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16. Abstract

The aim of this study were to identify corridors that are feasible candidates for the implementation of high occupancy toll (HOT) lanes, to conduct and analyze a commuter survey data to determine the feasibility of implementing value pricing in a corridor or corridors of the study area as well as survey stakeholders' opinions. The study area spans I-40 from the Davie and Forsyth County boundary to the divergence of I-85 and I-40 in Orange County.

Our study was divided into three parts:
1). A literature review of value pricing among ongoing programs in the United States;
2). A baseline analysis of the study area, including population and economic characteristics, current traffic volumes, road capacities and forecasted traffic along I-40 in the study are; and
3). Implementation and analysis of a commuter survey and completion of a stakeholders survey.

We present three possibilities (with the customary "do nothing" alternative as the fourth, but undesirable alternative):
1). Construct a new mixed-flow lane,
2). Construct a HOT lane within the next ten years, or
3). Initially construct HOV lanes with the possibility of turning them into HOT lanes within the next ten years.

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Interstate 40 Value Pricing Assessment in North Carolina

FINAL REPORT

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Executive Summary

The goals of this study were to (1) identify corridors in the study area which are candidates for the implementation of high occupancy toll (HOT) lanes, (2) conduct a commuter survey and analyze the data to determine the feasibility of implementing HOT lanes in a corridor or corridors, and (3) survey community leaders' opinions about the implementation of HOT lanes. The study area spans I-40 from the Davie and Forsyth County line to the divergence of I-85 and I-40 in Orange County.

The basic concept of HOT lanes (charging a fee only for using an HOV lane) is to give drivers of low occupancy vehicles (LOVs) a choice between (1) paying a fee to use rapidly moving, high occupancy lanes, and (2) fighting the slow, congested traffic in a free lane. The high occupancy lanes that may be accessed by LOVs for a fee are called HOT lanes. However, high occupancy vehicles (HOVs) do not pay a fee to use HOT lanes.

Past and current value-pricing projects on HOT lanes were reviewed. The literature suggested that there are both advantages and disadvantages of HOT lanes. Advantages include significantly reducing congestion and increasing traffic speed. Of course, disadvantages include a new toll and the added expense of building a new lane.

The objective of the baseline analysis was to identify corridors on I-40 which meet the criteria for successful use of HOT lanes. Analysis of several key factors such as vehicle-to-capacity information and level of service identified a corridor which was suitable for studying the viability of a HOT lane during the peak periods in the short-to-medium term. This corridor begins east of Winston-Salem, at the eastern junction of Business I-40 and I-40 and ends at the junction of I-40 and Business I-85 in Greensboro. It contains segments of I-40 with the lowest current level of service. Projections for growth in traffic by 2015 suggest that this segment will need an additional lane. Vehicular flows for this corridor are very unbalanced, with peak flows of as much as 1.7 to 1.8 times the average flow rate. The peak east-to-west traffic flows occur during morning hours and the reverse in the afternoon. Because of this, the possibility of having a reversible managed lane was considered.

This corridor differed from the typical HOT corridor in two major ways. This corridor is both an inter-city as well as a local commuter highway while most other deployments of managed lanes are within a single metropolitan area. The segment length is relatively short compared with the typical length of 8-14 miles. The analysis of right-of-way availability suggested that no major acquisitions would be required to add one lane.

Adding a HOT lane in this corridor in the mid-term (within ten years) would effectively increase the ability of people to travel in this corridor. Estimates suggest that, with recurring congestion, adding such a lane could save at least two minutes per vehicle for the vehicles using the HOT lane under current conditions. The assumptions of this estimate include no growth in traffic and no incident-induced congestion resulting from disabled vehicles and accidents. However, projections for growth in traffic by 2015 suggest that this segment will need an additional lane.

For the commuter survey, 658 respondents of a survey distributed among commutes of I-40 corridor provided their willingness to pay a fee to use a HOT lane. Results suggest that more than 35% of commuters on I-40 would be willing to pay for a HOT lane. Simulations modeling commuters' willingness to pay at different fee levels and time savings suggest that revenues are expected to be $360,000 (midpoint between $119,000 and $616,000) for a scenario that saved eight minutes of travel time and $890,000 (midpoint between $505,000 and $1,277,000) for scenarios that saved fifteen minutes. All income groups showed a willingness to pay a toll, however people with a higher income were willing to pay a higher amount. Minority group membership was not significantly related to the willingness to pay a toll.

Finally, a survey of stakeholders was conducted of three groups: political leaders, corporate executives and ministers. Approximately one third of each group favored the HOT lanes concept, one third were neutral to it and one third opposed to it. Similar proportions were observed for "would support this concept in the Triad" and "the potential usefulness of this concept".

Construction was completed on an additional lane on I-40 between the intersection with Business I-85 and Guilford College Road early in 2006. Two lanes were also added to I-40 between Kernersville and U.S. 68 and one lane was added for the rest of corridor 3B. The additional lanes have temporarily reduced the congestion in this area. However, by 2015, traffic on these sections of I-40 is projected to reach the minimum acceptable level of service. Our results suggest that HOT lane should deserve additional consideration as a potential solution to predicted congestion problems there.

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1. SCOPE AND OBJECTIVES

HOT lanes are high occupancy vehicle (HOV) lanes which may be accessed by low occupancy vehicles (LOV) for a toll. They are an example of value pricing (charging a fee only for a higher level of service) (Poole and Orski, 2002). People in carpools pay a reduced fee (which may be to ride for free) while cars that do not meet the required occupancy limit must pay a larger fee to use the lane. These restrictions in lane access result in more freely moving traffic. HOT lanes have not been considered or implemented in medium sized cities.

This study was an investigation of the use of high occupancy toll lanes (HOT) lanes for the Federal Highway Administration (FHWA) and for the North Carolina Department of Transportation (NCDOT). The study was authorized by Section 1216(a) of the Transportation Equity Act for the 21st Century (TEA-21). This report contains three major sections: (1) a literature review of HOT lane projects in the U. S.; (2) a baseline analysis of current and future traffic patterns and conditions along I-40 from the Davie-Forsyth County line to the point in Orange County where I-85 diverges from I-40; and (3) analyses of two surveys, one a survey of commuters' behavior and one a survey of community leaders' opinions on HOT lanes.

The study area features medium-sized metropolitan areas where public transit services are limited. The corridor picked for intensive study connects two closely-located urbanized areas with east/west traffic flow during peak hours. The area included in this study differs from the typical area in two major ways. The presence of alternative methods of transportation is often cited as a prerequisite for HOT lanes; this study investigated the potential effects of HOT lanes in an area where alternatives to the automobile are extremely limited. Before this study, HOT lanes had not been considered for inter-regional travel.

This report incorporates five types of data: (1) the 2000 US Census measures of travel in counties in and near the Piedmont Triad, (2) traffic counts and level of service data for the I-40 corridor between Forsyth and Orange Counties, (3) data on daily traffic peaking, (4) data from a study of commuter attitudes toward HOT lanes, and (5) data from a study of community leaders in the Piedmont Triad. Three HOT lane corridors are identified and a range of possible costs is estimated.

2. LITERATURE REVIEW FOR HOT LANES ON SINGLE OR MULTIPLE LANES

Highway congestion is the major problem for the interstate highway system in most urban areas. Typically, the means of reducing congestion in small urban areas has been to increase highway capacity by building more lanes (Schrank and Lomax, 2005). Another way to reduce congestion is to manage travel demand. The usual method in larger urban areas is to use high occupancy vehicle (HOV) lanes. However, these lanes often work at less than full capacity. Several metropolitan areas around the country have introduced high occupancy vehicle toll (HOT) lanes to reduce congestion and increase the number of vehicles using the managed lanes (Perez and Sciara, 2003).

2.1 Relevance of HOT Lanes

Frequently when goods, such as access to a road, are free or under-priced demand will outstrip supply. The heavy traffic surrounding metropolitan areas like Los Angeles, San Francisco, and Washington, D.C. is proof of this. Traffic congestion costs Americans billions of dollars each year in terms of lost time and productivity, air pollution, and wasted energy.

Current travel patterns are the results of the perceptions and choices of individuals. They evaluate the opportunities offered to them and the costs (as they perceive them) of those opportunities. Thus, pricing should provide an incentive for some drivers to change their behavior so that vehicles are removed from congested roadways. Traditional “first-best” **congestion pricing** strategies are meant to reduce traffic on highly congested roads by charging every user a toll (Small and Yan, 2001). The toll must be high enough to keep the traffic in the managed lane flowing freely at all times. Typically, the toll is highest during peak travel times. In its 1994 report, *Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion*, the Transportation Research Board predicted congestion pricing could change commuters’ behavior in one or more of several ways. It could persuade people to (1) carpool, use transit, or telecommute; (2) vary the times they travel, (3) alter their routes, (4) choose other destinations, and (5) avoid or combine some trips.

However, the intent of HOT lanes is not to divert drivers from congested areas. It offers them the option of paying for use of an adjacent, alternative road facility which provides a higher level of service. In transportation, HOT lanes are defined as a “system of optional fees paid by drivers to gain access to alternative road facilities providing a superior level of service and offering time savings compared to the free facility" (ITE, 1998). Drivers may choose between two adjacent roadways: one free but congested, the other costly but free-flowing. The implementation of such a radical system can be controversial. Brownstone and Small (2003) emphasize that reliability is also an important consideration.

2.2 Advantages of HOT Lanes

HOT lanes can present advantages to transportation agencies and the public. Some of these advantages that they provide are listed below.

Existing HOT lanes projects, such as San Diego's I-15, reduced congestion in non-priced lanes. In most cases, congestion was significantly reduced at first, and then over time, it increased to a new but lower level. The impact of HOT lanes differed depending on local conditions, particularly the level of latent demand and the availability of alternate routes.

Existing HOT-lanes lane projects resulted in overall improvements in speed and throughput. The period of time in which peak levels of traffic were handled was extended; this longer interval smoothed the flow of traffic. A shift in a relatively small proportion of peak-period trips can lead to substantial reductions in overall congestion.

2.3 Some Examples of HOT Lanes

There is data from two sets of HOT lanes projects. The first set is the original group of projects that were started at locations at the initiative of local authorities. They are the Katy Freeway and U.S. 290 in Houston, TX; and the I-15 in San Diego, CA. The second set is a group of projects that were initiated as part of the FHWA value pricing demonstration program. These projects include I-94 in Minneapolis, MN; and Colorado I-25 in Denver, CO. (See Table 1, Appendix 6 for details). A detailed discussion of the original set outlines the potential benefits of HOT lanes. A review of new programs examines techniques that have been used for implementing new programs. Essentially, the original programs in Houston and San Diego used excess capacity on HOV lanes to implement HOT lanes. Newer demonstration projects used a variety of approaches (construction of new lanes, for example). There are two original examples of HOT lanes (Perez and Sciara, 2003).

2.4 Original US Initiatives

Over the past few decades, the United States has been preparing for the implementation of its own value pricing measures. Legal authority for such projects is provided at the Federal level by the Value-Pricing Program included by Congress in the 1998 TEA-21 legislation. State legislation may be needed for one or more of the following: (1) to permit conversion of existing HOV lanes to HOT lanes, (2) to permit the implementation of fees for use of state highways, and (3) to permit enforcement of restricted lanes via video and electronic means. In reauthorizing the program (originally specified in the ISTEA legislation of 1991) as a pilot program, Congress recognized that value pricing is a new and innovative approach to relieving congestion and that much remains to be learned about its effectiveness in different urban settings. Both technical and financial support has been provided to support state and local efforts to plan, implement, manage, evaluate, and report on value-pricing initiatives (FHWA, 1998).

2.4.1 State Route-91, Orange County, CA

The State Route-91 Express Lanes project added four new lanes to the wide median for ten miles (plus a short stretch with an additional lane in each direction for HOV enforcement) of the Riverside Freeway at a total capital cost of $130 million. The SR-91 project was one of four private toll road ventures authorized by the California Legislature in 1989. A franchise agreement was signed between the Caltrans and the California Private Transportation Corporation (CPTC) in 1990 for construction, operation, and maintenance of two ten-mile toll lanes per direction.

An extensive four-year study by the Caltrans and the US DOT evaluated the impacts of the variable-toll express lanes exploring overall changes in traffic and travel behavior, vehicle occupancy, traveler demographics, alternative travel modes, operations and safety, and public opinions. “The express lanes constructed on California State Route 91 have demonstrated that providing new highway travel options, in this case, premium service for a premium price, can win public acceptance and produce significant travel changes” (ARDFA, 1998).

2.4.2 Interstate-15, San Diego, CA

The San Diego project is the most comprehensive. It took a much different approach than SR-91 in Orange County. There the system consists of two reversible lanes, constructed in 1988, along an eight-mile stretch of I-15 which is used to commute to downtown. The HOV lanes were underutilized, leading to a proposal by the San Diego Association of Governments (SANDAG) to create a HOT lane under the USDOT’s Value Pricing Pilot Program. Nearly eight million dollars of Federal money was provided. The Federal funds were matched by two million dollars from the State. The program first implemented a permit system on the lanes. Later they implemented the FasTrak Electronic Toll Collection (ETC) system, in which the flat monthly fee was replaced with a dynamic per-trip toll based on congestion levels. Tolls ranged from fifty cents during non-peak times to eight dollars during periods of severe congestion. Electronic signs in front of HOT lane entrances provided advance notice of the current fee. Daily traffic volumes on the express lanes averaged 18,500 vehicles in November 2001, a 102% increase from the pre-project level of 9,200. The desired high level of service was maintained. Under the worst traffic conditions, FasTrak users avoided about twenty minutes of delays over the ten-mile corridor (DeCorla-Souza, 2002).

The majority of users was from higher income groups, was more highly educated, was more likely to be middle-aged females, and come from households with two or more vehicles. An important feature of the I-15 lanes was that carpooling increased after conversion of the HOV lanes, despite fears that the HOT option would discourage carpooling (Poole and Orski, 2002). The project is self-sufficient. The conversion required just 1.85 million dollars in capital costs (not including the transponders paid for by individual drivers) and generated revenue at the rate of approximately one million dollars per year.

The success of this program led SANDAG and Caltrans to cooperate on a more ambitious managed lane project in the corridor. According to the FHWA Value Pricing Pilot Program, the extension of I-15 for another twelve miles to the north has been under construction since November 2003.

2.4.3 I-10 Katy Freeway, Houston, TX

As currently configured, the Katy Freeway has three general-purpose lanes and two frontage-road lanes for most of its length in each direction. A barrier-separated high-occupancy vehicle/toll (HOT) lane for carpools and buses was situated in the center of the freeway. This produced a total of eleven through lanes. A single reversible lane, the HOT facility, handles inbound traffic in the morning and outbound traffic in the evening.

When the Katy HOV lane first began operation, only buses and authorized vanpools were allowed to use the lane. The resulting under-utilization gradually encouraged a loosening of the HOV entry rules. The number of occupants required in registered carpools dropped from four or more, to three or more, and finally two or more. As restrictions relaxed, traffic on the facility grew and more restrictive carpool rules were eventually reinstated to three or more occupants at certain peak hours to reduce traffic on the highway. With two-person carpools no longer allowed, the number of persons moved by the lane during the peak hour declined thirty percent.

The QuickRide system was implemented in January 1998; at that time carpools with two people were permitted to use the lanes for a two dollar per trip fee during rush hours, while carpools with three or more occupants continued to use the lane for free. The project was a very limited value pricing experiment, designed to control traffic volume during the periods of highest usage. When the central lanes operated as a regular HOV lane, the Katy Freeway was near-gridlock. The decision by QuickRide operators to ban vehicles with only a single occupant from the lane (even if the SOVs were willing to pay the toll) was based on the corridor's high travel usage and its limited capacity.

The overall impact has been modest. However, most of the HOV lane users are now commuters who formerly used the general use lanes (Poole and Orski, 2002). Before and after studies of the Katy Freeway showed that the implementation of a HOT lane had the following positive results:

- The number of carpools with three or more occupants increased during the peak;
- Carpools with two or more occupants shifted to before and after the peak hours;
- Average traffic speeds increased and the HOV's level of service improved; and
- The same number of passengers was transported more efficiently.

While the evolution of the QuickRide system is a useful case study in itself, the number of paying users that these two facilities could accommodate was limited. An expansion for the Katy Freeway is currently under construction and could significantly increase the scale and scope of HOT lane operations in the corridor.

2.5 An Overview of New Projects

The new demonstration program or Group 2 projects will provide more information on a variety of different approaches and innovations, including traditional HOT lanes. New concepts being tested include cordon tolls, in which vehicles are charged a fee to enter the perimeter of a restricted area, and fair lanes, in which use of HOT lanes includes a method to make the tolled lanes available to people with low incomes. Also included are existing toll facilities with congestion pricing variations and facilities in which parking costs are reduced for car pools.

Although DeCorla-Souza, et al. (2003) list four strategies for value pricing projects, all of the second group of projects were based on either HOV lane conversions or construction of new managed lanes. In each project, an active outreach program resulted in public acceptance of the changes.

The overall plans of the Group 2 projects are similar. However, they differ in the extent of new construction that is required, the knowledge of the history of HOT lanes, and the acceptance of HOT lanes. The projects all started with a feasibility study.

The feasibility studies all consisted of baseline data in which the level of service was assessed for the highway being studied. Each feasibility study also examined public acceptance of the HOT lanes concept.

2.5.1 The Minneapolis Project

The project in Minneapolis was an HOV conversion to a reversible HOT lane. It was implemented in 2005 and the initial response was favorable. The Portland project is the construction of a new lane that will be used as a HOT lane. The Denver project and the Dallas project are also conversions of an HOV lane to a HOT lane. As of this time, the last three projects have not been implemented.

Halvorson, et al. (2006) present a summary of the new HOT lane project in Minneapolis. The project, which opened in May 2005, is based on the conversion of an HOV lane to HOT lane. “The lanes remain open to HOV use at no charge including transit riders, car pools and motorcyclists. I-394 MnPASS is the first tolling project which prices use on a facility directly adjacent to general purpose lanes separated only by a double-white stripe buffer.”

The Minnesota study (Munnich and Barnes, 2004) examined consumer attitudes in four phases. In the first phase, initial attitudes were examined in focus groups. The focus groups represented different groups that were defined either by socio-economic status or geographical location.

The second phase examined consumer attitudes by conducting surveys. Data on both the acceptance of the overall concept and consumers’ personal choices was recorded. The results for personal choices in Minneapolis showed that about twenty percent of the consumers said that they would use the HOT lanes (Munnich and Barnes, 2004). Similar results were found in the other studies.

The third phase forecasted demand using the data on stated preference. (Data on stated preference was collected for all four studies.) The projections were that 20 to 40 % of respondents said that they would use the HOT lane, depending on the toll and the location. It was assumed that if respondents chose not use the HOT lanes, they would travel at other times or by other routes.

A separate section of each report assessed equity issues. Groups of people, defined by low income or ethnicity, were asked for their opinions on the acceptability of HOT lanes.

All of the feasibility studies for the second group of projects contained descriptions of approaches to educate the public about HOT lanes. The first step was to educate the public, in advance, about HOT lanes, the projects' objectives, and accomplishments. An earlier study about acceptance, conducted in Minneapolis in 1997, revealed there was only a 30% level of support. In the second attempt to implement HOT lanes, the project leaders launched an aggressive publicity campaign which included mailings, information kiosks, and leadership groups. As a result, the approval rating rose to 70% with a large reduction in the undecided group. Similar results were observed at all of the sites.

2.5.2 The Denver Project

As of the writing of this report, this HOT lane is under construction. An analysis of public opinion for the Denver project is summarized in Ungemah, Swisher, and Tighe (2005). The report states that outreach efforts included "focus groups with commuters and business owners, stakeholder outreach to vested public officials and interest groups, conversations with the public in various open houses and a stated preference telephone survey." While there was concern that the HOT lanes would be controversial, opinions on the value of HOT lanes improved after the outreach efforts.

3. BASELINE CONDITIONS

3.1 Census Background

The first baseline conditions were taken from the 2000 US Census. The census provided data on who lives in the Piedmont study area and where its residents travel. The data are presented in Appendix 3.

The transportation choice data suggest that single occupancy vehicle travel dominates the study area, with an average of only 13% of all workers carpooling. Guilford (30%), Forsyth (22%), and Davidson (12%) Counties have the highest percentage of carpoolers in the study area, with Davie (2.5%) and Yadkin (3.2%) Counties exhibiting the lowest percentage. Within the counties, the highest percentage of workers who carpool occurs in the urban areas. More than 325,000 workers (51%) in the study area leave for work during the morning peak period. Of all workers leaving during this time, 53% originate in Forsyth and Guilford Counties.

3.2 Baseline Analysis and Identification of the Study Corridor

3.2.1 Data Sources

The majority of the data utilized in these analyses was provided by the North Carolina Department of Transportation. This information included shape files containing attributes of the segment in question, vehicle classification counts, ramp counts, and annual average daily traffic among other data. Manual classification count (MCC) data was the basis for the LOS calculations. The MCC data was provided in 15-minute intervals. Use of this shorter recording interval allowed calculation of the periods of peak use within each peak hour. The *Highway Capacity Manual*'s (HCM) base values (e.g. population factors, base free-flow speeds) and its formulas for calculating level of service were used (Transportation Research Board, 2000).

Data provided by other parties was used as was necessary. For example, for the number of new lanes needed in each direction between Kernersville and Greensboro, Long Range Transportation Plans for the area suggested, whereas data from PART suggested that only one additional lane in each direction was needed. The most up-to-date information available was used for these analyses when there was a choice.

Three distinct methods were used to forecast demand. This use of multiple methods allowed an examination of different assumptions and made the results more robust. (1) Data for the four-step regional model for 2025 was provided by PART. (2) AADT (Average Annual Daily Traffic) data for 1991-2001 was used to estimate a time-series regression model. An estimated model was then used to forecast average annual daily traffic for the years 2015 and 2025 for each mainline station point. According to the NCDOT, mainline hourly counts are collected at each station using two different equipment systems. ATR (Automatic Traffic Recorder) stations are continuous volume monitoring sites with permanent sensors and permanent counters; whereas TL stations are short-term volume monitoring sites where permanent sensors are installed but counter equipment is placed on a temporary basis (see Figure 63 in Appendix 1 for station locations). (3) The estimates of future traffic flows were generated using simple population projections.

One clarification regarding use of the words “corridor” and “segment” is necessary. The word “corridor” commonly refers to one of five areas along I-40. The following section provides a justification of how these five areas were identified. By contrast, the word “segment” refers to one or many of the smaller divisions of I-40 as originally provided in the universe shape file by NCDOT.

3.2.2 Study Area

The following criteria were used to identify key corridors in the study area: (1) Traffic density during the peak period; (2) Proximity to urban areas; and (3) Right-of-way characteristics. Six key corridors were identified in the area using these criteria, as seen in Figure 3.1 below.

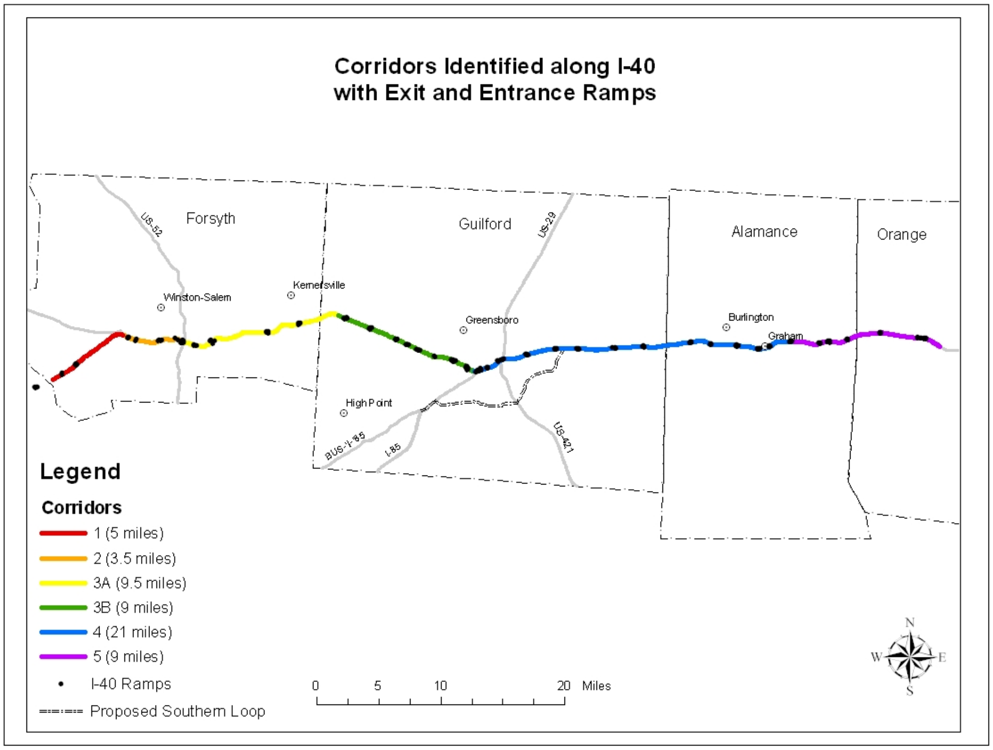
1. Davie and Forsyth County line to the junction of US-421 and I-40 west of Winston-Salem (5.0 miles);
2. From the junction of US-421and I-40 to the intersection of US-52 and I-40 in Winston-Salem (3.5 miles);

3A. From the junction of US-52 in Winston-Salem east to the junction of Business I-40 with I-40 (9.6 miles);

3B. From the junction of Business I-40 and I-40 eastwards to Greensboro to the point where Business I-85 turns south (9.2 miles);

4. From the divergence of I-85 from I-40 in Greensboro to Graham (20.9 miles); and
5. East of Graham (9.2 miles).

Figure 3.1 Corridors identified along I-40 with exit and entrance ramps



3.2.3 2000 US Census Data for the Counties in the Study Area

An explanation of the data collection procedures and of the use of data from the 2000 US Census can be found in Appendix 3.

3.2.3.1 Population

About 55% of the population of the eight counties lives in the center of the study area along I-40 in Guilford and Forsyth Counties. These areas in which the population is concentrated correlate with the location of the critical corridors in this study. The counties surrounding Guilford and Forsyth to the east (Alamance and Orange) and south (Davidson and Randolph) have larger populations than the counties in the west (Yadkin and Davie). Most of the urban areas in the region are located within ten miles of the I-40 corridor.

The average per capita income in the study area is about $21,000 (standard deviation ± $2,000), compared to an average of about $20,300 for all of North Carolina and about $21,600 for the United States. The average median income per household is about $40,000 (standard deviation ± $2,000), compared to about $39,200 for all of North Carolina and about $42,000 for the United States. The highest per capita and per household incomes are found in suburbs surrounding these urban areas. The lowest incomes are found in the rural areas and in the central business districts of the main cities in the area: Winston-Salem, Greensboro, and High-Point. Compared to the rest of North Carolina, which has a population density of 165 people per square mile, the range of population densities by county for the study area is from 100 to 750 people per square mile. At the census tract level, population densities reach as high as 10,000 people per square mile in the central business districts.

3.2.3.2 Economic Activity

Location quotients were used to compare counties employment share in an industry to the North Carolina averages. The goal was to better understand the industrial economic base within the study area in comparison with that of the entire State. The data is for the industries which occur within each county and does not take into account regional industries. More than 440,000 or over 68% of the employees in the study area are located in Forsyth and Guilford Counties. Since residents of these two counties make up a large majority of the employed workers in the area, it follows that commuter peak-period traffic would be higher in these areas. Counties to the east (Alamance and Orange) and south (Davidson and Randolph) have many more employees than the counties to the west (Yadkin and Davie).

The economic base for extraction activities (agriculture, fishing, forestry, hunting, mining, construction, and utilities) in the study area is low. Manufacturing is the largest industrial sector in the study area. It is particularly high (when compared to the State's averages) in the counties directly surrounding Forsyth and Guilford, including Randolph, Davidson, Yadkin, Davie, and Alamance. The figures for the trade and transportation industry in the study area are similar to the average for the State. The figures for professional and management industries in Orange, Forsyth, and Guilford Counties are just above the state average, while the rest of the study area is low in this sector of industry. The figures in education, health, and services for Orange County (location of the University of North Carolina at Chapel Hill and its medical school) are above the State's average, while the figures for the rest of the study area range from average to below average in these sectors.

3.2.4 Baseline Travel Conditions in Corridor

Current conditions of a freeway are important factors for determining the location and characteristics of HOT lanes in any feasibility study. The descriptors of current conditions used in the next section include: Congestion (captured by level of service, average speed in each corridor, and volume-to-capacity ratios); lanes currently available; peaking patterns; the width and type of right-of-ways; the percentage of trucks in the total traffic during the peaks; the number of movements by entrance and exit ramps; and the cost of constructing HOT lanes.

3.2.4.1 Traffic Parameters

Because I-40 goes through Winston-Salem and Greensboro and near High Point, the corridor is frequented by commuters going to and from work. The mean travel time to work is twenty-three minutes (standard deviation $\pm$ 1.94). Mean travel time to work decreases in urban areas and as distance from I-40 decreases. The areas with the longest travel times have the poorest transportation links to I-40.

A significant share of the carpoolers in the region (52%) is located in Forsyth and Guilford Counties, further supporting the designation of Corridor 2, and Corridors 3A and 3B as critical areas for study. Almost 45,000 workers in Forsyth and Guilford Counties carpooled, while more than 290,000 workers drove alone to work. About 12.9% of commuters in the study area use carpools to go to and from work; this figure is similar to those from other parts of North Carolina (14.0%) and the United States (12.2%) in terms of percentage of carpoolers. This translates into 85,000 carpoolers driving to and from work per day in the counties of the area of study. The percentage of carpoolers, by census tract, is largest in urban areas. Public transportation is most available in central business districts and is almost non-existent in rural areas where densities are too low to support it.

There is a pronounced peak in the number of vehicles on I-40 during the morning commute. HOT lanes can be especially useful in relieving congestion where such peaks in daily flow occur. Approximately 53% of the workers in Forsyth and Guilford Counties (almost 190,000 people) leave for work between 7:00 A.M. and 9:00 A.M. Over 50% of all workers leave for work at this time throughout the region; this figure can be compared to the figure of 48% for the rest of North Carolina and to the figure of almost 47% for the rest of the United States. This translates into 325,000 workers on their way to work during the morning peak period, further supporting the use of peak-period HOT lanes to help alleviate congestion.

3.2.4.2 Level of Service

Level of service (LOS) is a performance measure based on traffic density. It is used as an indication of congestion and of how well traffic flow is being accommodated by the freeway. Data for the calculation of LOS was provided by NCDOT (Kent Taylor and L.C. Smith, among others). The study area from the Davie and Forsyth County line to where I-85 diverges from I-40 in Orange County was divided into sixty-five segments. This segmentation of the corridor was based on data in the ArcView file named “universe” compiled by L.C. Smith. All formulae (below) and their suggested adjustments for calculating LOS were taken from the *Highway Capacity Manual* (Transportation Research Board, 2000). For a description of how LOS was calculated, see Appendix 2.

LOS levels for current conditions on this segment of I-40 were calculated for the morning and evening peak hours in each direction (Figures 3 through 6 in Appendix 1). The segment between Winston-Salem and Greensboro has an LOS at the “D” level or worse during the morning peak in eastbound lanes and during the evening peak in westbound lanes. This lower level of service is expected in this location because many commuters travel to work from Forsyth County to Greensboro (eastbound) during the morning and return home from Greensboro (westbound) in the evening. A reversible HOT lane is an appropriate option for dealing with the change in direction of high traffic flows in this area.

In addition, LOS levels on I-40 in and near Winston-Salem range from D to E for both peak hours and in both directions. Because the LOS for this stretch of I-40 is not dependent on direction, the traffic probably consists of more through traffic than commuter traffic. The addition of two dedicated HOT lanes (one in each direction) is an appropriate solution to relieve congestion in this critical corridor.

The average passenger car speed was used to calculate the average speeds for each corridor (Figures 2 in Appendix 1) and for smaller segments within the corridors (Figures 26 and 27 in Appendix 1). The data showed that the corridors experiencing the biggest change in speed from the free-flow speed are corridors 2, 3A, and 3B. With these figures, the average time in minutes that it would take to travel from one end of each corridor to the other during peak periods (as compared to the time during free-flow conditions) was calculated. The largest change in time occurred, again, in corridors 2, 3A, and 3B.

3.2.4.3 Volume-to-Capacity (V/C) Ratios

Volume-to-capacity (V/C) ratios compare traffic volumes to the capacity of existing lanes. However, because adequate data on current conditions was not available, no adjustments were made for prevailing conditions. This resulted in the following assumptions: lane capacity was 2,000 vehicles per lane per hour; and peaking factors, the presence of trucks in the vehicular flow, the grade of the right-of-way, and the presence of drivers unfamiliar with the right-of-way, were not important. As such, the V/C calculations should be regarded as lower limits to the real V/C ratio for each segment. In contrast, the LOS calculations did include all appropriate adjustments. The results for the V/C calculations are consistent with the results for the LOS calculations and can be observed in Figure 3.2 in Appendix 1 (see also Figures 7 through 10 in Appendix 1).

3.2.4.4 Patterns of Peak Usage

An examination of patterns of peak usage shows that travel demand is not uniform throughout the day. As shown in Figures 3.2 and 18 through 25 in Appendix 1, strong, definite patterns in the morning and the evening peaks in both directions are identified for Corridor 2 (in and west of Winston-Salem). This study of peaking patterns and the LOS and V/C analyses suggest that HOT lanes should be used only during peak periods rather than for all twenty-four hours in a day. Because congestion is highest during the peak periods of travel, the proposed HOT lane is expected to reduce the peak demand for the current road facilities. Furthermore, given the directionality of traffic, these results of this study suggests that a reversible HOT lane for Corridors 3A and 3B would be the most appropriate choice there while two dedicated HOT lanes (one in each direction) appear to be the appropriate choice for Corridor 2.

3.2.5 Right-of-Way Characteristics

The number of lanes in each direction was examined (Figure 17 in Appendix 1). Part of Corridor 3A, (the segment from Exit 196 in eastern Winston-Salem to the junction of I-40 and Business I-40 east of Kernersville), and a small segment on the far western end of the study area (from west of Clemmons to the Davie County line) are the only segments where there are only two general-purpose lanes in each direction. PART used current right-of-way characteristics (from the universe shape file) to estimate the costs of constructing HOT lanes. The width and type of the median, the width of the right shoulder, and the width of total available right of way were examined to find where the land was available to construct HOT lanes (see also Figures 11 through 14 in Appendix 1). The data was then used to create cost estimates for the corridor for adding either one HOT lane in each direction or two HOT lanes in each direction (Figures 15 and 16 in Appendix 1). The cost estimates for each segment were ranked as low, moderate, or high, based on the following criteria:

- ‘Low’ indicates that the lanes could be constructed in the median right-of-way,

- 'Moderate' indicates that the lanes could be constructed using the available right-of-way in the median and right shoulder, and
- 'High' indicates the lack of available right-of-way or some obstruction (e.g. a bridge) that would make constructing the HOT facility more costly.

The study's estimates indicated that:

- The lowest costs occur in Corridor 2 and Corridor 3B;
- There is currently enough available right-of-way to construct a HOT lane for Corridor 2 or Corridor 3B; and
- There is room for a maximum of two new lanes along Corridor 3B.

3.2.6 Truck Movements

Data on truck movements was obtained from the manual classification counts provided by the NCDOT. The percent of trucks in the total vehicular traffic and the number traveling during the peak periods by direction were calculated for each segment along I-40 (Figures 28 through 31 in Appendix 1). Truck traffic decreases during the evening peak period in both directions. During the morning peak period, the percent of trucks reaches as much as twenty percent. For the entire I-40 study area during all four (eastbound morning and afternoon and westbound morning and afternoon) peak periods, truck traffic is greater than ten percent for all segments east of US-52 in Winston-Salem. West of US-52, truck traffic decreases to as little as six percent during the peak periods.

3.2.7 Daily Ramp Counts

Daily ramp counts can be useful for determining the best places to install HOT lanes, especially if the HOT lane segment is designed like a pipeline, with only one entrance and exit. Daily ramp counts were compiled by recording the number of vehicles entering and exiting at each pair of ramps in the I-40 study area. The study area was divided into seven segments by proximity to urban areas (Figures 32 through 38 in Appendix 1). Corridor 3A from eastern Winston-Salem to east of Kernersville is a segment in which a pipeline design would be most suitable. It has both low interchange density and low movements per day on and off at the interchanges. Corridor 3B from Kernersville to Greensboro and Corridor 2 in Winston-Salem have too many interchanges for a pipeline to be effective. A more creative approach will be needed when determining the design of the HOT lanes in these locations.

3.3 Summary and Implications

The level of service per segment in each direction for the morning and evening peak periods for the baseline (i.e. current conditions) was analyzed using the methods suggested by the most recent edition of the *Highway Capacity Manual* (Transportation Research Board, 2000). From the LOS calculations, Volume-to-Capacity ratios (V/C) were derived for all the segments in the study area; however, there were no adjustments for lane conditions.

Based on the analysis of the baseline data, two main corridors are identified where the LOS is poor (D or F). The first is Corridor 3 from Winston-Salem to Greensboro (west to east), which was subdivided into Corridors 3A and 3B; these segments have poor LOS eastbound during the morning peak (Figure 3 in Appendix 1). The westbound lanes of the same segment have a poor LOS during the evening peak (Figure 4 in Appendix 1). The second segment, Corridor 2 west of Winston-Salem, has a poor level of service in both directions at both peak times (Figures 3 through 6 in Appendix 1). About thirty-five percent of the I-40 traffic from the west exits at US-52 in the morning and enters I-40 in the evening period at the same location.

In addition to Corridor 3 and 2, the western (3 mile) section of Corridor 4 between I-40/I-85 split and I-40/US29 merge has poor level of service due to commuters to Greensboro from eastern and northern Guilford, Rockingham, and Alamance Counties and through traffic on I-85 and I-40. However, these estimates of poor levels of service are based on the current configuration of I-40 and other highway networks in the area. Once a planned Southern Loop of Greensboro, a by-pass connecting I-40 east of Greensboro to I-40 west of Greensboro via I-85 south of Greensboro, is completed, this loop will divert through traffic away from southern Greensboro section of I-40 and it is expected to increase the level of service of the eastern section of Corridor 3B and western section of Corridor 4.

Finally, this examination of patterns of peak usage when combined with the LOS and V/C analyses suggest that HOT lanes should operate only during the peak periods and not twenty-four-hours a day. The addition of HOT lanes would reduce the peak demand on the current road facilities and thereby relieve congestion. Given the directionality of traffic, analysis of the available data suggests that the addition of reversible HOT lanes for Corridors 3A and 3B and two additional dedicated lanes (one in each direction) for Corridor 2 would be the best solutions for reducing congestion.

3.3.1 Future Travel Conditions in Corridor

3.3.1.1 Forecasting Methods

Due to the complexities inherent in forecasting future traffic, three methods were used to provide a range of data. The three methods used are:

- The four-step regional transportation model (provided by PART: Triad Regional Model);
- A population growth method: and
- Point estimates based on a linear regression analysis.

The four-step regional model provides data from the west end of the corridor to the Guilford and Alamance County line. Currently, the four-step regional model provides projections for 2025 only. The population growth method assumes traffic will grow at the same rate as the population, while other factors (percent of heavy vehicles, population parameters, number of lanes, etc.) remain constant. For this project, a twenty percent growth rate per decade (1.84 percent per year) was used to project LOS for 2015 and 2025. However, population projections made available after this project was completed suggest that lower population growth rates may apply. Projections provided by the regression analysis model are also for 2015 and 2025. All methods but the first assumed no additions to the transportation capacity; the first, however, included the presence of the southern loop of I-85. Similarly, the first methodology is the only one that accounted for potential network effects and behavioral adjustments by travelers.

In addition to these, the analytical method presented in the *Highway Capacity Manual* (Transportation Research Board, 2000) was used to calculate the "years until an additional lane is needed." The projections used current conditions to find the year in which the LOS on each segment would become an "F," assuming a 1.84 percent rate of growth in traffic per year (twenty percent per decade). These projections suggest that Corridor 3B will need an additional general-purpose lane before 2015. Figures 39 through 42 in Appendix 1 show the results of this analysis. The forecasts identify that the other highway segments in the corridor that might need long-term planning activities.

3.3.1.2 Implications

The forecasting methods available for 2015 are population growth, regression analysis, and the year an additional lane will be needed. This data supports the findings that there are two corridors which have reached critical levels of congestion and that there are no other segments in need of attention by 2015. Specifically, an additional lane will be needed for both directions and peak periods in Corridor 2 by 2015 (Figures 39 through 42 in Appendix 1). The population growth model and regression analysis model project an LOS value of “E” or “F” for this corridor (Figures 43 through 50 in Appendix 1). In Corridor 3A and Corridor 3B, an additional lane is needed in the eastbound-morning and westbound-evening directions by 2015 , which is expected in view of current LOS conditions (Figures 3 and 4 in Appendix 1).

The only other location where the forecasts from all methodologies predicted serious congestion was Corridor 1 (Figures 39, 47, 51 and 55 in Appendix 1). This corridor serves a rapidly growing area in Forsyth and Davie Counties and experiences an unbalanced peak flow during the eastbound-morning and westbound-evening peak-hours, as workers travel to and from Winston-Salem.

In summary, the forecasts predict that Corridors 2 and 3 will become congested very soon. Corridor 1 has also been identified as needing an additional lane for the eastbound-morning peak period sometime between 2015and 2025 (Figure 39 in Appendix 1). The forecasts from the different methods used do not agree on what will happen on the segment of I-40 from east of Greensboro to Orange County. What is clear, however, is that, based on the level of service, the first two corridors identified (Corridors 2 and 3) should be the focus of future HOT lane surveys.

