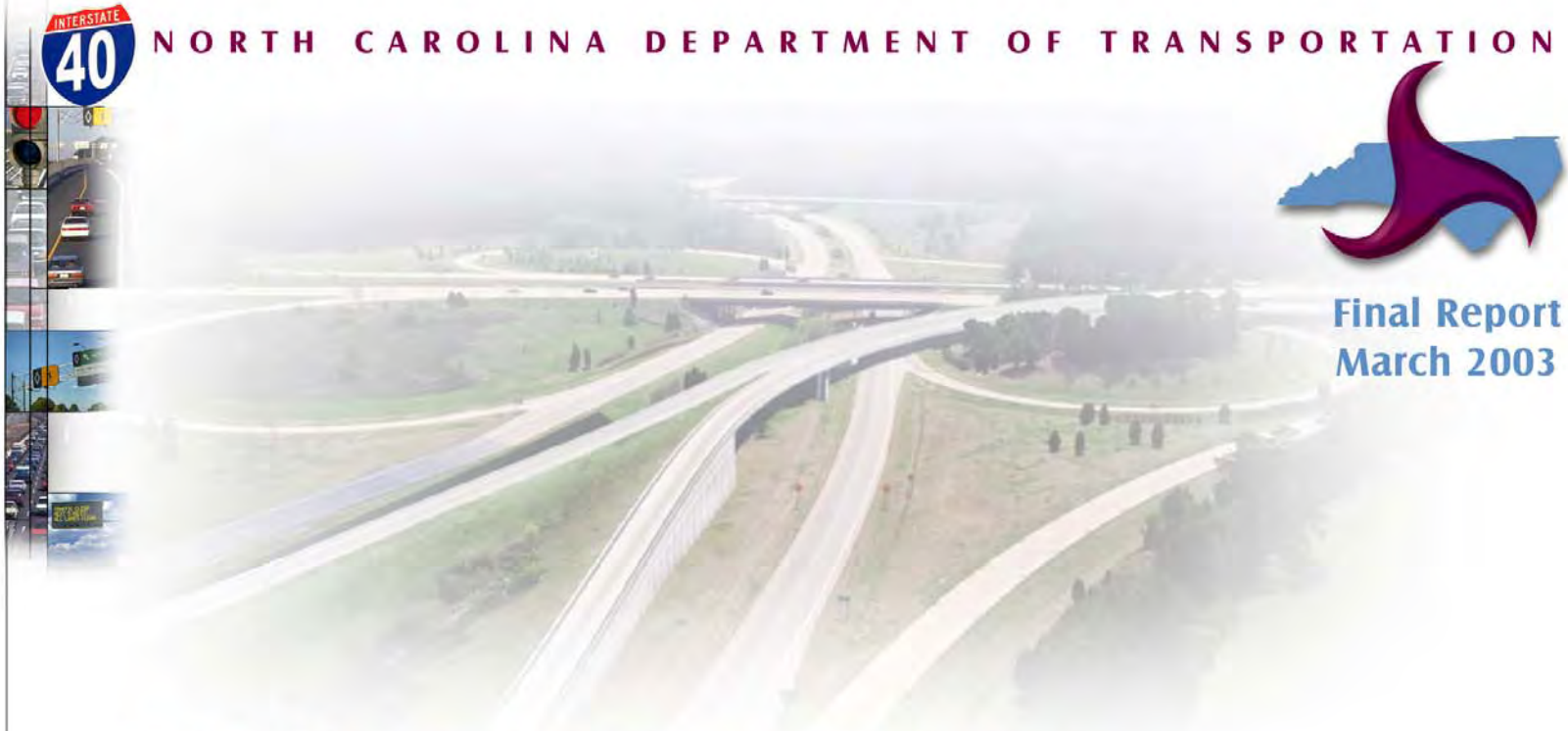
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION



Final Report
March 2003

I-40 High Occupancy Vehicle / Congestion Management Study

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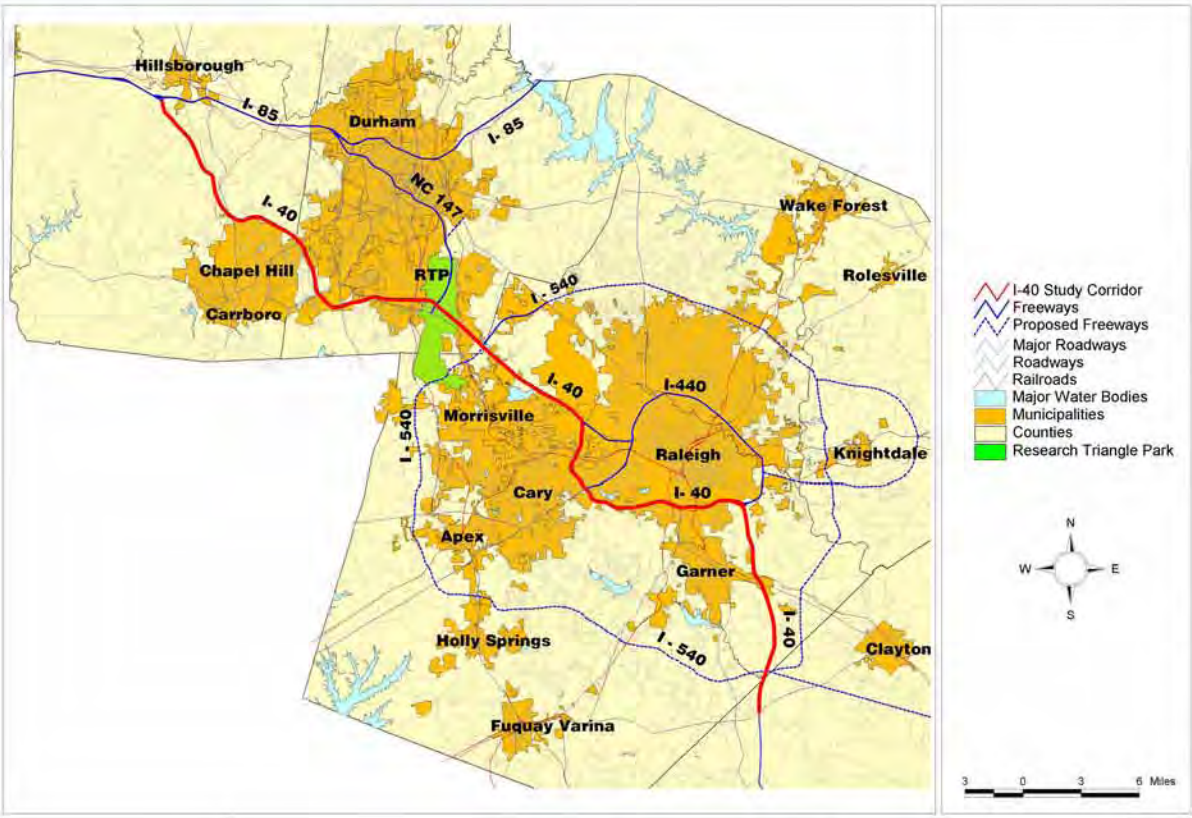
1. THE I-40 HIGH OCCUPANCY VEHICLE/CONGESTION MANAGEMENT STUDY

The I-40 High Occupancy Vehicle/Congestion Management Study was commissioned by the North Carolina Department of Transportation (NCDOT) to identify strategies that could improve mobility in the I-40 corridor between NC 42 in Johnston County and I-85 in Orange County. This corridor is the Triangle Region's primary commuting artery, serving major employment centers including Raleigh, Durham, Chapel Hill, and the Research Triangle Park (RTP). The study examines various strategies for effectively managing the increasing traffic volumes, as well as alternatives to regional commuting. While the focus of the study is the I-40 corridor, other major transportation facilities that intersect or parallel I-40 are considered in this analysis also. A map of the Triangle Region, including its major roadways, is shown in Figure 1-1.

Figure 1-1 Triangle Region Study Area



Triangle Region Study Area

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1.1 Transportation Objectives

In addition to evaluating potential congestion management strategies for the I-40 corridor, it was important to identify the objectives that these strategies should achieve. This required an understanding of the current and anticipated transportation problems in the corridor, the level of mobility desired by the community and the types of improvements that could realistically be achieved. The following specific objectives were established to assess the effectiveness of the various strategies in the I-40 corridor:

- Manage the corridor to enhance mobility for all travelers;
- Reduce the amount of single-occupant vehicle (SOV) travel;
- Increase the proportion of commuters using ridesharing programs and transit in the corridor;
- Improve the reliability (or predictability) of the trip time;
- Increase the people-moving capacity;
- Manage the single-occupant vehicle demand;
- Reduce the peak period congestion, delay and travel time;
- Reduce the peak period travel time for transit;
- Reduce the crash rates in the corridor;
- Reduce the incident response times; and
- Promote better traveler information.

These objectives served as guiding principles in the I-40 High Occupancy Vehicle/ Congestion Management Study (I-40 HOV/CMS).

1.2 Study Process

The I-40 HOV/CM study was undertaken in two major phases. This report documents the findings and recommendations from Phase I and Phase II including:

- An evaluation of a broad range of congestion management strategies, policies and actions;
- Identification of those congestion management strategies that have the potential to improve mobility and trip reliability within the I-40 corridor;
- Evaluation of the feasibility of HOV facilities in the Triangle Region;
- Identification of a potential phasing plan for the implementation of HOV facilities; and
- Detailed examination of four potential HOV alternatives.

While the study presents a broad overview of congestion management strategies and techniques, much of the analysis focused on High Occupancy Vehicle (HOV) lanes on I-40 and other major highways within Johnston, Wake, Durham, and Orange counties. Previously, these types of facilities have not been thoroughly evaluated for the region.

1.2.1 Phase I

Phase I of the I-40 HOV/CMS was commissioned by the NCDOT to review a broad range of strategies for addressing congestion in the Research Triangle. This study is not intended to justify or eliminate the need for transportation improvements currently planned and programmed; rather the purpose of the study is to find additional ways to maximize the transportation system investments already planned for this region.

Phase I, which was conducted over a six-month period, brought together many of the transportation leaders from the region. These leaders provided invaluable knowledge about the region's transportation issues, concerns and ongoing planning efforts. The study also provided the opportunity for transportation professionals from around the region to work together on regional challenges that go beyond geographical and institutional boundaries and to consider the impact that other ongoing initiatives and studies could play in managing congestion.

