by nearly 50%. The base commuter rail fares assumed in this study are generally higher than bus fares in both the Triangle and Piedmont Triad areas. In many cases, reducing commuter rail fares by half brings them to levels below the bus fares, especially for short trips. This can make commuter rail a more attractive option than bus. In addition, this fare reduction results in a greater absolute decrease in fares for longer trips, thus significantly increasing the attractiveness of commuter rail.
- At the same time, when fares are reduced by 50%, gross revenue decreases by approximately 20%. A larger portion of longer-distance trips divert to commuter rail because the 50% fare reduction translates into a larger decrease in the fare. Changes in fares also cause changes in travel patterns near fare zone boundaries. With higher fares, travelers are sometimes encouraged to drive to a commuter rail station that is not the closest to their trip origin, in order to travel a fewer number of zones and pay a lower fare rather than traveling a greater number of zones and paying the higher fare that they would experience if they boarded commuter rail at the station nearest to their origin.
- Ridership is somewhat less sensitive to increases in frequency. Reducing peak headways to 30 minutes and adding an additional peak train in each direction on the Greensboro-Raleigh and University Station Road-Goldsboro routes results in a 23% increase in ridership, and a corresponding 20% increase in gross revenue. Changing headways from 40 minutes to 30 minutes in the peak represents a somewhat moderate increase in service, which results in a corresponding moderate ridership increase. Increasing the off-peak number of trains from one to two still represents very infrequent service, and as a result has little impact on ridership.
- When population and employment are increased by 20% across the study area, increases in ridership and gross revenue of approximately 20% are seen. Significant traffic congestion already exists in the Triangle area in 2017. Hence, the additional increase in population and employment results in a disproportionate congestion increase, improving the attractiveness of commuter rail relative to auto and bus. Traffic congestion is less of an issue in the rest of the study area.

We performed similar sensitivity analysis for the year 2022, the results of which are presented in Table 5.3 and Figure 5.4.

TABLE 5.3 2022 SENSITIVITY ANALYSIS RESULTS

Scenario	Daily Ridership	Daily Gross Revenue	Annual Ridership	Annual Gross Revenue
2022 Base Scenario	11,150	$34,669	2.90M	$9.01M
2022 50% Fare Reduction from 2022 Base Scenario	15,855	$27,133	4.12M	$7.05M
2022 Increased Frequency	13,524	$41,922	3.52M	$10.90M
2022 Plus 20% Additional Growth from 2022 Base	15,364	$49,344	3.99M	$12.83M

FIGURE 5.4 2022 SCENARIO COMPARISON



The sensitivity analysis for 2022 shows results that are generally similar to those of the 2017 analysis. This is understandable, as the sensitivity analysis scenarios apply the same percentage changes to base scenario values for both 2017 and 2022. Specifically, we see very similar percentage changes in ridership and gross revenue in 2022 and 2017 in response to the 50% fare reduction and the increased frequency. However, due to increasing congestion in the Triangle area, the 20% population and employment increase scenario now results in approximately 40% increases in ridership and gross revenue compared to the base scenario. This result indicates that the 2022 base scenario has reached a much more congested state than the 2017 base scenario. With this level of base congestion, additional increases in trips cause an even greater increase in congestion, further improving the attractiveness of commuter rail relative to auto and bus.

To provide some context for the ridership estimates presented earlier in this section, Table 5.4 below shows the fourth quarter 2009 average daily ridership for the top twenty commuter rail systems in the US.

TABLE 5.4 TOP TWENTY US COMMUTER RAIL SYSTEMS BY RIDERSHIP

Rank	System	Largest City Served	Ridership (Average Weekday)	Route Miles
1	Long Island Rail Road	New York	330,200	700
2	Metra	Chicago	307,800	495
3	MTA Metro-North Railroad	New York	281,100	384
4	New Jersey Transit Rail Operations	New York	276,000	951
5	MBTA Commuter Rail	Boston	130,800	368
6	SEPTA Commuter Rail	Philadelphia	120,800	289
7	Metrolink	Los Angeles	38,400	512
8	Caltrain	San Francisco/San Jose	35,900	77
9	MARC	Baltimore/Washington DC	30,300	187
10	Virginia Railway Express	Washington DC	16,300	90
11	NICTD South Shore Line	Chicago	12,500	90
12	SFRTA Tri-Rail	Miami	12,400	72
13	Trinity Railway Express	Dallas/Ft. Worth	9,400	34
14	Sounder Commuter Rail	Seattle	8,900	80
15	UTA FrontRunner	Salt Lake City	5,300	44
16	NCTD Coaster	San Diego	4,200	41
17	New Mexico Rail Runner Express	Albuquerque	3,800	97
18	Altamont Commuter Express	San Jose	2,500	86
19	Shore Line East	New Haven	1,900	59
20	Westside Express Service	Beaverton	1,100	15

Source: American Public Transportation Association Quarterly Ridership Report

The 2009 base scenario weekday ridership estimate of 4,637 presented earlier in this section would rank the potential NCRR commuter rail service sixteenth among US commuter rail systems. The system's ranking would also be dependent on the assumed fare structure, frequency, and other service characteristics, as demonstrated in the sensitivity analysis above.