3.4 Future Conditions Applied to the Corridors Identified

After identifying the six corridors, the characteristics of each were examined in detail to identify problem areas. Table 3.1 summarizes the current and future characteristics of the six corridors, and the recommendations for the next phase of the study--the 2015 and 2025 periods.

Table 3.1: Alternatives in the Short-Term (2003-2015)

Corridor	Results of doing nothing	Year an additional mixed lane is needed*	Year two additional mixed lanes are needed	Appropriate HOV/HOT solutions
1	Severe/moderate congestion	2014-2025	n.a	
2	Severe congestion	prior to 2015	2019	Dedicated
3A	Severe/moderate congestion	prior to 2015	2034	Reversible
3B	Severe/moderate congestion	prior to 2015	2015	Reversible or Dedicated
4	Severe/moderate congestion	2026-2035	n.a	
5	Severe/moderate congestion	after 2035	n.a	

*As determined by use of the HCMs (2000, Ch. 23) procedure for when additional lane is needed

3.4.1 Corridor 1: Davie and Forsyth County line to US-421 west of Winston-Salem

Corridor 1 is five miles in length. LOS values are high (B or C) for all peak hours (Figures 3 through 6 in Appendix 1). There is a peak in the eastbound morning and westbound evening periods, but capacity is adequate at this time (Figures 18 through 21 and 7 through 10 in Appendix 1). Forecasts indicate that the eastbound segment may become congested during the morning period at sometime between 2015 and 2025 and the westbound segment, during the evening period at sometime between 2026 and 2035 (Figures 39 and 40 in Appendix 1). The segment will not see congestion conditions during the westbound-morning and eastbound-evening periods until some time after 2035 (Figures 41 and 42 in Appendix 1).

Count station A2901 was used to calculate LOS for the small segment at the far west of the study area (near the Davie County line). Although this segment is only two lanes, current LOS does not exceed B at any point (Figures 3 through 6 in Appendix 1). This segment should be representative of the conditions in Davie County, where I-40 is also only two lanes.

3.4.2 Corridor 2: From US-421 to US-52, in Winston-Salem

Corridor 2 is three and one half miles in length. It is one of the critical segments requiring immediate attention. LOS values are low (D or E) for all peak hours (Figures 3 through 6 in Appendix 1). Although there are three general-purpose lanes in each direction, an additional lane per direction is needed before 2015 to avoid queues on the freeway at exit ramps (LOS F) (Figures 39 through 42 in Appendix 1). Because the corridor is congested in both the eastbound and westbound directions for both peak hours, a reversible lane would not be feasible here. The right-of-way that is available in the median and on the right shoulder makes the cost of adding a HOT lane range from low to moderate, depending on the number of lanes that are constructed in each direction (Figures 11 through 16 in Appendix 1). This segment has a high concentration of interchanges, with five interchanges located along the four miles of roadway. Because these interchanges are heavily used, a HOT facility in this corridor would need multiple points of entrance and exit (Figure 33 in Appendix 1). Truck traffic ranges from six to ten percent of all vehicles during the peak hours, the lowest of any of the six corridors (Figures 28 through 31 in Appendix 1).

3.4.3 Corridor 3: US-52 in Winston-Salem to the junction of Business I-85 and I-40 in southwestern Greensboro

Corridor 3 is the other critical segment. Based on the right-of-way availability, the presence of Business I-40 (for which no usage data were available), and the presence of PART on parts of the corridor, this segment was split into Corridor 3A and 3B.

Both Corridors 3A and 3B are congested during the peak hours of the eastbound-morning and westbound-evening commutes. Because travel during the peak periods of congestion is largely unidirectional, a reversible HOT/HOV lane could be an effective solution to congestion (Figures 22 and 25 in Appendix 1). Projections show that an additional lane will be needed before 2015 for the eastbound-morning and westbound-evening peak hours to avoid queues forming on the freeway (LOS F) (Figures 39 and 40 in Appendix 1).

Corridor 3A (from downtown Winston-Salem to east of Kernersville) is 9.5 miles long, and like Corridor 2, has a total right-of-way of more than sixty feet available in the median, left shoulder, and right shoulder (Figures 11 thru 16 in Appendix 1). In addition, there are few interchanges in this location (five exits over eleven miles) and a low level of activity at these intersections. Truck traffic ranges from twelve to twenty percent of all vehicles during peak hours (Figures 28 thru 31 in Appendix 1). This section of Corridor 3 is characterized by having only two lanes per direction for most of its extent, compared to the other corridors that have three or four lanes per direction (Figure 17 in Appendix 1). A pipeline design, which has only one access and exit point on each end (Figure 34 in Appendix 1), is potentially a feasible and effective HOV/HOT lane configuration between the split of I-40 and US311 and the split of I-40 and Business I-40 on Corridor 3A where the entry to and exit from I-40 will not require much traffic shift.

Corridor 3B (from east of Kernersville to southwest Greensboro) is nine miles in length and currently has an LOS of "F" (Figures 3 and 4 in Appendix 1). The number of lanes here ranges from three to four (Figure 17 in Appendix 1). ATR count stations A4006 and A4007 were included into the analysis (Figure 26 in Appendix 1) to better evaluate LOS conditions on this segment. Analysis of the daily ramp count data reveals that this half of the corridor is characterized by heavy usage of its interchanges (Figure 35 in Appendix 1). Although improvements are needed in this location as soon as possible, the lack of an available right-of-way may limit what can be done (Figures 11 through 14 in Appendix 1). There is only adequate room for a lane in the median. This half of Corridor 3 is already needs an additional lane (Figures 39 and 40 in Appendix 1). In the short term, a reversible lane would help relieve congestion; however, the forecasts predict that congestion will occur in the westbound lanes during the morning and the eastbound lanes in the evening sometime between 2015 and 2025 (Figures 41, 42, 49, 50 and 58 in Appendix 1). When this happens, a dedicated lane in the opposite direction will be needed. Over time, as the level of service on this corridor deteriorates, the time savings generated by managed lanes will increase.

3.4.4 Corridor 4: From Greensboro to Graham

Corridor 4 is 21 miles in length and runs from southwestern Greensboro to Graham, approximately 21 miles (Figure 1 in Appendix 1). Current LOS conditions are at C or higher for all peak hours (Figures 3 through 6 in Appendix 1). Most segments of this corridor will need an additional lane sometime between 2026 and 2035 (Figures 39 through 42 in Appendix 1). Although an additional lane will be needed in Greensboro between 2015 and 2025, the effects of the Southern Loop on this segment during the westbound-morning and eastbound-evening peak hours are hard to predict (Figures 39 and 40 in Appendix 1). The forecast generated by the regression model suggests that this segment should not become congested until 2025 (Figures 39, 42, and 59 through 62 in Appendix 1). The other forecasted data do not project LOS lower than D for this segment.

3.4.5 Corridor 5: East of Graham

Corridor 5 is 9 miles in length and goes from east of Graham to the end of the I-40 corridor. This segment has four lanes in each direction, and the current LOS is at B or C

(Figures 3 through 6 and 17 in Appendix 1). According to the regression analysis model, this corridor has an LOS for 2025 of E or F for both the eastbound morning and westbound evening peak periods (Figures 59 and 60 in Appendix 1). However, no other data supports this decrease in LOS. Additional lanes for this segment are not needed until after 2035 for all peak periods (Figures 39 through 42 in Appendix 1). The population growth model for 2015 and 2025 does not forecast an LOS less than D (Figures 43 through 46 and 55 through 58 in Appendix 1). The four-step regional model's forecast was not available.

3.4.6 Corridor Study Findings This portion of the study examined the feasibility of high-occupancy vehicle/toll lanes in the Greensboro/Winston-Salem area of North Carolina. With the current level of growth, doing nothing will result in severe congestion in the future. (Severe congestion is defined here as a level of service of F). Based on current congestion levels, anticipated future traffic growth, right-of-way availability, and the need to fully use added capacity, adding a lane in Corridor 3B is recommend in the short-term (2005-2015). The only remaining question is whether to make it a mixed flow lane, an HOV lane, or a HOT lane. Although "doing nothing" is still an alternative, it will result in high levels of future congestion. The three alternatives to this are:

- Construct a mixed-flow lane. This may not be a good strategy because it does not provide attractive alternatives to single occupancy vehicles. There would be no incentive for people to rideshare and thus increase the carrying capacity of the lane. Under this option, public transit cannot provide its riders with an advantage in terms of shorter in-vehicle travel times.
- Construct a HOT lane. This option allows the added capacity to be fully utilized. High-occupancy vehicles would be able to use the lane free of charge. However, a key question (answered in the next chapter) is whether people are willing to pay tolls for using the lanes.
- Construct HOV lanes reserving the option of turning them into HOT lanes in the future. If the HOV lanes operate at less than full capacity after a trial period (to allow people to form carpools), the next option would be to allow SOVs to use the lane for a fee. This strategy entails the risk of alienating a portion of the population before corrective actions can be taken.

If HOT lanes are constructed, the I-40 project could serve as a test case for a tolling facility in the North Carolina. If the project was successful, it could stimulate the installation of HOT lanes in other corridors. Furthermore, there is potential for a more extensive HOT lane network that consists of Corridors 2 and 3A in the long term (2015-2025). However, the extensive HOT lane network does not necessarily include all corridors considered, because either the congestion levels are not severe or new highway projects will add sufficient capacity to keep congestion levels rather low.

Of course, implementation of HOV/HOT lanes will depend on many factors, especially the benefits and costs. If implemented, HOV/HOT lanes should be accompanied by supporting actions such as rideshare matching programs, park-and-ride lots, and higher levels of transit service in the corridor (Brownstone and Golob, 1992). Ultimately, it will be up to the stakeholders (e.g., NC DOT, citizens, planning organizations, transit agencies and the cities) to decide about adding road capacity and whether it should be unrestricted, restricted and/or tolled.

3.5 Study findings about Traffic

The feasibility of high-occupancy vehicle/toll lanes in the Greensboro Winston-Salem area of North Carolina was determined, based on current congestion levels, anticipated future traffic growth, right-of-way availability and the need to fully utilize added capacity.

- Based on the traffic density and LOS calculations for current and forecasted flows, the first corridor to consider is Corridor 3B. Two potential corridors to sequence after Corridor 3B are Corridor 2 and Corridor 3A.
- Examination of peaking patterns and the LOS and V/C analyses suggest that the concept HOT lanes should not be 24- hour lanes, but only peak period lanes. Because congestion is highest during the peak periods of travel, the concept HOT lane would attempt to shave the peak demand for the current road facilities.
- Given the directionality of traffic, a reversible concept HOT lane for Corridors 3A and 3B would be most appropriate while two dedicated lanes (one in each direction) appear appropriate for Corridor 2.
- In the short-term (2003-2015), a reversible HOT lane in Corridor 3B is most feasible, given its immediate need for additional lane(s) and effectiveness of HOT lane as congestion pricing strategy. This will be a test-case for a tolling in the State and, if successful, it can stimulate HOT lanes in other corridors.

- In the long-term (2015-2025) an expansion of a HOT lane network to Corridors 2 and 3A is a potentially effective measure to handle the increased traffic forecasted for 2025. However, the expanded HOT lane network does not necessarily include all corridors considered on I-40 in the North Carolina Piedmont because either the congestion levels are not severe or new highway projects will add sufficient capacity to keep congestion levels rather low.
- The main issue that needs further research is the existing vehicle occupancy levels and how many people will choose to rideshare and/or pay tolls if HOT lanes were implemented.

4 OPINION AND BEHAVIOR SURVEYS

4.1 Commuter Survey

To understand commuters' willingness to pay for managed lanes and to collect information about commuters' opinions and behaviors regarding travel on Interstate 40, a mail-back survey was designed and distributed (in late 2004) by the research team with input from NCDOT. The survey was handed out at exits along the study corridor beginning east of Winston-Salem (at the eastern junction of Business I-40 and I-40) and ending at Business I-85 in Greensboro. Although the research team proposed a survey containing repeated stated preference experiments, in the end NCDOT and the team agreed on a simplified survey that continued to satisfy the research objectives while simplifying the research effort. The survey contained forty-seven questions requesting information on details of travel patterns, respondents' opinions on I-40's traffic, and relevant demographic data (see Appendix 4). Question 34 of the survey instrument inquired explicitly about the possibility of saving commuting travel time by paying a toll for use of a carpool lane while driving alone. Question 35 offered two scenarios for travel time savings of 8 and 15 minutes for those respondents who are willing to pay to enjoy congestion-free lanes in Corridor 3 and possibly Corridor 2, depending on where respondents enter I-40. The two scenarios were developed based on the findings presented in the previous section. Under current conditions HOT lanes in the study corridor would reduce travel time from recurring congestion by two minutes in Corridor 3. Based on the forecasted level of service on Corridors 3 and 2 by year 2015, the eventual growth in traffic will result in longer delays due to recurrent congestion and extra time savings for those using HOT lanes. Additionally, non-recurring congestion delays vary widely, but according to FHWA's office of operations, they account for up to 50% of total congestion. This type of delay will increase as recurrent congestion worsens. Thus, it was estimated that a HOT lane in the study corridor could reasonably save 8 minutes of travel time, and more optimistically up to 15 minutes of travel time

Description of the daily commutes

- Opinions about traffic on I-40
- Preferences for managed lanes
- Socio-demographics

An initial analysis has been completed. The cumulative responses revealed the following socio-demographic information about the commuter population:

- The population was 54% women and 46% men.
- Eighty-four percent of the commuters had an annual family income of less than $90,000.
- Forty-five percent of the commuters had professional or managerial jobs.
- The ethnic/racial breakdown of the population was 17% black, 79% white, and 3% other.

The key question was whether people would pay a toll to travel on a managed lane. After a careful description of a managed lane and how tolls would be collected, the following two questions were asked:

1. Assuming that it would save you some time during your commute, would you consider paying a toll to be allowed to use a carpool lane while driving ALONE and enjoy congestion-free travel at full highway speeds?
   a☐ Yes (If "Yes" please answer questions 35 and 36)
   b☐ No (If "No" please SKIP question 35, and answer question 36)

2. Assuming you continue to use I-40 as you currently do, how much money would you be willing to pay (per one way trip) to be allowed to drive ALONE in a carpool lane on I-40 to avoid congestion and travel at full highway speeds? (Please respond to BOTH time saving conditions shown below)?

   CONDITION 1
   Knowing that it would save you eight minutes of travel time, on average, for each one way, peak period trip are you willing to pay
   a☐ Less than $0.25 per one way trip
   b☐ $0.25 to $1.25 per one way trip
   c☐ $1.26 to $2.50 per one way trip
   d☐ $2.51 to $4.00 per one way trip
   e☐ More than $4.00 per one way trip

   CONDITION 2
   Knowing that it would save you fifteen minutes of travel time on average for each one way, peak period trip are you willing to pay
   a☐ Less than $0.50 per one way trip
   b☐ $0.50 to $2.50 per one way trip
   c☐ $2.51 to $5.00 per one way trip
   d☐ $5.01 to $8.00 per one way trip
   e☐ More than $8.00 per one way trip

The "average" respondent came from a household of 2.8 individuals, owned 2.5 vehicles, and made 11.5 trips per week. The self-reported average travel time on I-40 was 21.9 minutes during the morning peak hours and 23.6 minutes during the evening peak hours. The average trip on I-40 was 18.4 miles during the morning and 18.6 miles during the evening. Eighty percent of the trips were made by single drivers. The average maximum time they are willing to commute is 32.3 minutes. The respondents' income distribution was normal, following a bell-shape curve with a range between $0 and $150 with an approximate median of $70,000. About forty-two percent (41.9%) of the commuters listed their occupational classification as professional/executive. The results of the complete analysis of the survey data are presented in Tables 2 and 3 of Appendix 4.

4.2 Survey Results

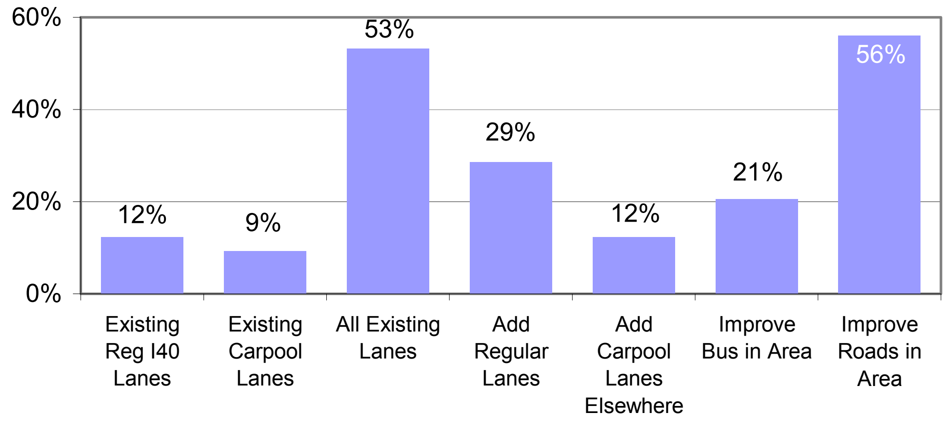
Survey data was used in statistical models to identify predictors of respondents' (a) willingness to pay, (b) preferred uses for funds collected, and (c) upper limit for tolls in various scenarios. The main findings of this analysis are summarized below. Detailed results are presented in Appendix 4.

An initial analysis of willingness to pay a toll (Table A4 15), indicates that there is no difference between men and women ($\chi^2 = 0.15$, $p>.05$). This table also indicates that about one third of the subjects would pay a toll to use the express lane. Of that one third of the subjects who were willing to pay a toll, the following responses were made to the second set of questions (Tables A4 4.2 and Table A4 4.3). The people who would pay a toll would pay as much as $1.25 for a small saving of time (39% said yes) and as much as $2.50 for a greater saving in time (44% said yes).

The survey showed that slightly more than 35% of respondents are willing to pay a toll to use a HOT lane while driving alone if it saved them a certain amount of time. A subsequent survey conducted by the NC Turnpike Authority states that focus group interviewees "…ultimately agreed that using tolls was the fairest way to pay for new roads" (Frank Wilson and Associates, 2006).

Most respondents prefer to use HOT funds to improve all existing lanes (on I-40) and all roads in the area. The least number of respondents prefer investing the funds in existing carpool lanes on I-40 (9%) or elsewhere (12%). It is important to note that there are no carpool lanes on I-40 at this time.

Figure 4.1. Preferred Uses of HOT Lane Funds



4.2.1 Predictors of Willingness to Pay

Logistic regression analysis was used to identify the key predictors of willingness to pay for HOT lanes. The main predictors are: (1) the maximum acceptable commuting time of the respondent (the greater the time the respondent is willing to commute, the greater the willingness to pay); (2) the number of children in the household (as the number of children increases, willingness to pay decreases); and (3) prior carpooling experience (respondents who had carpooled in the past expressed a greater willingness to pay). The results for children and prior carpooling experience are consistent with prior expectations. There were no differences in willingness to pay a toll by demographic variables such as gender and income, suggesting that equity may be less of a concern if HOT lanes are implemented in the study corridor.

The survey also provided scenarios in which individuals were asked to identify their willingness to pay to avoid delays of eight minutes and fifteen minutes. Analyses of their responses suggest that individuals with higher incomes and those who have experienced greater delays in the past are willing to pay more. This is consistent with the microeconomic interpretation that individuals with higher incomes place a higher value on time, and as a result, may be willing to pay more to save time. By contrast, respondents who are employed and respondents who have more children below seventeen years of age are willing to pay less than respondents who do not work or do not have minor children. Race and gender were not significant predictors of how much respondents are willing to pay to use a HOT lane to save delay time.

4.2.2 Predictors of Preferred Uses of HOT Lane Funds

Two groups of respondents prefer that HOT lane funds be used only for improving regular lanes: (1) those making a greater number of trips during which they experienced a delay of more than ten minutes due to unusual congestion in the past thirty days, and (2) non-white respondents. The number of cars in the household and employment status (1 = work, 0 = student/unemployed) were significant predictors of those respondents who prefer using HOT lane funds on all I-40 lanes. Those with a greater number of cars in the household and those not employed prefer that funds generated by HOT lanes **not** be used for the maintenance and improvement of all I-40 lanes.

Only those who had previous experience commuting by bus or other mass transit preferred that the collected funds be invested in the maintenance and improvement of these services. The analyses indicated that there were not a significant number of people who preferred the remaining choices.

4.3 Revenue Estimates

Based on commuter responses, a "back-of-the-envelope" analysis of the potential amount of funds that could be collected per hour per direction was conducted. The choices on the survey were given as intervals (i.e. 0 to $ 0.50). The analysis used the lower figure of the interval for determining the lower limit for the range and the higher figure for determining the upper limit. The percentages of commuters willing to pay a toll (by direction of travel and time of day) were based on the Commuter Survey. These figures are

- Morning westbound: 28.97%
- Morning eastbound: 36.76%
- Evening westbound: 35.31%
- Evening eastbound: 36.70%

The traffic flow in each direction for 2003 was predicted using the trend regression equation developed by NCA&T and mentioned in Section 3 of this report. (Mainline ATR counts, TL counts, AADT data and ramp counts provided by the NCDOT were from 2001.) In addition to the variables discussed below, the study controlled for the following independent variables: the travel times on I-40 during the morning and evening; the frequency of commuters riding as passengers; the number of trips per week; the number of miles driven on I-40 in the morning and evening; the number of trips with a duration of ten minutes or longer; the number of cars; the gender of the driver; past use of buses and/or mass transit; income; race; and employment status. Three assumptions need special note. (1) The percentage of commuters willing to pay a toll was reduced by 25% because stated preferences in surveys are often overestimated. (2) The lanes would operate during peak hours for 250 days a year. (3) The lanes would be operating in both directions during peak hours.

Table 19 in Appendix 4 summarizes the results of the analysis. Revenue is expected to be between $616,000 and $120,000,000 under the eight minutes saved scenario and between $506,000 and $1,277,000 under the fifteen minutes saved scenario. If the estimate of the number of commuters using the roadway is raised, the revenue generated under fifteen minutes saved scenario could be as high as $3,730,000.

4.4 Comparison to Other Studies

Comparisons between this project and other projects are difficult to make because of three factors: (1) There are no toll roads in North Carolina; (2) There are no carpool lanes on I-40; and (3) Construction of additional lanes has decreased congestion on parts of I-40. The other states (with existing toll roads) which have implemented HOT lanes have greater levels of congestion than what is presently found on I-40 in North Carolina. Nonetheless, the paragraphs below compare the results of this study with data from the established projects.

While only 34% of respondents in this study were willing to pay a toll to save time, saving this percentage is in line with responses in other states. Nationally, support for express toll lanes averages 36% (Walton, 2005). Forty-nine percent of the commuters on the Katy QuickRide system in Houston, TX who were surveyed stated they would pay a toll for improving traffic flow conditions (Kalmanje, 2005). Similarly, almost 98% of users of San Diego’s I-15 who were surveyed thought it was a good idea to have a time saving option. Today the Katy system is used by approximately 11% of the commuters. (This estimate was based on daily volume counts at the start and at the end of the roadway during 2001). During the busiest hours, California’s SR-91 HOT lane system carries around 40% of the area’s traffic (FHWA, 2004). Educating the public can improve the public’s perceptions of the value of HOT lanes and value pricing. Once the public understands that the options for relieving congestion are limited, support for HOT lanes increases. In the Washington, DC area, public support of express toll lanes is around 58% without an outreach program; this is considerably higher than the national average (Walton, 2005).

One of the key concerns identified in all of these studies is achieving equity between users and non-users. Most of the projects reviewed agree that all income groups must have the same access to the roadways, although different income groups have different marginal values for a dollar. There was little evidence indicating that commuters from higher income groups would use HOT lanes more often than commuters with lower incomes. (However, higher income individuals state a greater willingness to pay than lower income individuals.) Only the Katy QuickRide system in Houston has significant differences in use across income groups. There, wealthier users tend to use more HOT lanes, but the frequency of use is not income-related. The factors that do affect the likelihood of using QuickRide are the age of the user, the users' educational attainment, and the purpose of the trip (Burris, 2005). The users' income is not a strong determinate of usage of the highways in Orange County, CA (SR-91) or San Diego, CA (I-15). However, commuters in high income groups do use the HOT lanes more (FHWA, 2004). Ethnicity was not a significant predictor of the likelihood of using HOT lanes in any of the programs reviewed.

Table 4.1 below presents a comparison between findings of this study of I-40 in the Triad and those of other projects.

Table 4.1. Comparison among HOT Lane Projects

	SR-91	**I-15**	**I-10 (Katy Highway)**	**Proposed I-40 Value Pricing Project**
Stated willingness to use a HOT lane*	40%	11%	49%	34%
Equity concerns	No	No	Yes	No
Projected or actual revenue per year	$30 M	$2.2 M	$100 K	_
Funds cover capital investments available? (Y/N)	Yes	No	No	No

*Figures for SR-91 and I-15 are based on the current percentage of daily volume while the figures for I-10 and I-40 are based on survey respondents' stated willingness to use the HOT lane.

An aspect that clearly differentiates I-40 in North Carolina from other ongoing programs is the level of congestion. On the other highways, speeds were very low, averaging between fifteen and thirty miles per hour. According to Mark Burris, Associate Professor in the Department of Civil Engineering at Texas A&M University, the Katy Freeway would be totally congested (a level of service below E) for eleven hours a day without the HOT lanes. In contrast, this study found that the self-reported average speed on the I-40 corridors is 47 mph during the morning peak and 44 mph during the evening peak. (See Appendix 4).

According to the *Value Pricing Pilot Program Report* completed in March 2004 by the Federal Highway Administration, there is considerable variation in the revenues generated by different projects. Three examples are presented to show the wide range in the amount of funds collected by various projects (Table 4.1). Houston's Katy Freeway QuickRide program averages only 200 toll-paying vehicles per day, generating approximately $100,000 per year. San Diego's program averages more than 5,000 toll-paying vehicles per day, generating approximately $2.2 million annually. Finally, Orange County's SR 91 program averages around 30,000 toll-paying vehicles per day, generating about $30 million per year.

4.5 Summary Findings of Commuter Survey

The results of the behavioral survey are reasonable and consistent with results from other similar studies. The results presented in this study focus on the willingness-to-pay question, indicating that slightly more than 35% of respondents are willing to pay a toll to save some time during their commute by using a HOT lane while driving alone. While it is recognized that stated preference surveys have validity problems, this number seems reasonable, given the numbers reported in other studies. The results provide a stronger behavioral basis for constructing HOT lanes.

Simulations done by the researchers at the UNC-Chapel Hill used EXCEL models to predict commuters' willingness to pay. The results suggest that revenues of less than one million dollars per year could be expected. Using reasonable bounds, the estimated yearly revenues for an eight-minute time savings range between $120,000 and $620,000. Note that this is only if a HOT lane was installed on a relatively small portion of the entire study area (a 6.6 mile inter-city corridor). It is highly unlikely that these revenues would cover the full capital expenses of installing the HOT lane(s). However, at least part of the operating expenses would be recovered.

The amount recovered would depend on the choice of technology for toll collection and enforcement.

Depending upon revenues generated, different stages of a program can be financed. Houston's QuickRide funds only cover operational costs. The $2.2 million generated per year by San Diego's program cover operation costs of the current project and for some operating subsidy of the express bus service along the corridor. Last, the revenues from the SR 91 in Orange County, CA are sufficient to cover operating costs and for paying debt service charges on bonds used to finance the purchase of the project from a private operator.

4.6 Stakeholder Survey

The stakeholder survey was targeted to community leaders in Piedmont Triad, including elected officials, religious leaders, and CEOs of medium and large corporations, to explore their opinions toward managed lanes. A letter to the stakeholders and the questionnaire were distributed to 240 people in the middle of September 2003.

The stakeholders reported that they came from organizations which had an average of 884 members and they were familiar with transportation problems in the region but only 20 % were actively involved with transportation issues. Stakehoders' rating of the concept in the Triad is summarized in Table A7 4. Approximately as many leaders favor the concept as are neutral or opposed to it and that this is the same for all the different leadership groups ($\chi^2 = 1.11$, $p>.05$). Similar results were seen for "rate the "highway lane management" concept in Table A7 3 and "the potential usefulness of this concept" in Table A7 5.

5. SUMMARY OF FINDINGS AND IMPLICATIONS

5.1 Overall Findings

Three different ways of using HOT lanes have been reviewed for their suitability for use on I-40 in the study area. However, in the immediate future, the recent widening of I-40 in corridor 3B relieves congestion there. When additional capacity is needed, the first alternative is to build an additional lane in both directions for the length of corridor 3B. Building a new lane the entire length of the corridor would be very expensive. The costs of installing a new lane could be excessive because the amount of available land for its construction is very limited in some locations in this corridor.

The original HOT lanes in Houston and San Diego and the new lanes in Minneapolis changed the use of HOV lanes by allowing SOVs to use them for a fee. These original HOT lanes are about the same length as the new lane proposed for I-40 in the Triad. The percentage of people who initially supported the original HOT lanes and the percentage who would support their use in the Triad are similar.

The second alternative is to utilize the new lanes that have just been constructed (from the I-40/Business 40 split to the Hwy 68 exit) and add an additional lane in each direction from the remaining part of corridor 3B. Since the North Carolina General Assembly bill G.S. 20-146.2 states that only new lanes may be designated as HOV lanes, this option will require new legislation to allow the acquisition of an existing lane to become either a high occupancy vehicle lane or high occupancy toll lane.

The final alternative is to implement a reversible lane where the direction of flow would be determined by the level of peak hour traffic. Even though the increase in the number of lanes on I-40 has temporarily reduced congestion, those additional lanes will not have the same impact in 2015. In that year the traffic on sections of I-40 is projected to reach an LOS D. As residential and commercial development increases, so will the number of people with a need to travel.

A reversible lane would reduce the amount of space needed to implement the HOT lane. With this option a lane would be installed in the middle of the right of way. A concrete jersey wall would separate oncoming traffic. Daily procedures would reverse the position of the barriers to allow alternate flow of traffic.

5.2 Cost Estimates

The costs of construction vary for each alternative presented. The presence of curbs, pipes, drainage facilities, bridges, and ramps have a substantial influence on overall project cost. Projected costs in the study area vary from low, to medium, and to high depending upon factors such as median and shoulder width, the presence or absence of structures, these other costs and lane size. The estimated cost of constructing a single reversible lane ranges from \$5,000,000 to \$6,000,000 per mile. For Corridor 3B, the total cost would be between \$32,500,000 and \$39,000,000. The estimated cost would double if two lanes (one in each direction) were constructed (\$65,000,000 to \$78,000,000. Additional funds would be needed to pay for enforcement and toll collection.

5.3 Legislation

In 2002, North Carolina created a toll authority. Tolls may be collected on new highways for which traditional funding is not available. The highways must be in highly congested areas and there must be a free alternative. All vehicles would pay the toll and the revenue will be used to pay for the road and its supporting infrastructure. Currently, HOT lanes are not included.

New legislation defining enforcement and collection procedures is needed. The Legislature's choice of enforcement (video monitoring systems and/or systems relying on humans), will determine the operating procedures. HOT lanes which are physically separated from regular lanes require additional enforcement because of the barriers to access from the regular lanes. Tolls can be collected by automatic toll stations or by an electronic payment system. Toll fees could vary with the flow of traffic or the time of day. Legislation also is needed to regulate where the collected funds will be allocated.

5.4 Final Implications

The facts identified by this study are:

- Recently, some congestion has been reduced by the construction of additional lanes for I-40 in Greensboro. Delays in this area are not as long as they were when the study began. In other segments of study area, however, congestion remains high and is expected to increase substantially in the future.
- Traffic congestion and the resulting delays will increase with economic and population growth. The shipments from the new FEDEX hub and Dell plant may increase the number of trucks using one of the busiest parts of I-40 (Corridor 3).

- Nearly 35% of regular commuters on I-40 were willing to pay to reduce their commuting time. The amount each individual is willing to pay increases in direct proportion to income. Long distance travelers were not surveyed. They may form an important constituency that needs further investigation.

Although there is opposition to tolls by some consumers and stakeholders, the literature shows a growth in popularity after an outreach program once HOT lanes are started. There is support by a percentage of users that is similar to other studies.

Our premise is that HOT lanes will save commuters enough time that they will be motivated to rideshare. Ultimately, these managed lanes are likely to save commuters' time, increase the number of people using the highway, and reduce congestion, fossil fuel emissions, and total energy use. Several important advantages of managed lanes have been highlighted as have the disadvantages. For future studies, it is important to note the following needs.

- The data on traffic provided by NCDOT was collected on an hourly basis. This might obscure peaks in congestion. Data collected at fifteen minute intervals is preferable because congestion can vary substantially over short time intervals. Additional data collection that covers all periods of congestion is recommended.
- The I-40 corridor is vital artery for North Carolina, one that traverses the entire state. It carries a substantial amount of long distance, through traffic. The characteristics of this group of travelers were not examined. However, a more detailed understanding of long distance, through travelers will be important in any future study.

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Appendix 1

Baseline and Forecasted Conditions

Identification of Corridors

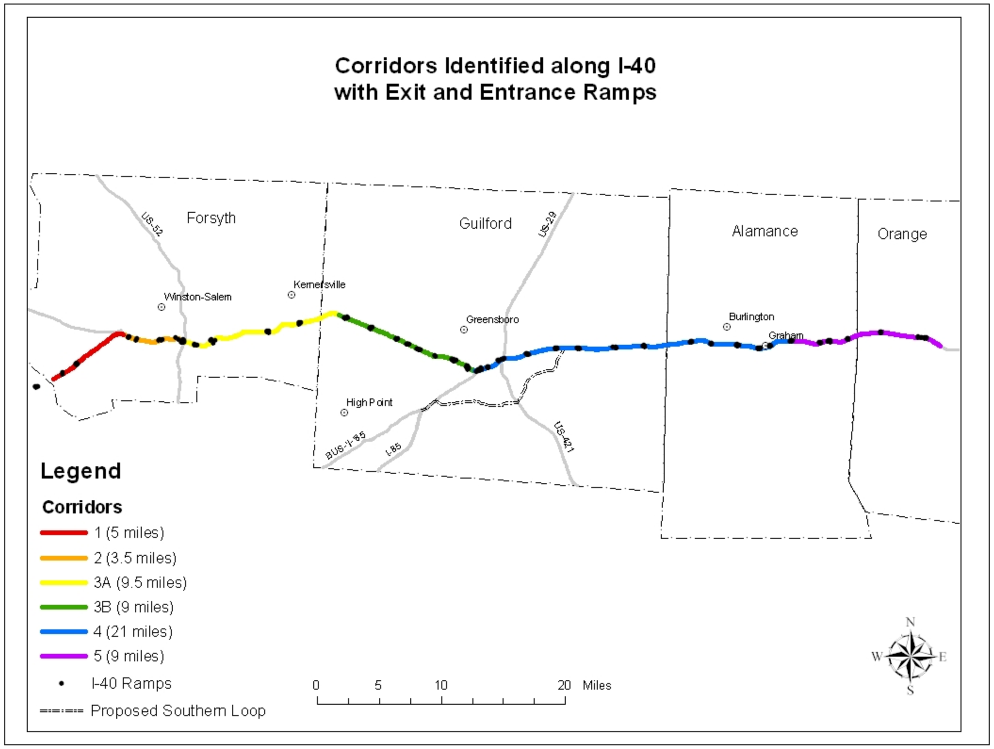


Figure 1: This map shows the locations and lengths of the six corridors of the I-40 area of study.

Corridor ID	Segment Length (miles)	Time needed to Travel Corridor (in minutes)					Average Speed for Corridor (in miles per hour)				
		Free-flow	Eastbound Morning	Westbound Evening	Westbound Morning	Eastbound Evening	Free-flow	Eastbound Morning	Westbound Evening	Westbound Morning	Eastbound Evening
1	5.0	4.7	4.7	4.7	4.7	4.7	65.3	65.3	65.3	65.3	65.3
2	3.5	3.4	3.4	**3.8**	3.4	**3.5**	63.3	**63.1**	**55.7**	**62.9**	**62.2**
3A	9.6	9.0	**9.2**	**9.1**	9.0	9.0	64.2	**63.0**	**63.6**	64.2	64.2
3B	9.2	8.5	**10.2**	**9.2**	8.5	**8.6**	65.0	**56.5**	**61.1**	65.0	65.0
4	20.9	18.8	18.8	18.9	18.9	18.8	66.0	66.0	65.5	65.5	66.0
5	9.2	8.2	8.2	8.2	8.2	8.2	66.4	66.4	66.4	66.4	66.4

Figure 2: The table above shows the time needed to travel each corridor in minutes, as well as the average speed traveled for each peak-hour in both directions. The data for free-flow speed is used as a comparison. The data highlighted correspond to levels of service, where yellow signifies LOS D and orange stands for LOS E.

LOS Current Conditions

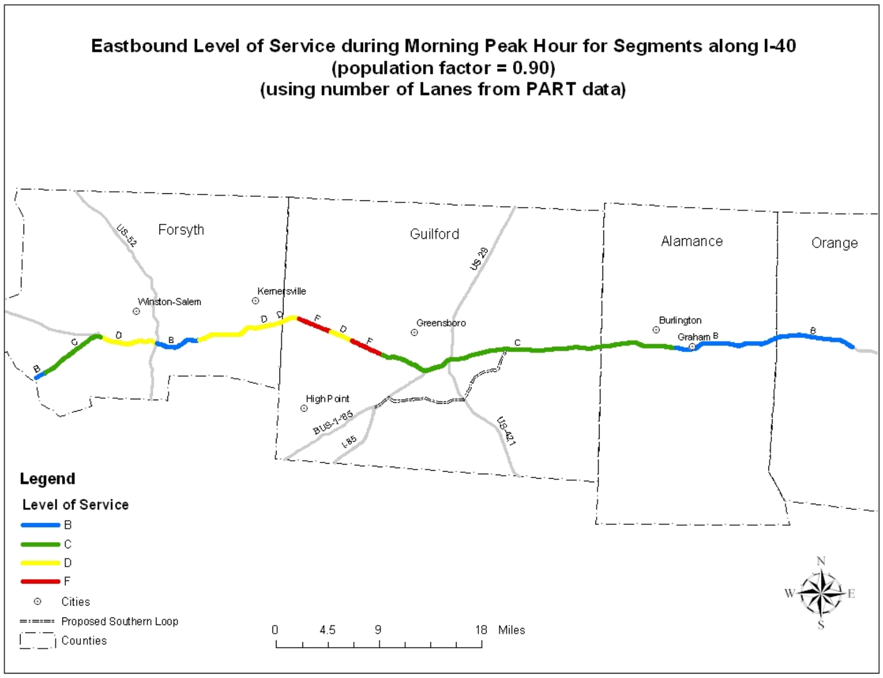


Figure 3: The critical areas during the eastbound-morning peak-hour are Corridors 1 and 2 which appear in yellow and red on the map above.

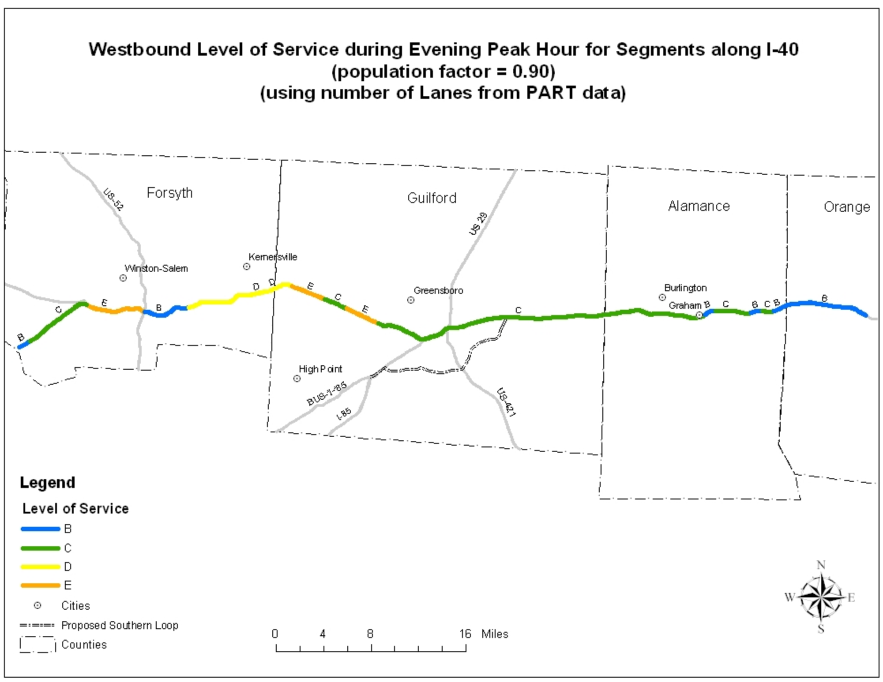


Figure 4: LOS in the westbound-evening peak-hour shows the same critical areas as the eastbound-morning peak-hour. Corridor 3 only faces a low level of service during these two time periods, and thus would be a possible location for a reversible HOT lane.