Key Recommendations from Phase I

- Move forward with congestion management strategies that can be implemented to provide alternatives to single occupancy vehicular travel within the region. These include managed lanes (particularly high occupancy vehicle (HOV) lanes), transit system improvements (rail and regional bus), travel demand management (TDM) strategies, and freeway management techniques including ramp metering, intelligent transportation systems (ITS) and transportation systems management (TSM).
- Strongly support recent public and private initiatives in ITS and TDM, which are essential elements of a congestion management program, and, along with transit initiatives, provide a solid foundation for strategies such as HOV lanes.
- Proceed with the transportation improvements currently planned and programmed in the NCDOT Transportation Improvement Program (TIP) and those identified in local agency plans and programs.
- Study short-term geometric improvements to enhance the efficiency of I-40, including addressing the bottlenecks between I-540 and NC 147 and Wade Avenue and US 1/ US 64.
- Establish a review process to ensure better coordination of ongoing transportation studies and projects in the region, including public involvement efforts.
- Establish an appropriate institutional framework for implementing an ongoing congestion management process.
- Study, promote and implement smart growth policies that support desired growth patterns, which can be effectively served by future transportation investments.
- Review current mechanisms and policies for funding transportation programs and identify new funding sources, which can provide financial resources for implementing congestion management strategies.
- Engage the public, in the broadest sense of the word, in developing future transportation strategies.

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1.2.2 Phase II

Phase II of the I-40 HOV/CMS developed a congestion management program for I-40 and other major roadways in the Triangle Region. The program identified specific projects and actions that could be adopted and incorporated into the NCDOT, Durham-Chapel Hill-Carrboro Metropolitan Planning Organization (DCHC), Capital Area Metropolitan Planning Organization (CAMPO), and Triangle Transit Authority (TTA) long range plans and Transportation Improvement Programs (TIPs).

Phase II built upon the works and recommendations of Phase I both in terms of strategies and process. Phase II focused, in greater detail, upon the feasibility of providing an HOV network for the region by 2025. Specifically, four alternative HOV configurations were developed and analyzed between NC 86 and US 1/US 64. The results of Phase II provide a transportation blueprint for I-40 that cut across geographical, institutional and modal boundaries.

A comprehensive public involvement program was implemented during Phase II. The purpose of the public involvement program was to educate the public, involve them in the formulation and evaluation of alternatives and gain widespread understanding and support for the final congestion management strategies for I-40.

Key Recommendations from Phase II

- Identify short term, low cost improvements to address existing bottleneck issues on I-40.
- Develop a detailed HOV phasing plan to maximize HOV ridership with a strategy that can be successfully implemented.
- Select a viable roadway alternative for future HOV design and assure that any interim improvements to I-40 do not preclude HOV.
- Implement and support additional congestion management strategies focused on providing additional capacity including planned roadway improvements, ITS implementation, ramp metering, and transportation systems management (TSM) improvements.
- Support and expand programs aimed at reducing single occupancy vehicle (SOV) trips including travel demand management and transit.

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2. REGIONAL GROWTH AND CONGESTION ON I-40

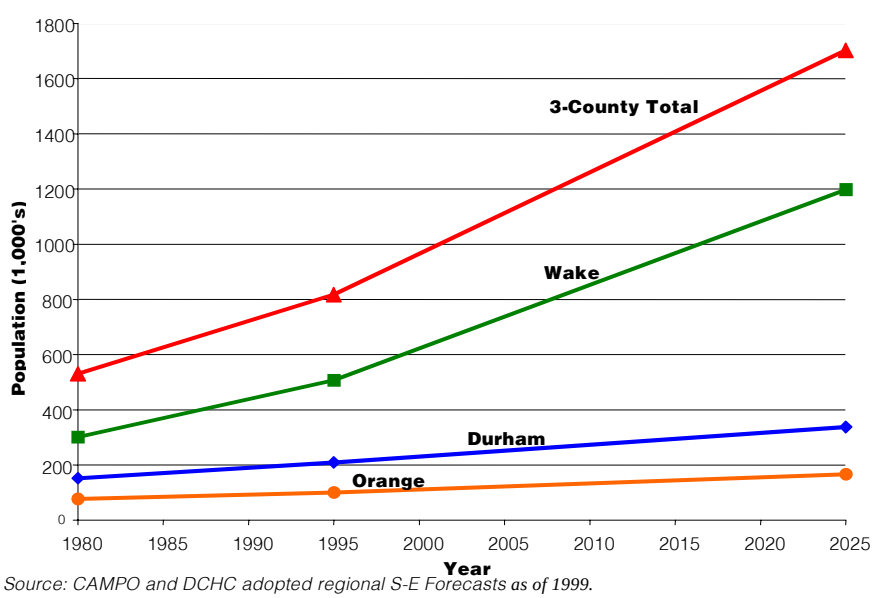
2.1 Growth in the Triangle Region

During the last few decades, the Triangle Region of North Carolina has seen enormous changes. Between 1980 and 2000, the population of the United States increased by 20 percent. During the same period, the population of North Carolina grew by 32 percent, and the population of the Triangle Region increased by a dramatic 74 percent. In particular, Wake County experienced a doubling of population. More recently, these high rates of growth have started to spill over into neighboring Johnston and Chatham Counties.

Economic forecasts for the region project the boom will continue through at least the next two decades. The population of the Triangle Region is predicted to more than double over the next 30 years. As shown in Figure 2-1, projections indicate that by 2025 the combined population of Durham, Orange and Wake Counties will exceed 1.7 million people.

These growth projections assume a reasonable level of mobility. Clearly, the capacity and quality of the transportation system and the ease with which people can travel within the region will influence whether this growth actually occurs. As in the past, population growth can bring with it many benefits, and in that respect, it is desirable. It must be recognized, however, that the accompanying transportation needs must be managed to support these benefits.

Figure 2-1 Population Growth in the Triangle Region



Source: CAMPO and DCHC adopted regional S-E Forecasts as of 1999.

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2.1.1 Congestion in the Triangle Region

Accompanying the population increases of the 80's and 90's was an increase in traffic volumes and travel demand. One clear manifestation of those increases was congestion levels that have worsened year by year, particularly on major roadways, in the peak commute periods.

Clearly, the rapid growth in travel demand has outpaced improvements to the region's transportation facilities. Despite large investments in our highway system, congestion is on the rise. Commuters, and sometimes those traveling in the off-peak periods, face delays that were not foreseen at the beginning of the RTP's development.

These conditions are expected to worsen in the next 25 years. **The region's total population is expected to increase by more than 100 percent by 2025. However, capacity is planned to increase by less than 50 percent.** Essentially, the pace of growth in the demand for travel will greatly exceed the abilities of the respective cities and the State to provide the necessary roadway capacity.

As a result, congestion is forecast to continue to increase. Specific factors contributing to the growing congestion problem include:

- Nationally, and within North Carolina, people are driving more and traveling longer distances. The vehicle miles of travel (VMT) are increasing at a greater rate than the population. (See Figure 2-2)
- The vast majority of commuters (90 percent) drive alone to work. This is understandable given the limited opportunities and incentives to use alternative modes of travel. (See Figure 2-3)
- The region has attempted to keep pace with the increase in demand for travel through heavy investment in new and upgraded highways. For many reasons, including financial constraints and concerns about the environmental and community consequences, this approach has proven to be insufficient.
- Response to the need for better management of the highways to improve their efficiency is slow. Intelligent transportation systems (ITS), including freeway management, are in the early stages of implementation on the I-40 corridor.
- While the region has invested heavily in highways, there has not been a similar investment in travel alternatives to the private automobile. Only recently has the region begun to understand the need for a high quality transit system and initiatives such as travel demand management. There is also a lack of public education, communication, and incentive programs for non-auto travel options.
- Opportunities for reducing the numbers of commuters traveling in the peak periods, or having to travel to work at all, are not being adequately considered. Flexible work hours (flextime) and compressed workweeks or telecommuting have potential for reducing peak period congestion. These options are beginning to be promoted by some Triangle Region employers.
- The single, largest contributor to congestion in the Triangle Region, aside from the high growth rate, is the low-density land development pattern. Often characterized as

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sprawl, this type of growth results in more and longer automobile trips, with little opportunity for transit use.

- There are institutional barriers to overcome in order to effectively deal with congestion and transportation issues in the region. The studies and projects currently underway would need to be coordinated and should support an integrated regional vision of mobility, congestion relief and mode choice.

Figure 2-2 Growth in Population and VMT in the Triangle Region

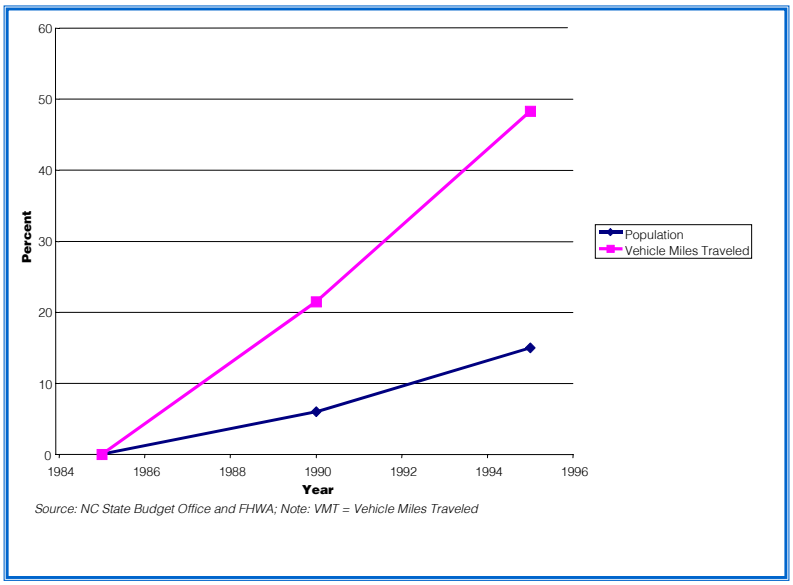
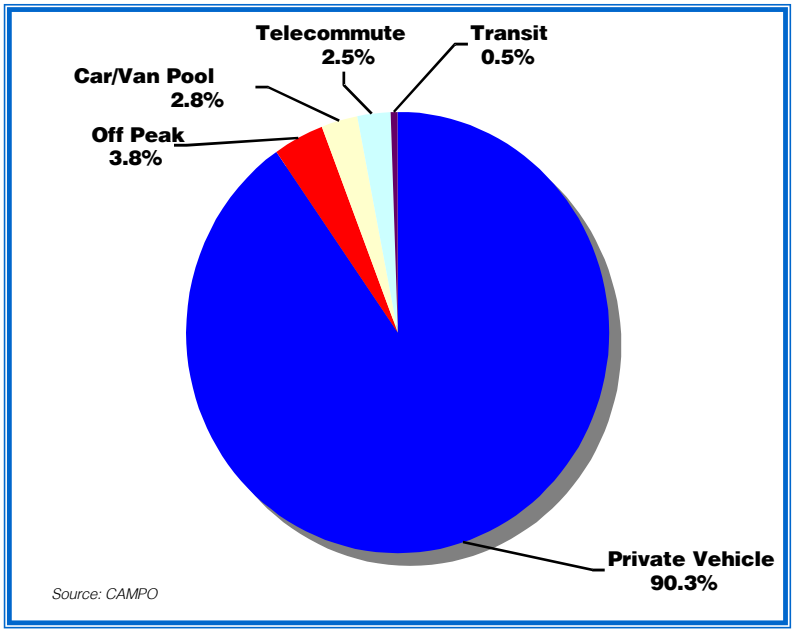


Figure 2-3 Existing Mode Split on I-40 in the Triangle Region



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2.1.2 The Impact of Congestion on Research Triangle Park

Interstate 40 (I-40) through the Research Triangle Park in particular experiences severe congestion at certain times, and the businesses and institutions in this area are considering the implications of this congestion as they make expansion decisions. In an era of tight labor markets, corporations are sensitive to the quality of life issues that concern their employees. Traveling on congested highways, with no practical alternatives to avoid delay, is now a common complaint of the employees of companies located in Research Triangle Park.