The Aggregate Rail Ridership Forecasting (ARRF) Model

As a high-level cross-check on our results, we applied the Aggregate Rail Ridership Forecasting (ARRF) Model, developed and maintained by the Federal Transit Administration (FTA), to produce ridership forecasts for the potential commuter rail system. The ARRF model produces order of magnitude system-level aggregate forecasts against which the corresponding high-level aggregations of the detailed forecasts produced by our models can be compared. The ARRF model does not provide estimates at a route- or station-level, and therefore is not a suitable substitute for a more in-depth forecasting model such as the one developed and applied in this study.

Model description

The ARRF model uses data from the year 2000 Census Transportation Planning Package (CTPP2000) to predict trips for light rail and commuter rail systems. FTA makes the model available to develop order-of-magnitude estimates of ridership for new rail lines in metropolitan areas where no existing fixed guideway transit facilities are present—often called "new" New Starts projects. Forecasts from the model are not intended to replace carefully prepared forecasts from local travel models; rather, they provide another source of insight into the reasonableness of those local forecasts.

The ARRF model has been calibrated using ridership on existing systems throughout the country that are generally similar to proposed "new" New Starts projects. The model applies expected rail mode shares to total work-travel flows (by any mode) in the rail corridor, as reported by the CTPP2000. In this way, the ARRF model estimates ridership from year 2000 socioeconomic data and travel flows. Future-year ridership estimates should be developed by adjusting the year 2000 results to account for expected growth in the corridor.

The basic inputs to the model are the CTPP2000 journey to work volumes, disaggregated by auto-ownership class and employment density at the work-end. To identify the travel markets served by a rail line, the model uses a series of concentric buffers around each rail station. Workers traveling between residence and workplace locations that are both within station buffers establish the overall markets from which rail riders are drawn. To qualify as a corridor trip, the model requires the buffers corresponding to the closest station to home to be different from the buffers corresponding to the closest station to the workplace. This prevents the model from considering trips where the rail line is unlikely to serve a transportation function. In essence, these data provide an estimate of the total market for a candidate rail line, which is used to produce information on the typical number of rail trips generated by these flows.

ARRF model results

Table 5.5 shows the ARRF model results for the potential commuter rail system for the years 2000, 2009, and 2017 for various average train speeds and frequencies. In the ARRF model, speeds represent actual average end-to-end running times excluding layover time, and frequencies represent trains per mile per direction. The base ARRF model results are always for year 2000. We used a weighted average annual growth rate from the US Census[5] for the eight main counties (the aggregate nature of the ARRF results doesn't allow the use of differential growth rates in different counties) in the study area to produce 2009 and 2017 model results.

TABLE 5.5 ARRF MODEL ESTIMATED TOTAL DAILY COMMUTER RAIL RIDERSHIP

Average Speed (MPH)	2000 Trains per day per direction		2009 Trains per day per direction		2017 Trains per day per direction	
	7	11	7	11	7	11
40	4,564	5,369	5,655	6,653	6,843	8,050
50	4,902	5,678	6,074	7,146	7,350	8,647
60	5,164	6,075	6,398	7,527	7,742	9,108

Notes: A 2.4% annual growth rate is applied to population and employment near stations for future years. This rate is a weighted average of area growth from 2000-2008, calculated based on Census data.

[5] Data from 2000 Census and 2006-2008 American Community Survey

To create the train schedules, the Shared Corridor Capacity Study assumed a maximum speed of 60 mph and an average speed close to 40 mph. Our base scenario, which follows the Shared Corridor Capacity Study recommendation, is equivalent to approximately 7 trains per day per direction according to the frequency definition in the ARRF model. Moreover, our increased frequency sensitivity analysis scenario is equivalent to about 11 trains per day per direction under the same ARRF model criteria. We produced ARRF model results for different combinations of the above frequencies and speeds in order to perform as consistent a comparison as possible with our results. Table 5.6 shows the comparison of our model results with ARRF model estimates.