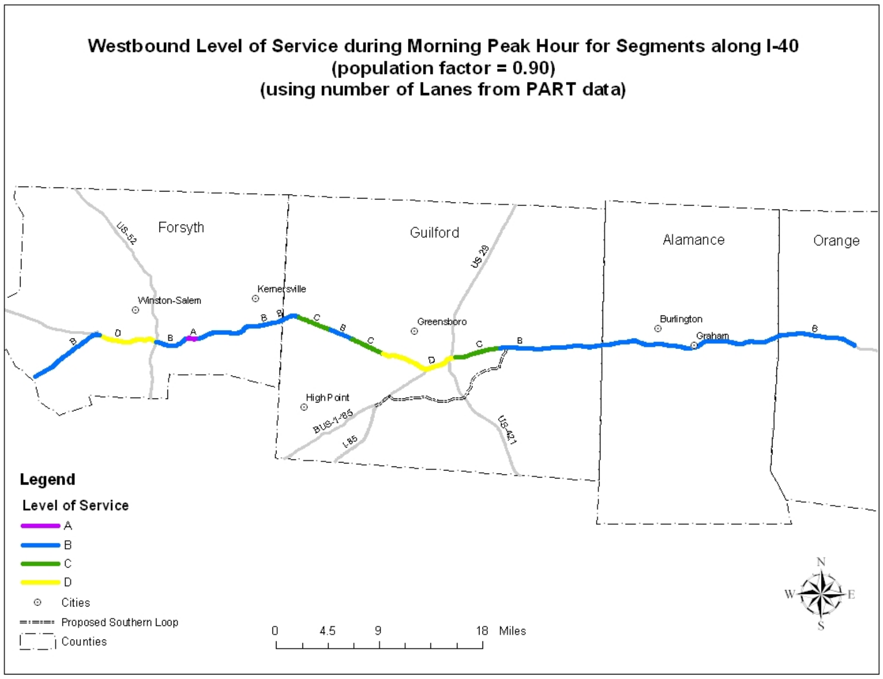


Figure 5: Critical areas appear near Winston-Salem and near Greensboro during the westbound morning peak-hour.

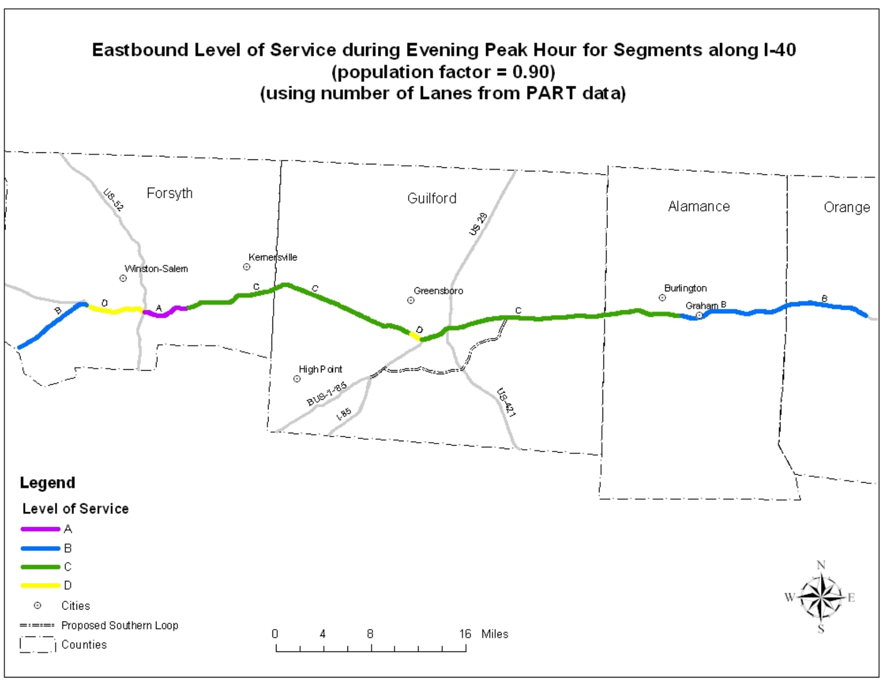


Figure 6: LOS D appears near Winston-Salem and near Greensboro. Corridor 2 near Winston-Salem has LOS ‘D’ for both peak-hours, regardless of direction. This indicates that HOT lanes running in both directions would be needed here, as opposed to a reversible lane.

Volume to Capacity (v/c)

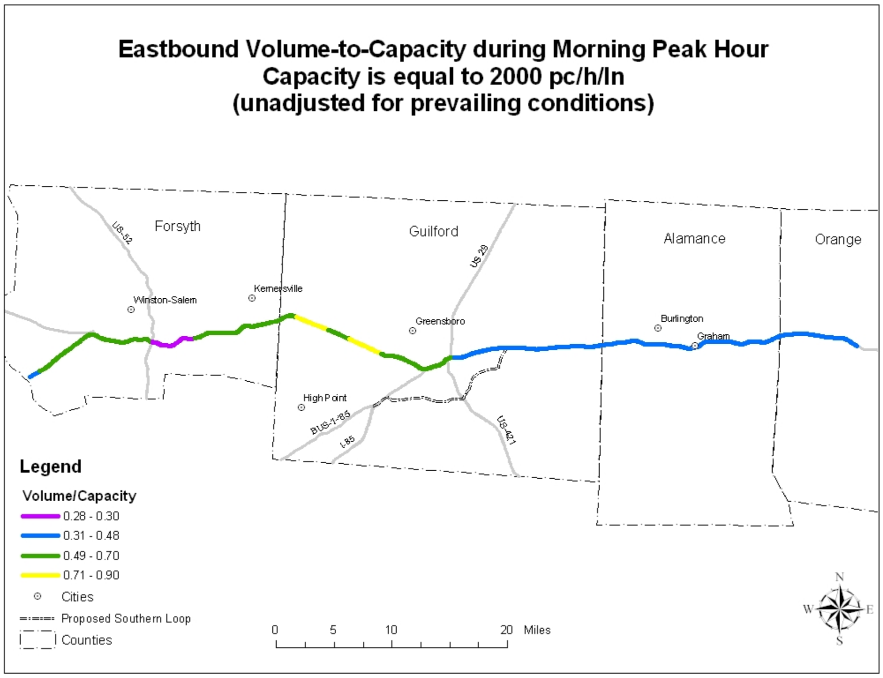


Figure 7: The highest volume to capacity ratios appear in Corridor 3.

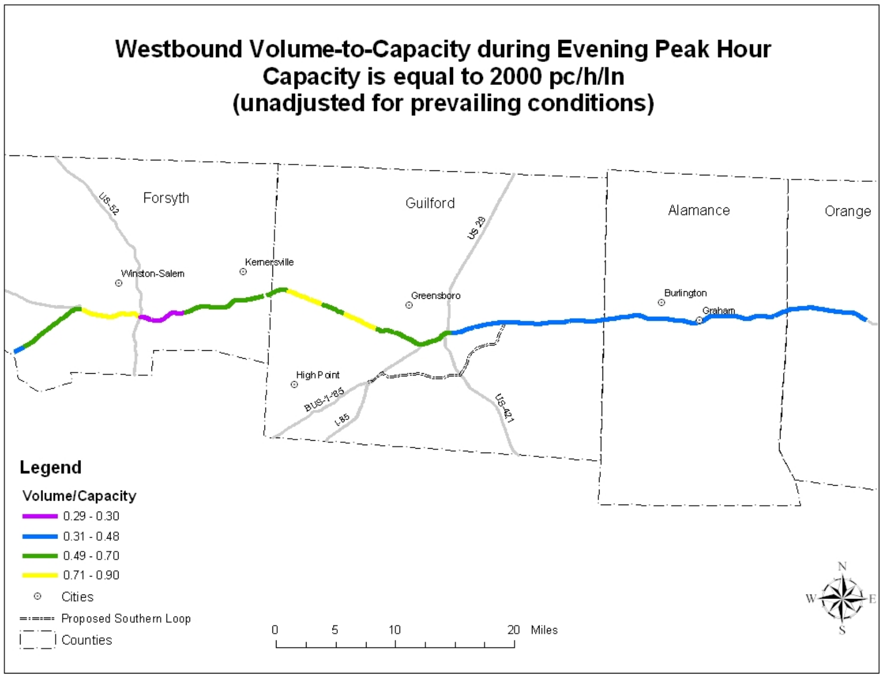


Figure 8: The highest volume to capacity ratios appear in Corridors 1 and 3. Corridor 1 shows further congestion compared to the eastbound-morning peak hour.

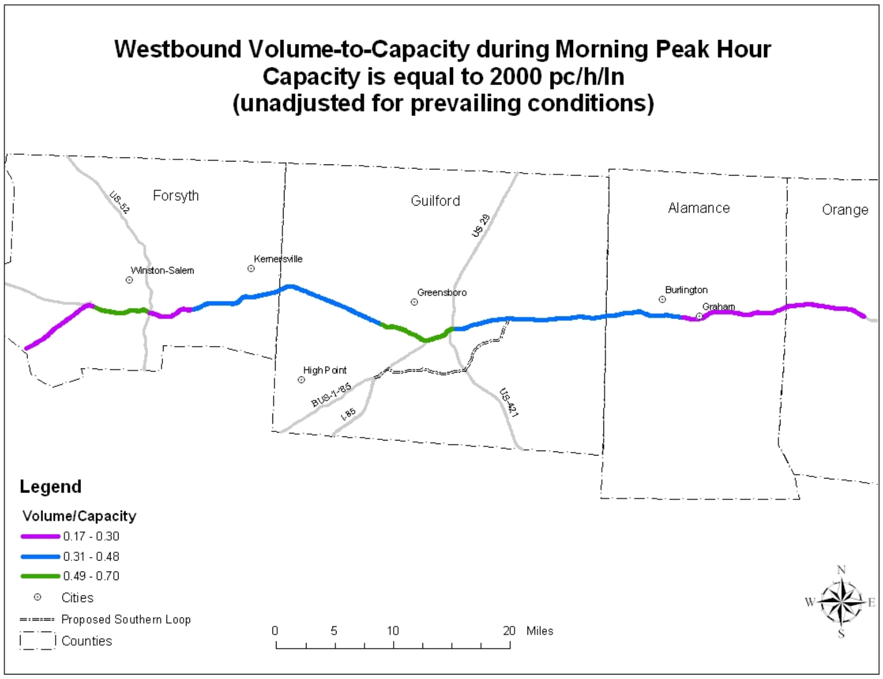


Figure 9: The highest volume-to-capacity ratio occurs near Winston-Salem and near Greensboro.

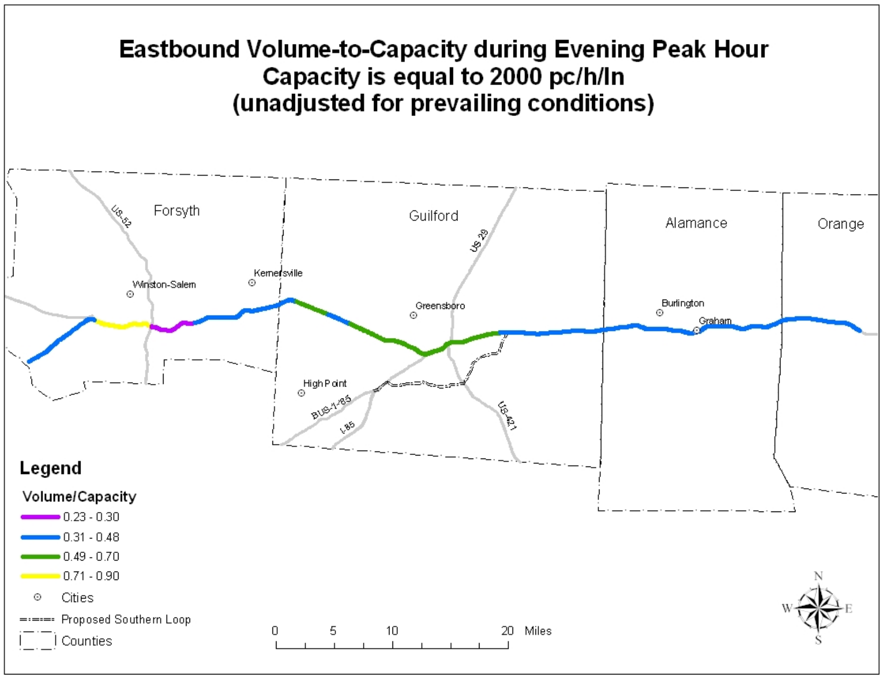


Figure 10: The volume-to-capacity ratio increases near Winston-Salem and between Kernersville and Greensboro as compared to the westbound-morning peak-hour.

Right of Way Characteristics

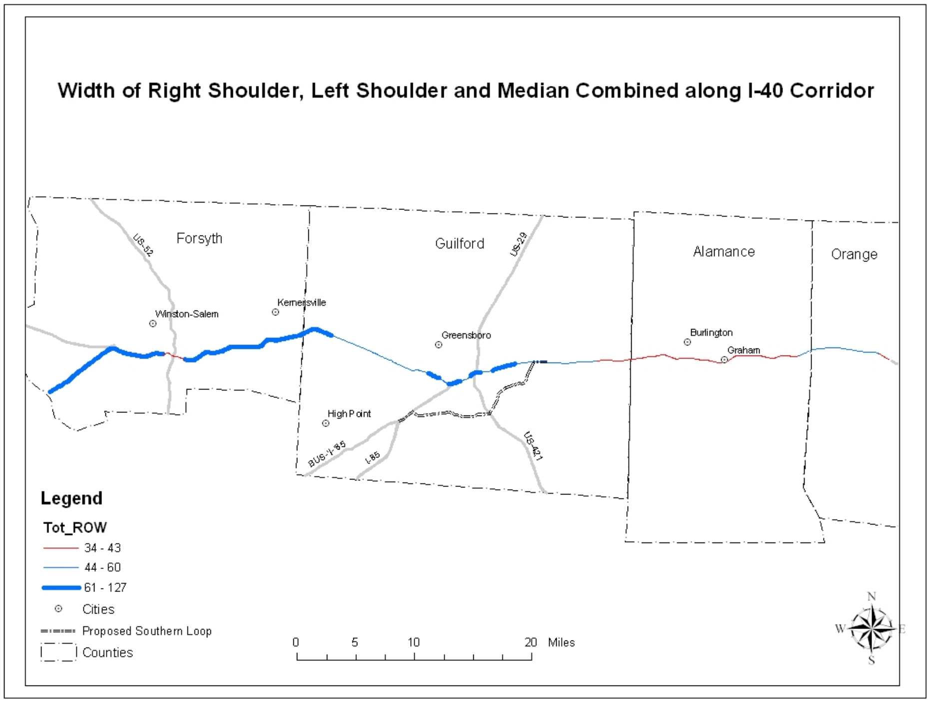


Figure 11: This map shows segments along I-40 by total right of way. The areas in blue represent segments that have more than 44 feet of total right-of-way, which is the desirable width of two reversible HOT lanes.

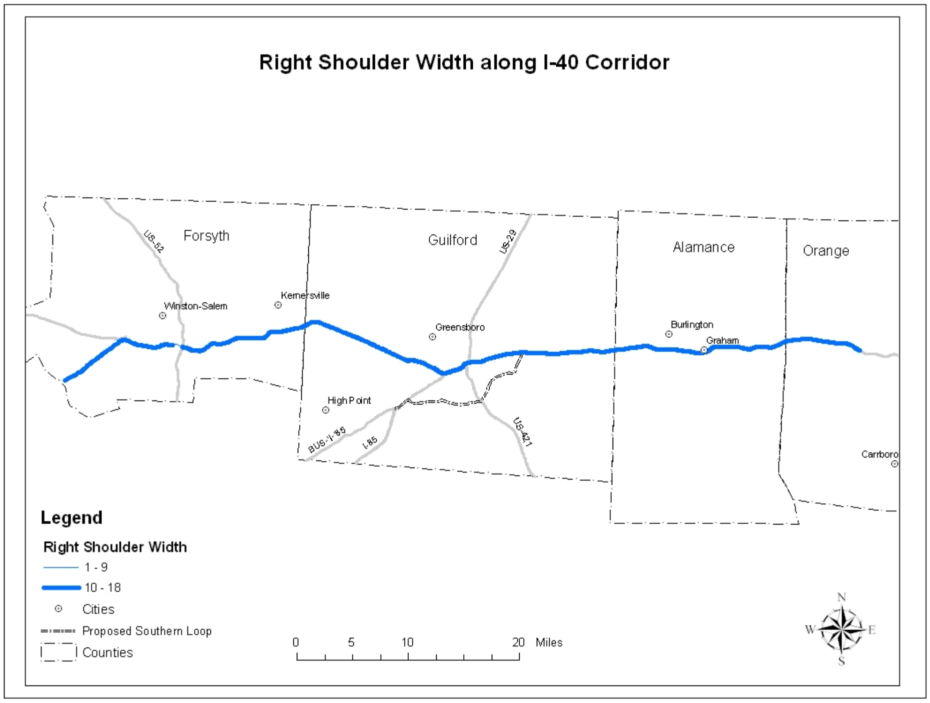


Figure 12: This map shows that throughout our study area, right-shoulder clearance is greater than ten feet at all locations except near US-52 in Winston-Salem, where the width is one foot.

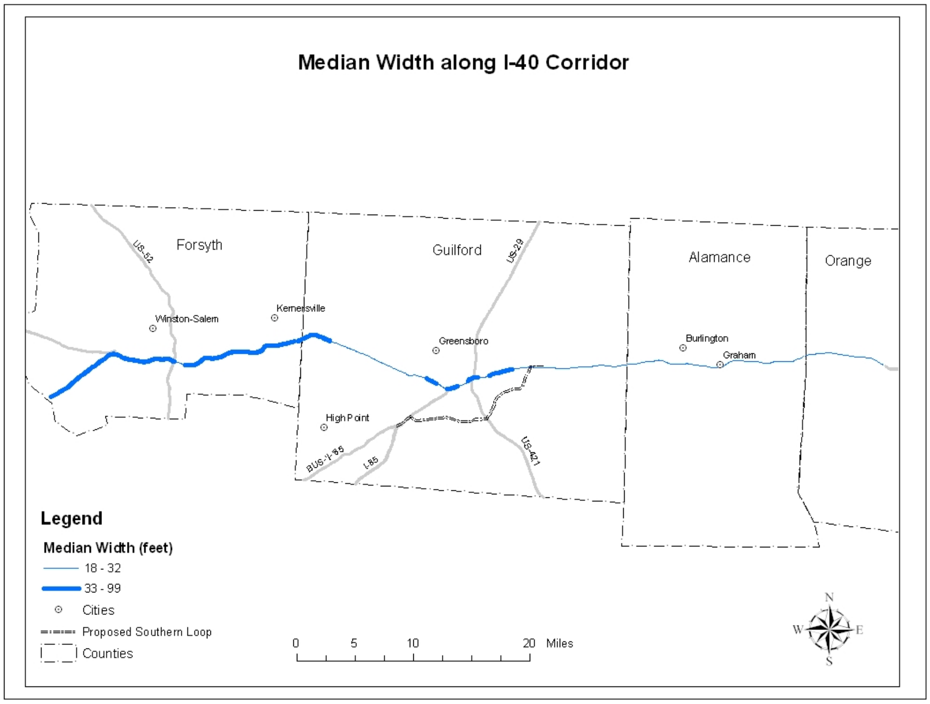


Figure 13: This map shows the range of median widths of segments on the I-40 corridor. The median is the least expensive place to construct a HOV/HOT facility. A wide median exists from the western part of the study area to Kernersville, and in places near Greensboro.

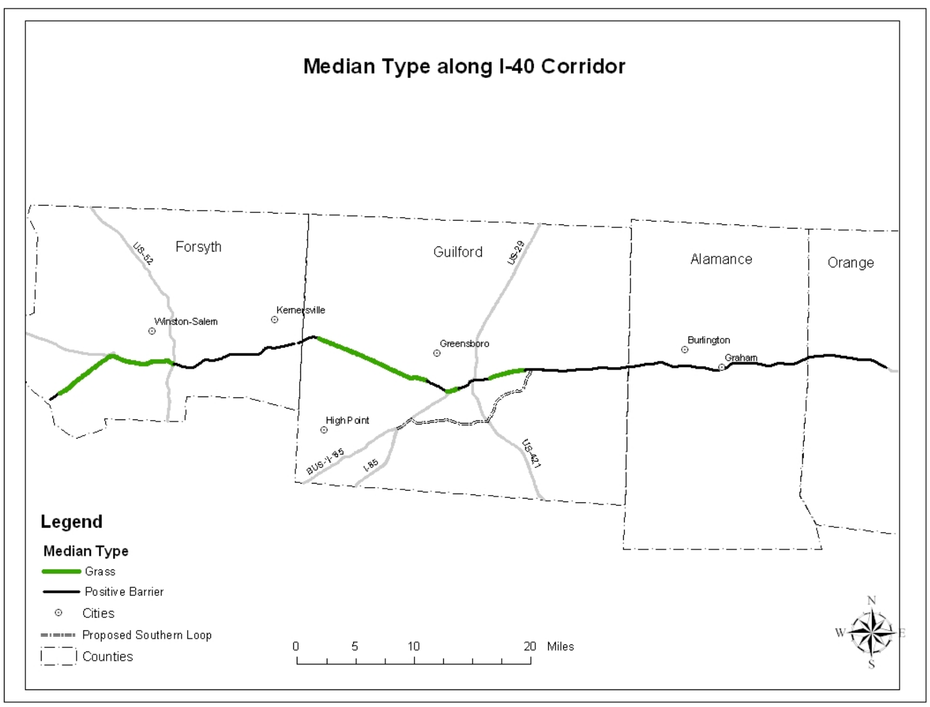


Figure 14: This map shows the location of either grass medians or positive barriers throughout the study area.

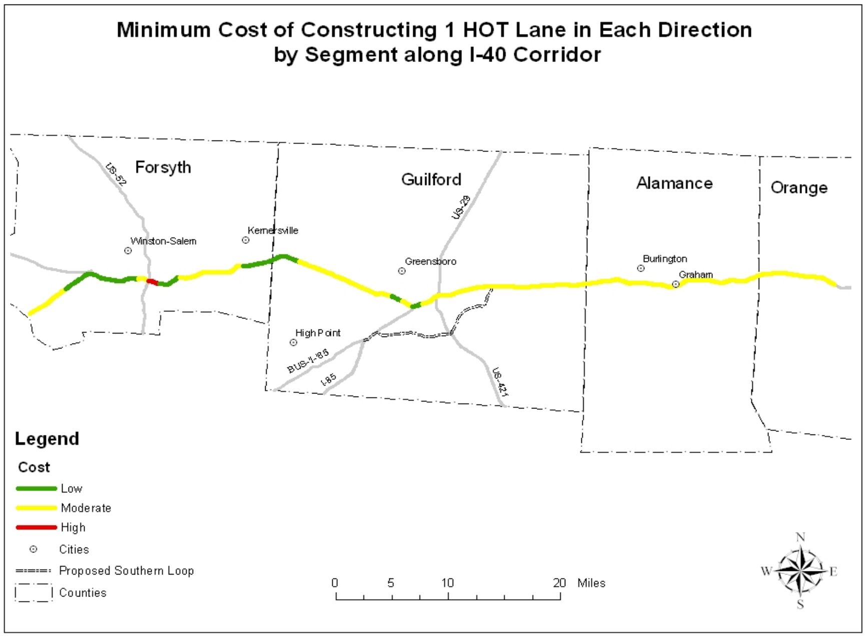


Figure 15: The map shows the estimated cost of constructing one HOT lane in each direction. A low cost means the lanes could be constructed in the median. A moderate cost means the lanes could be constructed in the combined right-of-way of the median and right shoulder. A high cost means that some obstruction (e.g. a bridge) would make constructing the HOT facility more costly. Please note that in the areas we recommend a reversible lane (Corridor 3), the costs suggested by this figure are about twice as high as they will be, should only one lane be constructed.

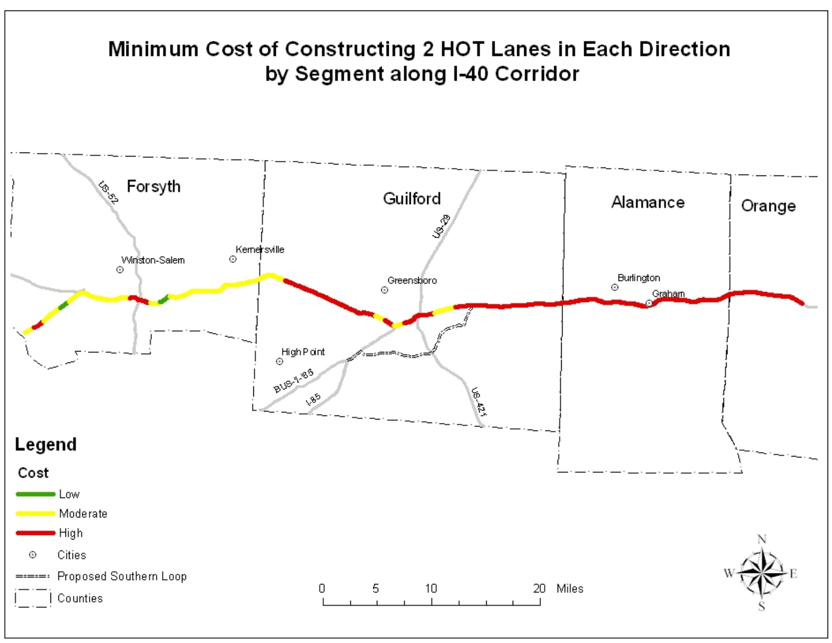


Figure 16: The map shows the estimated cost of constructing two HOT lanes in each direction. Comparatively, the lowest costs occur at Corridors 1, 2 and the first half of 3.

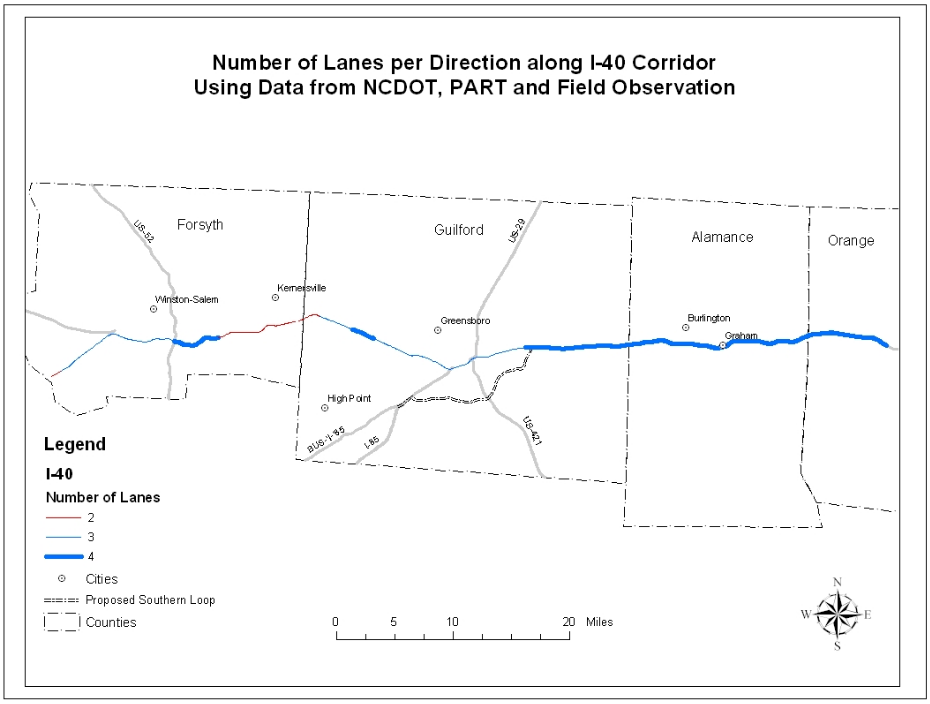


Figure 17: The following map shows the number of lanes of each segment along I-40. The segment between Winston-Salem and Kernersville and a small segment at the western end of the study area have only 2 lanes in each direction.

Peaking Patterns

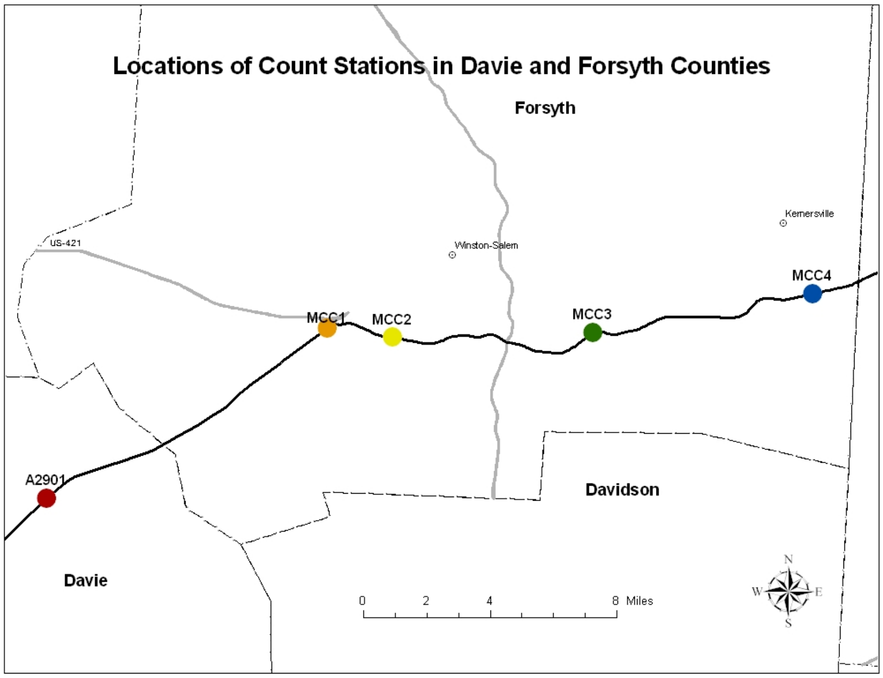


Figure 18: This map shows the locations of count stations where our data is taken from in Davie and Forsyth Counties. The colors coordinate with the graph below.

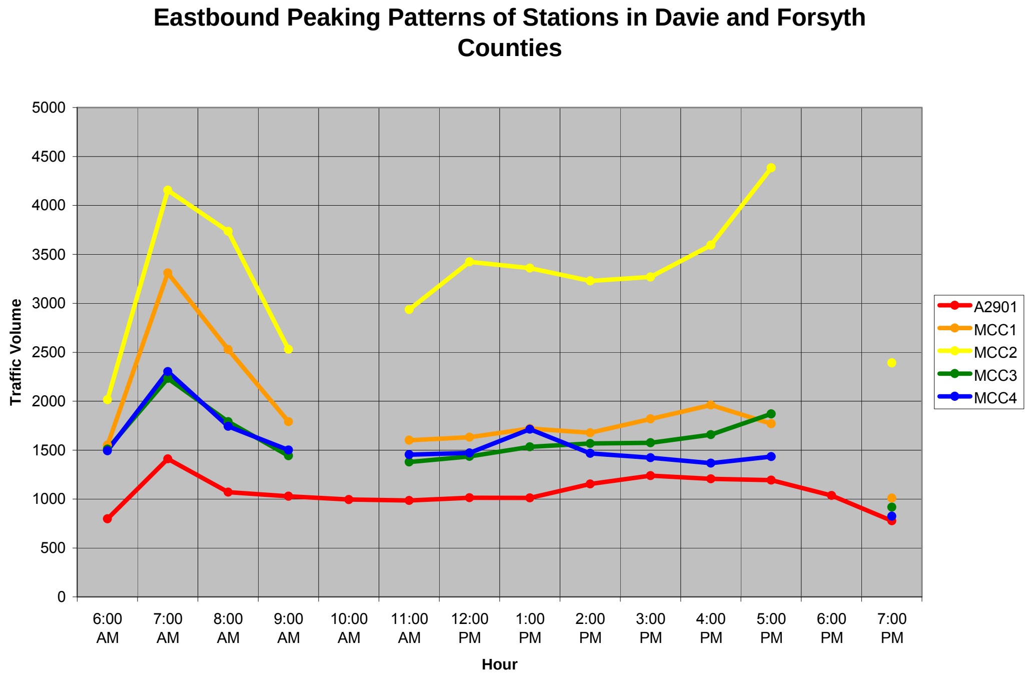


Figure 19: The graph shows peaking patterns at count stations in Davie and Forsyth Counties. Manual Classification Counts have missing data for the 10:00AM and 6:00PM peak-hours. The graph indicates a higher count of traffic in the morning hours than in the evening for eastbound traffic.

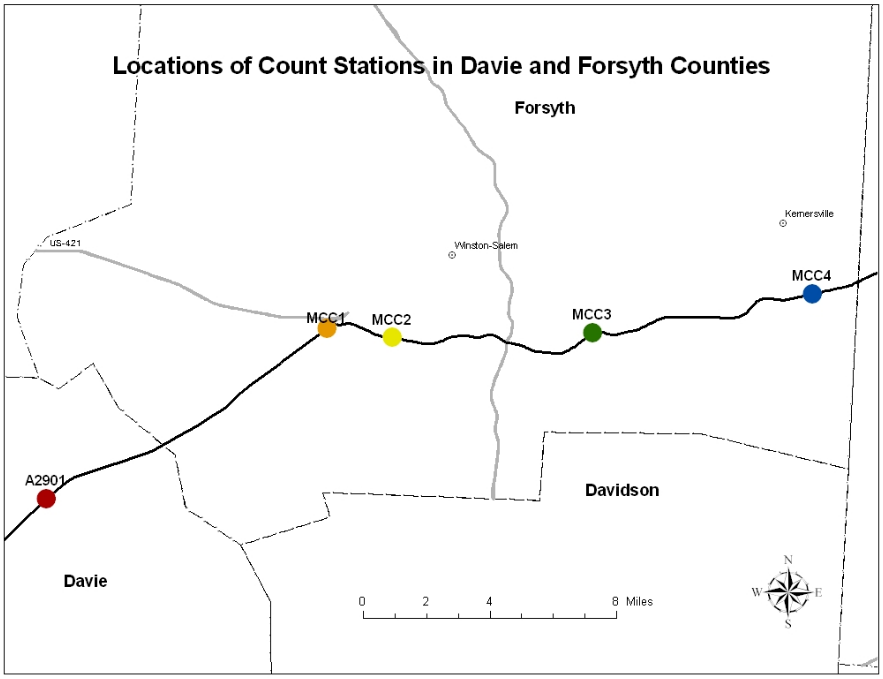


Figure 20: The map shows the locations of count stations where our data is taken from in Davie and Forsyth Counties. The colors coordinate with the graph below.

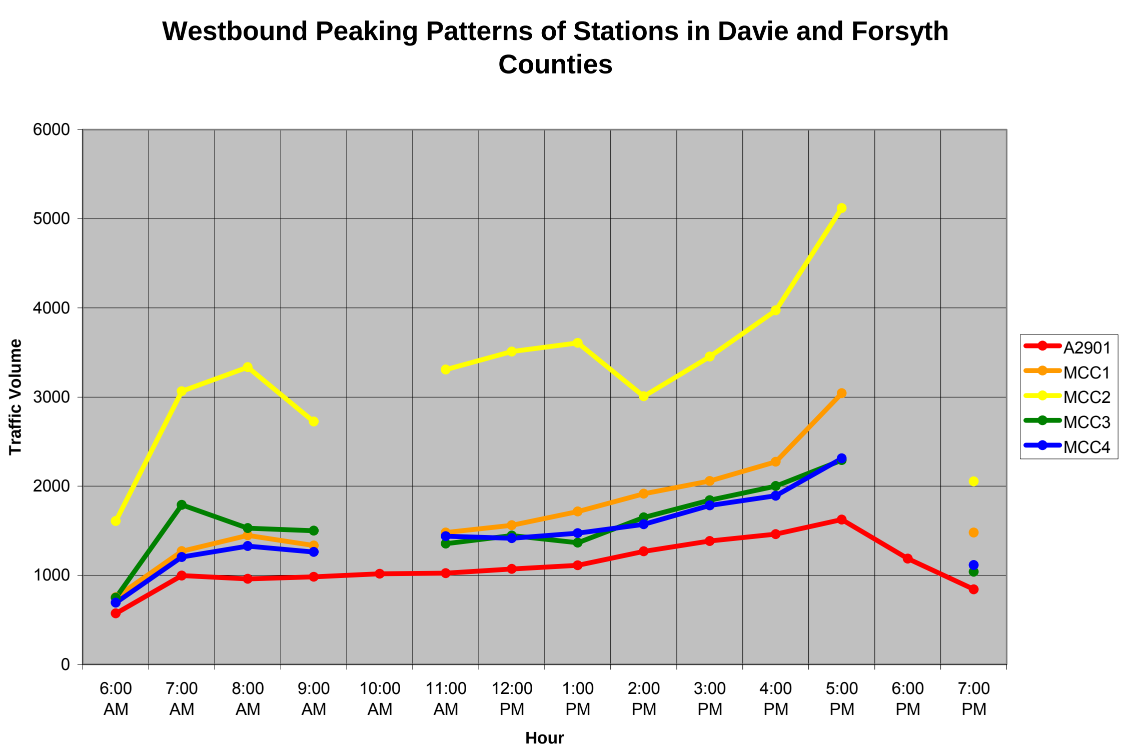


Figure 21: This graph indicates a higher flow of vehicles in the evening headed westbound than in the morning in Davie and Forsyth Counties.

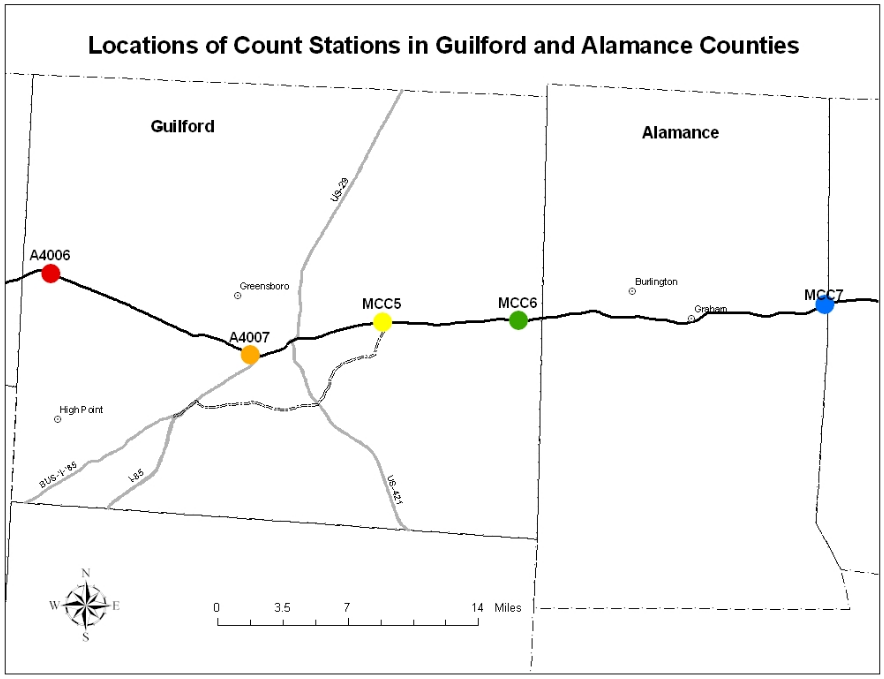


Figure 22: The map shows the locations of count stations in Guilford and Alamance Counties where data was taken. The points are color coded to match the graph below.

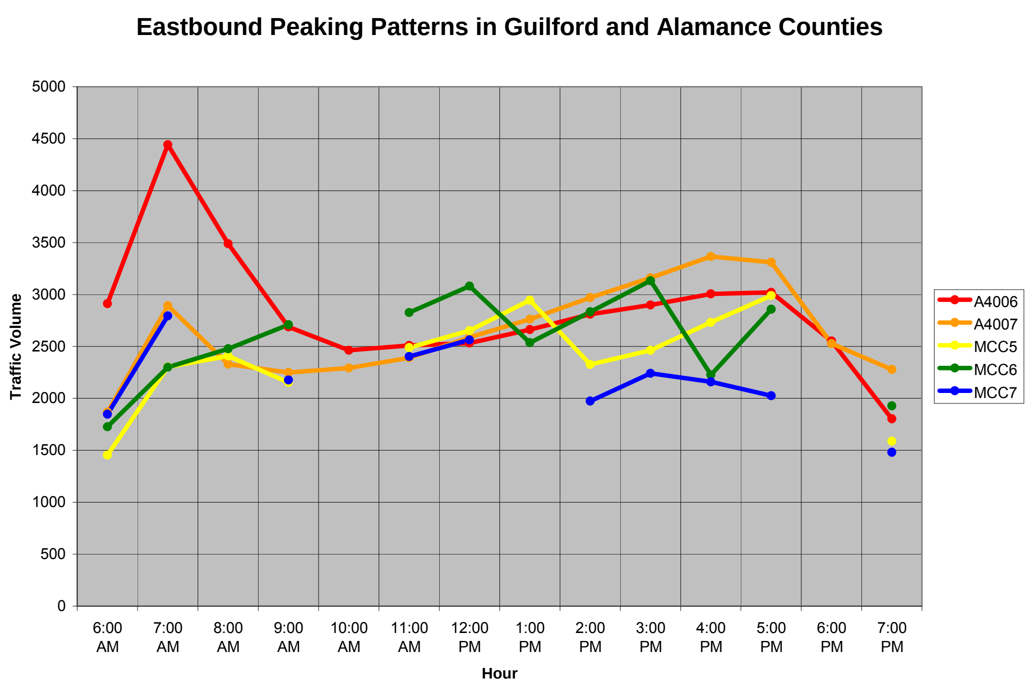


Figure 23: The graph shows the largest peak during the morning peak-hour for the count station located to the west of Greensboro. This count station is near the center of the critical Corridor 3.