Economic forecasts estimate that Research Triangle Park employment will double over the next 25 years (an additional 50,000 workers). But this growth is threatened by the declining mobility in the region. Current RTP firms may choose to expand at other locations while prospective companies could select sites with fewer congestion-related problems in other states.

I-40 provides the primary access for long distance commuter trips through the Triangle Region. However, congestion is particularly focused in RTP between NC 147 (the Durham Freeway) and I-540 (the Northern Wake Expressway). This section frequently becomes a traffic bottleneck for the entire Triangle Region.

2.2 Existing and Future Travel Demand

The Triangle Regional Model (TRM) was used to quantify, evaluate and compare projected future 2025 demand for the No-Build and four HOV configurations. This TRANPLAN model is the official regional planning model developed by NCDOT in cooperation with the DCHC and CAMPO. This model provides valuable input for the evaluation of the need for improvements in the corridor. The evaluation focused on volumes utilizing both general purpose (GP) lanes and, if provided, HOV lanes.

This section of the report identifies the future 2025 No-Build conditions without HOV facilities in place. HOV facilities are examined in greater detail in Chapter 6. A more detailed description of the modeling effort is discussed in the Modeling Technical Memo on file at NCDOT.

2.2.1 Regional Trip Growth

Over the period from 1995 to 2025, population and employment are expected to increase 112 percent and 129 percent, respectively. As shown in Table 2-1, the TRM analysis projects an 111 percent increase in total vehicular trips with a 133 percent increase in carpool vehicle trips during this same period. This closely correlates with projected increases in population and employment. SOV trips will increase approximately 110 percent between 1995 and 2025, making up over 95 percent of the total trips. Auto occupancy is not forecast to noticeably change during this period.

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Table 2-1 Regional Growth in Daily Vehicular Trips – 1995 to 2025

Analysis Year	Vehicle Trips			Carpool Share
	Total	Drive Alone	Carpool	
1995	589,000	562,000	27,000	4.5%
2025	1,243,000	1,180,000	63,000	5.0%
Difference	654,000	618,000	36,000	
Growth	111%	110%	133%	

The model also allows for an examination of the impact of transit trips under existing and future conditions. As shown in Table 2-2, the total person trips increase by 116 percent between 1995 and 2025, slightly higher than the 111 percent increase in vehicular trips. The primary reason for this difference is that the transit share of total trips is forecast to almost double from 2.2 percent in 1995 to 3.9 percent in 2025. This reflects an increase of 35,000 transit trips between 1995 and 2025. The increase results primarily from the planned construction of the Triangle regional transit system.

Table 2-2 Growth in Regional Daily Person Trips and Transit Use – 1995 to 2025

Analysis Year	Person Trips			Transit Share
	Total	Drive	Transit	
1995	631,000	618,000	13,000	2.2%
2025	1,364,000	1,316,000	48,000	3.9%
Difference	733,000	698,000	35,000	1.7%
Growth	116%	113%	269%	

2.2.2 I-40 Corridor Trip Growth

Of particular interest to this study are the growth rates on the analysis links in the I-40 corridor. The analysis links include I-40, the I-40 interchange ramps, roadways intersecting I-40 (i.e., cross-streets), and roadways adjacent to I-40. These analysis links are shown in Figure 2-4.

Growth rates for daily vehicle trips on the analysis links are shown in Table 2-3. Growth rates for the I-40 mainline and its ramps are also shown graphically in Figure 2-5. Overall, there is a 153 percent average growth rate in total vehicle trips in the I-40 corridor – considerably higher than the overall growth of 113 percent vehicle trips in the region as shown in Table 2-2. Vehicle trips are growing at a faster rate on the adjacent roadways and cross streets than on I-40, and the I-40 ramps are growing at an even faster rate.

Figure 2-4 2025 Analysis Links by Type

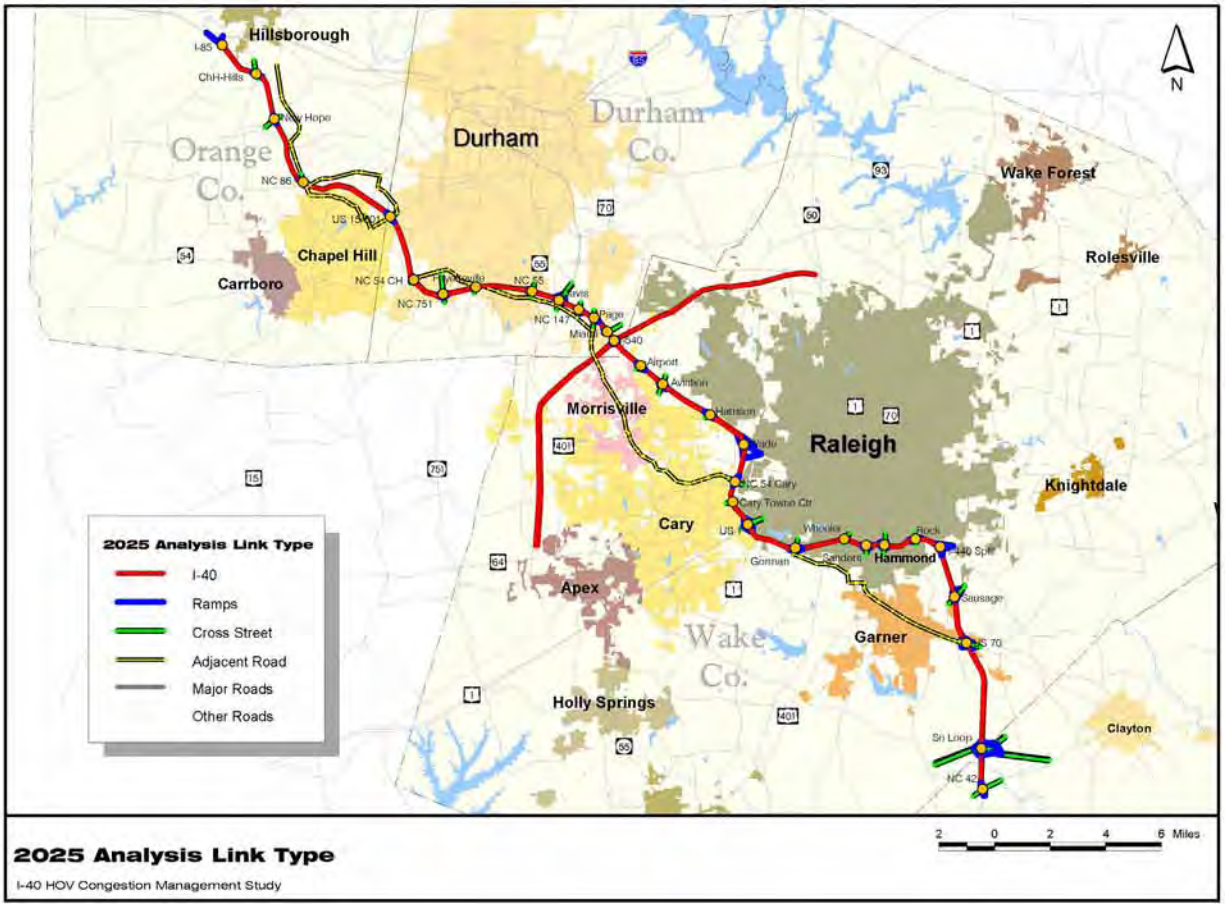
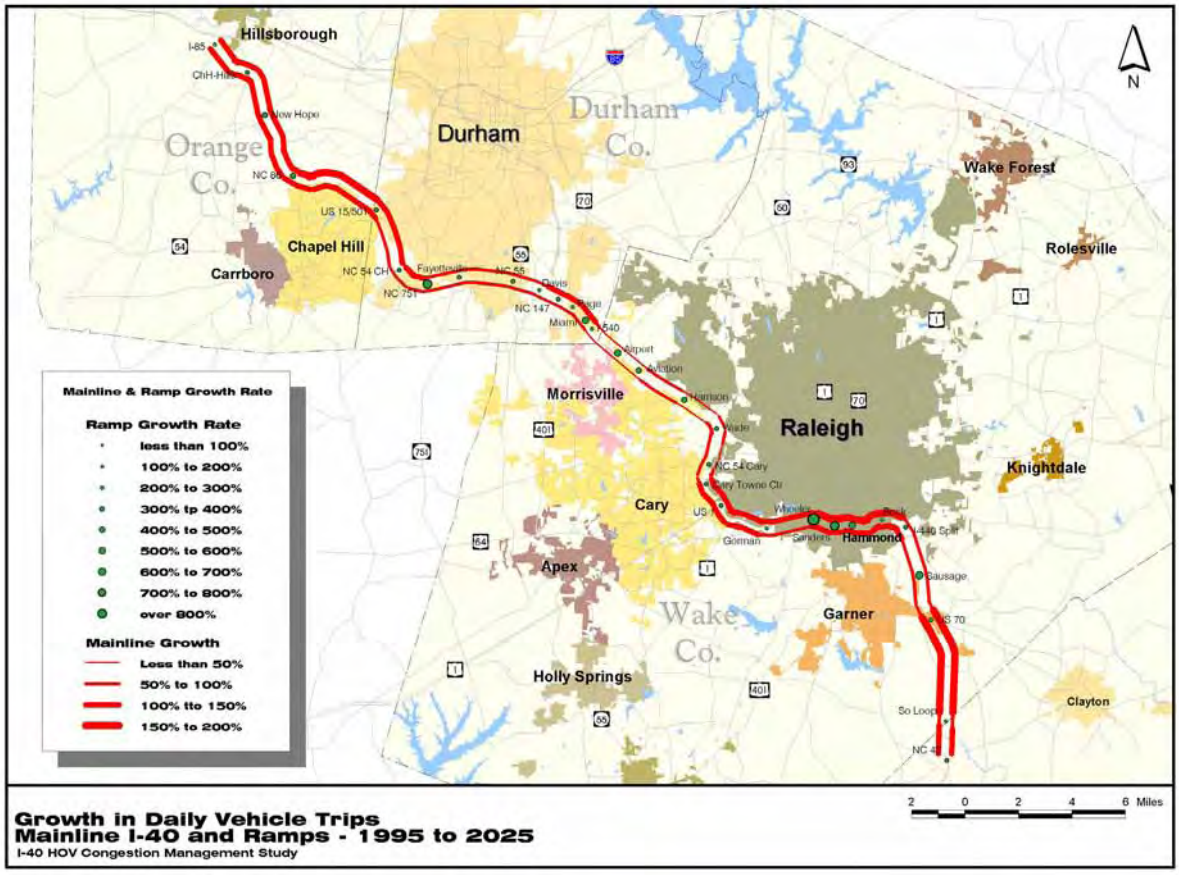