TABLE 5.6 COMPARISON OF SDG MODEL TOTAL DAILY COMMUTER RAIL RIDERSHIP ESTIMATES WITH ARRF MODEL ESTIMATES

Scenario	SDG Model	ARRF Model	% Difference
2009 Base Scenario	4,637	5,655	22.0%
2017 Base Scenario	6,275	6,843	9.1%
2017 Increased Frequency	7,690	8,050	4.7%

Note: ARRF estimates use an average train speed of 40 MPH

As shown in Table 5.6, the ARRF model results are 22.0% higher than our 2009 base scenario results. This difference is significantly lower in 2017 where the ARRF daily ridership number is only 9.1% higher than our model results for the base scenario and is even closer (only 4.7% higher) for the increased frequency scenario for 2017. The similarity of our results and the ARRF estimates points to the overall reasonableness of our more detailed forecasts.

6 Conclusions

This study is a ridership forecasting study undertaken by Steer Davies Gleave to assess the viability of commuter rail service on the 143-mile section of the NCRR corridor between Greensboro and Goldsboro. To evaluate commuter rail on the corridor, we developed a new regional demand model, incorporating three existing models: the Triangle Regional Model (TRM), the Piedmont Triad Regional Model (PTRM), and the Goldsboro Travel Demand Model (GTDM). Ridership forecasts were produced for three future years—2012, 2017 and 2022. The major conclusions from this study are:

- Commuter rail ridership on the study corridor is largely dependent on the extent and service quality of area bus service. As a result, if commuter rail is to be implemented in the area, it is important to have discussions with local transit agencies to ensure a well-coordinated regional effort, so that the local transit agencies plan routes that complement—rather than compete with—the commuter rail system.
- The most promising portion for commuter rail service on the NCRR corridor in terms of ridership and gross revenue is between Durham and Wilson's Mills. Ridership is initially limited on the Goldsboro-Wilson's Mills portion of the corridor, but increases substantially by 2022, as growth and traffic congestion in the area increase. As a result, it is worth considering initially moving the eastern terminus of the University Station Road-Goldsboro route to Wilson's Mills or Selma, and later extending the route to Goldsboro.

- The Burlington to Greensboro portion is the second logical choice for commuter rail service. However, the ridership and gross revenue for this portion are significantly lower than for the Durham to Wilson's Mills portion, and many riders on the Burlington to Greensboro route originate at Burlington. The proposed 2022 bus route between the Greensboro area and Elon, if extended to Burlington, could work as a competing/substitute route, providing service that is similar to better than that of the commuter rail. This is exactly what happens in Elon in 2022 when the new Greensboro area to Elon bus service captures a large amount of the commuter rail ridership to and from Elon.
- The Burlington to University Station Road section may be better served with well-planned bus service than with commuter rail. This is evident from the decrease in commuter rail ridership (and hence gross revenue) between 2009 and 2012 with the introduction of a bus route from Burlington to Durham; and a further decrease between 2012/2017 and 2022 when another similar bus route is introduced. These competing bus routes capture many riders away from the commuter rail because of their greater accessibility and lower fares.
- Very little ridership is seen in any of the scenarios on the University Station Road-Carrboro/Chapel Hill spur. This is due to the fact that people who want to travel from the Chapel Hill area to other locations, particularly the Triangle area, already have a number of efficient, inexpensive (and sometimes free) bus options, which are generally more attractive than the option of riding commuter rail to University Station Road, then transferring to a second commuter rail route.
- Little ridership is seen between Greensboro and destinations east of Burlington. As a result, it is worth considering moving the western terminus of the Greensboro-Raleigh route to Burlington. This would save some operating cost, and possibly some capital cost as there would no longer be two overlapping commuter rail routes on the Greensboro-Burlington portion of the corridor. It might also be reasonable to consider moving the western terminus of this route further east to Durham, as ridership is generally light on the Burlington-West Durham portion of the corridor.
- Commuter rail ridership will depend heavily on service characteristics of the system, which will be a function of the underlying objectives of the stakeholders. For example, significantly higher ridership can be obtained with lower fares; however, this will come at the expense of gross revenue, as observed in our sensitivity analysis. If an objective of the commuter rail service is to increase ridership and associated public benefits, a reduced fare might be an option.
- The base scenario ridership forecast for 2009 would rank the Greensboro-Raleigh-Goldsboro commuter rail service sixteenth out of 23 commuter rail systems in the nation with respect to ridership.
- Our results are generally consistent with those of the FTA's Aggregate Rail Ridership Forecasting (ARRF) model.