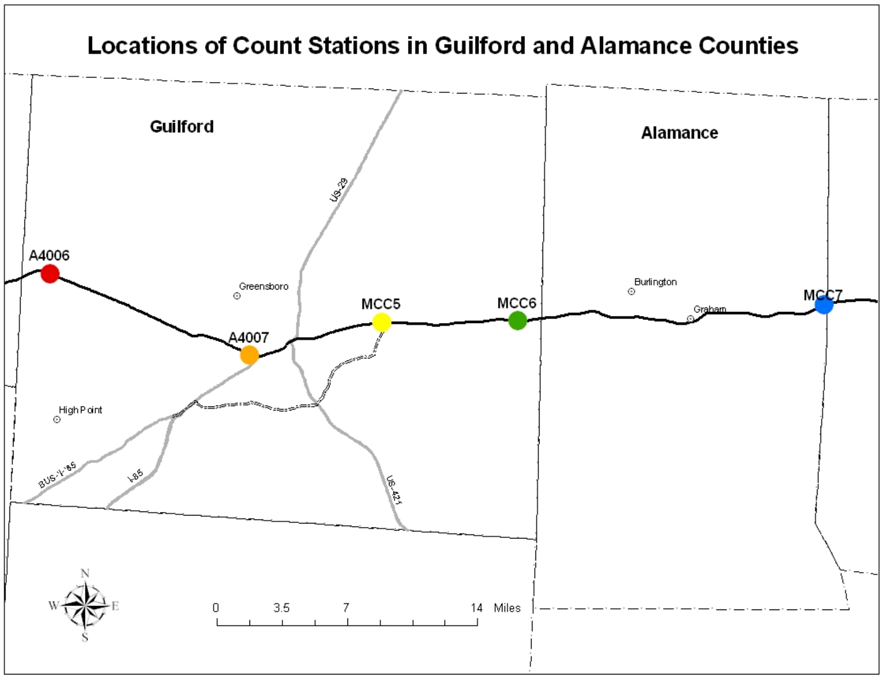


Figure 24: The map shows the locations of count stations in Guilford and Alamance Counties where data was taken. The points are color coded to match the graph below.

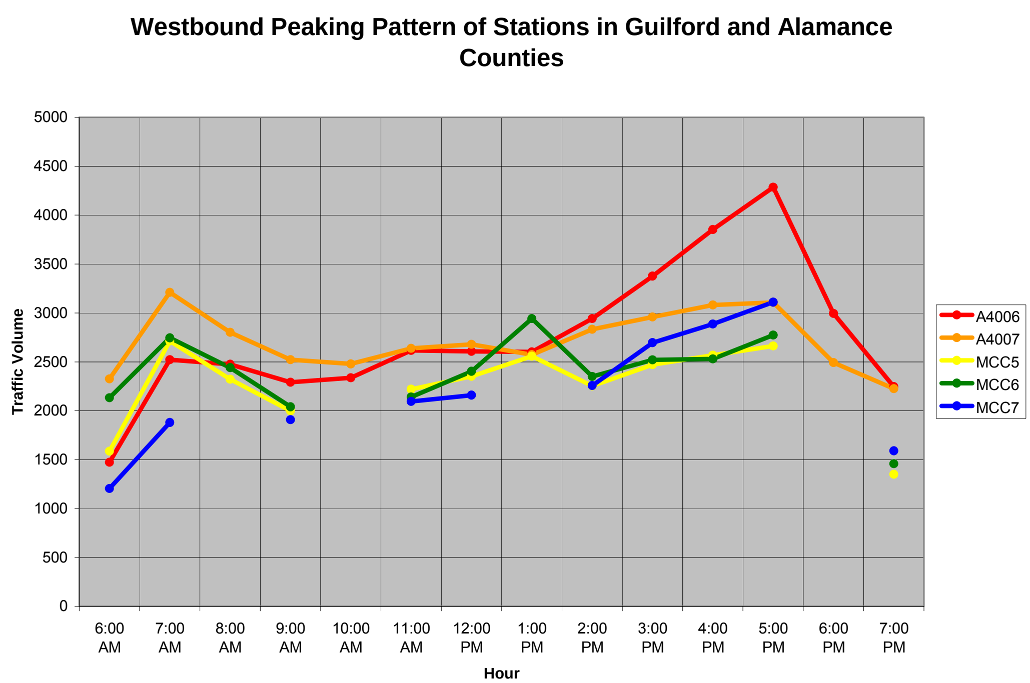


Figure 25: This graph shows a high evening peak for the count station west of Greensboro. This unbalanced peaking pattern also represents our critical area at Corridor 3.

Appendix 1

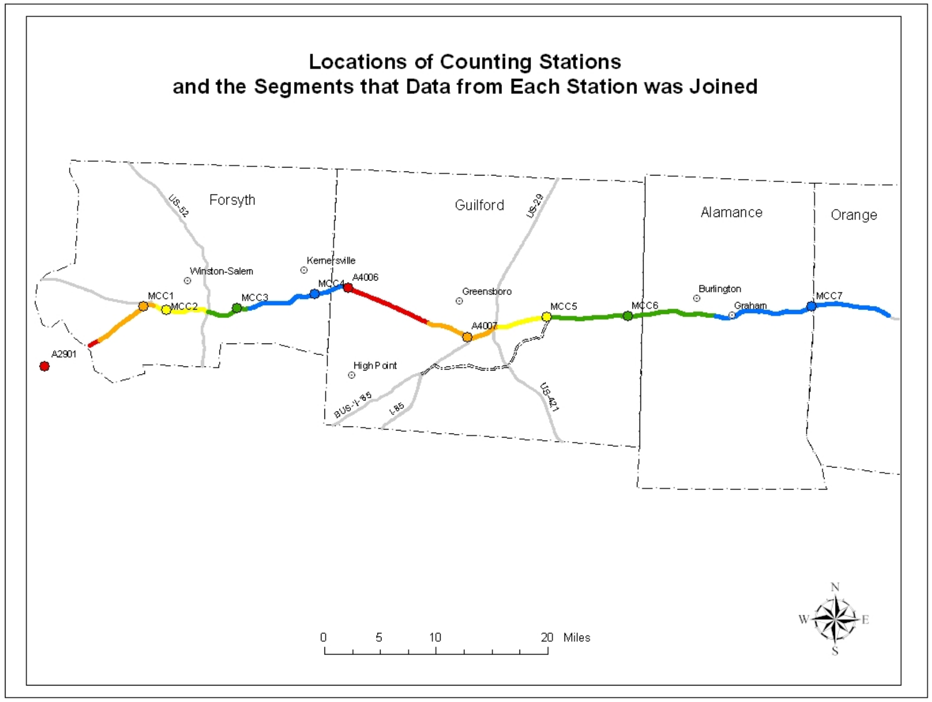


Figure 26: This map shows the location of the count stations where we obtained data for calculating LOS and the segments that correspond to this data.

Count Station ID	Segment Length (miles)	Time needed to Travel Segment (in minutes)					Average Speed for Segment (in miles per hour)				
		Free-flow	Eastbound Morning	Westbound Evening	Westbound Morning	Eastbound Evening	Free-flow	Eastbound Morning	Westbound Evening	Westbound Morning	Eastbound Evening
1	0.65	0.6	0.6	0.6	0.6	0.6	63.8	63.8	63.8	63.8	63.8
2	4.36	4.1	4.1	4.1	4.1	4.1	65.4	65.4	65.4	65.4	65.4
3	3.51	3.4	3.4	**3.8**	3.4	3.5	63.1	63.0	**55.5**	62.7	62.1
4	1.98	1.8	1.8	1.8	1.8	1.8	66.7	66.7	66.7	66.7	66.7
5	7.59	7.2	7.4	7.3	7.2	7.2	63.8	62.3	63.1	63.8	63.8
6	6.59	5.9	**7.6**	**6.6**	5.9	6.0	65.4	**53.6**	**60.0**	65.4	65.4
7	4.45	4.3	4.3	4.3	4.3	4.3	63.1	63.1	63.1	63.0	63.1
8	3.32	3.1	3.1	3.1	3.1	3.1	65.3	65.3	65.3	65.3	65.3
9	14.15	12.6	12.6	12.7	12.7	12.6	66.8	66.8	66.0	66.0	66.8
10	10.75	9.6	9.6	9.6	9.6	9.6	66.5	66.5	66.5	66.5	66.5

Figure 27: The table above shows the time needed to travel each segment and the average speed for each segment for differing peak hours and directions. The free-flow speed data is also provided to make comparisons. The critical area is at Count Station 6, which corresponds with our critical area, Corridor 3.

Percent of Flow is Trucks during the Peak

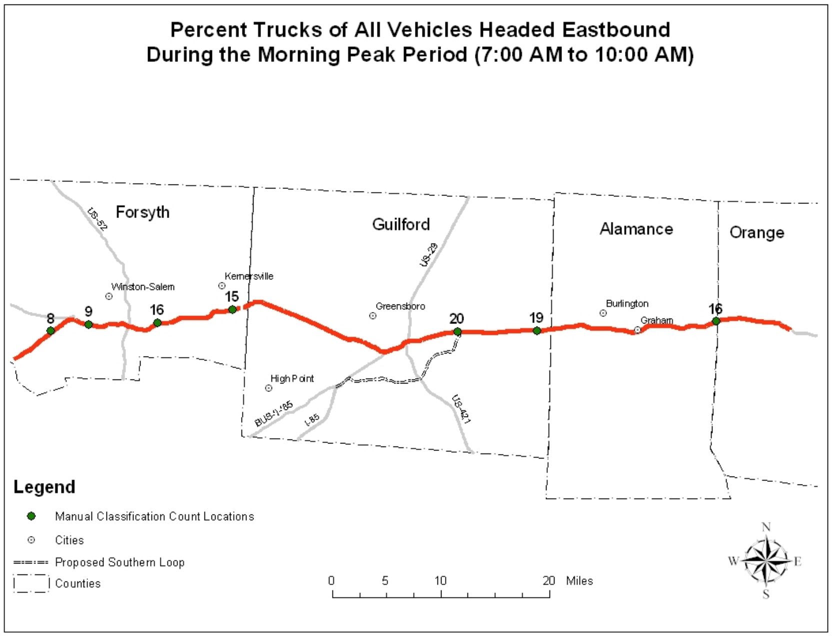


Figure 28: The percent of trucks to all vehicles ranges from 15-20 percent during the morning peak hour headed eastbound for segments east of US-52 near Winston-Salem.

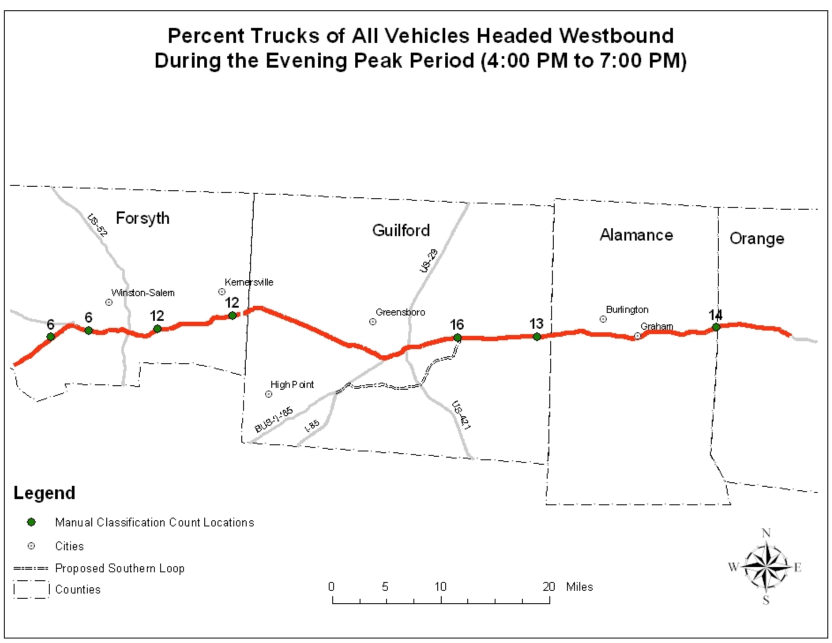


Figure 29: The percentage of trucks to all vehicles declines in the evening.

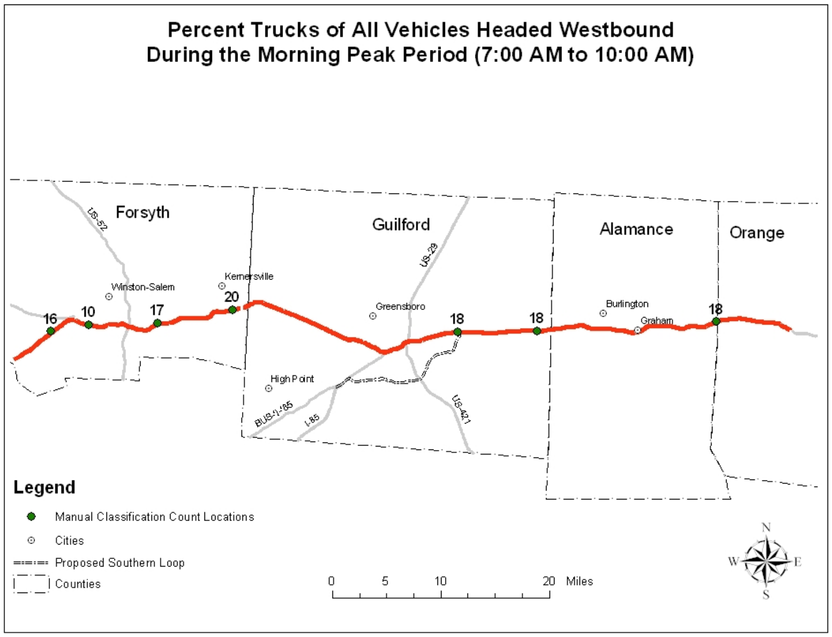


Figure 30: The percent of trucks to all vehicles ranges from 16 to 20 percent east for all segments except corridor 1 in Winston-Salem.

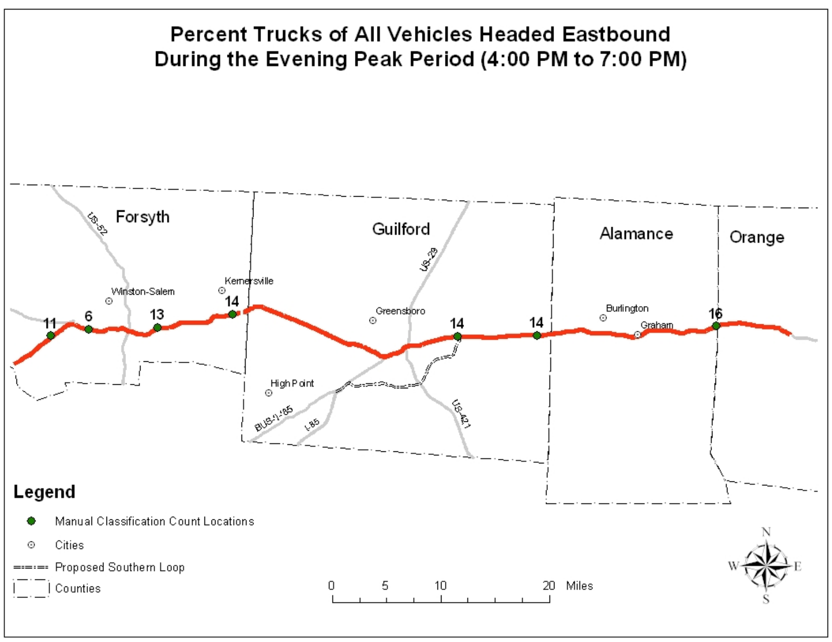


Figure 31: Similar to the other peak periods, truck traffic decreases during the eastbound-evening peak period as compared to the westbound-morning peak period.

Daily Ramp Counts

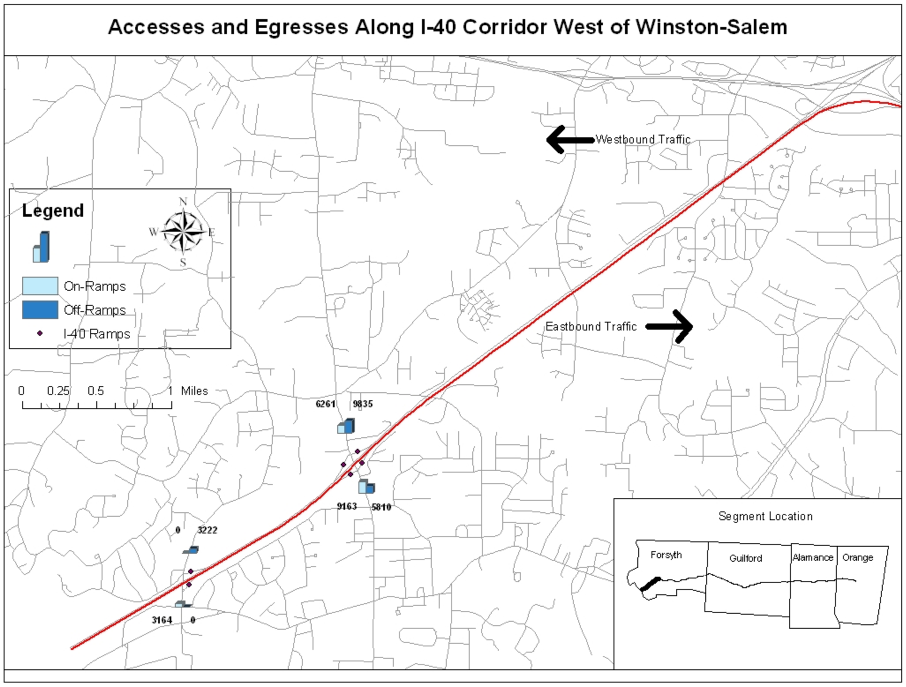


Figure 32: Daily ramp counts show the number of movements by accesses and egresses in both the eastbound and westbound directions per day for each exit on the I-40 study area. The entire length of I-40 was divided into six segments to show ramps by their proximity to cities. Data for the US-421/I-40 intersection was not provided. This segment spans approximately seven miles west of Winston-Salem.

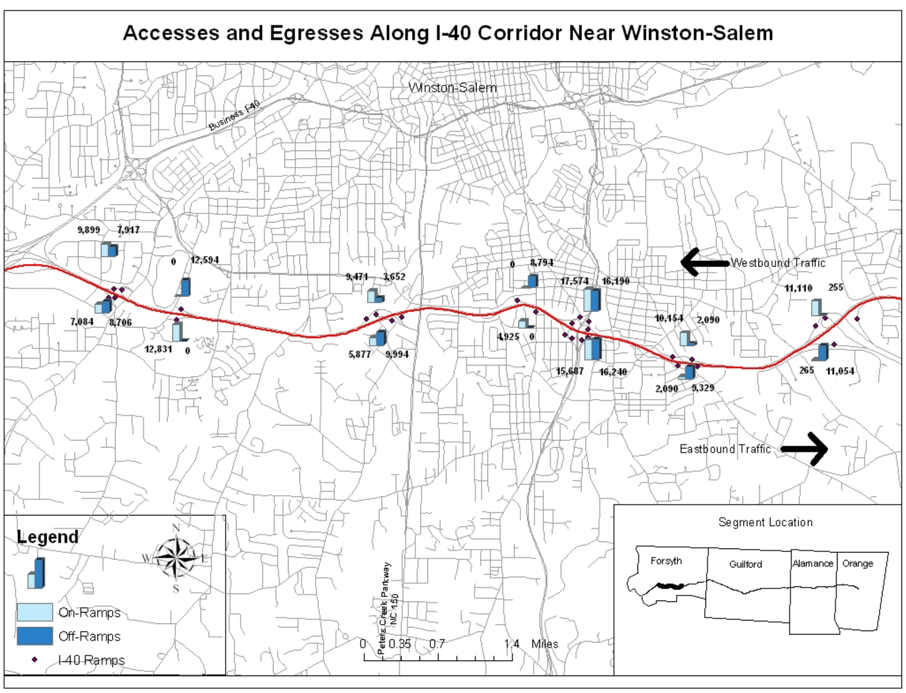


Figure 33: This segment spans 4.5 miles near Winston-Salem. More than 210,000 accesses and egresses are made on these 7 exits daily (an average of 30,000 per exit).

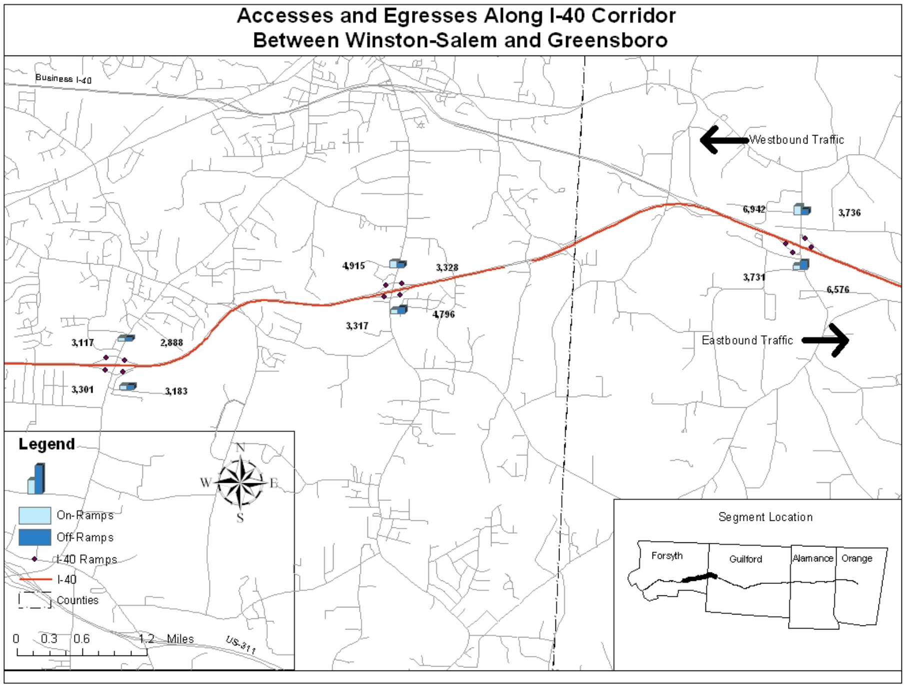


Figure 34: These 3 exits span 11 miles between Winston-Salem and Kernersville. About 50,000 accesses and egresses are made on these exits daily (an average of about 17,000 per exit).

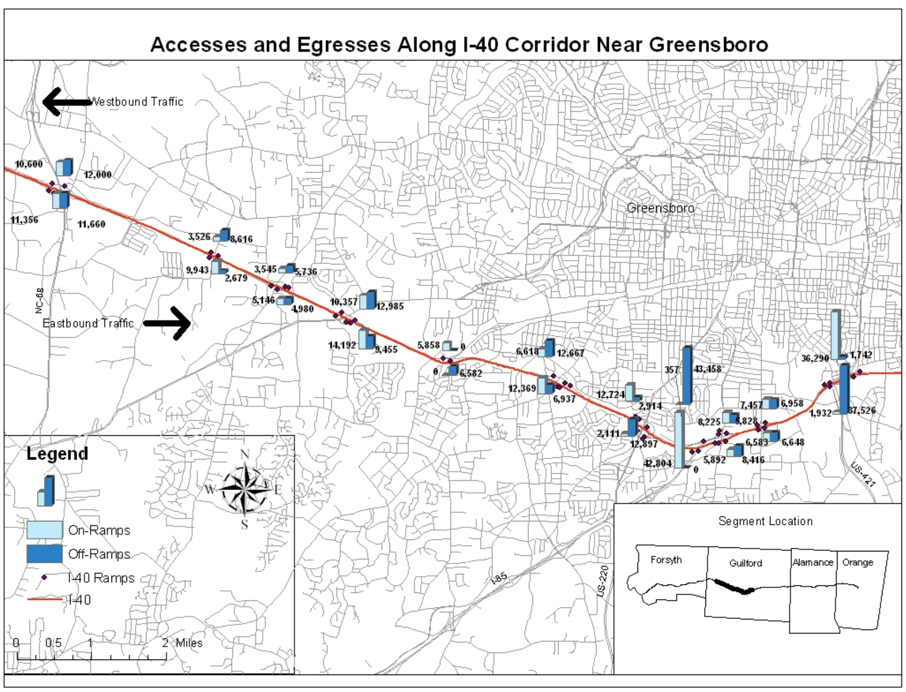


Figure 35: This segment of I-40 spans approximately 10 miles near Greensboro. About 440,000 accesses and egresses are made on these 11 exits daily (an average of about 40,000 per exit).

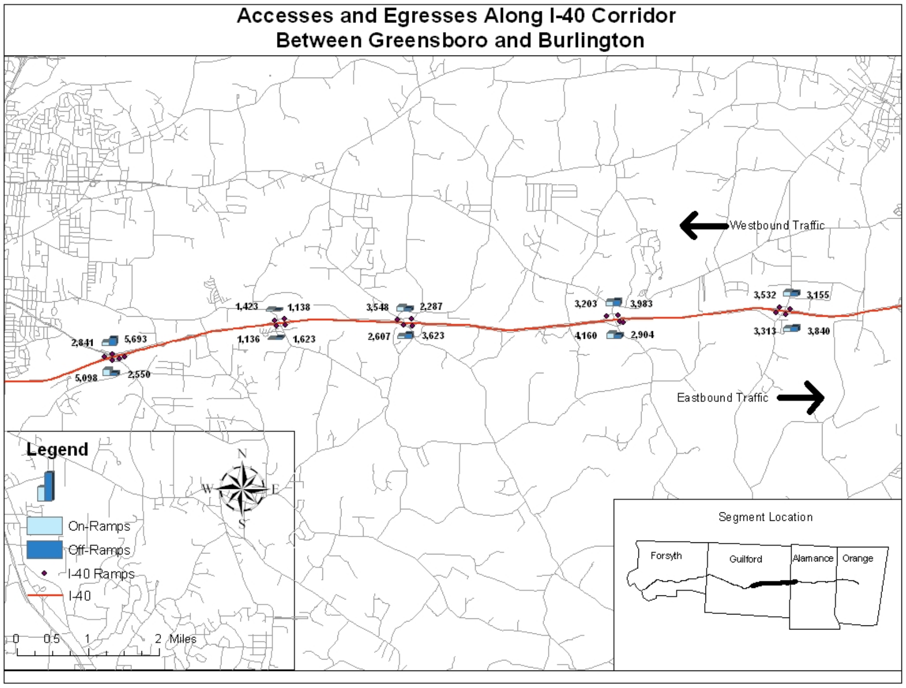


Figure 36: This segment of I-40 spans approximately 14 miles between Greensboro and Burlington. About 60,000 accesses and egresses are made on these 5 exits daily (an average of about 12,000 per exit).

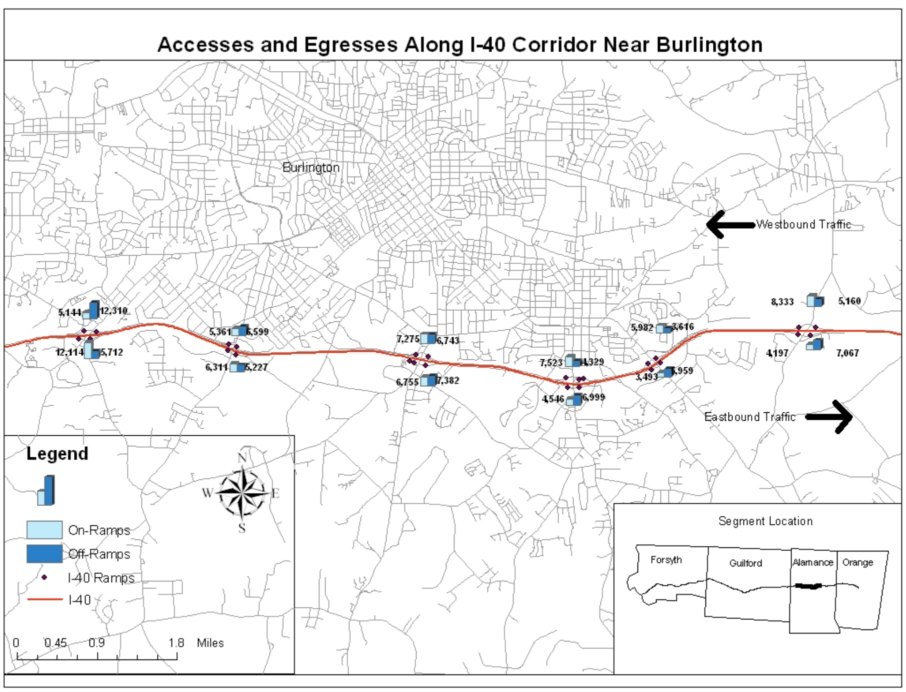


Figure 37: This segment of I-40 spans approximately 6 miles and 6 exits near Burlington. About 155,000 accesses and egresses are made on these exits daily (an average of about 26,000 per exit).

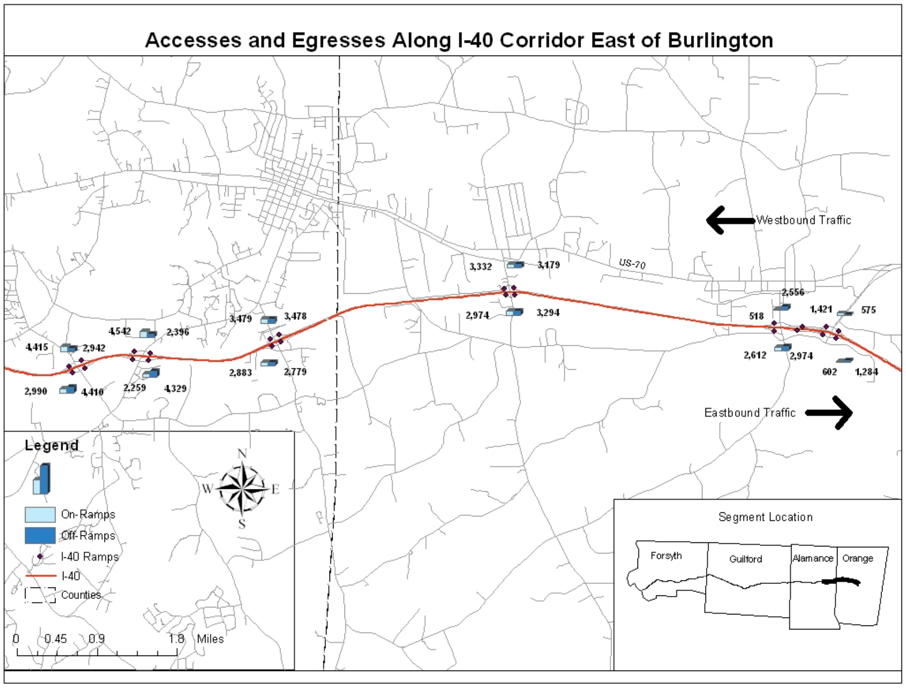


Figure 38: This segment of I-40 spans the 7 miles and 6 exits east of Burlington. About 65,000 accesses and egresses are made on these exits daily (an average of about 11,000 per exit).

Number of Years until an Additional Lane is Needed

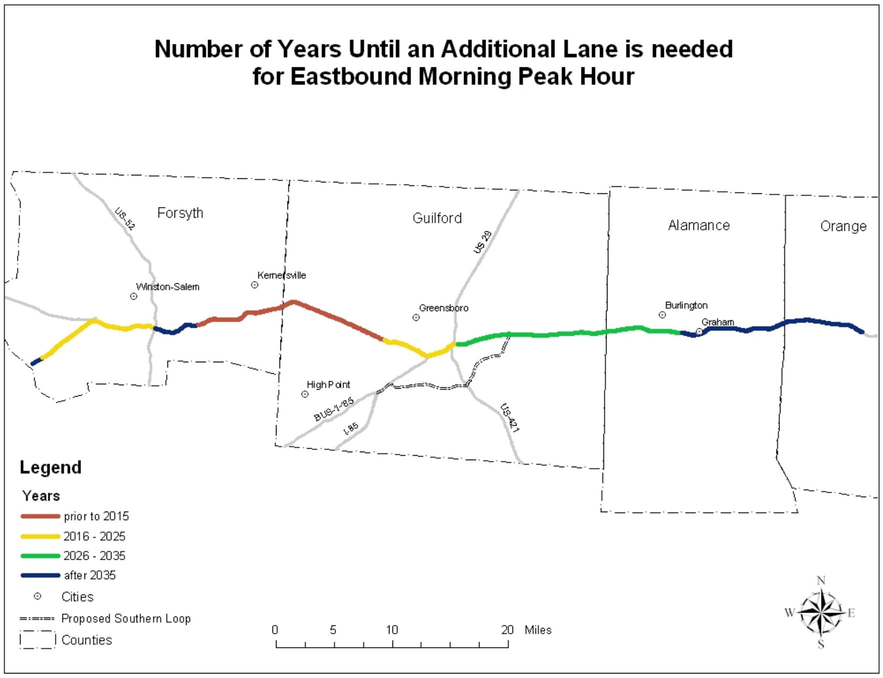


Figure 39: These maps show when additional lanes are projected to be needed to handle congestion throughout the I-40 area of study. Corridor 2 and Corridor3 are the critical corridors that need to be addressed shortly.

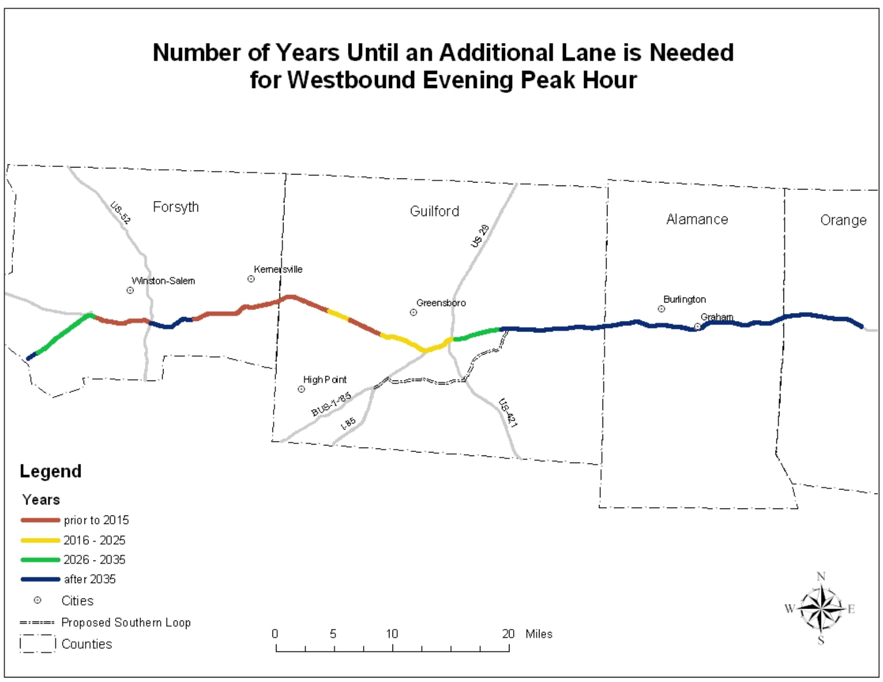


Figure 40: These maps show that the congestion at Corridor 3 occurs during the eastbound-morning and westbound-evening peak hours only.

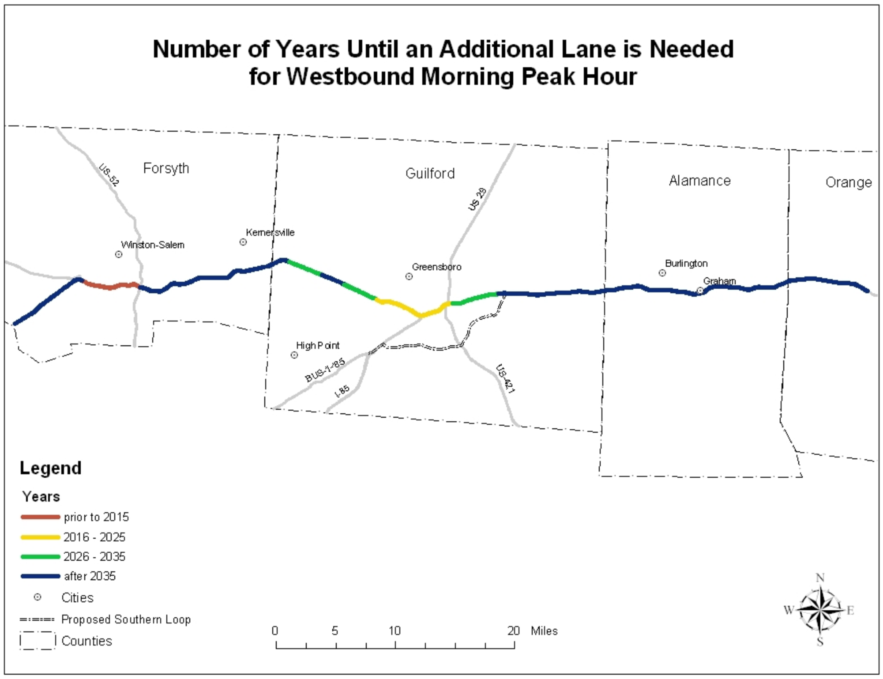


Figure 41: The maps confirm that traffic congestion in Winston-Salem occurs in both directions for both peak hours. The area near Greensboro has more congestion during the westbound-morning and eastbound-evening peak=hours.

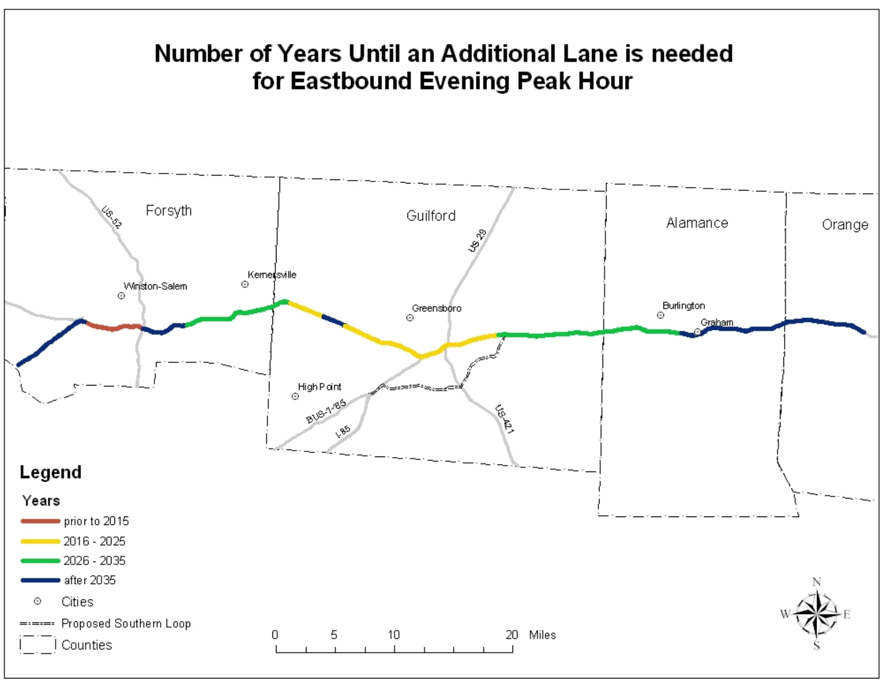


Figure 42: The westbound-morning and eastbound-evening show level of service 'F' around Greensboro sometime between 2016 and 2025.

2014 Forecasts
Population Growth

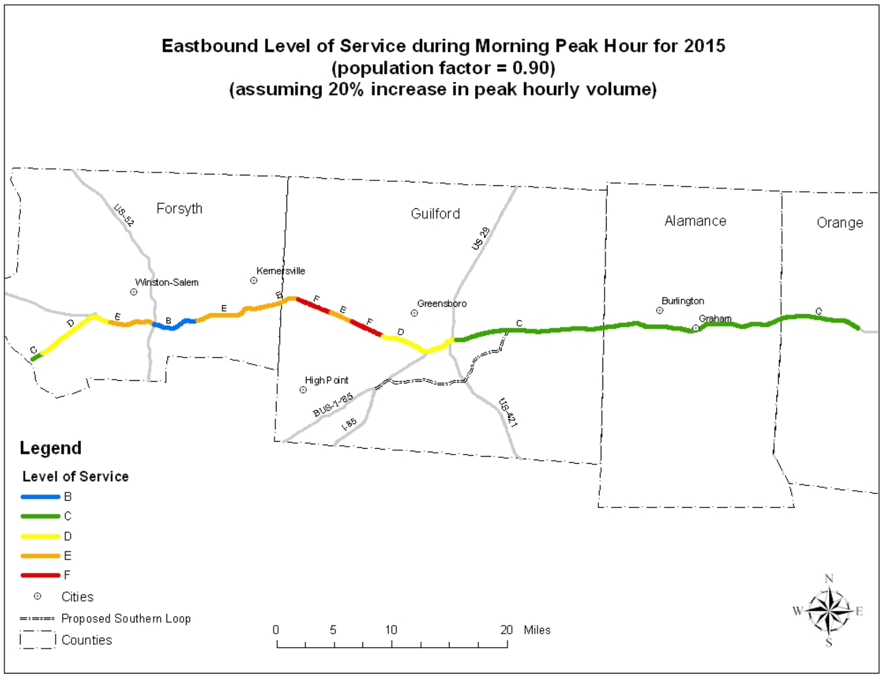


Figure 43: This map shows LOS F in Corridor 3 only. Corridor 2 and half of Corridor 3 have LOS E.