Table 2-3 Growth Rates for Daily Vehicle Trips in the I-40 Corridor by Type – 1995 to 2025

Analysis Link Type	Growth Rate
I-40	104%
Ramps	215%
Cross St	181%
Adjacent	131%
Total	153%

Figure 2-5 Growth in Daily Vehicle Trips on Mainline I-40 and Ramps - 1995 to 2025



2.2.3 I-40 2025 No-Build Volumes

The growth rates illustrated in Section 2.2.2 forecast heavy growth in total vehicle travel (i.e., SOV plus HOV) through 2025 for the I-40 corridor from I-85 in Orange County to NC 42 in Johnston County. In this section of the report, HOV demand is shown separately from SOV demand. This presentation, as shown in Table 2-4, was limited to a focused I-40 corridor from NC 86 to US 70, where HOV solution was deemed reasonable and HOV demand was projected to be significant. The Table shows that carpool shares (i.e., percent HOV) on the focused I-40 corridor (NC 86 to US 70) range between 11 and 23 percent. The Table uses shading to distinguish different roadway sections defined for summarizing HOV volume analysis. This shading will become more relevant in Chapter 6 (see Figure 6-1) of this report, where No-Build statistics are compared to several build configurations.

Note that in the future, average daily traffic volumes increase dramatically. The impact during the peak hour is less pronounced due to the spreading of the peak period. Instead of a peak two-hour period, as is typical under existing conditions, the TRM predicts a future four-hour AM peak period. Peak period spreading occurs when the absolute capacity of the peak hour is exceeded, forcing traffic to begin their trips earlier or later than they normally desire.

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Table 2-4 2025 Forecasted AM Peak Hour Vehicles and HOV Share on I-40

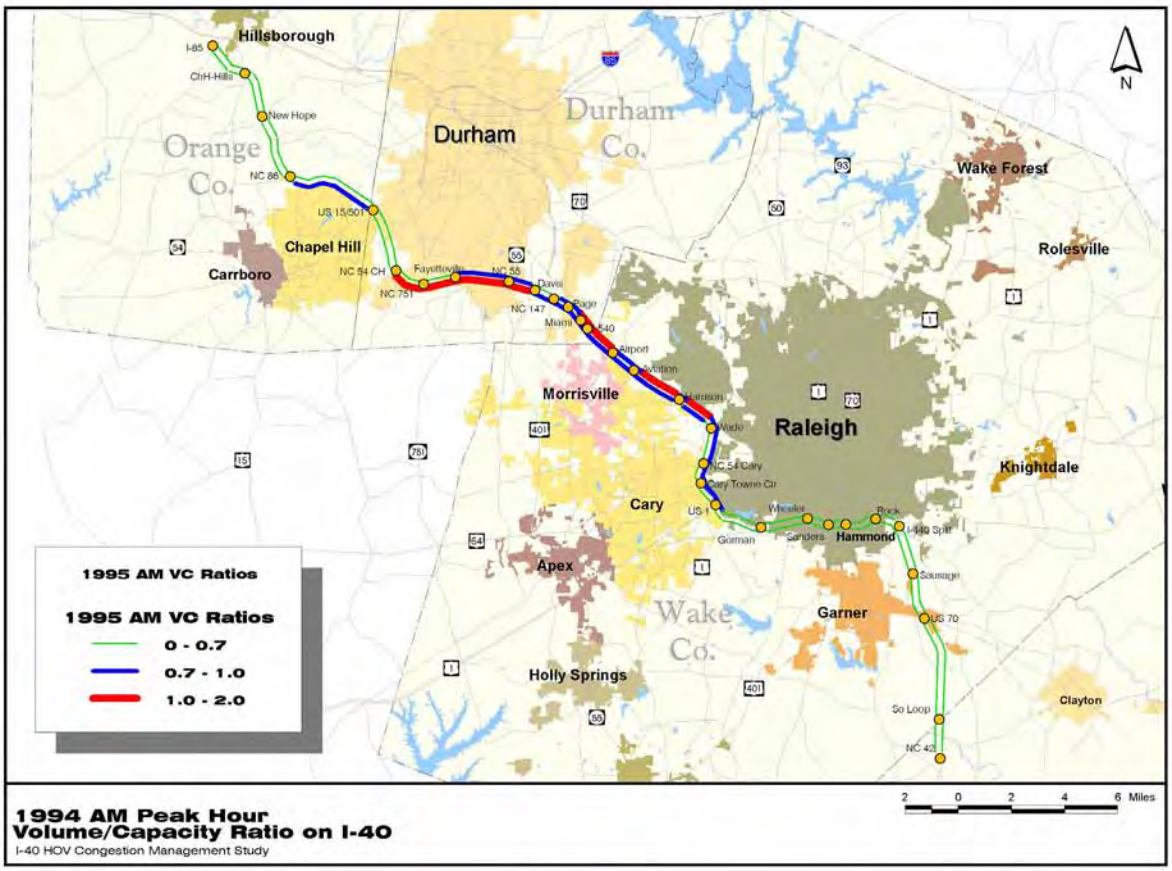
SEGMENT	Eastbound			Westbound		
	SOV	HOV	% HOV	SOV	HOV	% HOV
NC 86 to US 501	4,940	760	13.3%	3,200	500	13.5%
US 501 to NC 54	4,550	670	12.8%	3,650	610	14.3%
NC 54 to NC 751	6,660	940	12.4%	4,360	880	16.8%
NC 751 to Fayetteville Rd.	6,700	890	11.7%	4,370	890	16.9%
Fayetteville Rd. to NC 55	6,880	890	11.5%	4,460	940	17.4%
NC 55 to NC 147	6,270	850	11.9%	4,790	950	16.6%
NC 147 to Davis Drive	7,770	1,220	13.6%	6,540	1,330	16.9%
Davis Drive to Miami Blvd.	7,450	1,240	14.3%	8,460	1,580	15.7%
Miami Blvd. to Page Road	7,520	1,310	14.8%	9,880	1,810	15.5%
Page Road to I-540	7,830	1,450	15.6%	11,410	2,090	15.5%
I-540 to Airport Drive	6,300	1,190	15.9%	6,920	1,240	15.2%
Airport Dr. to Aviation Pkwy.	4,900	900	15.5%	6,430	1,140	15.1%
Aviation Pkwy. to Harrison Ave.	5,830	1,110	16.0%	8,130	1,470	15.3%
Harrison Ave. to Wade Ave.	5,230	1,100	17.4%	8,040	1,420	15.0%
Wade Ave. to NC 54	3,410	570	14.3%	4,740	730	13.3%
NC 54 to Cary Towne Center Blvd.	3,810	660	14.8%	5,460	840	13.3%
Cary Towne Center Blvd. to US 1/US 64	4,710	860	15.4%	6,050	960	13.7%
US 1/US 64 to Gorman Street	4,590	1,000	17.9%	6,130	980	13.8%
Gorman St. to Lake Wheeler Dr.	4,530	830	15.5%	6,090	980	13.9%
Lake Wheeler Drive to S. Saunders Drive	5,090	990	16.3%	7,140	1,660	18.9%
Saunders Dr. to Hammond Rd	4,290	880	17.0%	6,650	1,480	18.2%
Hammond Rd. to Rock Quarry Rd.	4,930	1,050	17.6%	7,440	1,610	17.8%
Rock Quarry Rd. to I-440 split	4,700	1,020	17.8%	7,170	1,750	19.6%
I-440 split to Jones Sausage Rd.	4,250	1,030	19.5%	5,390	1,590	22.8%
Jones Sausage Rd. to US 70	3,700	960	20.6%	5,490	1,590	22.5%

Notes: Volumes shown in vehicles per hour (vph), rounded to 10.
Shading represents different roadway sections defined for comparative analysis – Western (NC 86-NC 54), RTP West (NC 54-NC 147), RTP East (NC 147-Aviation), Airport (Aviation-Wade), Eastern (Wade-US 1/US 64) and Other (US 1/US 64-US 70). See Chapter 6, Section 6.1.2.

2.2.4 I-40 2025 No-Build Volume to Capacity Ratios

Using the 1995 and 2025 traffic volumes on I-40, a volume-to-capacity (V/C) ratio was developed to indicate locations with higher demand volume than capacity in the corridor. As shown in Figure 2-6, the I-40 V/C ratio exceeds 1.0 between NC 54 and Davis Drive, and between Miami Boulevard and Wade Avenue in 1995. As shown in Figure 2- 7 in 2025 the I-40 V/C ratio exceeds 1.0 between NC 54 in Chapel Hill and Airport Boulevard, Aviation Parkway and Wade Avenue, and NC 54 in Cary and NC 42 south of Garner.