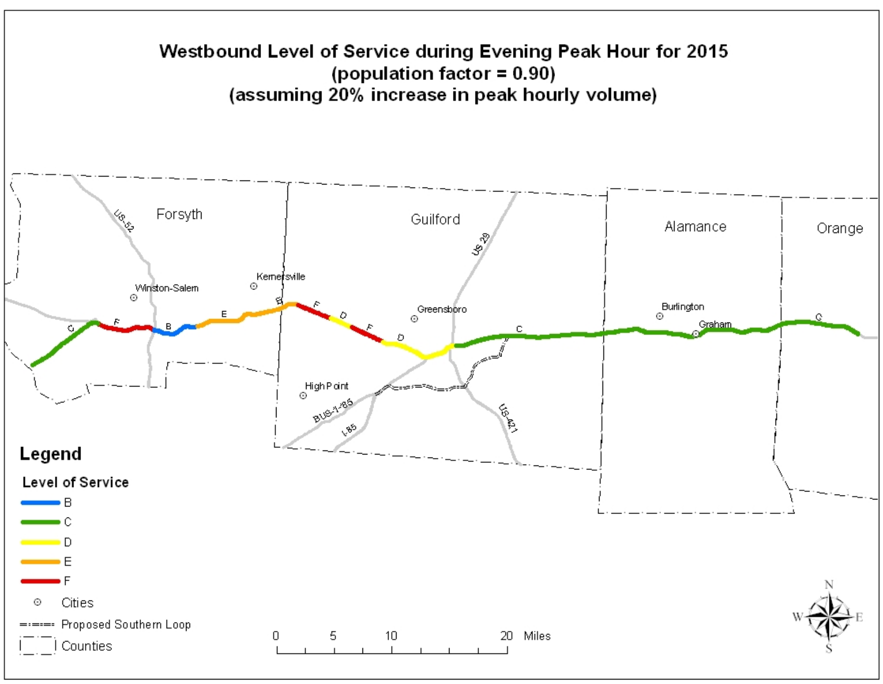


Figure 44: This map shows the same peaking phenomenon as the eastbound-morning map.

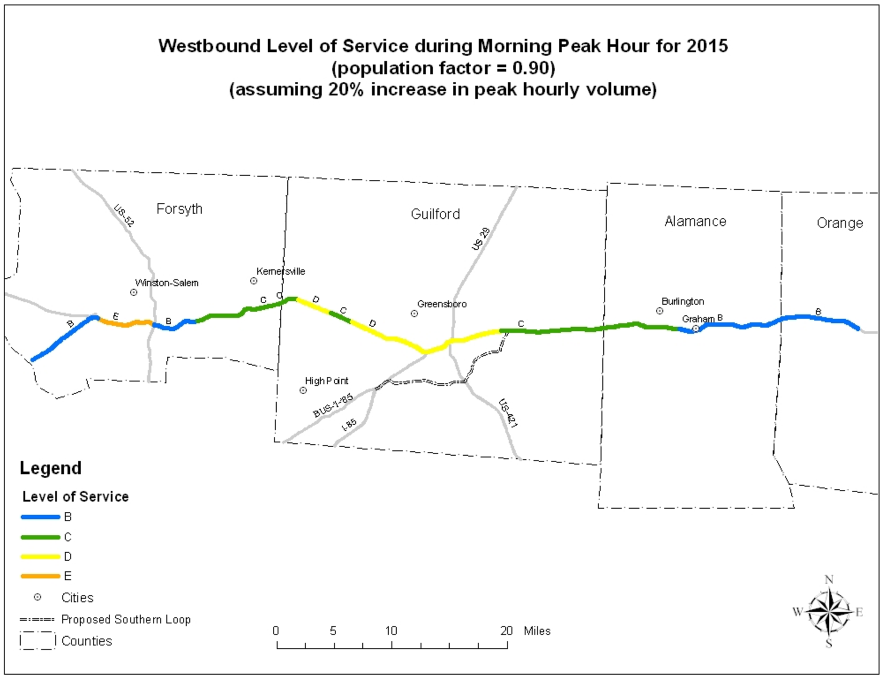


Figure 45: Corridor 2 has LOS E for this peak period. Corridor 4 near Greensboro is starting to experience a lower level of service.

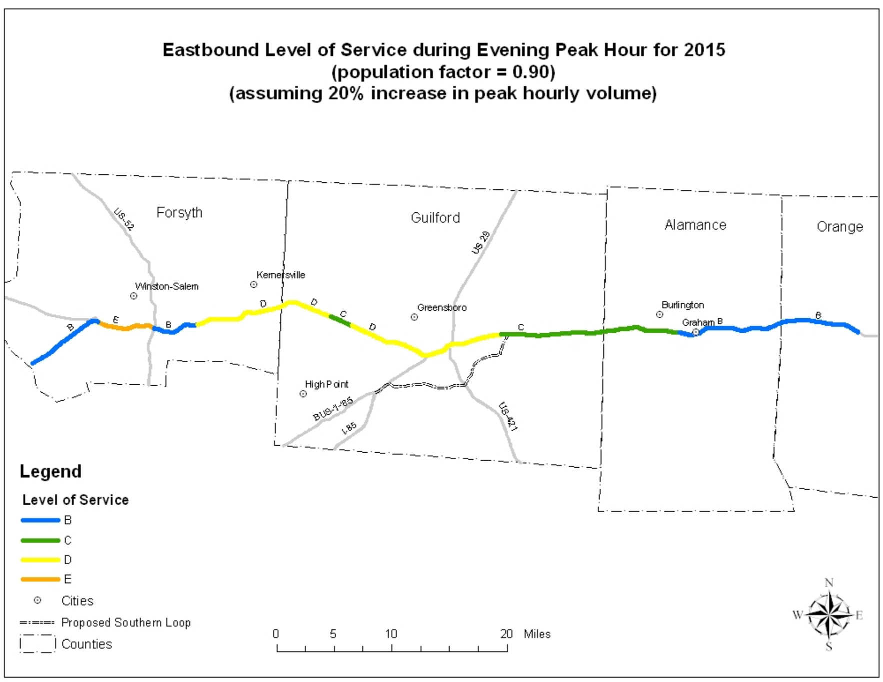


Figure 46: Corridor 2 continues to have a low level of service for all peak periods. Corridor 3 is showing a decreasing level of service for this time period, indicating congestion on this corridor may not only be in one direction.

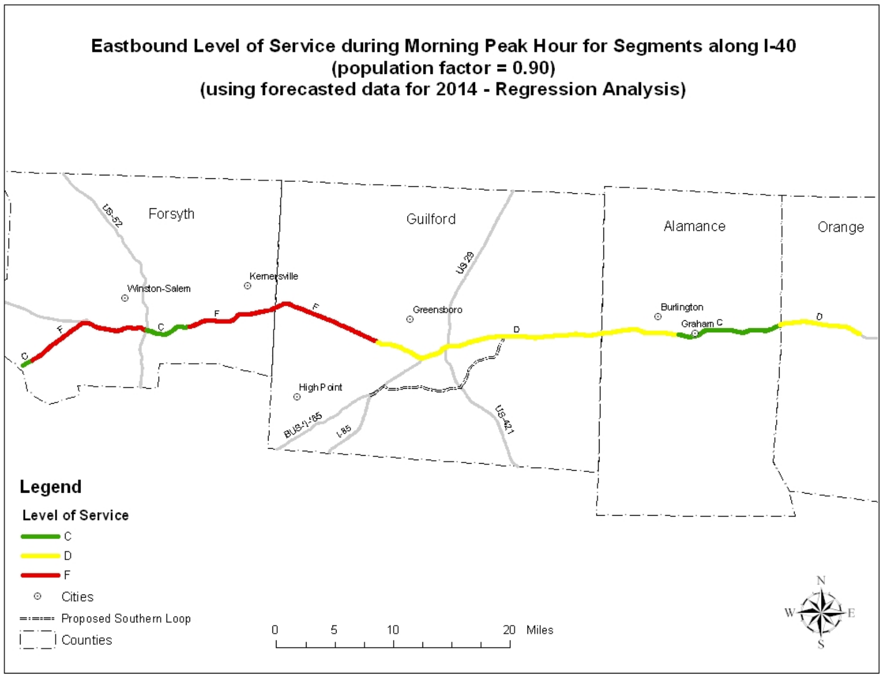


Figure 47: This map shows the deterioration of service for Corridors 1, 2 and 3.

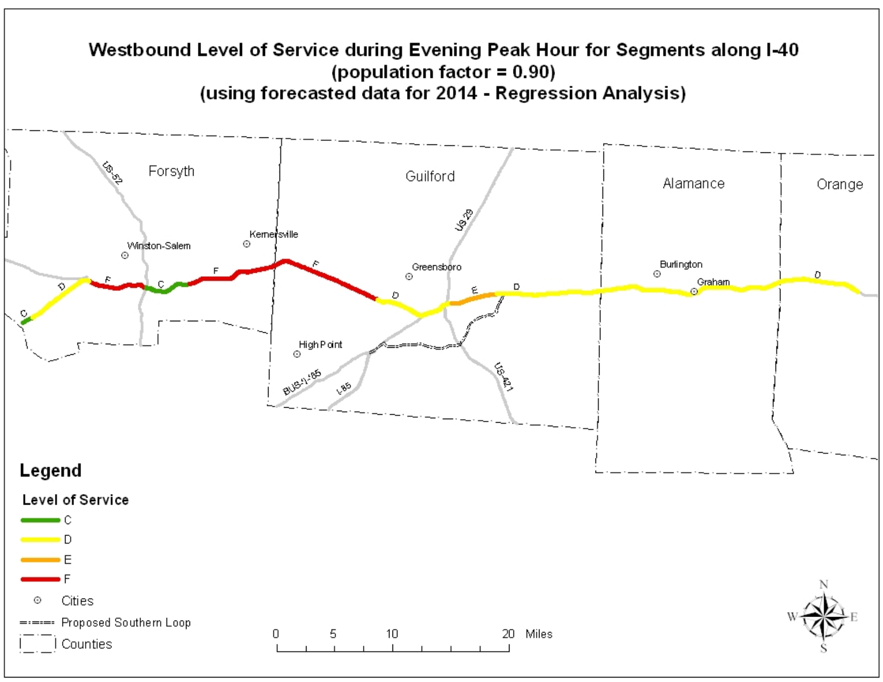


Figure 48: This map shows LOS F for Corridors 2 and 3.

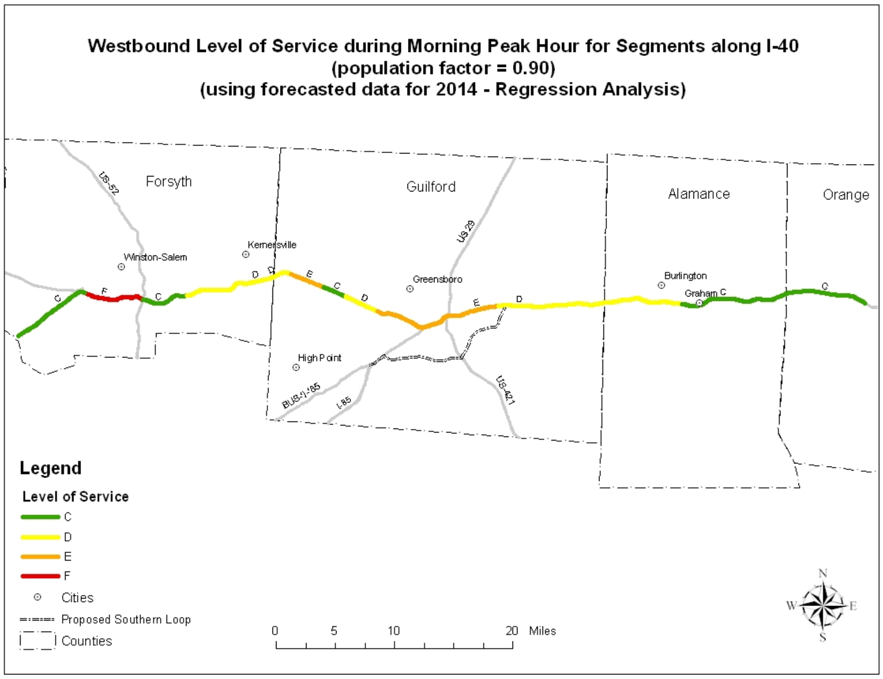


Figure 49: Corridor 2 has a projected level of service F. Corridor 3 is showing a projected LOS D for this peak-hour, indicating that congestion may occur in both directions in several years.

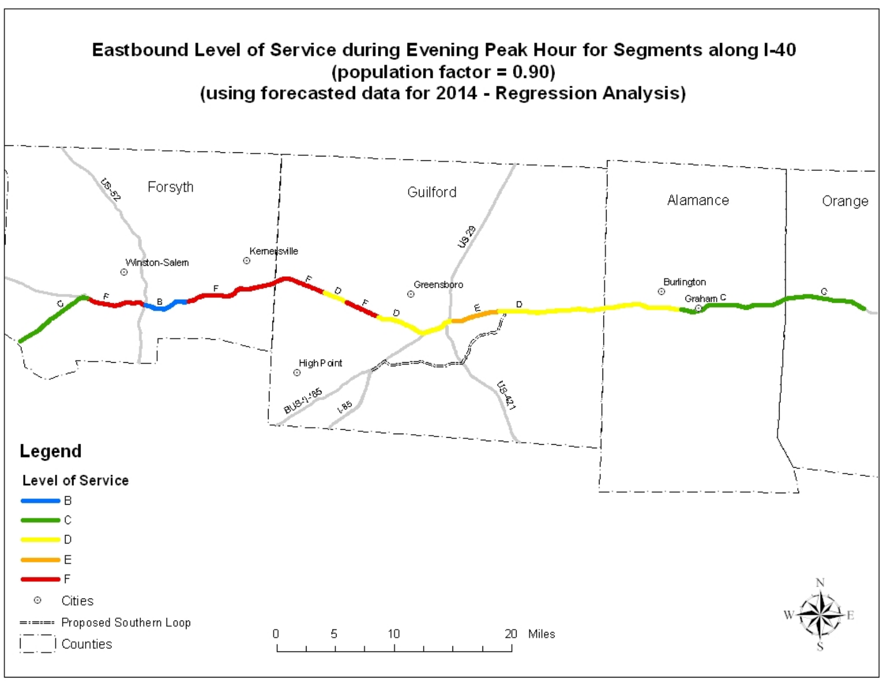


Figure 50: Corridors 2 and 3 have a projected LOS F for the eastbound-evening peak hour for 2014.

2025 Forecasts
PART Four-step Regional Model

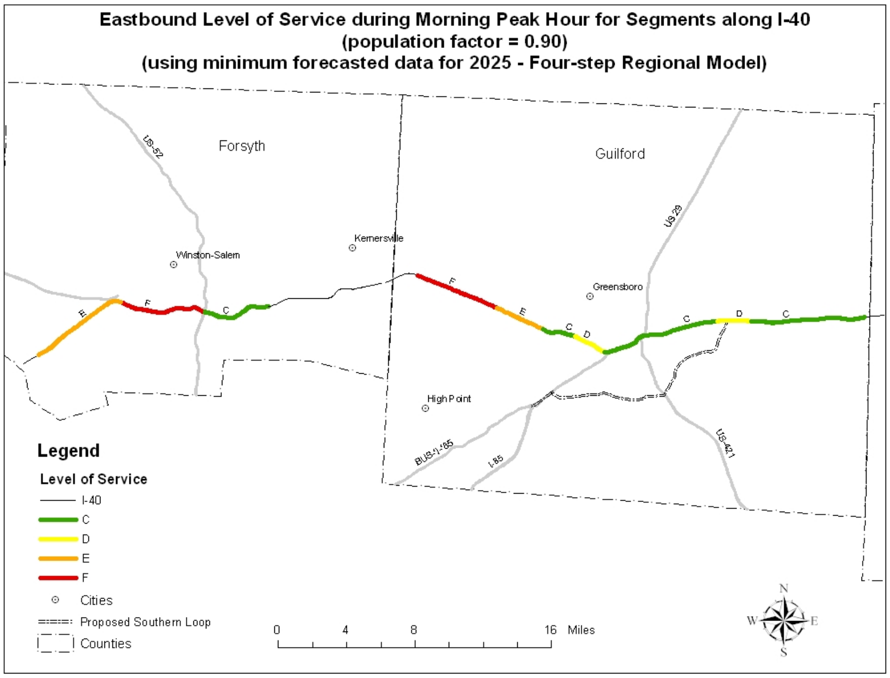


Figure 51: This map shows the minimum forecasted data for the eastbound-morning peak-hour for 2025. This model confirms LOS F for our critical corridors.

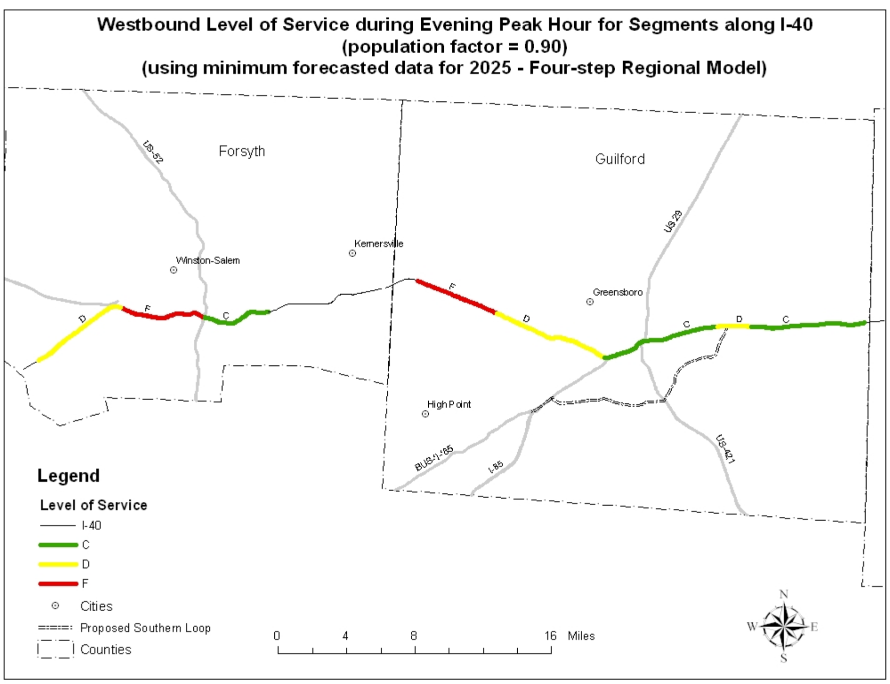


Figure 52: This map shows the same pattern as the eastbound-morning peak-hour.

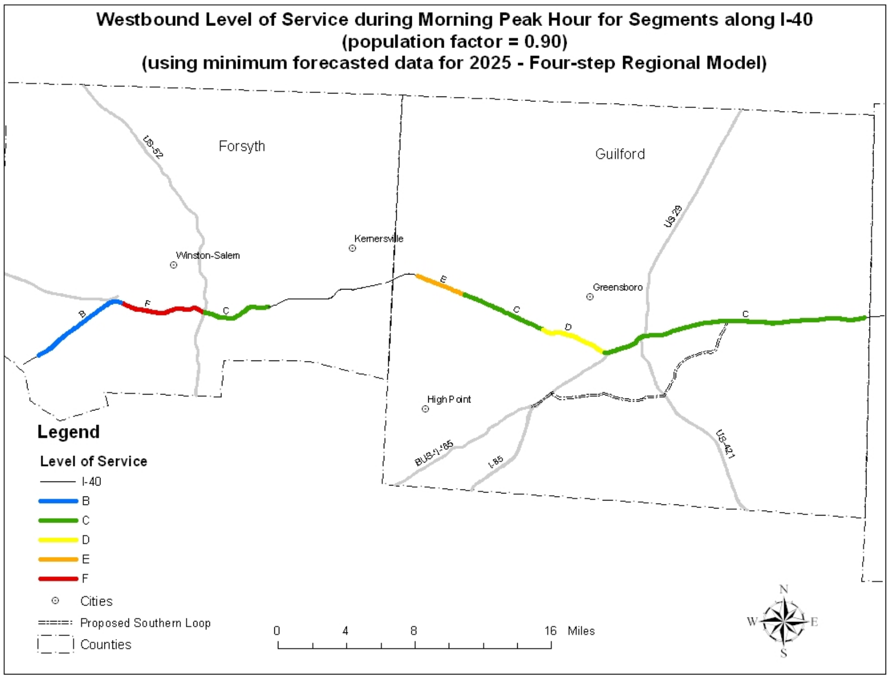


Figure 53: This map continues to show congestion on Corridor 2 in Winston-Salem.

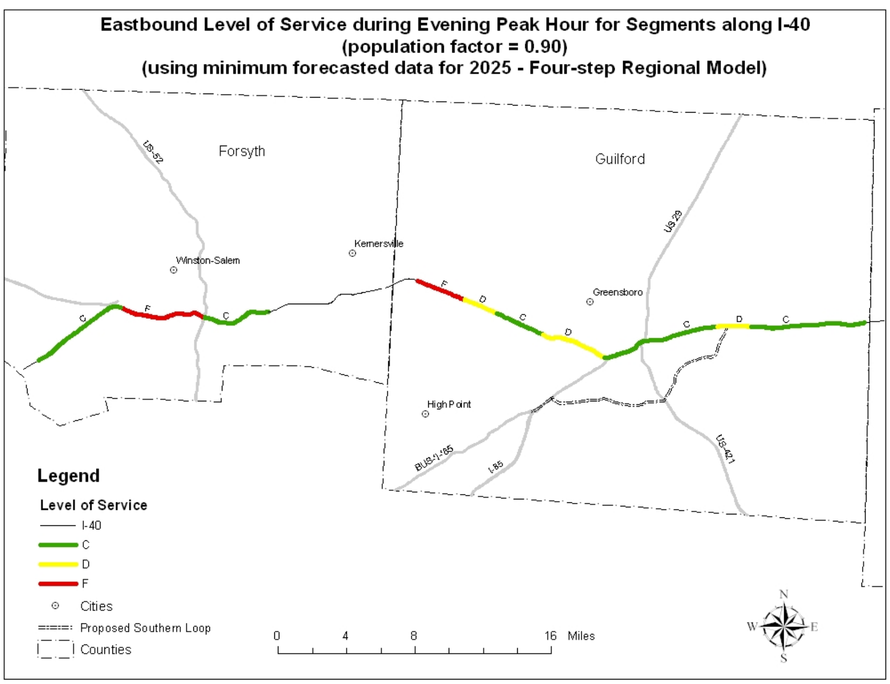


Figure 54: This map further supports congestion in Corridor 3 for the other peak period by 2025.

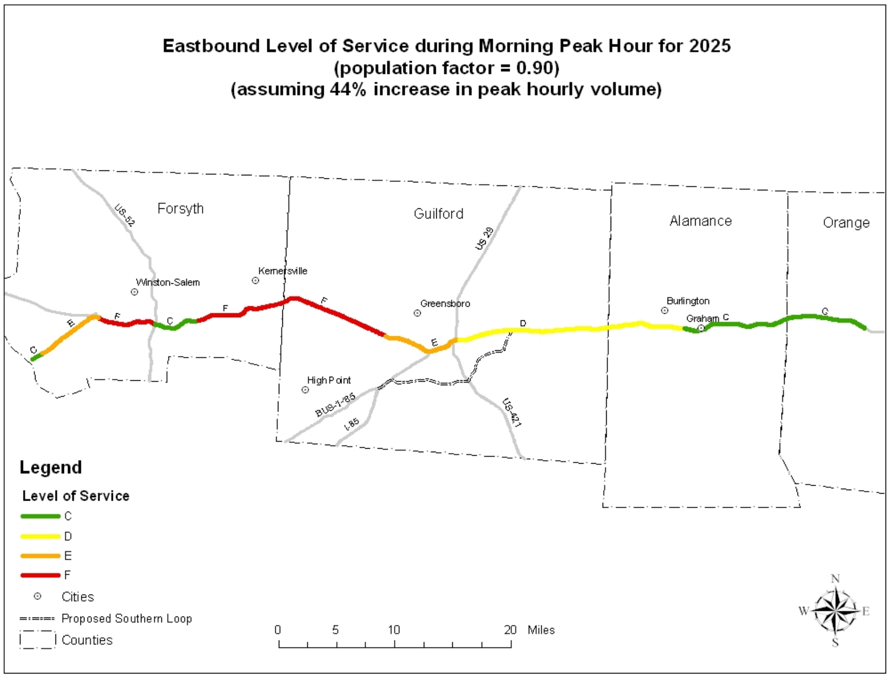


Figure 55: By 2025, Corridor 1 and the area around Greensboro drop to LOS E.

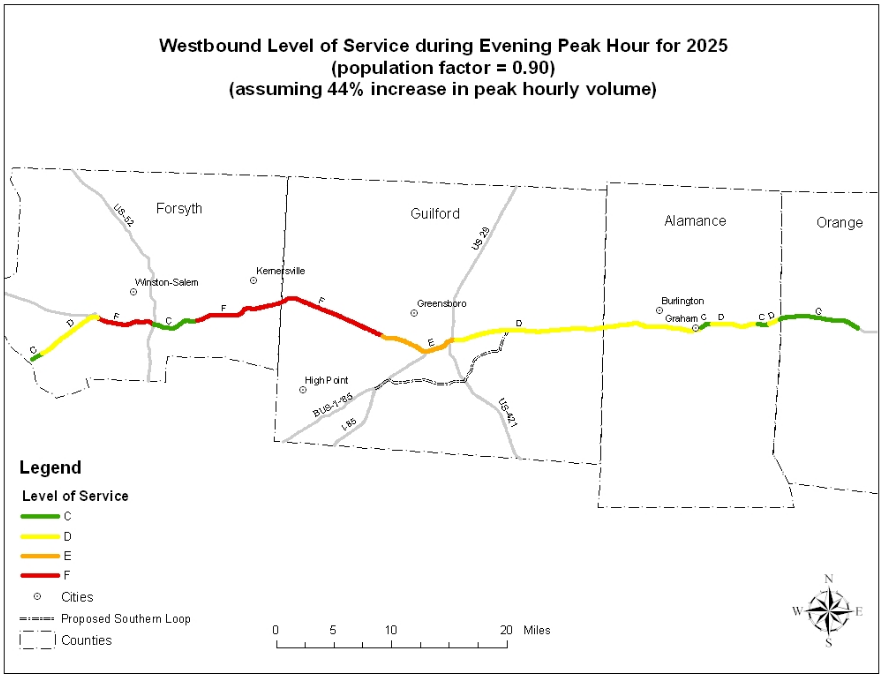


Figure 56: Corridors 2 and 3 continue to be the critical areas.

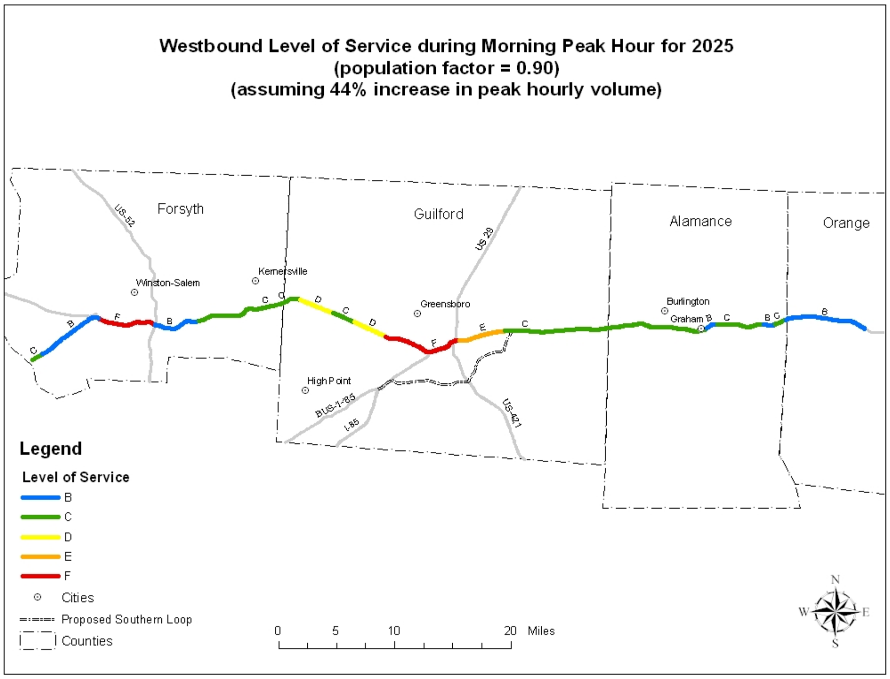


Figure 57: Segments near Winston-Salem and Greensboro become more congested in this peak-period by 2025.

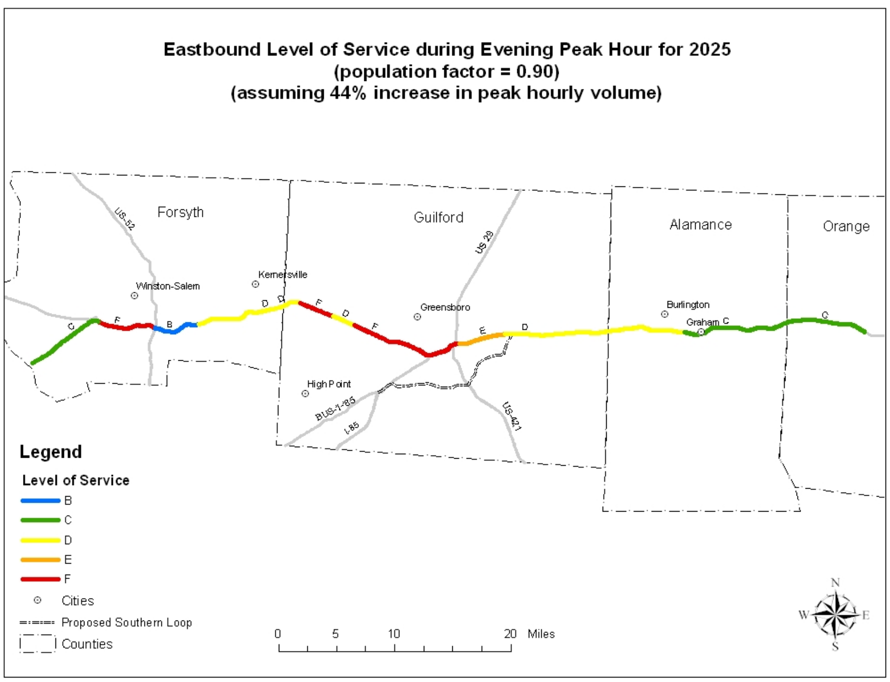


Figure 58: Corridor 3 shows deterioration in service for this time period by 2025.

Regression Analysis

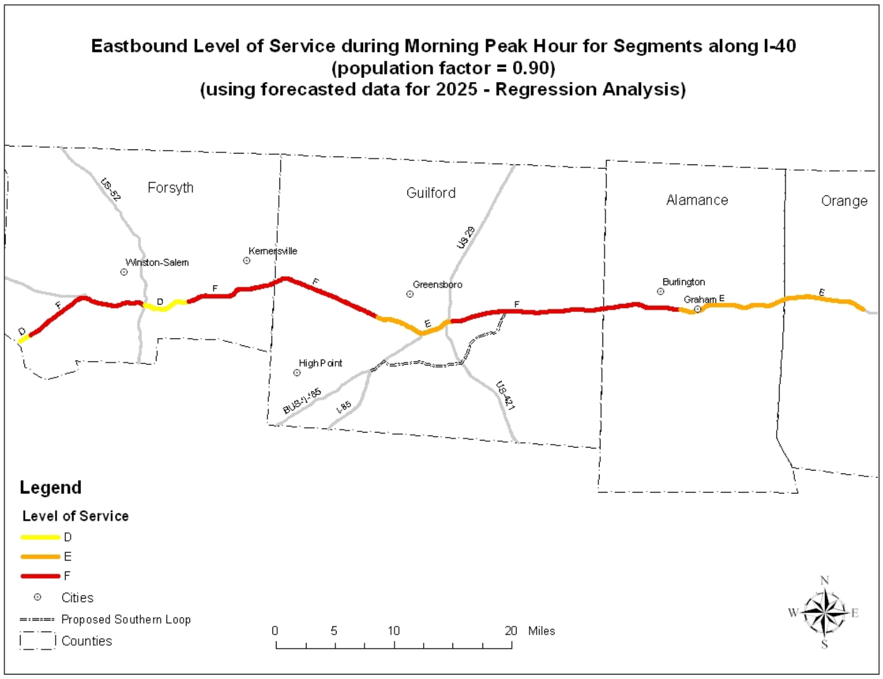


Figure 59: The regression analysis model shows LOS D or worse for all segments during this time period.

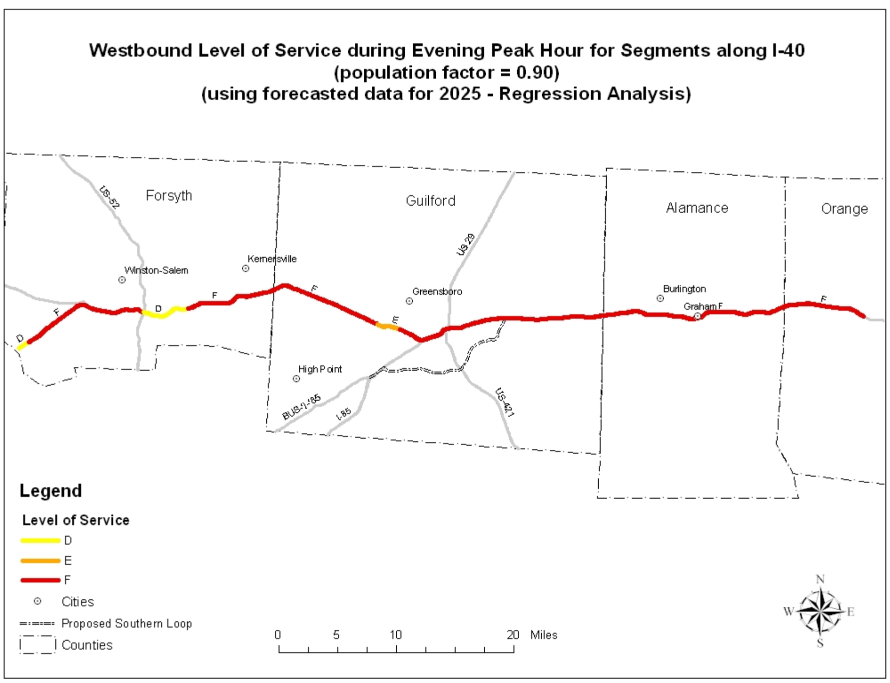


Figure 60: Most of the study area has LOS F by 2025, using the Regression Model.

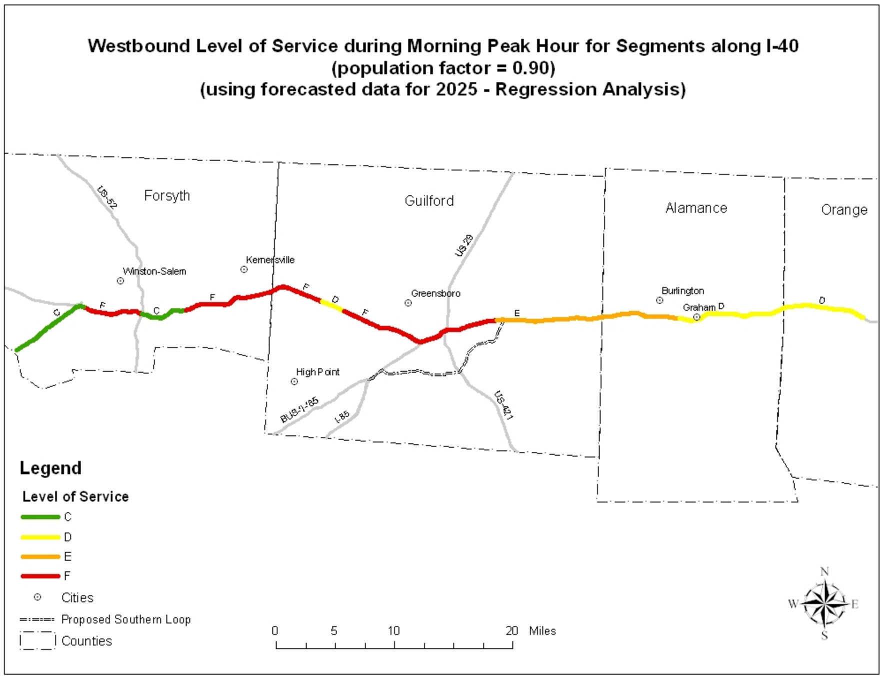


Figure 61: The regression model continues to show deteriorating level of service for 2025.

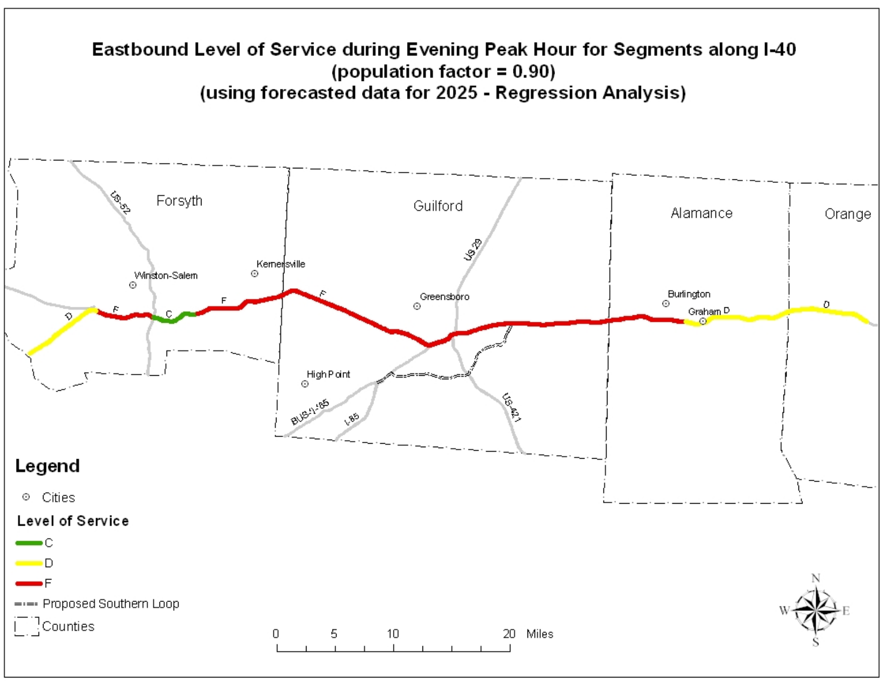


Figure 62: I-40 from Winston Salem to Burlington is almost all LOS F by 2025 for the eastbound-evening peak period using Regression Analysis.

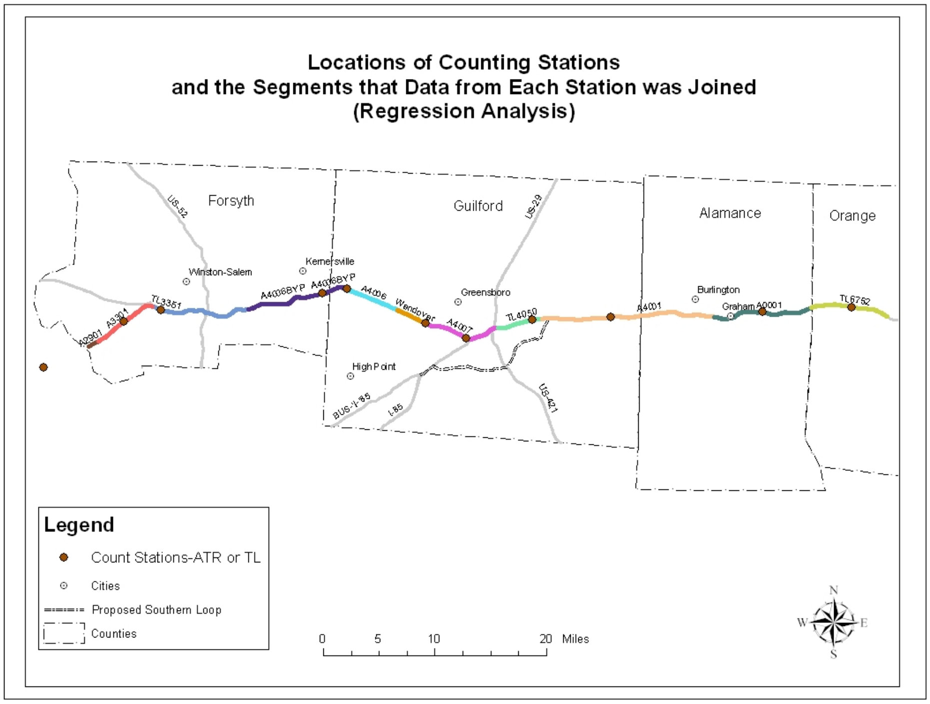


Figure 63: The map above shows the location of ATR and TL count stations. Data used in calculating forecasts using the Regression Model were taken from these points. The map also shows the segments of the road that have been assigned the data from each of the stations.