Figure 2-6 1995 AM Peak Hour Volume/Capacity Ratios on I-40



1994 AM Peak Hour Volume/Capacity Ratio on I-40
I-40 HOV Congestion Management Study

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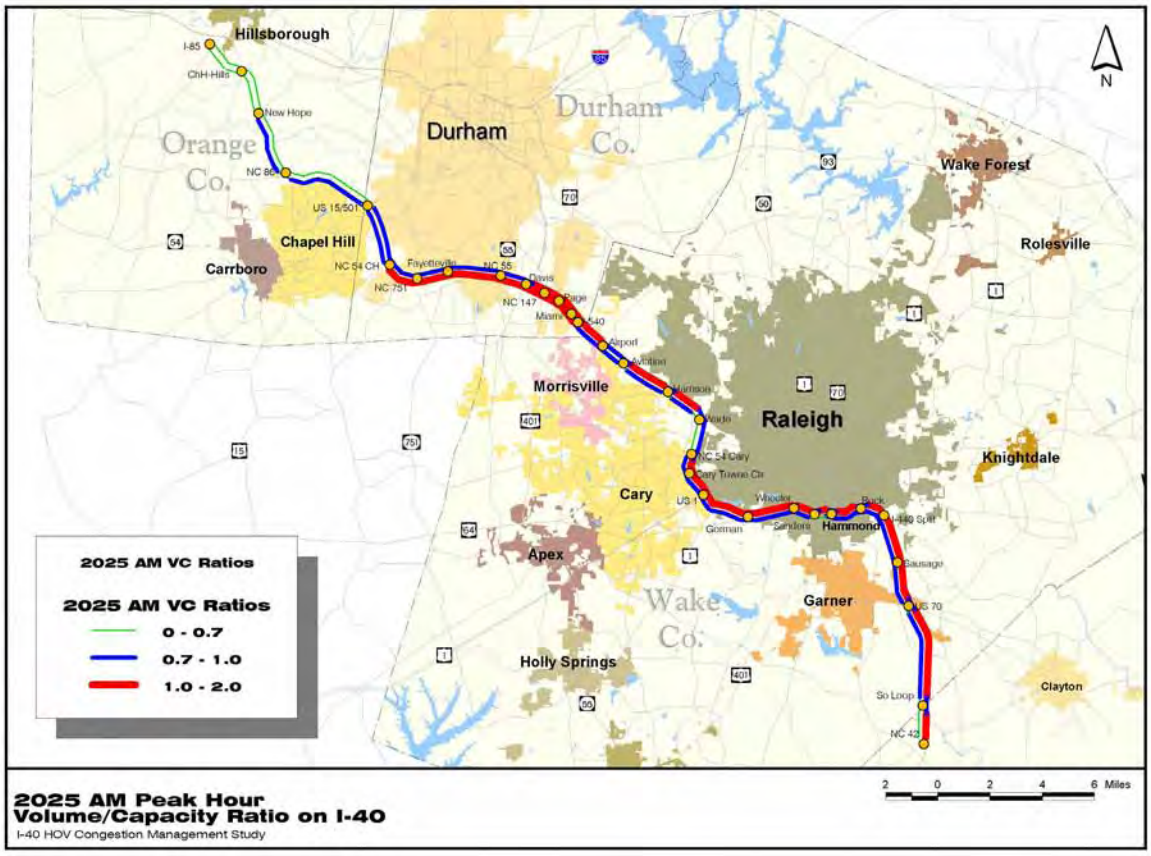
Figure 2-7 2025 AM Peak Hour Volume/Capacity Ratios on I-40



2.2.5 2025 Travel Speeds on I-40

The TRM was used to estimate speeds along I-40 in the year 2025 No-Build scenario. The estimated travel times to RTP from the west and the east are shown in Table 2-5. A more detailed travel time analysis was conducted for each alternative as part of the traffic analysis in Chapter 6.

Table 2-5 AM Peak Period Travel Times and Speeds- I-40 Toward RTP

Section of I-40	Minutes	Miles	Speed (MPH)
NC 86 to RTP	21	15	45
US 1 to RTP	24	11	29

2.3 Traffic and Operational Issues

In Phase I of the I-40 HOV/CM Study, a planning level traffic analysis was performed. In Phase II, a more detailed traffic analysis was carried out. The Phase II traffic analysis included intersection capacity analysis and microscopic simulation of freeway segments and interchanges. Each of these analyses is presented in this section.

2.3.1 Phase I – Planning Level Capacity Analysis

A planning level analysis for the I-40 corridor was developed to determine an overall congestion level under existing and 2025 No-Build conditions. This analysis was based on average daily traffic volumes.

Level of Service Definition

The peak hour planning level of service (LOS) is a measure of the adequacy of the number of lanes during the peak hour of travel. This planning LOS analysis does not incorporate the effects of weaving and merging of ramps at interchange junctions. The analysis of the ramps and interchanges, including the effects of downstream congestion, was done as part of Phase II traffic analysis.

Level of service is measured on a scale of "A" through "F," with LOS A being the best operating condition and LOS F being the worst. Although LOS D represents a desirable minimum for traffic operations in larger urban areas, LOS E is considered tolerable in areas with very severe congestion.

Table 2-6 provides a general description of the various LOS categories and congestion levels.

Table 2-6 Level of Service Descriptions for a Freeway

LOS	Description	Congestion Level
A	Free traffic flow with low volumes and high speeds. Speeds controlled by driver desires, speed limits, and roadway physical conditions.	Low
B	Stable traffic flow, with operating speeds remaining near free flow. Drivers still have reasonable freedom to maneuver.	Low
C	Stable flow, but higher volumes more closely control speeds and maneuverability.	Moderate
D	Approach unstable flow with tolerable operating speeds maintained, but considerably affected by changes in operating conditions.	Moderate
E	Unstable flow with low speed and momentary stoppages.	Severe
F	Forced flow with low speed. Stop-and-go with stoppages for long periods are possible.	Severe

Source: 1997 Highway Capacity Manual

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Findings

The I-40 corridor currently experiences congestion as a result of insufficient capacity to accommodate the peak hour traffic demand. Some of the factors constraining capacity include an inadequate number of travel lanes and critical traffic bottlenecks caused by lane drops, merges, diverges, and weaving areas.

Problem areas along the I-40 corridor were identified during the Phase I study. These areas experience peak period levels of service of E or F. LOS E is an unstable condition that can easily become LOS F (stop-and-go conditions).

Several problem areas on I-40 were identified for the A.M. and P.M. peak travel periods. Although delays may be observed on almost any section of I-40 throughout the Triangle Region on a typical weekday, the areas experiencing the longest delays are identified below:

- Between US 15/US 501 and NC 54 delays are observed, but are primarily the result of queuing from the NC 54 interchange.
- Between NC 54 and NC 147, a high number of Chapel Hill and south Durham commuters travel to/from RTP daily.
- The section between NC 147 and I-540 is the most congested area in the I-40 corridor, serving as the primary access to RTP as well as connecting two freeways.
- Between I-540 and Wade Avenue, high volumes of commuters as well as airport traffic contribute to the congestion on this portion of the freeway. Very long queues are observed almost daily in the westbound direction during the A.M. peak period as a result of merging traffic at the I-540/I-40 Interchange.
- Between Wade Avenue and US 1/US 64, the traffic volumes fall slightly but this section is often congested. The primary reasons are (1) a lane drop on I-40 between Wade Avenue and US 1/US 64 and (2) merge/diverge operations at both the Wade Avenue and US 1/US 64 interchanges.
- Between US 1/US 64 and I-440/I-40 on the south side of the Beltline, some delays are encountered because this section serves a combination of RTP and Raleigh commuters.
- Between I-440/I-40 and NC 42, the corridor is congested because of extensive residential development in Southern Wake and Northern Johnston Counties. Recent improvements to the I-440/I-40 interchange have improved this critical bottleneck.

The results of the planning level analysis of the peak hour LOS for I-40 are presented in Table 2-7 and Table 2-8 for 1998 and 2025, respectively. As expected, congestion increases over the period. Note that LOS E represents unstable flow and LOS F represents severe congestion and failed traffic operations. Also note that this planning level analysis does not include the additional congestion resulting from ramp merges, diverges and weaves.

Table 2-7 Existing Peak Hour Level of Service Analysis

Segment Number	I-40 Corridor Segment	Length (miles)	1998 Number of Lanes	1998 ADT**	1998 LOS*
1.	I-85 to US 15/US 501	11.8	4	48,900	C
2.	US 15/US 501 to NC 54	2.8	4	65,600	D
3.	NC 54 to NC 147	6.3	4	87,400	F
4.	NC 147 to I-540	3.2	6	135,400	F
5.	I-540 to Wade Avenue	6.5	8	133,700	D
6.	Wade Avenue to US 1/US 64/I-440	3.8	4	78,500	F
7.	US 1/US 64/I-440 to Lake Wheeler Rd.	4.5	6	97,800	D
8.	Lake Wheeler Road to I-440/I-40	4.2	8	96,600	C
9.	I-440/I-40 to US 70	4.4	6	82,200	D
10.	US 70 to NC 42	6.3	4	46,000	D

**LOS based on planning level V/C ratios*
***ADT = average daily traffic*

Table 2-8 Future Levels of Service for Segments on the I-40 Study Corridor

Segment Number	I-40 Corridor Segment	Length (miles)	2025 Number of Lanes	2025 ADT**	2025 LOS*
1.	I-85 to US 15/US 501	11.8	6	105,000	F
2.	US 15/US 501 to NC 54	2.8	6	128,000	F
3.	NC 54 to NC 147	6.3	6	157,000	F
4.	NC 147 to I-540	3.2	8	233,000	F
5.	I-540 to Wade Avenue	6.5	8	210,000	F
6.	Wade Avenue to US 1/US 64/I-440	3.8	6	120,000	F
7.	US 1/US 64/I-440 to Lake Wheeler Rd.	4.5	6	141,000	F
8.	Lake Wheeler Road to I-440/I-40	4.2	8	170,000	F
9.	I-440/I-40 to US 70	4.4	6	142,000	F
10.	US 70 to NC 42	6.3	4	93,000	F

**LOS based on planning level V/C ratios*
***ADT = average daily traffic*

2.3.2 Phase II – Operational Analysis

In Phase II, an operational level of service analysis was conducted focusing on peak hour volumes. The goal of the traffic analysis was to identify potential capacity deficiencies in the I-40 corridor in the year 2025. In addition, it analyzes various concurrent and barrier separated HOV configurations and identifies improvements for the future. The corridor traffic operations analysis is divided into two main components:

- A detailed Highway Capacity Manual (HCM)-based analysis using FREEVAL of all freeway segments, ramps and weaving operations.
- A detailed microscopic simulation analysis using FRESIM of all freeway segments and interchanges.