Figure 3.1

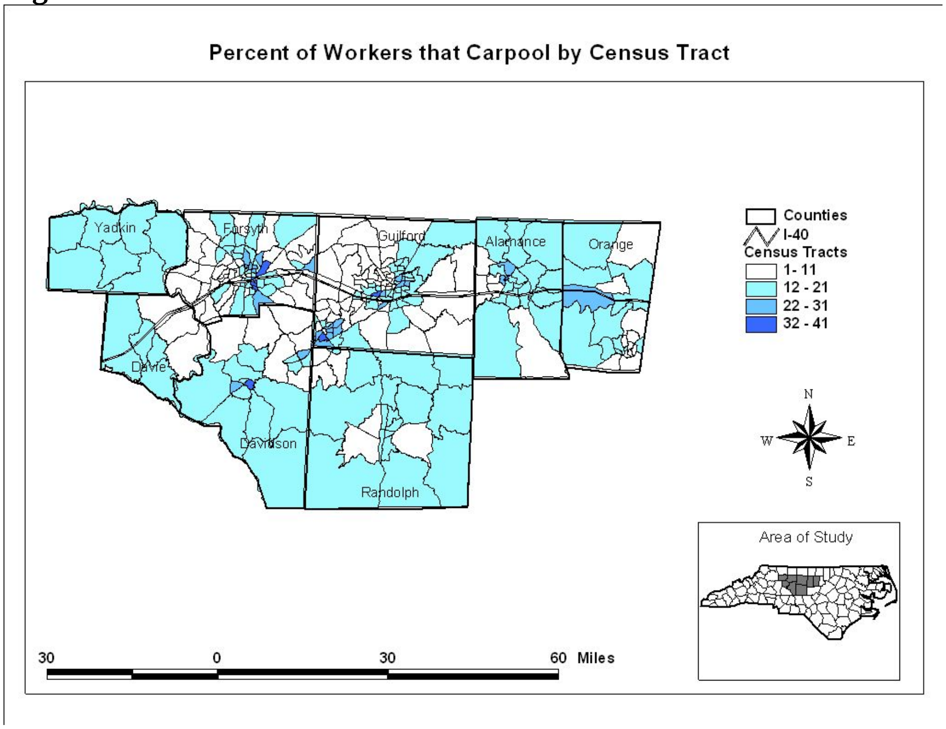
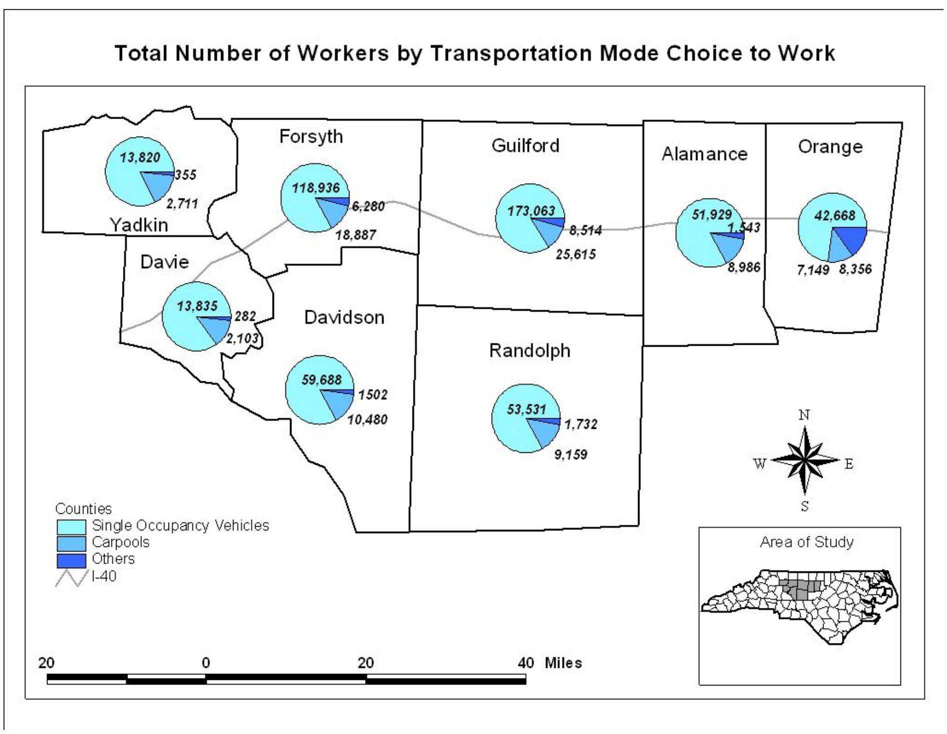


Figure 3.2



Appendix 2

Calculation of Level of Service (LOS)

1. Introduction

The steps and formulas used to calculate level of service are taken from the Highway Capacity Manual 2000 , "Chapter 23 --Basic Freeway Segments" (HCM). Data used in the calculations was provided by NCDOT (Kent Taylor and L.C. Smith from NCDOT, among others). The corridor from US-421 in Forsyth County to where I-85 diverges from I-40 in Orange County was divided into 60 segments, according to data provided by L.C. Smith in one of the ArcView files named 'universe'. A new segment exists when an attribute of the road (e.g., speed limits, number of lanes) changes. The segment that will be used in this example has an ID number of 43246, located in Orange County. Values given will be for the morning peak hour in the eastbound direction.

Three key ingredients are used in developing the LOS calculation for a given segment: 1) free-flow speed, 2) actual flow rate, and 3) actual speed. From these, 4) vehicle densities are calculated and the LOS for the segment identified. We review these next.

2. Free-flow Speed

The first step in calculating LOS is to calculate free-flow speed (km/h) using the following formula:

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

where

FFS = free-flow speed (km/h);
BFFS = base free-flow speed;
f_{LW} = adjustment for lane width (km/h);
f_{LC} = adjustment for right-shoulder lateral clearance (km/h);
f_N = adjustment for number of lanes (km/h);
f_{ID} = adjustment for interchange density (km/h) (calculated, see Table 4 in Appendix).

For this study, 110 km/h (68 mph) was used for BFFS. This number is suggested for urban areas in the HCM. The lane width for all lanes in the corridor is greater than 3.6 meters. Therefore, according to the following table, f_{LW} is equal to zero.

EXHIBIT 23-4. ADJUSTMENTS FOR LANE WIDTH

Lane Width (m)	Reduction in Free-Flow Speed, f_{LW} (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

Next, from the universe file provided by LC Smith, the right shoulder lateral clearance is determined to be greater than 1.8 meters for the segment in question. Therefore, according to the following table, f_{LC} is equal to zero.

EXHIBIT 23-5. ADJUSTMENTS FOR RIGHT-SHOULDER LATERAL CLEARANCE				
	Reduction in Free-Flow Speed, f_{LC} (km/h)			
	Lanes in One Direction			
Right-Shoulder Lateral Clearance (m)	2	3	4	≥ 5
≥ 1.8	0.0	0.0	0.0	0.0
1.5	1.0	0.7	0.3	0.2
1.2	1.9	1.3	0.7	0.4
0.9	2.9	1.9	1.0	0.6
0.6	3.9	2.6	1.3	0.8
0.3	4.8	3.2	1.6	1.1
0.0	5.8	3.9	1.9	1.3

The number of lanes for each segment is another input to the formula. In the universe table, number of lanes was given in both directions. Thus, we assumed that the same number of lanes exist in both directions and simply divided the number of lanes by two to get the number of lanes per direction. Using the following table, a value for f_N was determined for each segment. The segment in our example has 2 lanes in each direction, so f_N equals 7.3 for this segment.

EXHIBIT 23-6. ADJUSTMENTS FOR NUMBER OF LANES

Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (km/h)
≥ 5	0.0
4	2.4
3	4.8
2	7.3

Note: For all rural freeway segments, f_N is 0.0.

The final input into the formula is interchange density, f_{ID}. Following the instructions in the HCM, we identified the midpoint of each segment and tallied the number of interchanges (containing at least one on-ramp) five kilometers up and downstream. Using the following table, each segment was given a value for f_{ID} depending upon the number of interchanges per kilometer. The segment in our example had an interchange density of 0.3, so f_{ID} for this segment equals 0.

EXHIBIT 23-7. ADJUSTMENTS FOR INTERCHANGE DENSITY	
Interchanges per Kilometer	Reduction in Free-Flow Speed, f_{ID} (km/h)
≤ 0.3	0.0
0.4	1.1
0.5	2.1
0.6	3.9
0.7	5.0
0.8	6.0
0.9	8.1
1.0	9.2
1.1	10.2
1.2	12.1

With these values, the estimate of free-flow speed can be determined. The FFS value for the segment in this example is 102.7.

3. Flow Rate

The flow rate is calculated using the Manual Classification Counts (MCC) data provided by Kent Taylor at NCDOT. These counts were taken at seven locations along the corridor. The locations were spatially joined to the universe shapefile in order to provide a spatial rendering of the information. Each segment in the universe shapefile was given the ID of the closest Manual Classification Count location. By doing this we were able to assign hourly data to all segments along I-40. Manual Classification Count data was given for both the eastbound and westbound directions. From this data, we could determine the peak morning and peak evening hours for both directions, yielding four different values (direction and peak period).

The next step in calculating LOS is to determine the flow rate for each segment using the following equation:

$$v_p = (V)/(PHF * N * f_{HV} * f_p)$$

where

- v_p = 15-min passenger-car equivalent flow rate (pc/h/ln),
- V = hourly volume (veh/h)
- PHF = peak-hour factor
- N = number of lanes (for the direction in question)
- f_{HV} = heavy-vehicle adjustment factor
- f_p = driver population factor (used values 1.0 and 0.90).

Hourly volume was calculated as the total volume for the peak hour for morning and evening in both directions. For our segment, the morning eastbound peak hourly volume equals 2,758.

The peak-hour factor (PHF) reflects traffic fluctuations within a peak traffic hour. The HCM recommended a value between 0.80 and 0.95 if no data are available to calculate this empirically. Because MCC data was given in 15-minute intervals, we were able to calculate the peak 15-minute period of the peak hour for morning and evening in both directions. We calculated PHF using the following equation:

$$PHF_i = \frac{\left(\frac{V_i - x_i}{3}\right)}{x_i}$$

where

PHF_i = peak-hour factor for segment *i*
V_i = hourly volume for segment *i*
x_i = peak 15-minute period of the peak hour for segment *i*.

The formula finds the ratio between the average flow of the non–peak time intervals and the peak flow interval. Because the data come in 15-minute intervals, in every hour there are three non-peak intervals and one peak interval. This explains why the numerator is normalized by three. Applying this procedure to the segment in the example, the PHF is equal to 0.80 for the eastbound morning peak hour.

The number of lanes was for one direction only and was the same value calculated when solving for FFS. For this segment, the number of lanes in one direction is 2.

The heavy-vehicle adjustment factor f_{HV} was calculated using the following equation:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad (23\text{-}3)$$

where

E_T, E_R = passenger-car equivalents for trucks/buses and recreational vehicles (RVs) in the traffic stream, respectively;
P_T, P_R = proportion of trucks/buses and RVs in the traffic stream, respectively; and
f_{HV} = heavy-vehicle adjustment factor.

We assumed that trucks were the only heavy-vehicle types present, and that RV traffic was negligible. The passenger-car equivalents needed to estimate the heavy-vehicle adjustment factor was determined using the following formula:

EXHIBIT 23-8. PASSENGER-CAR EQUIVALENTS ON EXTENDED FREEWAY SEGMENTS

Factor	Type of Terrain		
	Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

The universe shapefile indicated that the type of terrain was rolling. Since no grade information was available, a value of 2.5 was used for E_T for all segments along I-40 to indicate that each truck was equivalent to 2.5 passenger cars. The proportion of trucks P_T in the peak hour was determined using the truck counts provided by Kent Taylor at NCDOT. The total number of dual, TTST and twin trucks was divided by the hourly volume to give P_T. For this segment, P_T is equal to 0.20. Substituting these values into the equation for heavy-vehicle adjustment factor gave a value for f_{HV} for each segment. The value for the segment in this example is 0.77.

The driver population factor measures the percent of drivers who are familiar with the corridor. Values of 0.90 and 1.0 were used, which were recommended in the HCM. A value of 1.0 suggests that all drivers are familiar with the corridor. A value of 0.9 suggests that only 90% of drivers are familiar with the corridor.

Once the above inputs were determined, the flow rate for each segment could be estimated. The flow rate for the segment in this example (assuming a population factor of 0.90) is equal to 2,476.

4. Speed

Speed is calculated using the following formula. This formula uses the flow rate and free-flow speed to determine the speed-flow relationship.

For $90 \le FFS \le 120$ and for flow rate (v_p)
$(3100 - 15FFS) < v_p \le (1800 + 5FFS)$,

$$S = FFS - \left[\frac{1}{28}(23FFS - 1800)\left(\frac{v_p + 15FFS - 3100}{20FFS - 1300}\right)^{2.6}\right]$$

Top formula

For $90 \le FFS \le 120$ and
$v_p \le (3100 - 15FFS)$,
$S = FFS$

Bottom formula

According to the formula above, first one must estimate (3100 – 15*FFS) for each segment. According to the bottom part of the formula, any segment that has a flow rate that is less than or equal to this number has a speed equal to the free-flow speed. If the flow rate is greater than (3100 – 15*FFS), speed is calculated using the top part of the formula. For this example, with FFS equal to 102.7, (3100 – 15*FFS) equals 1560. Since the flow rate of 2476 is greater than this number, the top formula is used. Speed for this segment is 69.4 in the morning headed eastbound.

5. Density and Level of Service Determination

Having identified the three key ingredients, the last step is to determine vehicle density for each segment. Density is measured using the following equation for each segment:

$$D = v_p/S$$

where

D	=	density (pc/km/ln),
Vp	=	flow rate (pc/h/ln), and
S	=	average passenger-car speed (km/h).

For this example, where flow rate equals 2,476 and speed equals 69.4, density equals 35.7.

The level of service for a segment is noted by using a letter A-F, where 'A' indicates a high level of service and 'F' indicates a low level of service. To be within a given LOS, the density criterion must be met. The relationship is shown in the following table:

LOS	Density Range (pc/km/ln)
A	0–7
B	> 7–11
C	> 11–16
D	> 16–22
E	> 22–28
F	> 28

For the segment in this example, since the density value of 35.7 is greater than 28, the LOS is given a value of 'F' for the peak hour. This process was duplicated for all segments in the corridor for the morning and peak hours in both the eastbound and westbound directions, as suggested by the maps provided.

Appendix 3

Census Data

1. Collection Procedures

We collected census data for eight counties: Yadkin, Davie, Forsyth, Davidson, Guilford, Randolph, Alamance and Orange (from west to east). Population, income and employment data from the 2000 Census was downloaded for these eight counties at the census tract level. Data was also downloaded for the United States and the state of North Carolina for comparison purposes. In addition, economic data from Census 2001 that is classified by the North American Industry Classification System (NAICS) was downloaded for the study area at the county level. NAICS was developed to provide new comparability in statistics about business activity across North America. NAICS classifies industries and then groups them together using codes. Single digit NAICS codes are the broadest industries. When more digits are added, the NAICS codes correspond to more detailed occupations.

The data was formatted in Microsoft Excel for use in ArcView 3.2. Using ArcView, thematic maps and charts were used to display the downloaded data. The maps created for use in analyzing the study area are as follows;

- Cities in Study Area;
- Total Population by County;
- Population Density by Census Tract (per square mile);
- Per Capita Income by Census Tract (dollars);
- Median Household Income by Census Tract (dollars);
- Percent of Workers 16 Years and Over That Work Outside County of Residence by Census Tract;
- Mean Travel Time to Work by Census Tract (minutes);
- Mean Travel Time to Work by County (minutes);
- Total Number of Workers by Transportation Mode Choice to Work;
- Total Number of Workers by Transportation Mode Choice to Work (Single Occupancy Vehicles and Carpools only);
- Percent of Workers that Carpool by Census Tract;
- Percent of Workers using Public Transportation by Census Tract;
- Total Number of Workers Who Left for Work Between 7:00 A.M. and 9:00 A.M.;
- and Percentage of Workers Who Left for Work Between 7:00 A.M. and 9:00 A.M.

Using data that was classified by using NAICS, location quotients were estimated at the one-digit NAICS level to better understand the economic base of each county relative to the state of North Carolina. From this data, a map was produced displaying the number of employees by county for the study area ("Total Number of Employees by County"). In addition, seven maps were created to allow analysis on economic activity for each of the following industry classes:

- Agriculture, Forestry, Fishing and Hunting;
- Construction, Mining and Utilities;
- Manufacturing;
- Trade and Transportation;
- Professional and Management;

- Educational and Health Services; and
- Services.

Census Data Figures
Travel Behavior

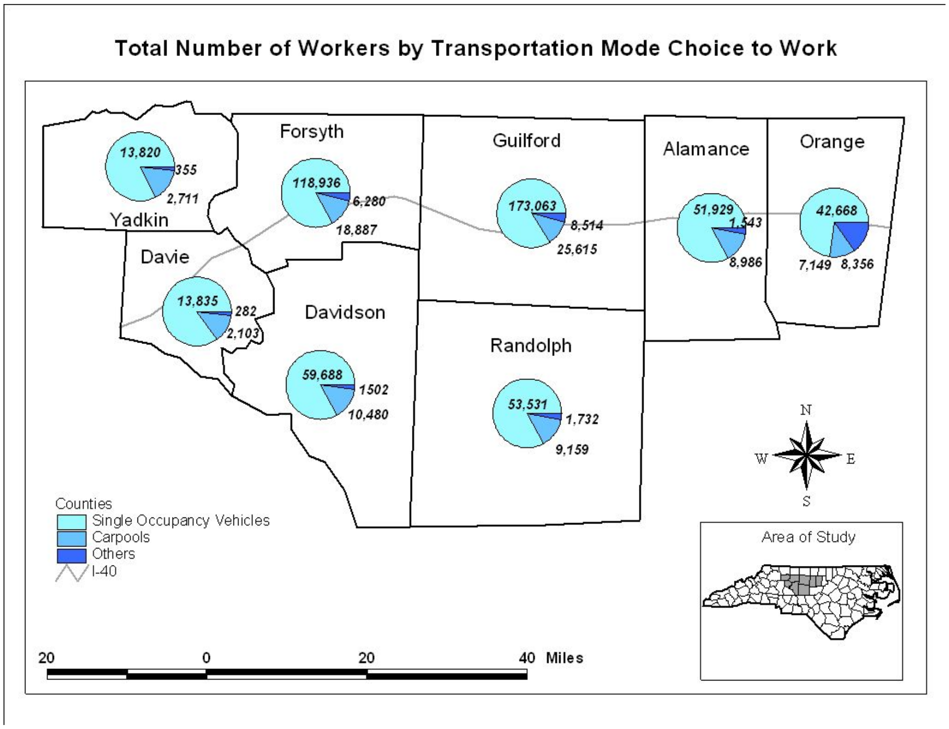


Figure 1: The mode choice distribution suggests that single occupancy vehicle travel dominates the study area. Carpooling consists of 13% of all commuter trips, with Guilford (30%), Forsyth (22%) and Davidson (12%) counties having the highest percentage throughout the study area.

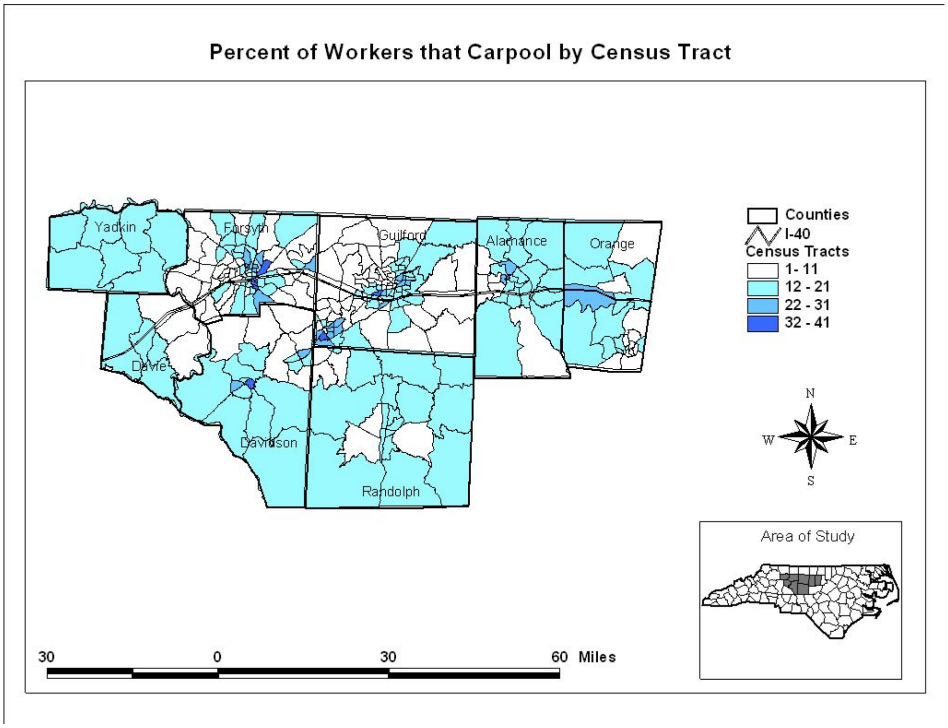


Figure 2: The highest percentage of workers that carpool occurs in the urban areas.

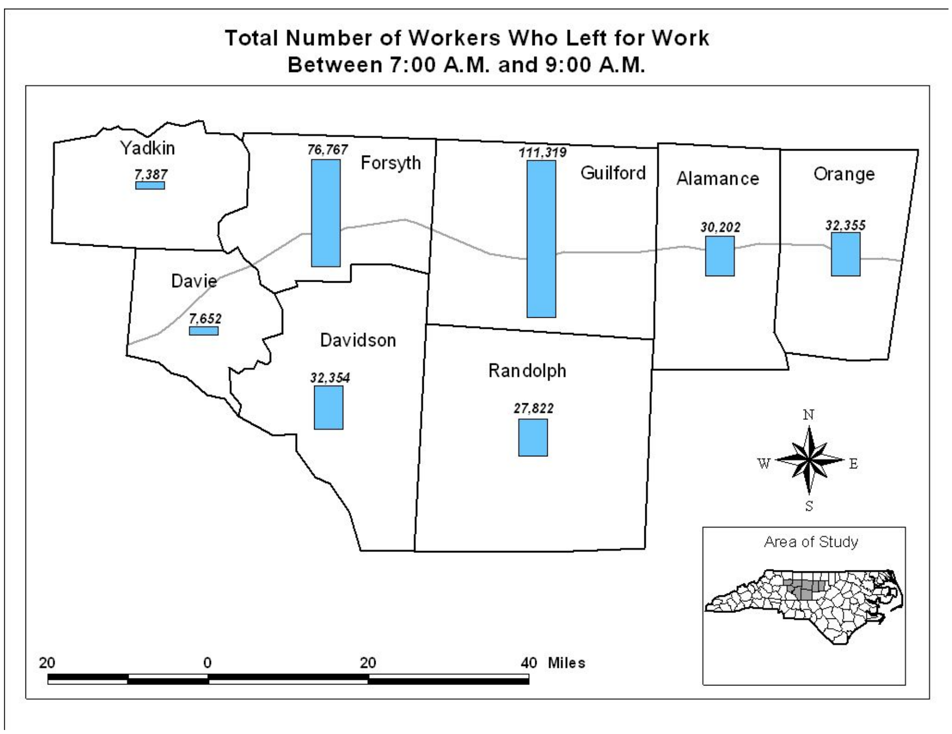


Figure 3: More than 325,000 workers (51%) in the study area leave for work during the morning peak period. Of all workers leaving during this time, 53% originate in Forsyth and Guilford counties.

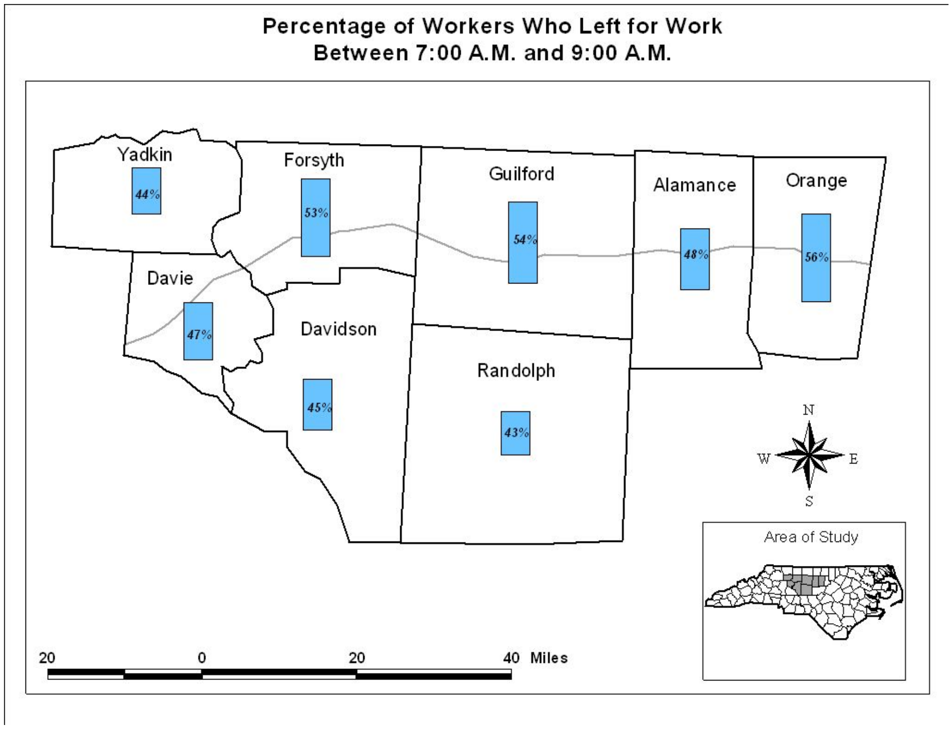


Figure 4: The counties on the I-40 corridor have a higher percentage of workers who leave for work during the morning peak period than counties that do not contain a section of the corridor.

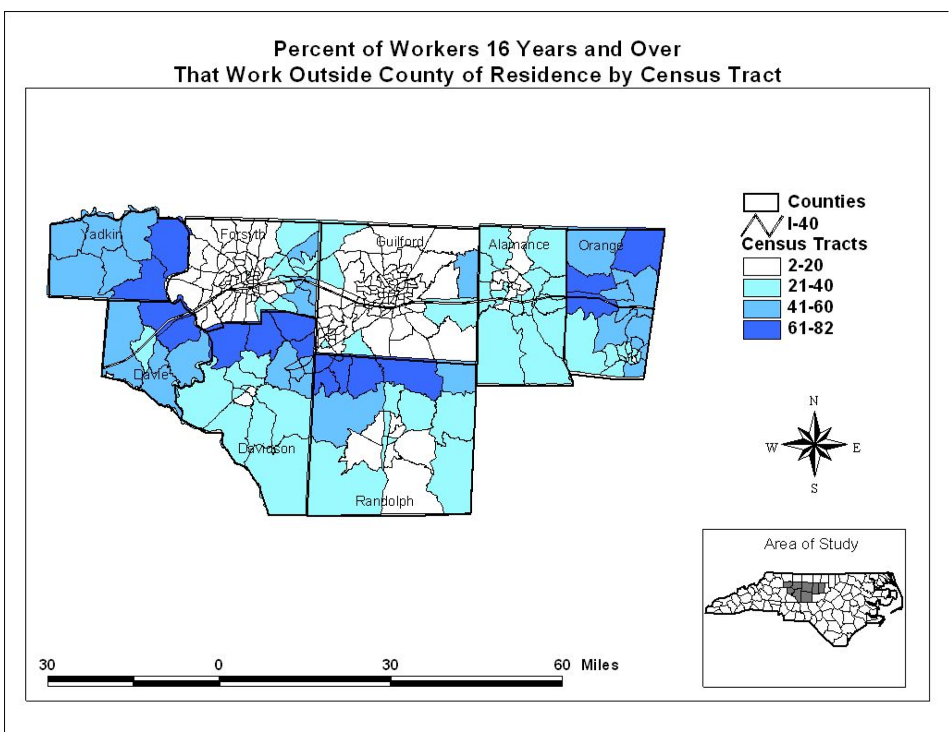


Figure 5: The large urban areas located on I-40 attract employees from surrounding counties. The lack of origin-destination data has precluded us from identifying specific destinations for commuters. However, economic Census data (summarized by place of work, as opposed to by place of residence) helps us identify major activity magnets (see below).

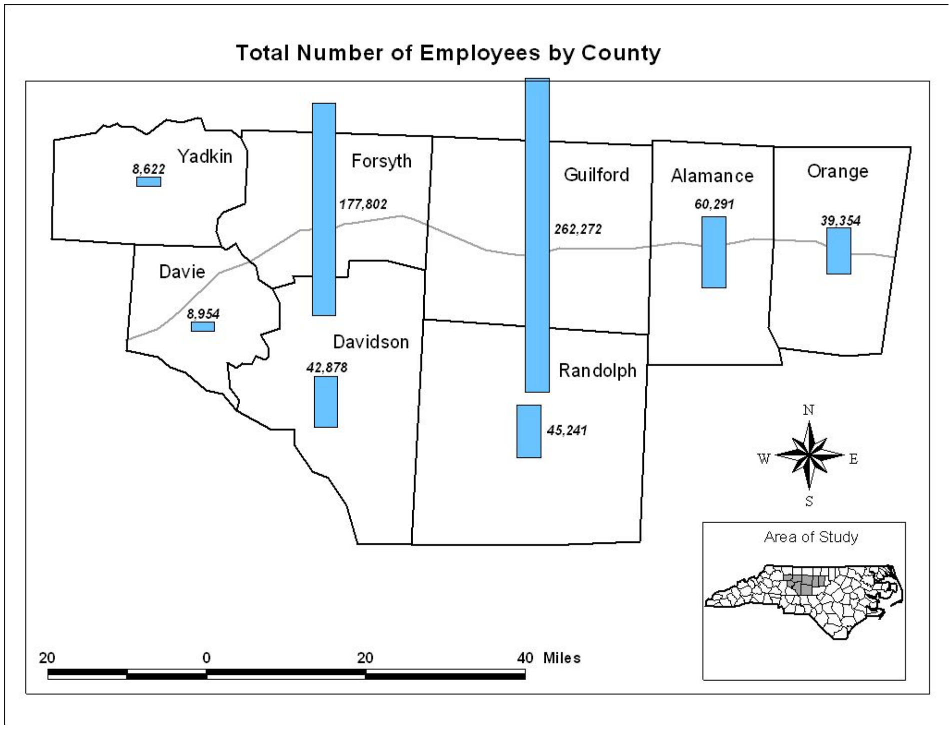


Figure 6: Forsyth and Guilford counties act as major activity magnets for the study area. Sixty-eight percent of the workers employed in the study area works in these two counties.

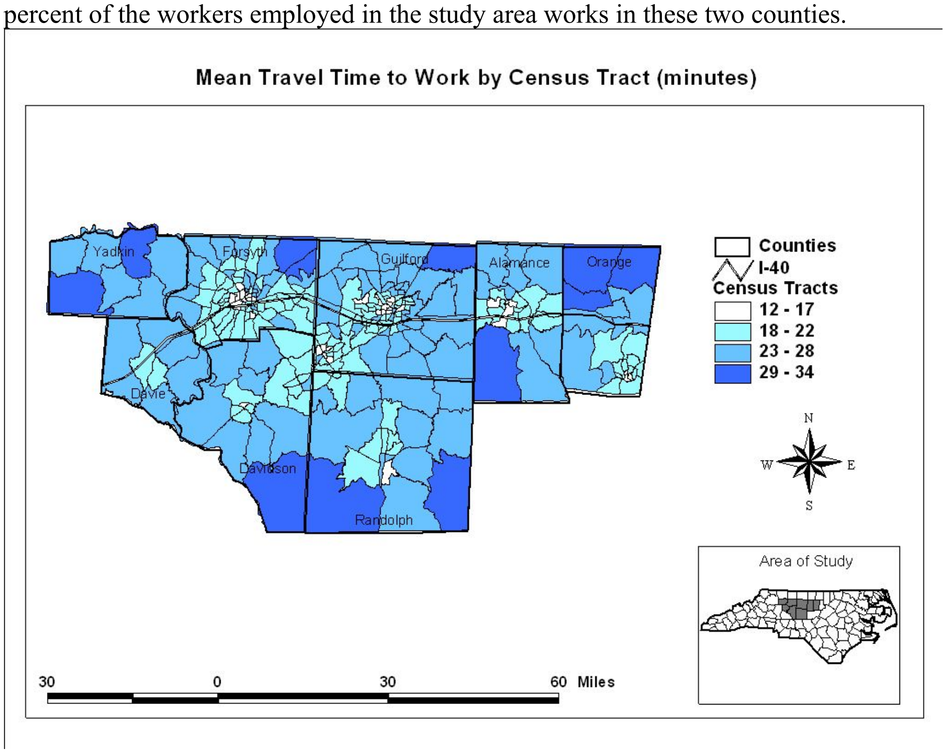


Figure 7: Mean travel time to work decreases with proximity to urban areas and to interstates. The average travel time for the study area is 23 minutes (standard deviation = 1.94).

Population

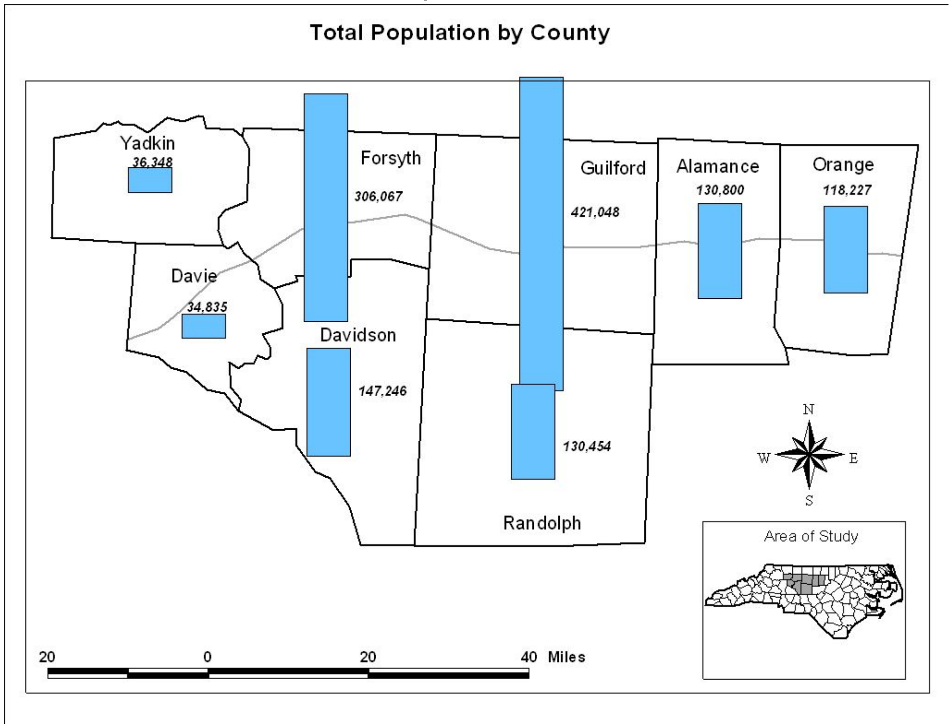


Figure 8: Forsyth and Guilford contain about 55% of the population in the region. Counties to the east and south of Forsyth and Guilford are more populated than those to the west.

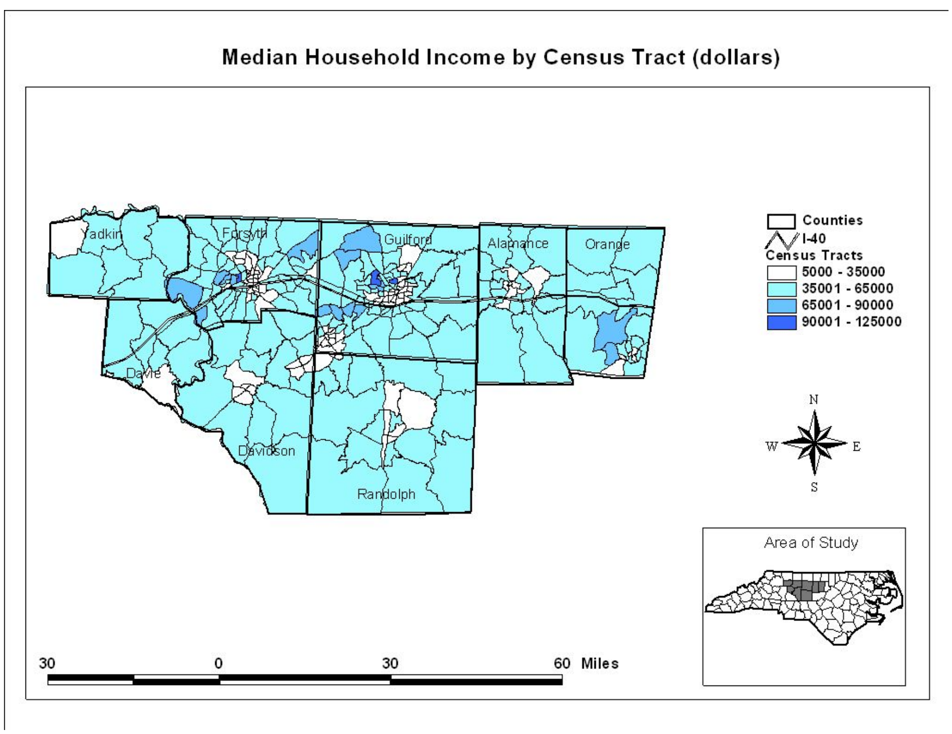


Figure 9: The highest incomes are found in suburbs surrounding the urban areas, in close proximity of the I-40 study area. By contrast, the lowest incomes are found in the central business districts and in rural areas.

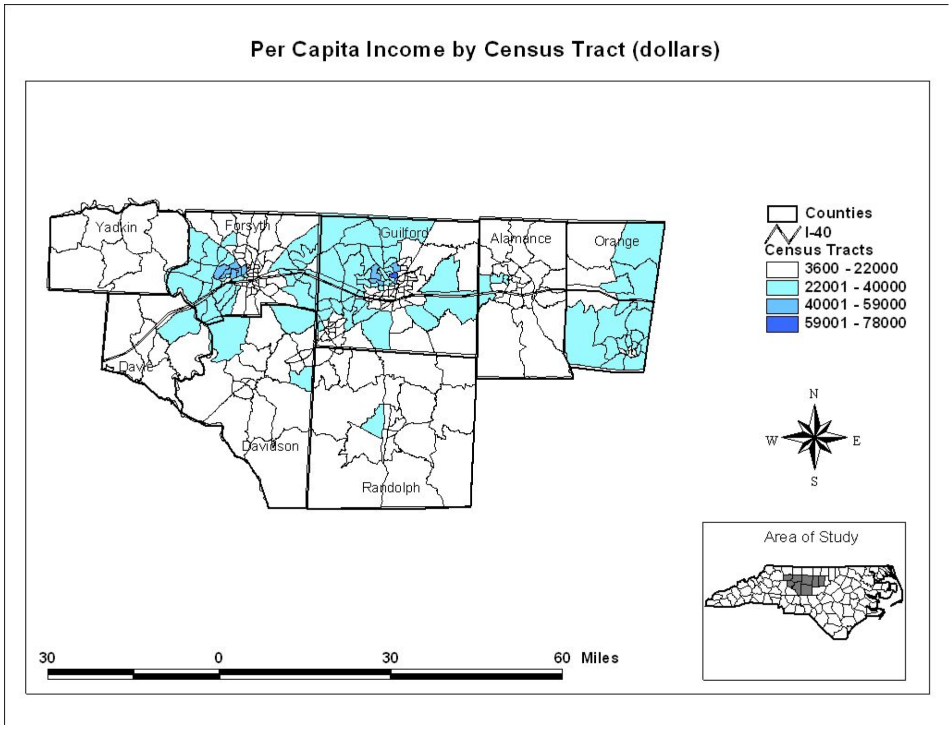


Figure 10: Average per capita income for the study area is about $21,000 (standard deviation = $2000). The trends in location of highest and lowest incomes are similar to median household income (see above).

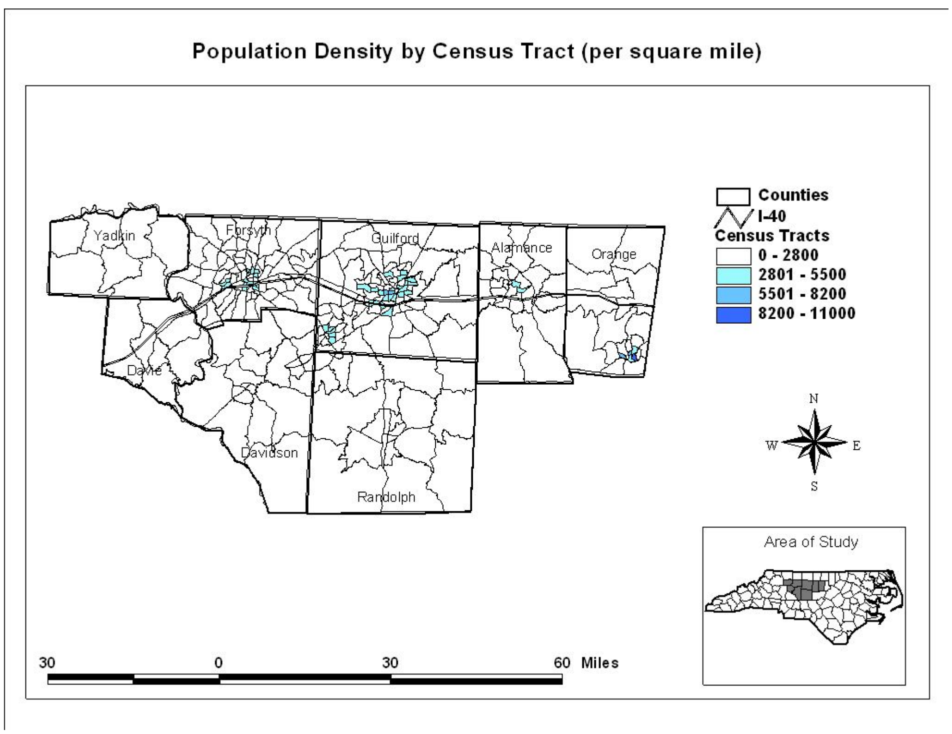


Figure 11: Population density per square mile at the census tract level ranges from 400 in rural areas to 10,000 in the central business districts.

Economic Activity

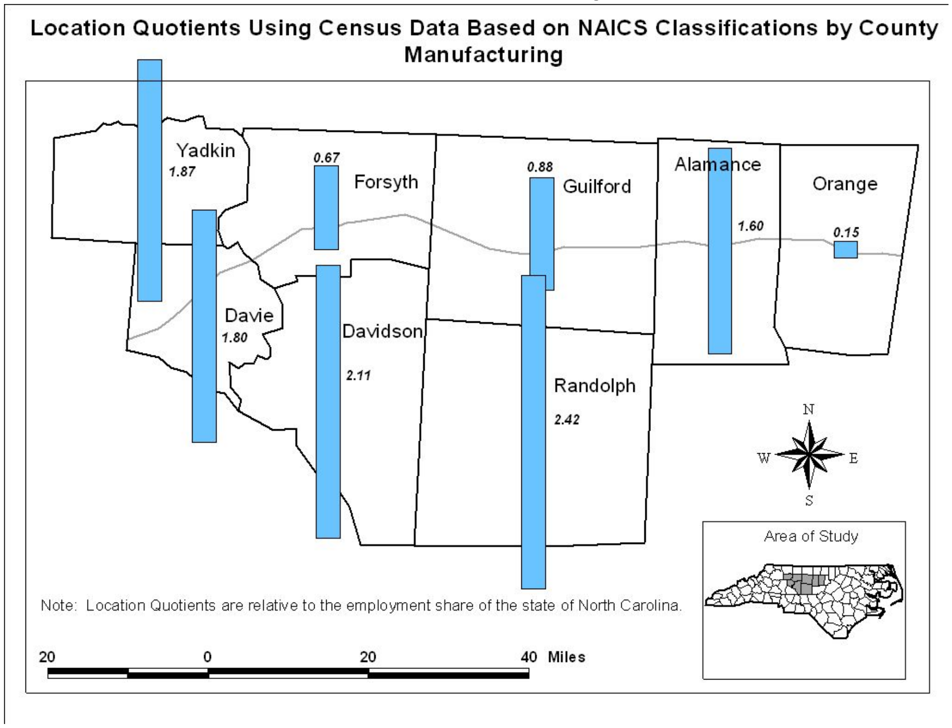


Figure 12: Manufacturing is the largest industry in the study area relative to the state of North Carolina. It is particularly high in the counties surrounding Forsyth and Guilford.

Location quotients for other occupations at the one-digit level, such as trade and warehousing, and professional services did not appear over or under represented in these counties, as compared to the entire state of North Carolina.

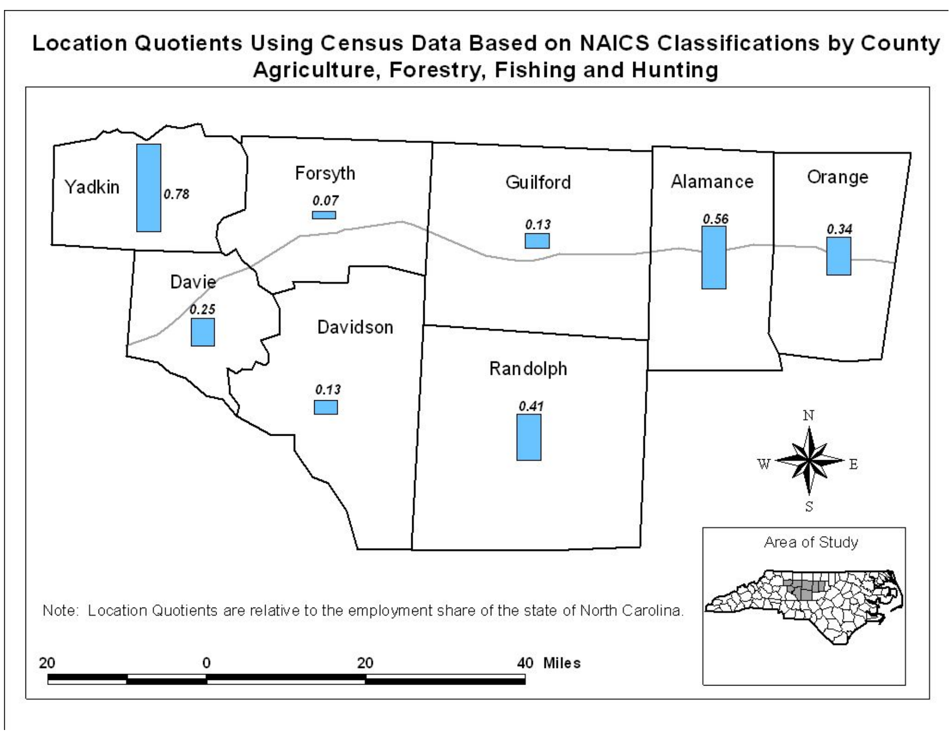


Figure 13: Location quotients for agriculture show this industry is underrepresented as compared with North Carolina.

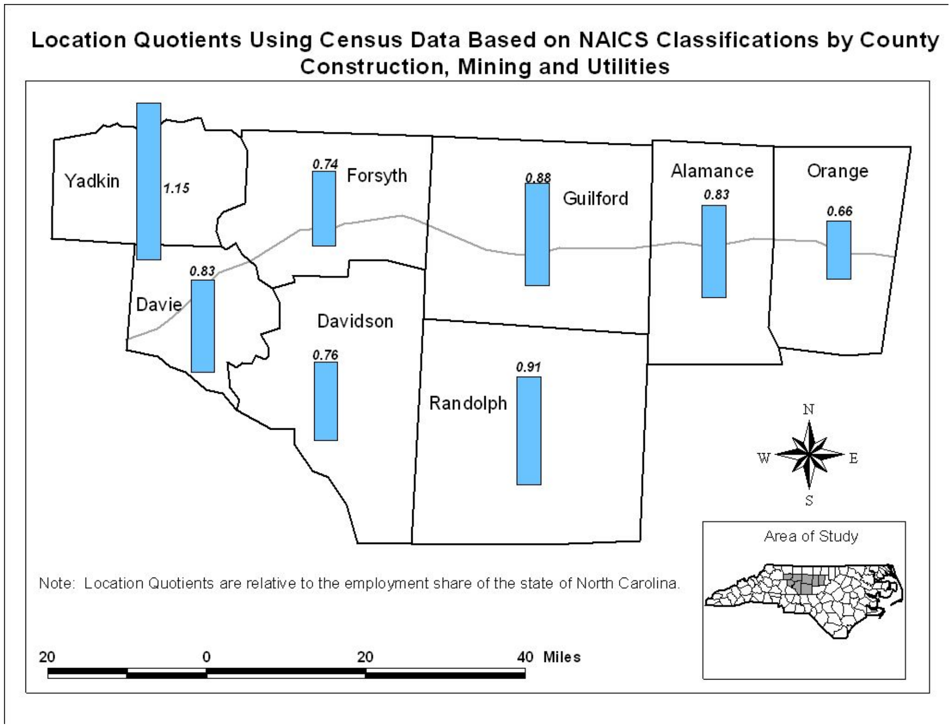


Figure 14: Construction, mining and utility industries only exceed the state average in Yadkin County. Overall, this industry is neither over nor under represented in the study area.

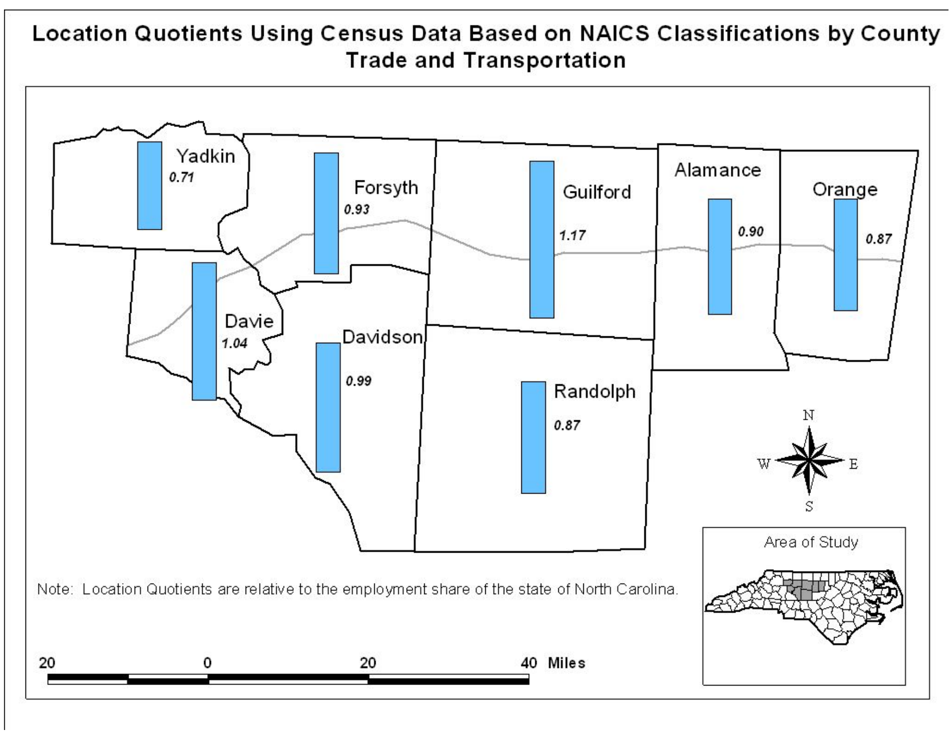


Figure 15: The trade and transportation industry in the area of study is similar to the average for the state of North Carolina.

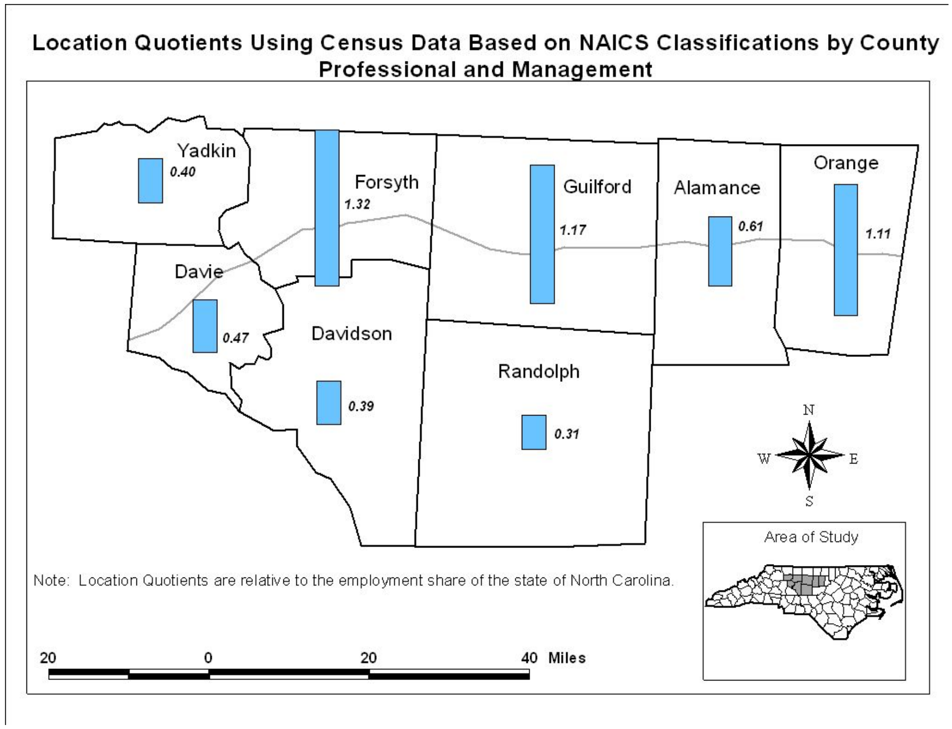


Figure 16: Professional and management industries are underrepresented in most counties in the study area except Forsyth, Guilford and Orange which are similar to the state's average.

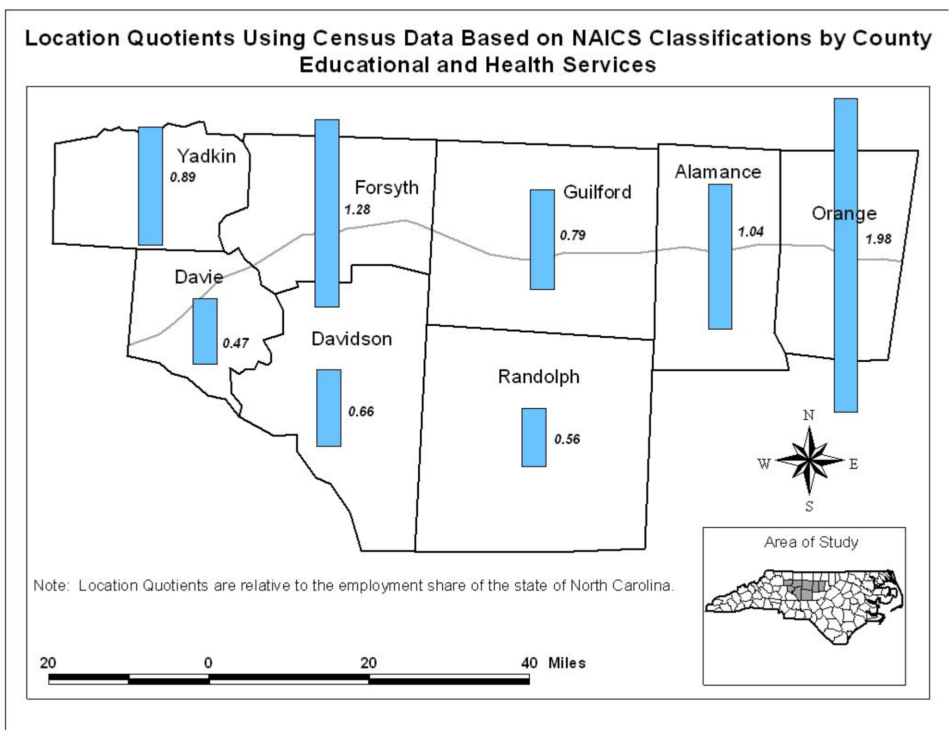


Figure 17: Although Orange County is above the state average, educational and health services are not over or under represented in the study area.

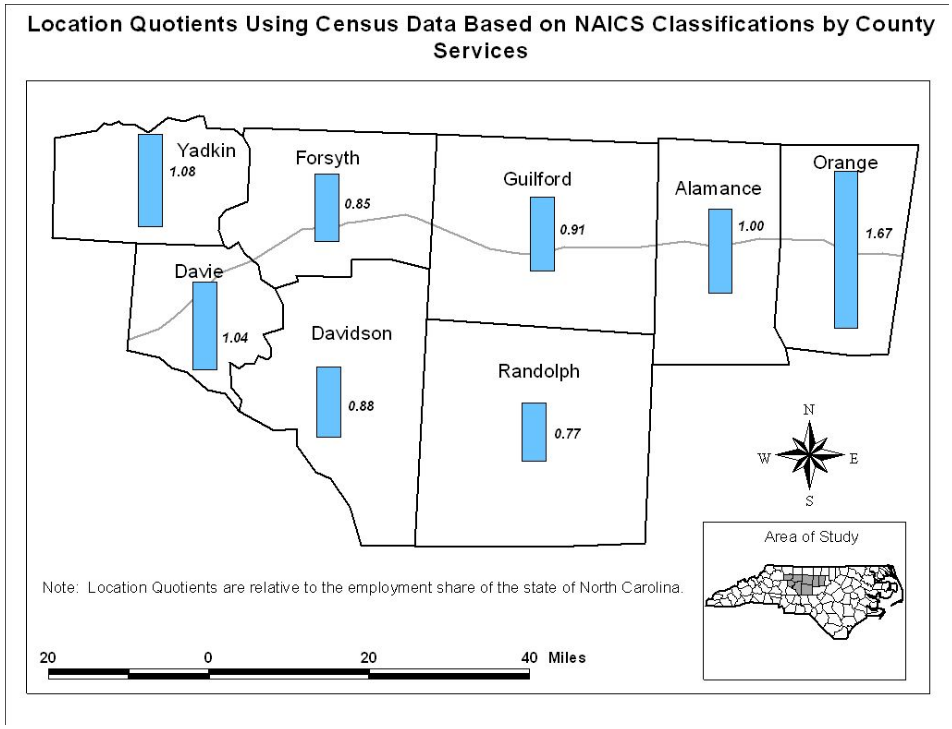


Figure 18: The service industry mirrors the state of North Carolina average in the study area.

Appendix 4

Commuter Survey and Analysis

YOUR COMMUTE ON I-40

Please answer the following questions to help us understand your experience with commuting on Interstate 40:

1. For each of the following three vehicle occupancy conditions and time periods, approximately how many times during a typical week do you use Interstate 40:

Vehicle occupancy condition / Time period:	*Morning peak 7:00-10:00am	*Evening peak 3:00-7:00pm	Other times
Drive alone	___Times/wk	___Times/wk	___Times/wk
Drive, and have one or more passengers	___Times/wk	___Times/wk	___Times/wk
Ride as a passenger, with someone else driving	___Times/wk	___Times/wk	___Times/wk

*If you never use I-40 during the morning and evening peak periods, please SKIP questions 2 through 10.

2. During peak periods, I travel approximately:
   ___ miles on I-40 in the morning, and ____ miles on I-40 in the evening
   ___ miles NOT on I-40 in the morning, and ____ miles NOT on I-40 in the evening

3. What is your longest acceptable commute time to or from work or school during a peak period?

   a☐ Less than 15 minutes one way
   b☐ 15 to 25 minutes one way
   c☐ 26 to 40 minutes one way
   d☐ 41 to 60 minutes one way
   e☐ More than 60 minutes one way

4. During peak periods, what time of day do you typically get on I-40? _____ AM (Morn.) _____ PM (Eve.)

5. During peak periods, where do you usually ENTER I-40? Enter name of connecting road or highway:
   For morning peak: ______________________ For evening peak: ______________________

6. During peak periods, where do you usually EXIT I-40? Enter name of connecting road or highway:
   For morning peak: ______________________ For evening peak: ______________________

7. During peak periods, approximately how much time do you TYPICALLY spend traveling on I-40 between entering and exiting? _____ Minutes (Morn.) _____ Minutes (Eve.)

8. In your estimation, how much time would the I-40 portion of that trip take if you entered I-40 shortly AFTER the end of the peak period? _____ Minutes (Morn.) _____ Minutes (Eve.)

9. In the past 30 days, during peak periods, what was the LONGEST approximate time you spent traveling on I-40 between entering and exiting? _____ Minutes (Morn.) _____ Minutes (Eve.)

10. In the past 30 days, approximately how many peak period trips on I-40 were at least 10 minutes longer than typical because of unexpectedly higher congestion (for example, due to a traffic accident up ahead)?

    a☐ Less than five peak period trips
    b☐ Five to nine peak period trips
    c☐ Ten to fourteen period trips

d☐ Fifteen or more peak period trips

YOUR OPINIONS

For each statement, please circle the number that best corresponds to your opinion. Circle number 1 if you agree strongly, number 2 if you somewhat agree, number 3 if you are neutral about it, number 4 if you somewhat disagree, and circle number 5 if you disagree strongly.

	Agree strongly ↓				Disagree strongly ↓
11. Traffic congestion on I-40 during the MORNING peak period is a problem	1	2	3	4	5
12. Traffic congestion on I-40 during the EVENING peak period is a problem	1	2	3	4	5
13. If it did not take as long as it presently does when I travel on I-40 during the MORNING peak period, I would use I-40 more often	1	2	3	4	5
14. If I-40 became more heavily congested in the future during a typical MORNING peak period, I would use it less often	1	2	3	4	5
15. Truck traffic on I-40 is heavy	1	2	3	4	5
16. Many drivers on I-40 have poor driving habits	1	2	3	4	5
17. Major traffic back-ups on I-40 entrance and exit ramps often occur	1	2	3	4	5
18. I have several reasonably good alternatives to taking I-40	1	2	3	4	5
19. Carpooling opportunities for me would be greater if I did not take I-40	1	2	3	4	5
20. Information that is made available about I-40 traffic congestion and other travel conditions is timely and generally reliable	1	2	3	4	5
21. For me, driving alone makes my schedule much more flexible	1	2	3	4	5
22. I would be willing to increase the total number of miles that I commute to work, if the time it takes to get there was about the same as it is now	1	2	3	4	5
23. Along heavily congested sections of I-40, carpool lanes should be available to bypass the congestion	1	2	3	4	5
24. If I could reduce my commuting time simply by paying a small fee, I would.	1	2	3	4	5
25. Drivers in single occupant vehicles should be allowed to pay a fee to use a carpool lane if the revenue would be used for transportation improvements	1	2	3	4	5
26. It is hard to find people who are interested in carpooling with me	1	2	3	4	5
27. Traffic congestion is a major problem for me	1	2	3	4	5
28. To help reduce traffic congestion, I believe it is important for employers to offer "Flex-Time" (options for work hours, and days worked per week)	1	2	3	4	5
29. I must be at work (or school) at a certain time, and not be late	1	2	3	4	5
30. I must be home at a certain time, and not be late	1	2	3	4	5
31. I'm able to moderately adjust my schedule in the morning and late afternoon in order to get important things accomplished in my life	1	2	3	4	5

32. Charging tolls on a new or improved highway is fair and reasonable, provided that the highway offers a substantially faster way to commute	1	2	3	4	5
33. Taking public transportation is fairly convenient for me	1	2	3	4	5

HIGHWAY LANE MANAGEMENT

In this section we would like you to read the following brief description of "Highway Lane Management" and then answer a few related questions:

"Highway Lane Management" is used to improve travel conditions on major roadways. For rush hour commuters, it can allow drivers to travel quickly (at the speed limit), and avoid heavily congested travel lanes. One approach is to allow single-occupant vehicles to use an HOV lane after the driver pays a fee at an efficiently operated electronic toll collection facility. Most often the money is then used to plan and implement additional transportation improvements in the region (city or metro area) where the tolls are collected. Vehicles that meet the occupancy requirements of the HOV facility would continue to use the lane for free.

34. Assuming that it would save you some time during your commute, would you consider paying a toll to be allowed to use a carpool lane while driving ALONE and enjoy congestion free travel at full highway speeds?
    - a☐ Yes (If "Yes" please answer questions 35 and 36)
    - b☐ No (If "No" please SKIP question 35, and answer question 36)

35. Assuming you continue to use I-40 as you currently do, how much money would you be willing to pay (per one way trip) to be allowed to drive ALONE in a carpool lane on I-40 to avoid congestion and travel at full highway speeds? (Please respond to BOTH time saving conditions shown below)

    CONDITION 1

    Knowing that it would save you 8 minutes of travel time on average for each one way, peak period trip

    - a☐ Less than $0.25 per one way trip
    - b☐ $0.25 to $1.25 per one way trip
    - c☐ $1.26 to $2.50 per one way trip
    - d☐ $2.51 to $4.00 per one way trip
    - e☐ More than $4.00 per one way trip

    CONDITION 2

    Knowing that it would save you 15 minutes of travel time on average for each one way, peak period trip

    - a☐ Less than $0.50 per one way trip
    - b☐ $0.50 to $2.50 per one way trip
    - c☐ $2.51 to $5.00 per one way trip
    - d☐ $5.01 to $8.00 per one way trip
    - e☐ More than $8.00 per one way trip

36. If tolls or fees were collected to allow single occupant drivers on carpool lanes, how should the money be used (you can check more than one box)?

    - a☐ To maintain and improve only the existing regular lanes on that highway
    - b☐ To maintain and improve only the existing carpool lane on that highway
    - c☐ To maintain and improve all existing lanes on that highway
    - d☐ To add more regular lanes on that highway
    - e☐ To add more carpool lanes on OTHER highways
    - f☐ To improve bus (or commuter rail) service in the area

g☐ To maintain and improve existing (or build new) roads and highways in the area

ABOUT YOU

Please answer the following questions to help us understand the circumstances that contribute to your travel decisions:

37. How many people live in your household? 18 years or older: ___ 17 years or younger: ___

38. How many licensed drivers are in your household? ___

39. What is the total number of vehicles owned (or leased) by licensed drivers of your household? ___

40. Have you ever used a carpool lane before? a☐ Yes b☐ No

41. In the past, have you ever regularly used a bus or train to commute to work? a☐ Yes b☐ No

42. What is your gender? b☐ Male b☐ Female

43. What best describes your employment status? (choose all that apply)
    - a☐ Work full-time outside the home
    - b☐ Work part-time outside the home
    - c☐ Student
    - d☐ Work full-time at home
    - e☐ Work part-time at home
    - f☐ Unemployed (non-student)
    - g☐ Retired
    - h☐ Other [Specify]________________

44. What best describes your occupation?
    - a☐ Clerical/Secretary
    - b☐ Service
    - c☐ Professional
    - d☐ Executive/Managerial
    - e☐ Skilled Trades
    - f☐ Retired
    - g☐ Sales/Retail
    - h☐ Computer/Technical
    - i☐ Medical/Health
    - j☐ Other[Specify]________________

45. How often have you used the Internet in the past 6 months at home?
    - a☐ Everyday
    - b☐ At least once a week
    - c☐ Several times a month
    - d☐ Very rarely or never

46. What is your racial / ethnic origin?
    - a☐ Black
    - b☐ White
    - c☐ Hispanic
    - d☐ Other

47. What is your approximate annual household income before taxes (your response is optional)?
    - a☐ Under $20,000
    - b☐ $20,000-$50,000
    - c☐ $50,001-$90,000
    - d☐ $90,001-$150,000
    - e☐ over $150,000

Thank You for your participation !!

Table 1. Variable Description

Variable	Units	Description
Miles driven on I40 am	Mi	Miles driven on I40 am
Miles driven on I40 pm	Mi	Miles driven on I40 pm
Miles driven elsewhere am	Mi	Miles driven elsewhere am
Miles driven elsewhere pm	Mi	Miles driven elsewhere pm
Travel time on I40 am	Minutes	Travel time on I40 am
Travel time on I40 pm	Minutes	Travel time on I40 pm
Used carpool	Yes=1/ No=0	Prior experience with carpool lanes
Used bus/transit	Yes=1/ No=0	Prior experience commuting by bus or transit
Number of cars at home		Number of cars at home
Number of licensed drivers at home		Number of licensed drivers at home
Number of people 18 years and older		Number of people 18 years and older
Number of children 17 years or younger		Number of children 17 years or younger
Drive alone frequency on I40	%	Drive alone frequency per week
Drive w/passenger frequency on I40	%	Drive with a passenger frequency per week
Ride as a passenger frequency on I40	%	Ride as a passenger frequency per week
Trips per week	Yes=1/ No=0	Number of trips per week on I40
Maximum delay	Minutes	Maximum delay experienced in the last 30 days
Trip_10min		Number of trips that were 10 minutes or longer, due to unexpected congestion on I40
Interaction work on time & max delay		Interaction term between being on time at work and maximum delay
Being at work on time	Yes=1/ No=0	Being at work on time
Maximum acceptable commuting time	Minutes	Maximum acceptable commuting time
Race	White=1/ Other=0	Race
Work	Yes=1/ No=0	Work (students who work are represented as students)
Willingness to pay	Yes=1/ No=0	Willingness to pay a toll for the right to use HOV lane while driving alone for time savings
Drivers per cars	Ratio	Ratio of licensed drivers over number of cars at home

Table 2. Descriptive Statistics for Non-categorical Variables

Variable	N	Mean	Std. Dev.	Min	Max
Miles driven on I40 am	566	18.42	12.98	0	85
Miles driven on I40 pm	546	18.56	13.66	0	85
Miles driven elsewhere am	307	11.72	12.98	0	100
Miles driven elsewhere pm	308	11.96	12.94	0	150
Travel time on I40 am	567	21.91	13.49	0	80
Travel time on I40 pm	539	23.63	15.28	3	130
Used carpool	656	0.41	0.49	0	1
Used bus/transit	652	0.14	0.35	0	1
Number of cars at home	654	2.57	1.27	0	14
Number of drivers at home	654	2.13	0.75	1	5
Number of people ≥ 18	642	2.06	0.71	0	5
Number of children <17 years	360	1.33	1.02	0	5
Drive alone freq on I40 (per week)	628	0.80	0.27	0	1
Drive w/passenger frequency on I40 (per week)	628	0.14	0.25	0	1
Ride as passenger frequency on I40 (per week)	628	0.04	0.10	0	1
Trips per week	658	11.50	7.21	0	73
Maximum delay (minutes)	621	17.09	24.48	0	335
Drivers per cars	653	0.90	0.28	0	2
Average speed AM*	518	47.89	16.84	6	96
Average speed PM*	438	44.96	16.59	0	96

* Speed values were approximated with the time and distance values stated by the respondents

Table 3. Descriptive Statistics for Categorical Variables

Variable	Response	Percent	N
Gender	Female	54.1%	655
Race	White	79.8%	647
Willingness to pay	Yes	35.7%	647

Figure 1. Income Distribution n=569 ($1,000)

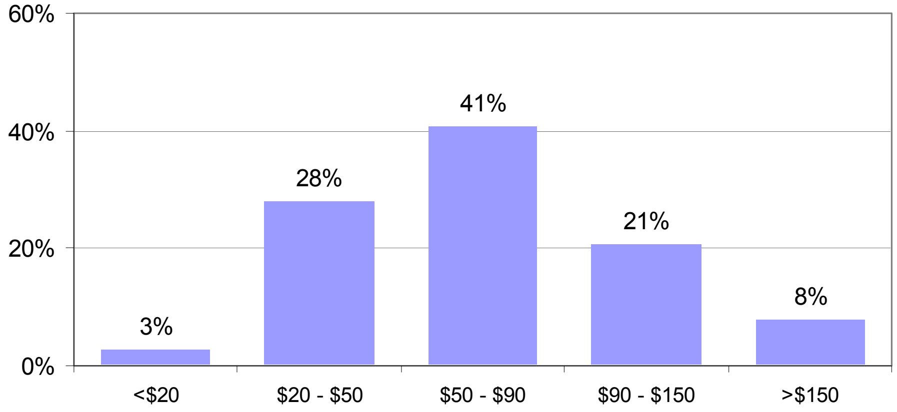


Figure 2. Maximum Acceptable Commute Time n=593 (minutes)

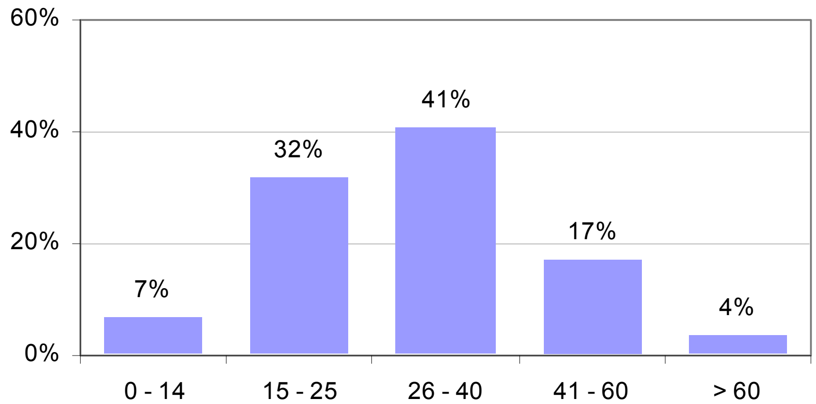


Table 4. Occupations of Survey Respondents

Occupation	Frequency	Percent	Cumulative
Clerical/secretary	60	9.19	9.19
Service	71	10.87	20.06
Professional	175	26.80	46.86
Executive/managerial	99	15.16	62.02
Skilled trades	38	5.82	67.84
Retired	5	0.77	68.61
Sales/retail	46	7.04	75.65
Computer/technical	43	6.58	82.24
Medical/health	59	9.04	91.27
Other	57	8.73	100
Total	653	100	

Figure 3. Use of HOT Lane Funds

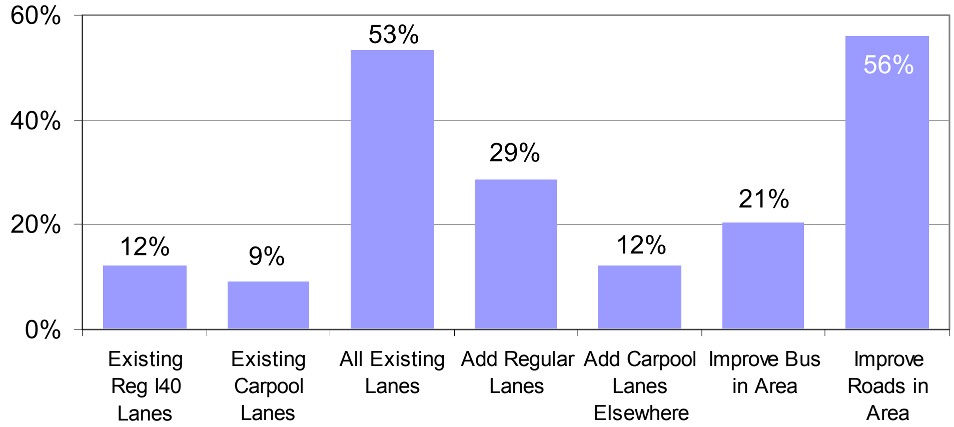


Table 5. Cross Tabulation Betweenbetween Willingness to Pay and Funds Distribution

Funds Distribution		WTP					
		NO		YES		TOTAL	
Existing Regular Lanes I40	NO	295	60.3%	194	39.7%	489	100%
	YES	37	55.2%	30	44.8%	67	100%
Existing Carpool Lanes I40	NO	302	59.9%	202	40.1%	504	100%
	YES	30	57.7%	22	42.3%	52	100%
All Existing Lanes I40	NO	167	64.5%	92	35.5%	259	100%
	YES	165	55.6%	132	44.4%	297	100%
Add Regular Lanes I40	NO	252	63.5%	145	36.5%	397	100%
	YES	80	50.3%	79	49.7%	159	100%
Add Carpool Lanes other	NO	310	63.7%	177	36.3%	487	100%
	YES	22	31.9%	47	68.1%	69	100%
Improve Bus in the Area	NO	268	60.8%	173	39.2%	441	100%
	YES	64	55.7%	51	44.3%	115	100%
Improve Roads in the Area	NO	145	59.4%	99	40.6%	244	100%
	YES	187	45.5%	224	54.5%	411	100%

Table 6. Cross Tabulation between Willingness to Pay and Funds Distribution

		Existing Regular Lanes I40		Existing Carpool Lanes I40		All Existing Lanes I40		Add Regular Lanes I40		Add Carpool Lanes Other		Improve Bus in the Area		Improve Roads in Area	
		YES	%	YES	%	YES	%	YES	%	YES	%	YES	%	YES	%
	No	37	55%	30	58%	165	56%	80	50%	22	32%	64	56%	187	60%
WTP	**Yes**	30	45%	22	42%	132	44%	79	50%	47	68%	51	44%	125	40%
	Total	67	100%	52	100%	297	100%	159	100%	69	100%	115	100%	312	100%

Figure 4. Willingness to Pay for 8-minute Travel Time Savings n=223

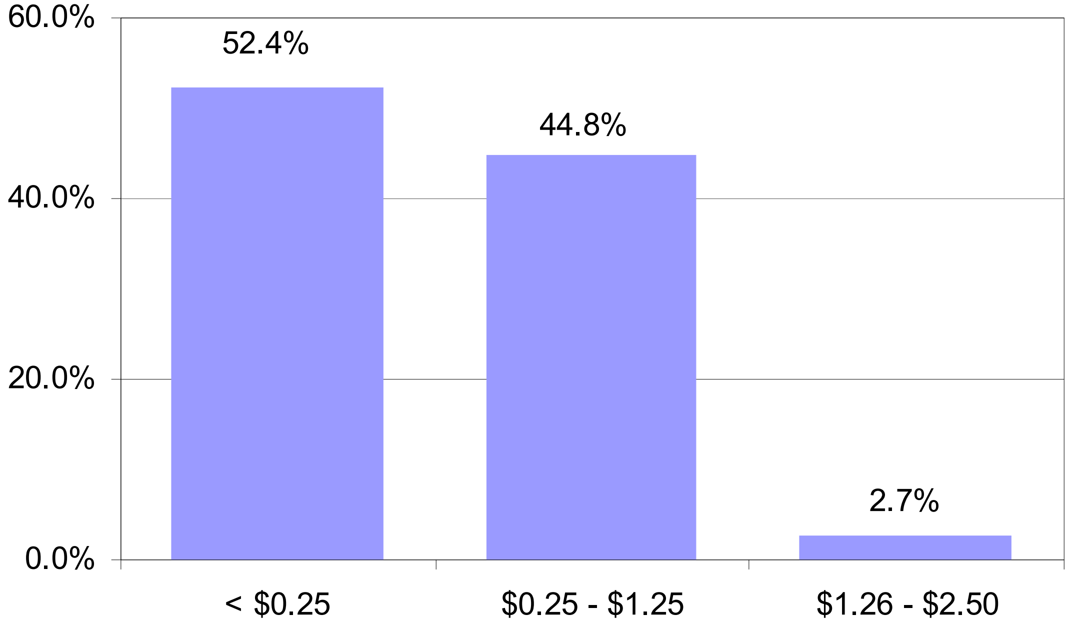


Figure 5. Willingness to Pay for 15-minute Travel Time Savings n=219

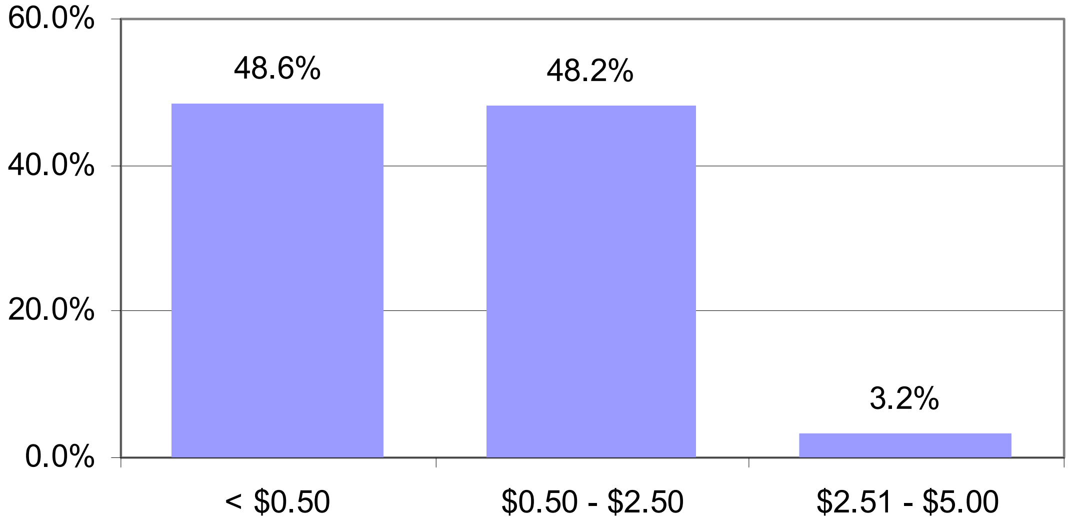


Figure 6. Willingness to Pay for 8-minute Travel Time Savings Overall n=647

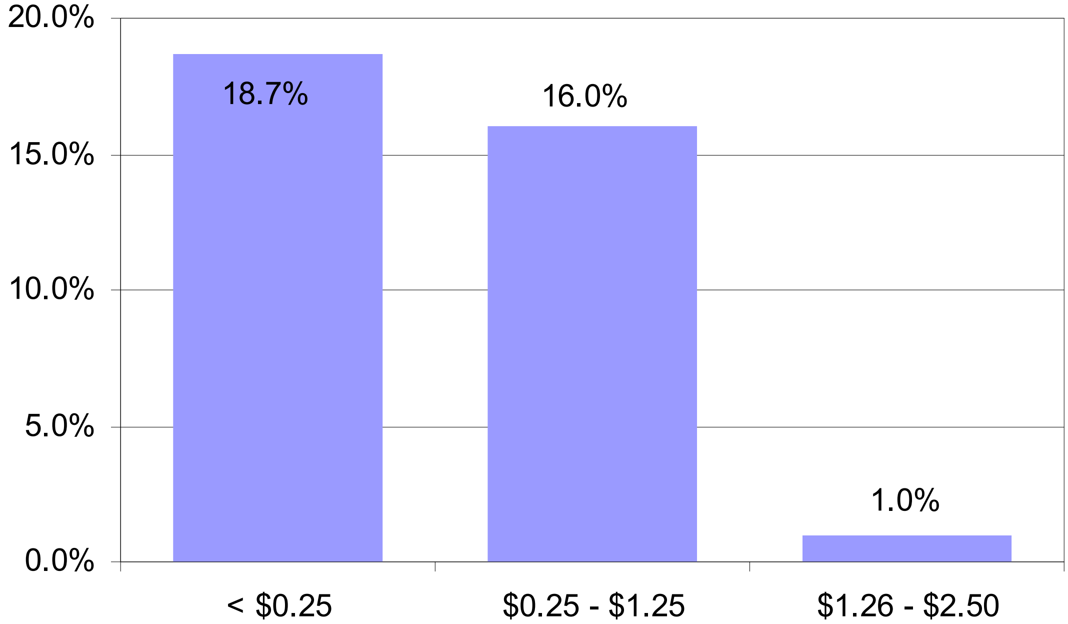


Figure 7. Willingness to Pay for 15-minute Travel Time Savings Overall n=647

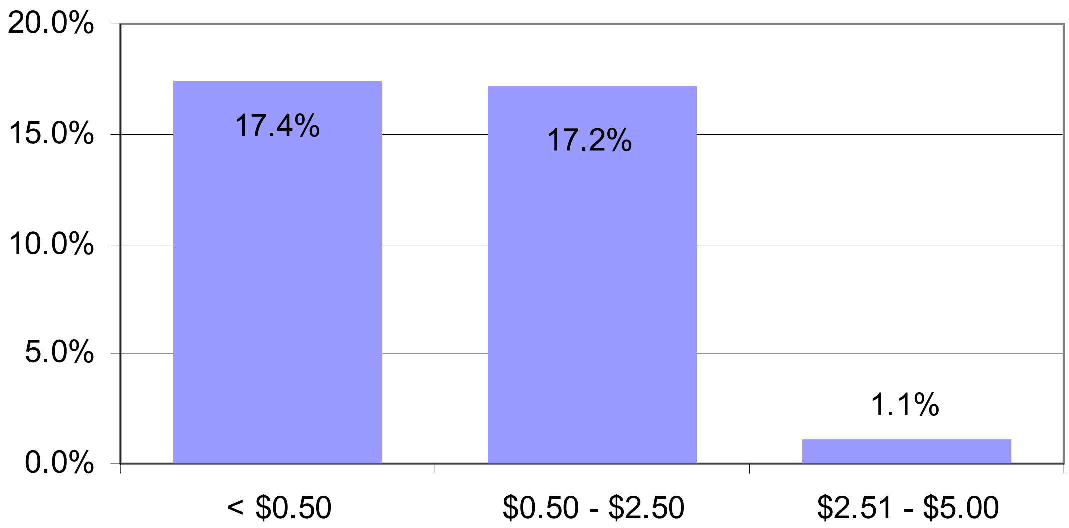


Figure 8. Willingness to Pay for 8-minute Travel Time Savings, for the Eastbound (Congested) Direction on the AM Peak n=145