The operational analysis is presented in greater detail in the Traffic and Operations Technical Memorandum on file at the NCDOT.

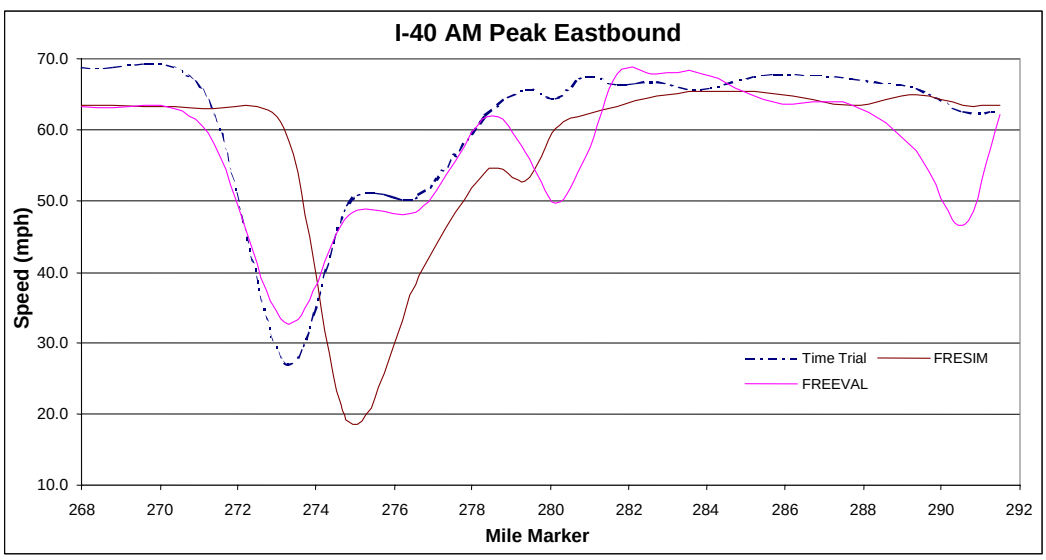
Traffic Models and Calibration

A detailed analysis of the I-40 corridor was performed using FREEVAL for each future design scenario. A simulation model analysis was performed using FRESIM. A critical step in using these programs is calibrating the model to simulate existing travel speed conditions.

To determine existing speeds for the I-40 corridor, speed data was collected using a Global Positioning System (GPS). The GPS recorded longitude/latitude and travel speed information along the corridor at one-second intervals for as many as five runs along the corridor in each direction and peak period.

Both the FREEVAL and FRESIM models were successfully calibrated to existing conditions, as illustrated in Figure 2-8.

Figure 2-8 FREEVAL and FRESIM Model Calibration to Existing Travel Times



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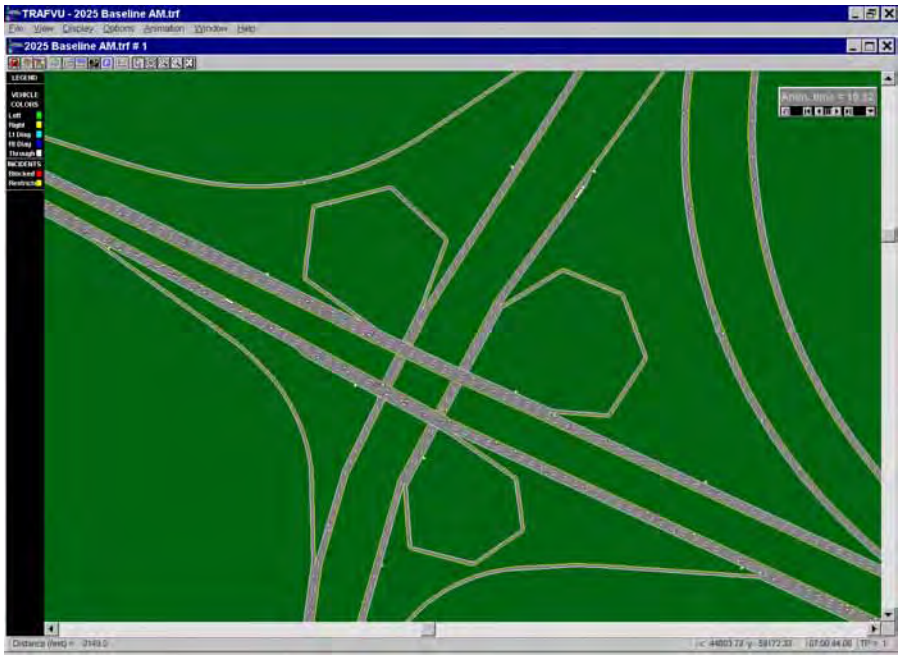
The combination of the two freeway evaluation tools provided a comprehensive analysis of future traffic conditions for each design scenario. The FREEVAL analysis showed the locations of potential future bottleneck locations, and the FRESIM analysis illustrated the impacts of congestion and queuing on upstream ramps and freeway segments. Further, the FRESIM model allowed consideration of the impacts of weaving in concurrent HOV lane systems compared to barrier-separated HOV systems.

A typical illustration of the FRESIM animation model focusing on the I-40/NC 147 interchange is shown in Figure 2-9.

Figure 2-9 Illustration of FRESIM Animation Model for I-40 Corridor



2025 No-Build Network

The 2025 No-Build configuration used for the capacity analysis includes all improvements funded in the NCDOT 2002-2008 Transportation Improvement Program (TIP) as well as the 2025 fiscally constrained regional transportation model. Projects along the I-40 corridor included in the No-Build network are:

- I-40 widened to six lanes between I-85 in Hillsborough and NC 147 in Durham,
- I-40 widened to eight lanes between NC 147 in Durham and I-540 in RTP and
- I-540 extended as a six-lane freeway from I-40 south to US 1 in Apex.

Initial traffic planning model projections showed that the section of I-40 from Wade Avenue to US 1/US 64 will have peak demand exceeding twice the roadway capacity. It was

decided to re-run the 2025 model with this section of I-40 widened to six lanes, noting that this improvement is not included in the 2002-2008 North Carolina Department of Transportation TIP. No additional widening is proposed for I-40 or I-540 in the 25-year plan.

2.3.3 FREEVAL Capacity Analysis

The FREEVAL model is a spreadsheet version of the Highway Capacity Software (HCS) to analyze complex freeway traffic operations, including the impact of weaving traffic. Because of the efforts involved in modeling, the FREEVAL model was run for a shorter I-40 corridor (NC 86 to US 1/US 64). This shorter I-40 corridor provided a reasonable basis for subsequent comparative analysis across different HOV configurations (see Chapter 6). Table 2-9 and Table 2-10 summarize the 2025 No-Build analysis for AM and PM peak hour respectively. Figure 2-10 and Figure 2-11 graphically illustrate the same results, indicating by color the segment V/C ratios.

2.3.4 FRESIM Capacity Analysis

FRESIM is a microscopic simulation model that replicates the flow of individual vehicles. As such, it can simulate the impact of bottlenecks on traffic flow upstream or downstream of the critical sections. It provides more detail than a FREEVAL analysis, particularly in sections with queuing.

Initial runs of the simulation model provided optimistic and unreliable results for travel on I-40 because of the effect of downstream metering. Specifically, the upstream bottlenecks in the system prevented the network from sending an accurate number of vehicles further downstream. Examples include:

- Westbound on I-40, a significant bottleneck occurred with the I-540 interchange. As a result, the traffic on I-40 through RTP was artificially restricted resulting in overly optimistic downstream traffic operations.
- Eastbound on I-40, the merge of NC 54 from Chapel Hill created a bottleneck restricting I-40 flows downstream, which resulted in optimistically low volumes downstream.
- Eastbound on I-40, the merge of NC 147 from Durham created a bottleneck also resulting in overly optimistic flows through RTP.

Note that even though these bottleneck restrictions do occur in actual operations, the model tends to overestimate the impact. Specifically, drivers in the model do not always yield to other vehicles attempting to merge in severely congested conditions. As a result, vehicles do not proceed as smoothly as they would in actual operations, particularly under slow conditions. Also, the elimination of peak period bottlenecks may actually increase volumes and increase congestion on downstream links during the non-peak periods.

The simulation was re-run with some bottleneck improvements. The addition of a two-lane on ramp from NC 54 to I-40 improved operations significantly, however the I-540 interchange still showed severe congestion. Other roadway capacity improvements such as the Triangle Parkway connection between I-540 and the Durham Freeway (NC 147) were not modeled as part of the Phase II study.

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Table 2-9 2025 No-Build AM Peak Hour Volume and LOS

Segment	2025 No-Build AM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	5,700	0.83	D	3,703	0.57	C
US 15/US 501 to NC 54	5,220	0.76	D	4,259	0.65	C
NC 54 to NC 751	7,598	1.11	E	5,232	0.80	D
NC 751 to Fayetteville Road	7,597	1.11	E	5,261	0.80	D
Fayetteville Road to NC 55	7,771	1.16	F	5,393	0.82	D
NC 55 to NC 147	7,118	1.06	F	5,738	0.88	D
NC 147 to Davis Drive	8,984	1.00	F	7,873	1.16	D
Davis Drive to Miami Blvd	8,698	0.78	F	10,043	1.08	F
Miami Blvd to Page Road	8,827	0.89	F	11,691	1.18	F
Page Road to I-540	9,274	1.30	F	13,499	1.79	F
I-540 to Airport Blvd	7,493	0.57	C	8,154	0.93	F
Airport Blvd to Aviation Pkwy	5,798	0.66	C	7,570	0.87	F
Aviation Pkwy to Harrison Ave	6,941	0.79	D	9,602	1.10	F
Harrison Ave to Wade Avenue	6,329	0.69	C	9,460	0.83	F
Wade Avenue to NC 54	3,974	0.44	B	5,465	0.80	D
NC 54 to Cary Towne Blvd	4,463	0.54	C	6,297	0.82	D
Cary Towne Blvd to US 1/US 64	5,576	0.80	D	7,011	0.77	D

Note: V/C = volume to capacity ratio (There is no direct correlation between v/c ratio and LOS).
Shading represents different roadway sections defined for comparative analysis – Western (NC 86-NC 54), RTP West (NC 54-NC 147), RTP East (NC 147-Aviation), Airport (Aviation-Wade) and Eastern (Wade-US 1/US 64). See Section 6.1.2.