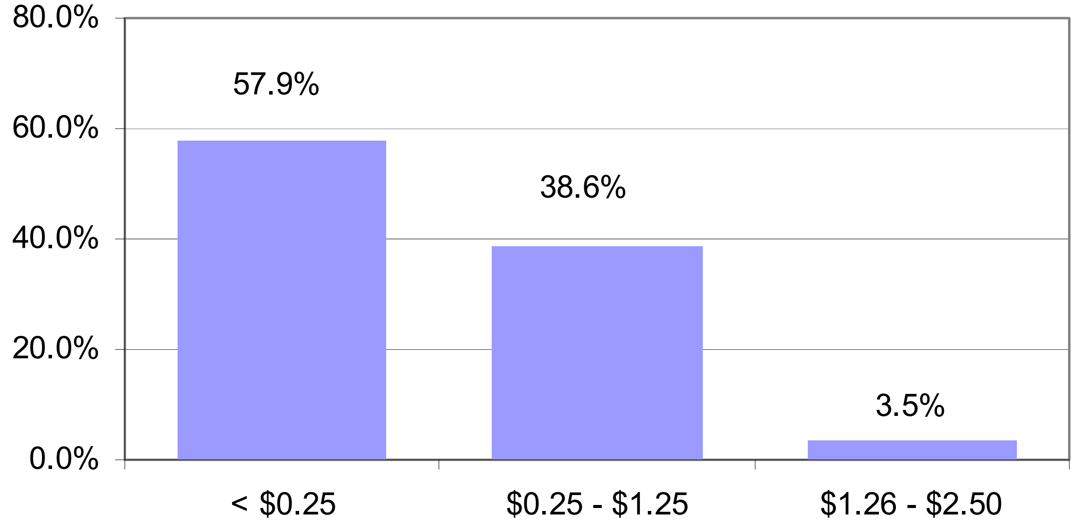


Figure 9. Willingness to Pay for 8-minute Travel Time Savings, for the Westbound Direction on the AM Peak n=30

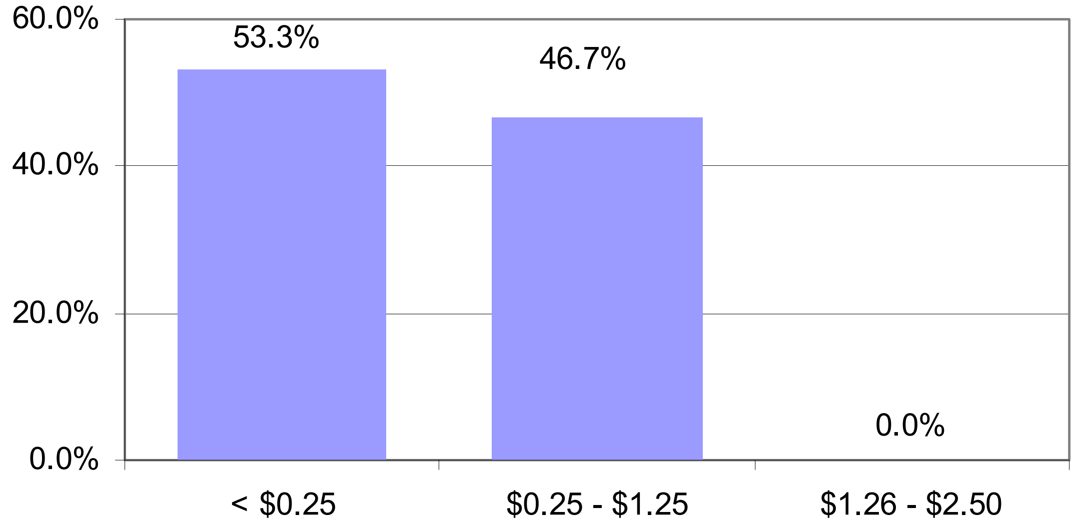


Figure 10. Willingness to Pay for 8-minute Travel Time Savings, for the Eastbound Direction on the PM Peak n=39

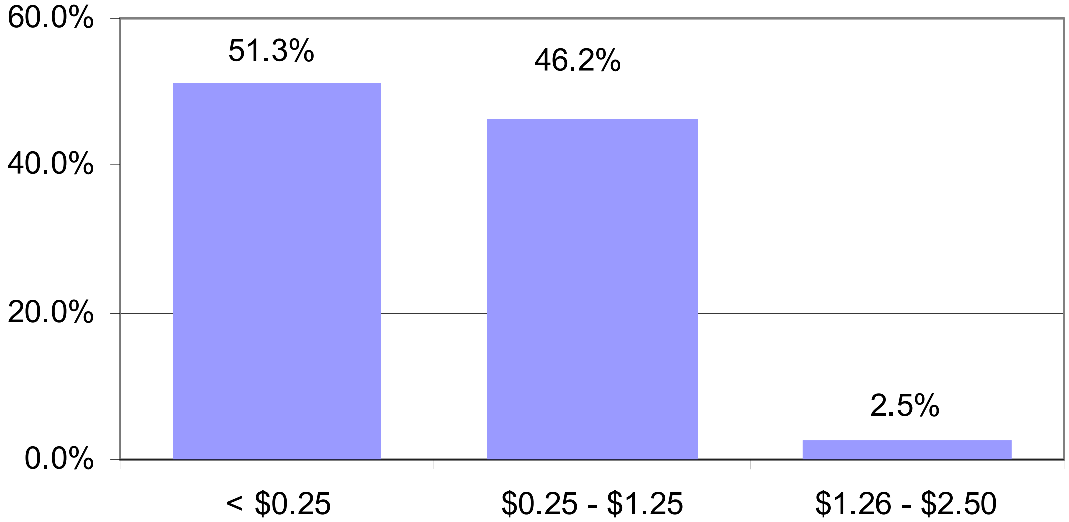


Figure 11. Willingness to Pay for 8-minute Travel Time Savings, for the Westbound (Congested) Direction on the PM Peak n=128

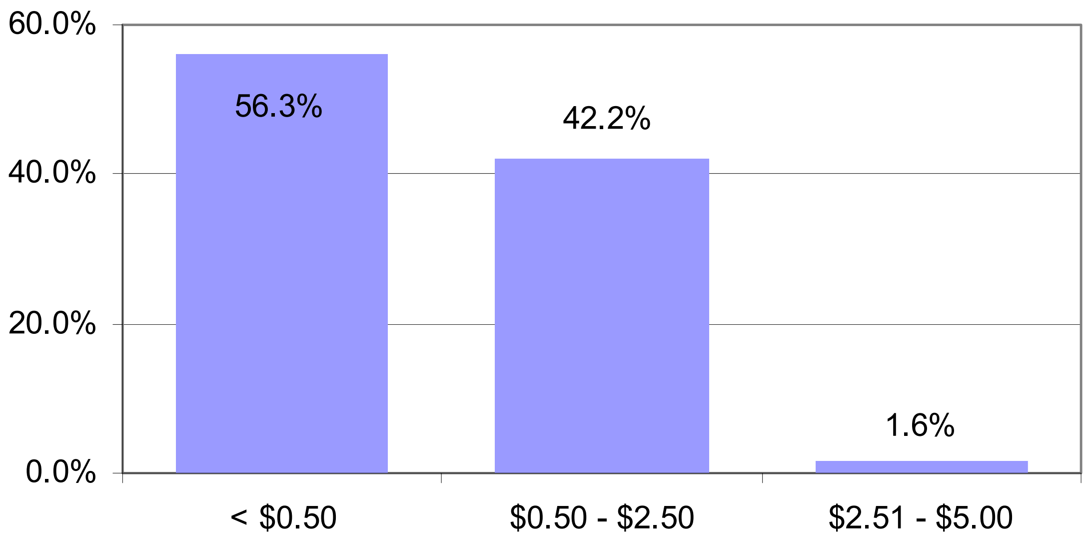


Figure 12. Willingness to Pay for 15-minute Travel Time Savings, for the Eastbound (Congested) Direction on the AM Peak n=141

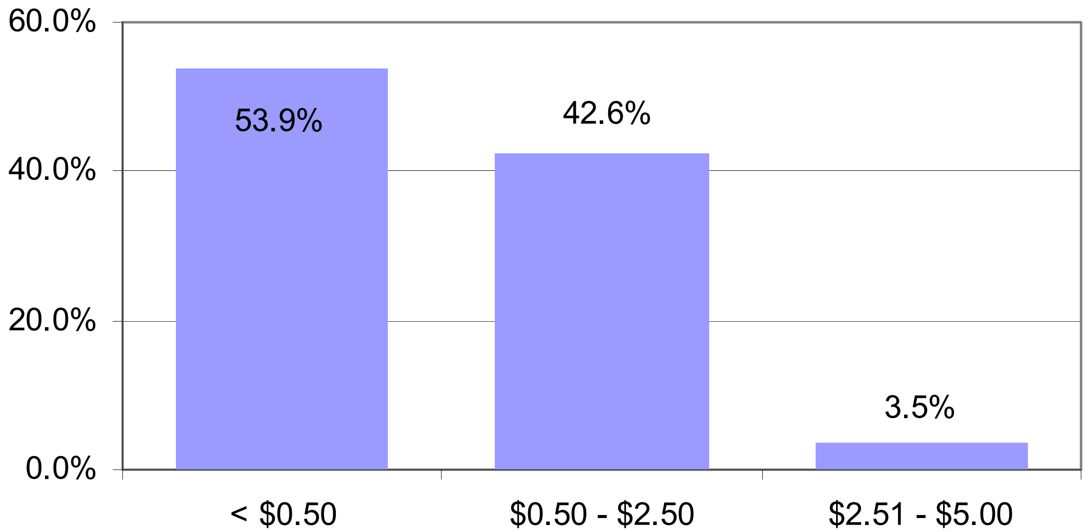


Figure 13. Willingness to Pay for 15-minute Travel Time Savings, for the Westbound Direction on the AM Peak n=30

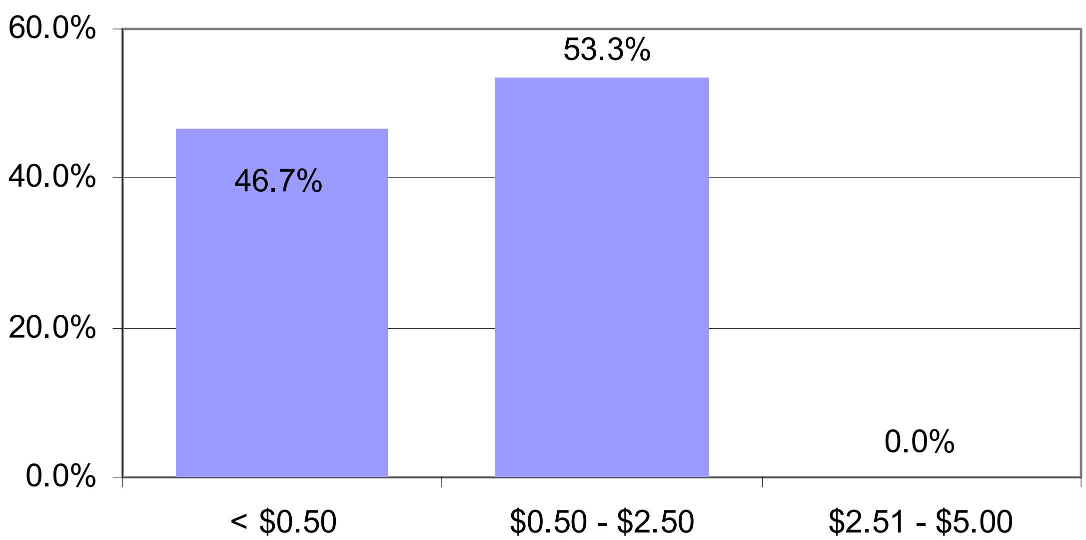


Figure 14. Willingness to Pay for 15-minute Travel Time Savings, for the Eastbound Direction on the PM Peak n=39

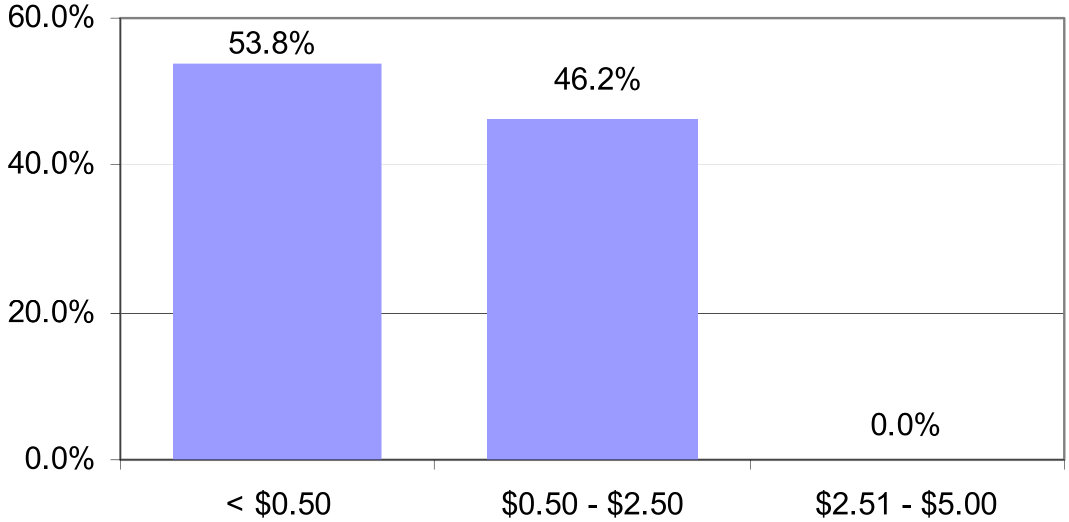


Figure 15. Willingness to Pay for 15-minute Travel Time Savings, for the Westbound (Congested) Direction on the PM Peak n=124

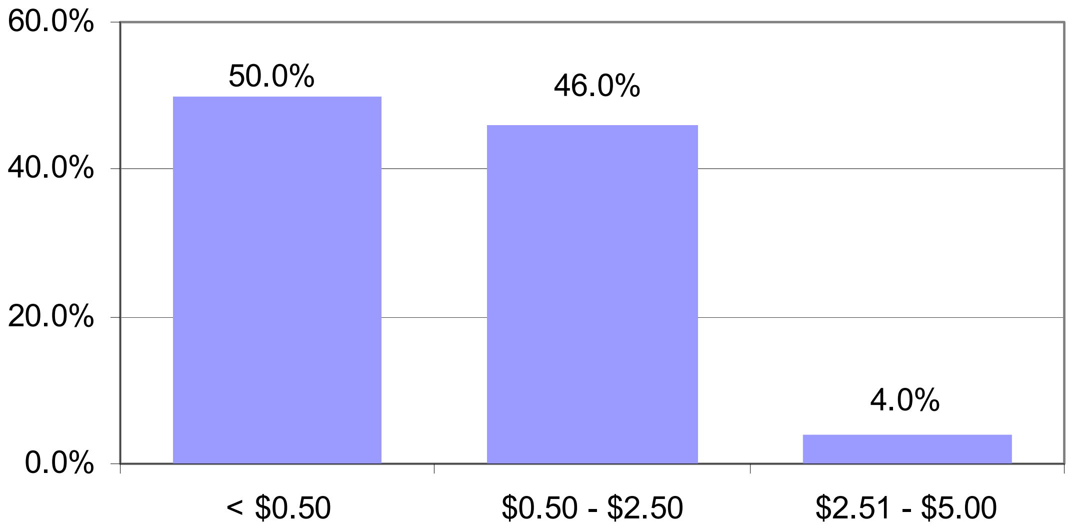


Table 7. Predictors of Willingness to Pay for HOT Lane Use, Including Interaction Term bBetween Being on Time at Work and Maximum Delay, and Being on Time at Home and Maximum Delay

Estimation Methodology: logit
Dependent variable: WTP (No=0; Yes=1)
Logit estimates

Number of obs	=	469
LR chi2(12)	=	31.25
Prob > chi2	=	0.0031
McFadden's R2	=	0.0504

Log likelihood = -294.19603

WTP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Drive alone	-0.193	0.417	-0.46	0.644	-1.011	0.625
Ride as pax	-1.718	1.278	-1.34	0.179	-4.223	0.786
Max delay	0.033	0.018	1.87	0.062	-0.002	0.067
Max accept time	0.296	0.119	2.5	0.013	0.063	0.528
Income	0.066	0.117	0.56	0.574	-0.164	0.295
Work	-0.724	0.395	-1.83	0.067	-1.497	0.050
Number of children <17 years	-0.195	0.110	-1.77	0.076	-0.411	0.020
Drivers/cars	0.550	0.374	1.47	0.142	-0.184	1.283
Used_carpool	0.619	0.206	3	0.003	0.214	1.023
Race	-0.126	0.268	-0.47	0.639	-0.651	0.399
Gender	-0.158	0.209	-0.75	0.45	-0.569	0.252
Trip_10min	0.155	0.145	1.07	0.285	-0.129	0.439
Interaction work on time & max delay	-0.007	0.004	-1.81	0.07	-0.014	0.001
Being at work on time	0.040	0.106	0.38	0.707	-0.167	0.247
Constant	-1.498	0.800	-1.87	0.061	-3.067	0.070

Figure 16. Willingness to Pay Odds Ratio for Selected Independent Variables (95% CI)

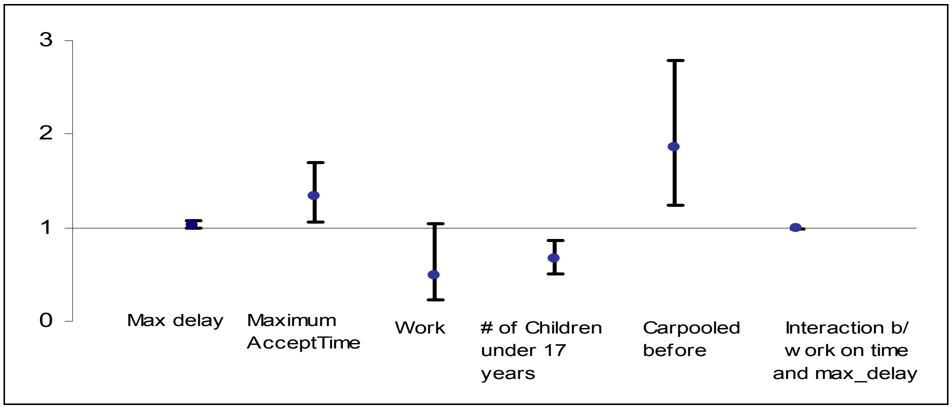


Table 8. Predictors of Stated Maximum Toll Paid, Saturated Model

Estimation Methodology. OLS

Dependent variable: Maximum toll paid

Number of obs	=	477
F(13, 463)	=	3.32
Prob > F	=	0.0001
R-squared	=	0.0852
Adj R-squared	=	0.0595
Root MSE	=	.67025

Max_toll_paid	Coef.	Std. Err.	T	P>|t|	[95% Conf.	Interval]
Max_delay	0.003	0.001	1.95	0.052	0.000	0.005
Income	0.082**	0.036	2.27	0.024	0.011	0.153
Race	-0.037	0.083	-0.45	0.656	-0.199	0.125
Number of children <17 years	-0.079**	0.033	-2.4	0.017	-0.144	-0.014
Max accept_time	0.077**	0.035	2.23	0.026	0.009	0.145
Drive alone_am	-0.040*	0.021	-1.95	0.051	-0.081	0.000
Drive alone_pm	0.010	0.017	0.62	0.538	-0.022	0.043
Drive w/pax_am	-0.132***	0.033	-3.94	0	-0.198	-0.066
Drive w/pax_pm	0.149***	0.031	4.78	0	0.088	0.210
Ride as pax_am	0.165*	0.086	1.92	0.056	-0.004	0.334
Ride as pax_pm	-0.207***	0.075	-2.76	0.006	-0.354	-0.060
Work	-0.234*	0.124	-1.88	0.06	-0.478	0.010
Number of cars	-0.027	0.029	-0.93	0.354	-0.085	0.030
Constant	0.395**	0.182	2.17	0.031	0.037	0.754

Sample selection models (Heckman) were estimated, but no evidence of the need to use sampling selection was found (rho = 0, p = 0.1123)

Table 9. Predictors of Preferring HOT Lane Funds for Existing Regular Lanes on I-40

Estimation Methodology: logit
Dependent variable: funds for use in: Existing regular lanes on I40 (No=0; Yes=1).

Estimation Methodology: logit
Dependent variable: Existing regular lanes (No=0; Yes=1)
Logit estimates

Number of obs = 373
LR chi2(12) = 19.97
Prob > chi2 = 0.0959
McFadden's R2 = 0.0663

Log likelihood = -140.6647

Existing reg lanes	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	-0.008	0.026	-0.33	0.744	-0.059	0.042
Travel time_pm_I40	0.007	0.020	0.35	0.725	-0.033	0.047
Ride as passenger	1.222	1.626	0.75	0.452	-1.965	4.410
Trips per week	0.009	0.020	0.45	0.65	-0.030	0.048
Miles driven am_I40	-0.051	0.036	-1.4	0.16	-0.123	0.020
Miles driven pm_I40	0.038	0.034	1.13	0.259	-0.028	0.105
Trip_10min	0.444	0.208	2.14	0.033	0.037	0.852
Number of cars	0.211	0.137	1.55	0.122	-0.056	0.479
Gender	0.220	0.330	0.67	0.505	-0.428	0.868
Used bus/transit	0.355	0.446	0.8	0.426	-0.519	1.229
Income	-0.265	0.188	-1.41	0.158	-0.632	0.103
Race	-0.719	0.378	-1.9	0.057	-1.460	0.023
Work	1.223	0.853	1.43	0.152	-0.450	2.896
Constant	-2.936	1.036	-2.83	0.005	-4.965	-0.906

Table 10. Predictors of Preferring HOT Lane Funds for Existing Carpool Lanes on I-40

Estimation Methodology: logit

Dependent variable: Existing regular lanes (No=0; Yes=1)

Logit estimates

Number of obs	=	373
LR chi2(12)	=	9.59
Prob > chi2	=	0.7268
McFadden's R2	=	0.0482

Log likelihood = -94.627

Existing carpool lanes	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	0.016	0.037	0.44	0.657	-0.056	0.088
Travel time_pm_I40	-0.014	0.031	-0.45	0.651	-0.075	0.047
Ride as passenger	4.027	1.904	2.12	0.034	0.296	7.759
Trips per week	-0.016	0.029	-0.56	0.573	-0.073	0.041
Miles driven am_I40	-0.028	0.054	-0.52	0.604	-0.133	0.077
Miles driven pm_I40	0.016	0.050	0.32	0.751	-0.083	0.115
Trip_10min	0.241	0.289	0.83	0.404	-0.325	0.806
Number of cars	0.121	0.178	0.68	0.497	-0.228	0.471
Gender	0.359	0.423	0.85	0.396	-0.471	1.188
Used bus/transit	0.174	0.593	0.29	0.77	-0.989	1.336
Income	-0.279	0.245	-1.14	0.254	-0.758	0.200
Race	-0.631	0.498	-1.27	0.205	-1.606	0.345
Work	1.798	1.398	1.29	0.198	-0.941	4.538
Constant	-3.555	1.596	-2.23	0.026	-6.683	-0.426

Note: I-40 currently does not have any carpool lanes.

Table 11. Predictors of Preferring HOT Lane Funds for All Existing Lanes on I-40

Estimation Methodology: logit
Dependent variable: Existing regular lanes (No=0; Yes=1)

Logit estimates

Number of obs	=	373
LR chi2(12)	=	19.46
Prob > chi2	=	0.1096
McFadden's R2	=	0.0377

Log likelihood = -278.4272

All existing lanes I40	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	-0.012	0.021	-0.58	0.559	-0.052	0.028
Travel time_pm_I40	0.002	0.018	0.12	0.908	-0.032	0.036
Ride as passenger	-0.371	1.259	-0.3	0.768	-2.838	2.095
Trips per week	0.025	0.016	1.59	0.111	-0.006	0.057
Miles driven am_I40	0.025	0.028	0.9	0.367	-0.030	0.080
Miles driven pm_I40	-0.034	0.027	-1.29	0.197	-0.087	0.018
Trip_10min	-0.039	0.164	-0.24	0.813	-0.360	0.282
Number of cars	-0.201	0.104	-1.94	0.053	-0.404	0.002
Gender	0.203	0.224	0.9	0.366	-0.237	0.643
Used bus/transit	0.270	0.330	0.82	0.413	-0.377	0.916
Income	0.195	0.128	1.53	0.126	-0.055	0.446
Race	0.083	0.297	0.28	0.781	-0.500	0.665
Work	-0.934	0.450	-2.08	0.038	-1.816	-0.052
Constant	0.789	0.624	1.27	0.206	-0.434	2.012

Table 12. Predictors of Preferring HOT Lane Funds for Add Regular Lanes on I-40

Estimation Methodology: logit
Dependent variable: Existing regular lanes (No=0; Yes=1)
Logit estimates

Number of obs	=	373
LR chi2(12)	=	15.35
Prob > chi2	=	0.2858
McFadden's R2	=	0.0343

Log likelihood = -215.8690

Add regular lanes I40	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	0.0195475	0.021129	0.93	0.355	-0.0218646	0.0609597
Travel time_pm_I40	0.0030436	0.0179337	0.17	0.865	-0.0321057	0.0381929
Ride as passenger	1.909433	1.319417	1.45	0.148	-0.6765776	4.495443
Trips per week	0.0222219	0.0168151	1.32	0.186	-0.0107351	0.0551788
Miles driven am_I40	-0.0142963	0.029109	-0.49	0.623	-0.0713489	0.0427563
Miles driven pm_I40	-0.0066993	0.0273025	-0.25	0.806	-0.0602111	0.0468126
Trip_10min	0.0546062	0.1753417	0.31	0.755	-0.2890572	0.3982696
Number of cars	-0.0281703	0.1106406	-0.25	0.799	-0.2450219	0.1886814
Gender	-0.5306607	0.2495235	-2.13	0.033	-1.019718	-0.0416037
Used bus/transit	-0.1844887	0.3703789	-0.5	0.618	-0.910418	0.5414407
Income	0.0988308	0.1374922	0.72	0.472	-0.1706489	0.3683106
Race	0.1078141	0.3330681	0.32	0.746	-0.5449873	0.7606155
Work	0.1354524	0.4538342	0.3	0.765	-0.7540463	1.024951
Constant	-1.670925	0.661027	-2.53	0.011	-2.966514	-0.3753361

Table 13. Predictors of Preferring HOT Lane Funds for Add Carpool Lanes Elsewhere

Estimation Methodology: logit

Dependent variable: Existing regular lanes (No=0; Yes=1)

Logit estimates

Number of obs = 373
LR chi2(12) = 18.00
Prob > chi2 = 0.1576
McFadden's R2 = 0.0665

Log likelihood = -126.3418

Add carpool lanes elsewhere	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	-0.077	0.034	-2.22	0.026	-0.144	-0.009
Travel time_pm_I40	0.058	0.026	2.26	0.024	0.008	0.108
Ride as passenger	1.386	1.645	0.84	0.4	-1.838	4.610
Trips per week	0.037	0.021	1.74	0.082	-0.005	0.078
Miles driven am_I40	0.058	0.041	1.4	0.16	-0.023	0.138
Miles driven pm_I40	-0.046	0.037	-1.25	0.212	-0.118	0.026
Trip_10min	-0.131	0.264	-0.5	0.619	-0.647	0.386
Number of cars	-0.224	0.175	-1.28	0.201	-0.568	0.119
Gender	-0.140	0.352	-0.4	0.691	-0.831	0.551
Used bus/transit	0.545	0.449	1.21	0.224	-0.334	1.425
Income	0.209	0.203	1.03	0.304	-0.189	0.607
Race	1.404	0.658	2.13	0.033	0.114	2.695
Work	-0.692	0.547	-1.26	0.206	-1.764	0.381
Constant	-3.066	0.982	-3.12	0.002	-4.991	-1.142

Table 14. Predictors of Preferring HOT Lane Funds for Improving Bus/Transit in Area

Estimation Methodology: logit

Dependent variable: Existing regular lanes (No=0; Yes=1)

Logit estimates

Number of obs	=	373
LR chi2(12)	=	24.05
Prob > chi2	=	0.0307
McFadden's R2	=	0.0657

Log likelihood = -170.9657

Improve bus/transit in area	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	0.004	0.028	0.16	0.875	-0.051	0.060
Travel time_pm_I40	-0.001	0.023	-0.05	0.961	-0.045	0.043
Ride as passenger	1.401	1.478	0.95	0.343	-1.497	4.298
Trips per week	-0.050	0.028	-1.77	0.077	-0.106	0.005
Miles driven am_I40	-0.016	0.041	-0.38	0.703	-0.096	0.065
Miles driven pm_I40	0.007	0.038	0.18	0.861	-0.068	0.082
Trip_10min	-0.083	0.226	-0.37	0.713	-0.526	0.360
Number of cars	-0.214	0.144	-1.49	0.137	-0.496	0.068
Gender	0.066	0.287	0.23	0.817	-0.496	0.629
Used bus/transit	1.208	0.347	3.48	0.001	0.528	1.889
Income	0.138	0.164	0.84	0.398	-0.183	0.459
Race	-0.001	0.369	0	0.998	-0.724	0.722
Work	0.038	0.546	0.07	0.944	-1.031	1.108
Constant	-0.851	0.827	-1.03	0.303	-2.471	0.770

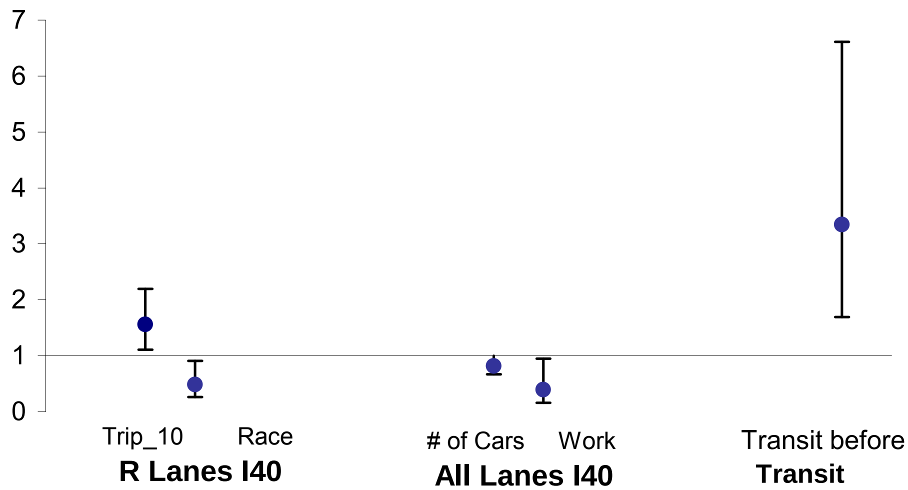
Table 15. Predictors of Preferring HOT Lane Funds for Improving Roads in Area

Estimation Methodology: logit
Dependent variable: Existing regular lanes (No=0; Yes=1)
Logit estimates

Number of obs = 373
LR chi2(12) = 16.29
Prob > chi2 = 0.2336
Log likelihood = -246.6184
McFadden's R2 = 0.032

Improve roads in area	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Travel time_am_I40	-0.022	0.020	-1.07	0.285	-0.062	0.018
Travel time_pm_I40	0.014	0.017	0.78	0.436	-0.021	0.048
Ride as passenger	1.254	1.440	0.87	0.384	-1.569	4.076
Trips per week	-0.020	0.016	-1.19	0.232	-0.052	0.013
Miles driven am_I40	0.000	0.029	0	0.996	-0.056	0.056
Miles driven pm_I40	0.003	0.027	0.12	0.908	-0.050	0.056
Trip_10min	-0.168	0.164	-1.03	0.305	-0.489	0.153
Number of cars	-0.057	0.101	-0.57	0.572	-0.254	0.140
Gender	-0.354	0.224	-1.58	0.115	-0.794	0.086
Used bus/transit	-0.461	0.323	-1.43	0.154	-1.094	0.172
Income	-0.031	0.127	-0.25	0.806	-0.280	0.218
Race	0.215	0.295	0.73	0.466	-0.363	0.792
Work	-0.469	0.453	-1.04	0.3	-1.356	0.418
Constant	1.564	0.634	2.47	0.014	0.321	2.807

Figure 17: Odds Ratio for Use of Funds*



*Controlling for the following independent variables (travel times on I40 am and pm, ride as passenger frequency, number of trips per week, miles driven on I40 am and pm, number of trips 10 min longer, number of cars, gender, used bus/transit, income, race and work)

Table 16. Willingness to Ppay Ttoll and Ggender

Count of toll/gender	Toll		
Gender	No	Yes	Grand Total
Female	34.67%	19.50%	54.18%
Male	29.57%	16.25%	45.82%
Grand Total	64.24%	35.76%	100.00%

*An initial analysis of whether people would pay a toll, indicates that there is no bias toward paying tolls between men and women. ($\chi2 = .15$, $p>.05$)

Table 17. Willingness to Ppay for Eexpress Llane: Ccondition 1.

Condition 1	
Less than $0.25	57.25%
$0.25 to $1.25	39.31%
$1.26 to $2.50	3.05%
$2.51 to $4.00	0.38%
Grand Total	100.00%

Table 18. Willingness to Ppay for Eexpress Llane: Ccondition 2.

Condition 2	
Less than $0.50	52.87%
$0.50 to $2.50	43.68%
$2.51 to $5.00	3.07%
$5.01 to $8.00	0.38%
Grand Total	100.00%

Table 19. Revenue Estimate for Two Possible Scenarios

	Scenario 1 8-minute Time Savings		Scenario 2 15-minute Time Savings	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
AM Westbound	**$116.20**	**$557.77**	**$240.15**	**$1,169.76**
50%	$58.10	$278.88	$120.07	$584.88
150%	$174.30	$836.65	$360.22	$1,754.64
AM Eastbound	**$161.92**	**$896.76**	**$1,768.61**	**$2,042.63**
50%	$80.96	$448.38	$884.31	$1,021.31
150%	$242.87	$1,345.14	$2,652.92	$3,063.94
PM Westbound	**$200.91**	**$966.87**	**$301.36**	**$1,783.05**
50%	$100.45	$483.43	$150.68	$891.53
150%	$301.36	$1,450.30	$452.04	$2,674.58
PM Eastbound	**$159.01**	**$863.17**	**$386.16**	**$1,817.20**
50%	$79.50	$431.59	$193.08	$908.60
150%	$238.51	$1,294.76	$579.23	$2,725.80
TOTAL per Year	**$119,630.49**	**$615,856.21**	**$505,552.62**	**$1,277,370.07**
50%	$116,440.35	$599,433.38	$492,071.22	$1,243,306.87
150%	$349,321.04	$1,798,300.14	$1,476,213.66	$3,729,920.60

*These values were calculated with the hourly peak volume regression

Table 20. Community Lleaders' Rresponse to Ttoll Llanes

		Business Leaders	Political Leaders	Clergy Leaders	Total
1 & 2	Bad idea	15	2	7	24
3	Neutral	15	2	5	22
4 & 5	Good idea	18	1	5	24
	N/A	0	0	0	0
	Total	48	5	17	70

Appendix 5

Stakeholders Survey

I-40 Value Pricing Project
Stakeholders Survey

"Highway Lane Management" is used to improve travel conditions on major roadways. For rush hour commuters, it can allow drivers to travel quickly (at the speed limit), and avoid heavily congested travel lanes. One approach is to allow single-occupant vehicles to use an HOV lane (which is reserved for vehicles with passengers) after the driver pays a fee at an efficiently operated electronic toll collection facility. Most often the money is then used to plan and implement additional transportation improvements in the region (city or metro area) where the tolls are collected. Vehicles that meet the occupancy requirements of the HOV facility would continue to use the lane for free.

You have been selected as a community leader to respond to our survey. Please take a moment to complete all questions. Your answers will be used for scientific purposes only and your name will be kept confidential. Although this is important, your participation is voluntary.

1 Name the organization in which you are a leader.___________

____

2 What is your position within the organization (e.g., CEO, upper management, minister)? ___________________________________

3 What size is the membership of your organization? ___________

4 How familiar are you with transportation problems in the Piedmont Triad?

1. very familiar __2. familiar __ 3. not familiar __ 4. not familiar at all __

5 Are you actively involved with transportation issues in your city or region?

Y __ N__

Please answer the following questions.

6 Do you support tolls for some new highways? Y __ N__

7 Do you commute regularly on I-40? Y __ N__

8 Do you carpool each day? Y __ N__

9 If you commute on I-40, do you still experience traffic congestion on I-40 after the recent construction was completed? Y __ N__

10 If you commute on I-40, would you use a "congestion free" managed lane as a

[please turn to the other side of the paper]

single occupant driver if a fee for each trip is $0.50 Y __ N__

$1.00 Y __ N__ $ 2.00 Y __ N__?

11 Would you say that the fees collected should be used to pay for (you may check more than one) the managed lane ___ transit ___

other ___ (specify) ______________________________?

12 Rate the "highway lane management" concept on a scale of 1 to 5 where 1 is a bad idea and 5 is an excellent idea.

1. very bad ___ 2. bad ___ 3. neutral ___ 4. good ___ 5. excellent ___

13 Would you support using this concept in the Triad? 1. greatly support ___

2. support ___ 3. neutral ___ 4. not support ___ 5. not support at all ___

14 Rate the potential usefulness of this concept.

1. very useful __ 2. useful __ 3.neutral __ 4.not useful __ 5.not useful at all __

15 If you have additional thoughts about highway lane management, please write them here.

____

____

____

____

____

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____

16. If we mail separate surveys to you with question 6-15, would you distribute them among members of your organization? Y __ N__

This questionnaire was completed by ________________________________

Position ________________________________

Thank you for completing this questionnaire.

Appendix 6

Beginning HOT Lane Projects

Table 2.1 Beginning HOT Lane Projects

Existing Projects	I-15	*I-10 (Katy Highway)*	*US 290 (Northwest Freeway)*
Region	San Diego, CA	Houston, TX	Houston, TX
Authority	SANDAG	Houston Metro, TxDOT	Houston Metro, TxDOT
Number of Miles	8	13	13.5
Additional Lanes Built	no	no	no
HOV Conversion	yes	yes	yes
Name of HOT Lane Project	FasTrak	QuickRide	QuickRide
Date HOT Lane Project Started	1997	1998	2000
Design of HOT Lanes	1 HOT Lane in each direction	1 lane reversible flow facility, five access points	1 lane barrier separated reversible flow facility
Lane Capacity		1500veh/hour/lane	6400veh/day
Tolling Structure	2+ carpools ride free, SOV pay toll	2+ carpools may pay to use the lane when the 3+ HOV is in effect, no SOV	3+ carpools ride free, 2+ pay toll
ATI	fully automated; must have FasTrak Transponder	fully automated, Harris County Toll Road Authority QuickRide transponders	fully automated, Harris County Toll Road Authority QuickRide transponders
Cost of Project	$7.96 million from FHWA Value Pricing Pilot Program		
Use of Proceeds	transit service in the corridor (Inland Breeze peak-period express bus)		
Expansion Plans	extend I-15 HOT lanes, creating a 20 mile, reversible flow managed lane	possiblity of major expansion, HCTRA has offered $250 million to finance construction of Katy special use lanes	n/a

Appendix 7

Stakeholders Results

Table A7 1 Stakeholders response to toll lanes concept for new highways

		Business Leaders	Political Leaders	Clergy Leaders	Total
1 & 2	Bad idea	15	2	7	24
3	Neutral	15	2	5	22
4 & 5	Good idea	18	1	5	24
	N/A	0	0	0	0
	Total	48	5	17	70

Table A7 2 Stakeholders commute on I - 40

Response	Frequency	Cumulative %
1- yes	37	52.86%
2 – no	33	100.00%
Total	70	

Table A7 2 Stakeholders support for tolls for some new highways

Response	Frequency	Cumulative %
1- yes	25	39.06%
2 - no	39	100.00%
Total	64	

Table A7 3 Stakeholders rate the “highway lane management” concept

		Business Leaders	Political Leaders	Religious Leaders	Total
1 & 2	Bad idea	15	2	7	24
3	Neutral	15	2	5	22
4 & 5	Good idea	18	1	5	24
	Total	48	5	17	70

Table A7 4 Stakeholders use the concept in the Triad

Response		Business Leaders	Political Leaders	Religious Leaders	Total
1 & 2	Support	17	1	4	22
3	Neutral	16	2	6	24
4 & 5	Not Support	14	2	7	23
	N/A	1	0	0	1
	Total	48	5	17	70

Table A7 5 Stakeholders rate the potential usefulness of the concept

		Business Leaders	Political Leaders	Religious Leaders	Total
1 & 2	Useful	18	2	6	26
3	Neutral	15	1	4	20
4 & 5	Not useful	14	2	7	23
	N/A	1	0	0	1
	Total	48	5	17	70