Table 2-10 2025 No-Build PM Peak Hour Volume and LOS

Segment	2025 No-Build PM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	4,356	0.67	C	5,538	0.81	D
US 15/US 501 to NC 54	4,598	0.70	D	5,487	0.80	D
NC 54 to NC 751	6,133	0.94	E	6,552	0.96	E
NC 751 to Fayetteville Road	6,039	0.92	E	6,892	1.01	F
Fayetteville Road to NC 55	5,849	0.89	F	7,155	1.05	E
NC 55 to NC 147	6,112	0.93	F	6,965	1.02	F
NC 147 to Davis Drive	8,055	0.92	F	7,952	0.98	F
Davis Drive to Miami Blvd	9,323	0.92	F	8,893	0.86	F
Miami Blvd to Page Road	10,269	1.03	F	9,802	0.99	E
Page Road to I-540	11,620	2.15	F	10,210	1.16	F
I-540 to Airport Blvd	7,197	0.53	C	7,494	0.86	F
Airport Blvd to Aviation Pkwy	6,499	0.71	D	6,218	0.71	D
Aviation Pkwy to Harrison Ave	8,885	0.97	E	7,454	0.85	D
Harrison Ave to Wade Avenue	8,699	0.95	E	7,138	0.65	C
Wade Avenue to NC 54	5,083	0.56	C	4,382	0.67	C
NC 54 to Cary Towne Blvd	5,949	0.73	D	5,005	0.69	C
Cary Towne Blvd to US 1/US 64	7,009	0.90	E	5,817	0.67	C

Note: V/C = volume to capacity ratio (There is no direct correlation between v/c ratio and LOS).
Shading represents different roadway sections defined for comparative analysis – Western (NC 86-NC 54), RTP West (NC 54-NC 147), RTP East (NC 147-Aviation), Airport (Aviation-Wade) and Eastern (Wade-US 1/US 64). See Section 6.1.2.

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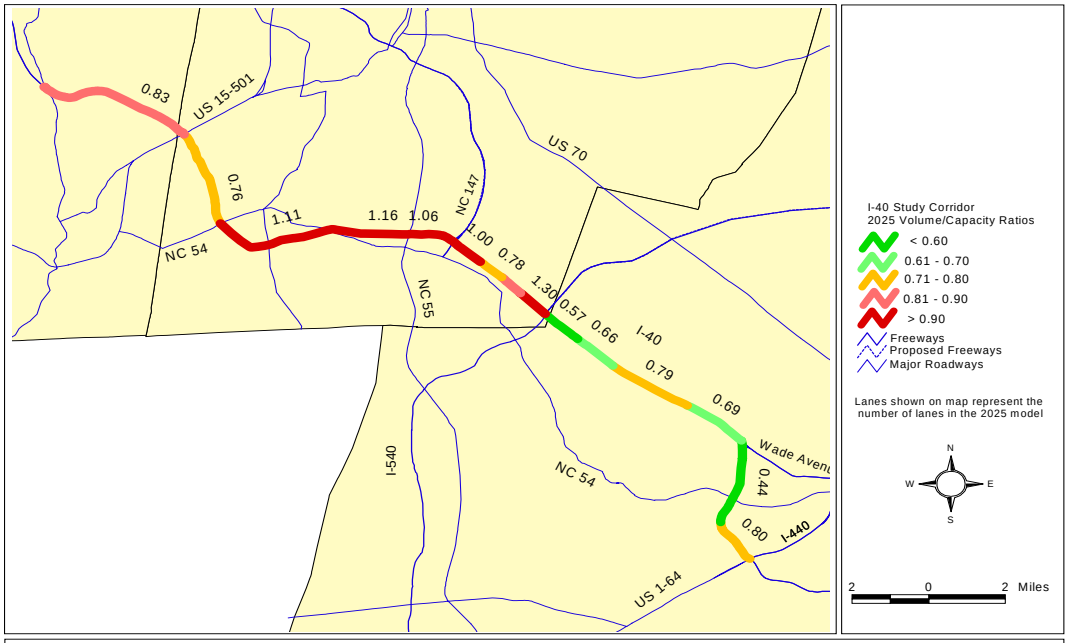
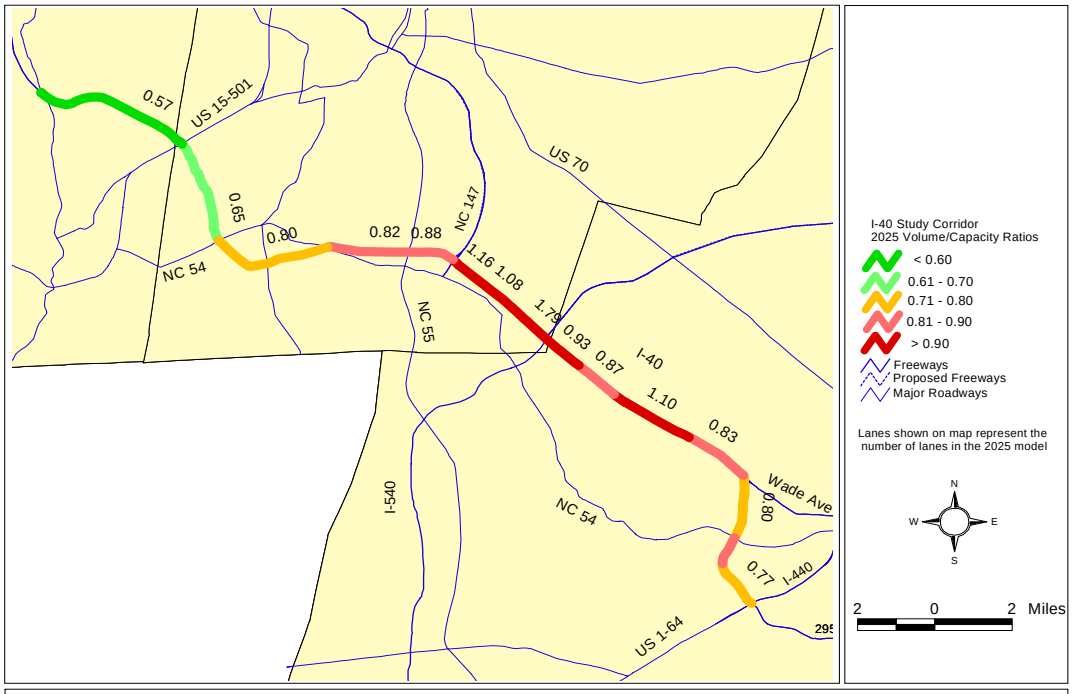
Figure 2-10 FREEVAL 2025 No-Build AM Peak Hour Traffic Analysis Results



No-Build Eastbound AM Volume/Capacity (V/C) Ratios



No-Build Westbound AM Volume/Capacity (V/C) Ratios

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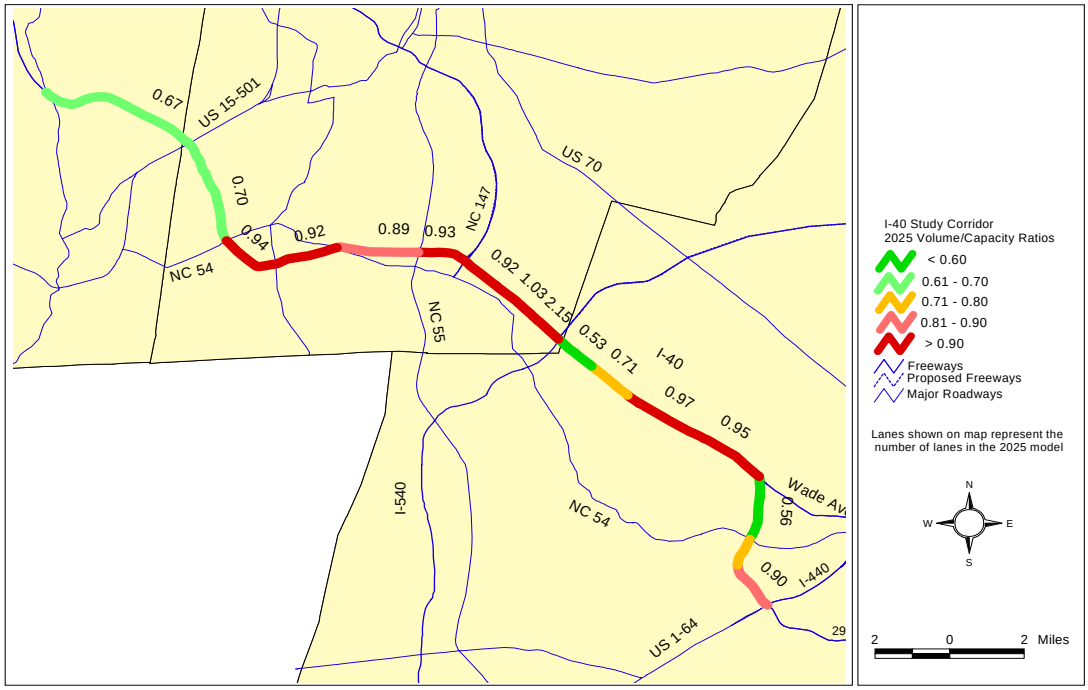
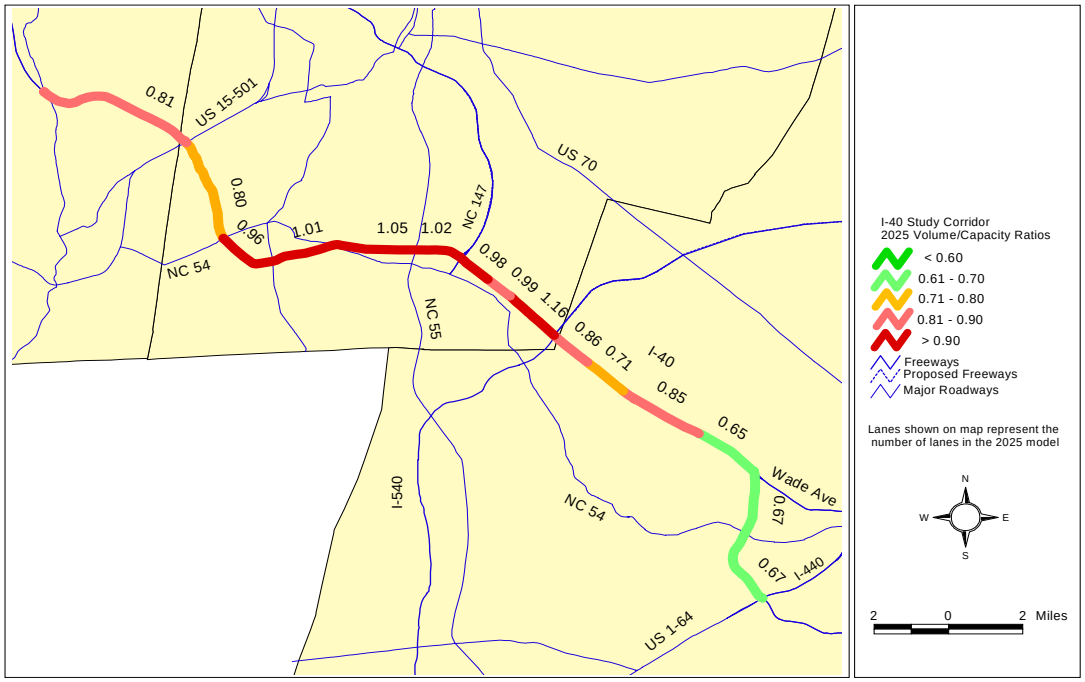
Figure 2-11 FREEVAL 2025 No-Build PM Peak Hour Traffic Analysis Results



No-Build Eastbound PM Volume/Capacity (V/C) Ratios



No-Build Westbound PM Volume/Capacity (V/C) Ratios

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2.3.5 Key Findings of Capacity Analysis

- The widening of I-40 between Wade Avenue to US 1/US 64 from four to six-general purpose lanes, exclusive of any future HOV lane development would significantly improve operations on I-40.
- The main focus of congestion in the 2025 baseline network is on I-40 through the Research Triangle Park between NC 147 and I-540.
- High future demands on the I-540/I-40 interchange may require interchange modifications and/or development of additional roadway capacity such as the Triangle Parkway.
- Access management techniques to increase spacing between traffic signals near I-40 interchanges could improve arterial operations substantially and reduce ramp traffic queuing onto I-40.
- The Bottleneck Analysis (February 2002) conducted early in the Phase II study provides a list of short-term, low-cost improvements for enhancing operations on I-40. Three interchanges along the corridor were studied in detail:
  - NC 54 near Chapel Hill
  - Aviation Parkway
  - Airport Boulevard

2.4 Crash Analysis

Using data provided by NCDOT, a crash analysis was conducted to evaluate existing crashes and the potential impact of crashes in the future. This analysis is detailed in the following sections.

2.4.1 Existing Crashes

Vehicle crashes can result in serious reductions in the capacity of a roadway. A recent travel time study conducted for I-40 estimates that the occurrence of a vehicle crash typically reduces travel speeds by 50 percent. A significant increase in the duration of the peak period results from queues and congestion created by crashes.

Crashes not only cause congestion but are themselves caused by congested conditions. It is estimated that crashes account for approximately 50 percent of traffic delays in most urban areas. Therefore, increasing roadway capacity is generally expected to both reduce the number of sideswipe and rear end crashes and alleviate congestion due to the crashes that occur. The three-year crash rate summary for I-40 is provided in Table 2-11.

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Table 2-11 Crash Rate Summary by Segment

I-40 Corridor Segment	Length (Miles)	Total Number of Crashes	Crash Rate (crashes/100 mvm)
1. I-85 to US 15/US 501	11.9	332	53.7
2. US 15/US 501 to NC 54	3.0	83	26.8
3. NC 54 to NC 147	6.0	379	60.8
4. NC 147 to I-540	3.9	691	170.7
5. I-540 to Wade Avenue	6.1	1059	187.7
6. Wade Avenue to US 1/US 64/I-440	4.0	308	83.5
7. US 1/US 64/I-440 to Lake Wheeler Rd.	4.0	400	107.8
8. Lake Wheeler Road to I-440/I-40	4.0	333	88.9
9. I-440/I-40 to US 70	4.6	281	65.1
10. US 70 to NC 42	5.8	157	35.4

Source: NCDOT data 7/1/96 – 6/30/99
Note: mvm = million-vehicle-miles

Some observations on the crash trends include:

- In North Carolina, the 1996-1998 average rate for rural interstate routes was 67.42 crashes/100 mvm while the average rate for urban interstate routes was 163.70 crashes/100 mvm.
- Only two segments had higher crash rates than the statewide averages. Those two segments (Segments 4 and 5, i.e., NC 147 to I-540 and I-540 to Wade Avenue) are also the two segments with the highest traffic volumes.
- Unusually high crash locations were identified and are listed below. Several of these locations coincide with the spots where traffic queues normally occur. The following five worst spots on the I-40 corridor are ranked according to collision experience in descending order:
  - US 1/US 64/I-440 Interchange
  - I-540/Wake County Line
  - Davis Drive
  - NC 55
  - South Saunders Street

2.4.2 Future Crashes

As shown in the previous discussions, traffic on most segments of I-40 is forecast to double by 2025. Therefore, if existing crash rates remain constant, it can be expected that traffic crashes, especially sideswipe and rear end crashes, will double in the future as well.

This increase will be especially critical during the peak hours. As occurs under current circumstances, future crashes will cause severe congestion, with many motorists seeking alternate routes. Unfortunately, the alternate routes will also be congested. Therefore, enforcement and emergency vehicles will be prevented from getting to crash sites quickly. The impacts of this scenario on future traffic conditions would be severe and could occur on an almost-daily basis.

As an example, the section of I-40 between I-540 and Wade Avenue averages one crash per day during the peak period (i.e., either a crash during the A.M. or P.M. peak period). In the future, if the number of crashes double as expected, there will be two crashes per day during the peak period (i.e. one crash during the A.M. peak period and one crash during the P.M. peak period). Of course, this is a simplified discussion and would vary based on actual conditions.

2.5 Overall Key Findings

Congestion is a significant problem in the Triangle Region and on the I-40 corridor today. Even with anticipated roadway improvements, future congestion will continue to increase in the region. Specific findings of this analysis of existing and future traffic conditions include:

- The primary reason for increasing congestion is the projected increases in population and roadway use that significantly exceeds the planned roadway capacity. Under existing forecasts, population and employment are expected to increase approximately 100 percent compared to a 48 percent increase in lane-mileage for major arterials and freeways.
- Average daily traffic is expected to increase by 70 to 100 percent along the entire I-40 corridor. Traffic volumes are projected to exceed 200,000 vehicles per day (vpd) between NC 147 in RTP and the Wade Avenue/I-40 split in Raleigh.
- Very high volumes in the AM and PM peak periods will continue to result in peak hour spreading as commuters adjust their travel time to avoid the most congested periods of travel. As a result, more of the corridor will experience congestion over more hours of the day.
- Future roadway level of service is expected to decrease to LOS E and F along most sections of the I-40 corridor. This finding occurs even with the currently planned improvements on I-40 and other roadways assumed in the 2025 Triangle Regional Model.
- The most congested section of the I-40 corridor is the section between NC 147 and I-540 serving the Research Triangle Park.
- The I-40 interchanges with US 15/US 501, NC 54, and I-540 require significant capacity and operational improvements to provide desirable 2025 peak hour operations on I-40.
- Future crashes will increase as traffic volumes increase on I-40. The provisions of future strategies to improve safety or reduce incident times would reduce delays resulting from crashes.

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3. PUBLIC AND COMMUNITY INVOLVEMENT

The goal of I-40 HOV/CMS public involvement activities is to provide a framework within which NCDOT is able to secure broad-based support for implementing I-40 HOV/CMS findings as well as technical advice and input regarding the study process.

In order to reach this goal, the project employed numerous tools. Throughout the study process, public agencies were involved through a series of technical and policy committee meetings. In addition, numerous regional initiatives were reviewed to determine the extent of regional awareness and coordinated outreach efforts between local transportation officials. In the early stages, an attitudinal survey was conducted to determine local perceptions of I-40 operations and potential improvement options. Later, to ensure that the community had a variety of opportunities to participate in the study, several community participation strategies were used to increase awareness and knowledge of the project. Regional meetings, newsletters, a website, and hotline were developed.

3.1 Review Committees

3.1.1 Study Participation

The I-40 HOV/CMS, conducted over a two year period, brought together many of the transportation leaders from the region. These leaders provided invaluable knowledge about the region's transportation issues, concerns and ongoing planning efforts and directed the technical work of the study team. They participated through membership in one of two committees: the Technical Committee and the Policy Committee. Agencies and organizations involved in these committees included:

- North Carolina Department of Transportation
- Durham-Chapel Hill-Carrboro Metropolitan Planning Organization
- Capital Area Metropolitan Planning Organization
- Triangle Transit Authority
- Federal Highway Administration
- Research Triangle Park employers
- North Carolina Department of Environment and Natural Resources (Air Quality Division)
- Raleigh-Durham Airport Authority

3.1.2 Technical Committee

The complex nature of the I-40 HOV/CMS and its potential impact on regional traffic operations, airport services, and the local economy required that technical experts have opportunity for developing the course of the study. To address these issues, the Technical Committee was established. This Committee met periodically to review and refine the technical elements of the I-40 HOV/CMS. During both Phases of the project, the role of the Technical Committee was to:

- Assist in developing regional transportation objectives and priorities for the study;

- Assist in developing strategies to be evaluated;
- Assist in developing measures and methodologies for testing strategies;
- Assist in interpreting the results of the evaluations;
- Assist in summarizing the issues and alternatives for consideration by the stakeholders;
- Assist in identifying the scope and direction of Phase II;
- Provide guidance to the study team relating to specific technical issues; and
- Foster regional cooperation.

3.1.3 Policy Committee

The multi-disciplinary nature of the I-40 HOV/CMS and its policy ramifications on local and regional transportation management required that the regional transportation leaders have opportunities to review and comment on broader, policy-level issues associated with the findings of the study. The role of this Policy Committee was to:

- Review and approve recommendations of the Technical Committee;
- Provide credibility to the study for acceptance by other agencies and organizations;
- Assist in promoting policy and legislative changes needed for study findings to be implemented;
- Provide insight into public perception of transportation problems and issues and potential mitigation strategies;
- Assist in identifying critical issues and potential obstacles associated with any particular strategy;
- Assist in dealing with study process issues that could affect the outcome or schedule for the study; and
- Promote regional cooperation.

3.1.4 Stakeholders Group

Ongoing efforts in the region to encourage the use of alternative modes of transportation, including transit improvements and commute trip reduction initiatives, are rapidly changing the circumstances in which congestion management techniques would be introduced. For this reason, it is important to obtain input from business and community leaders before assessing the viability of potential congestion management strategies.

Therefore, early in the process, several meetings were held with key stakeholders in the region to receive input regarding their concerns and ideas on congestion management. Additional input into study issues was solicited by hosting two breakfast meetings that were attended by corporate, community, and political leaders. The purpose of these meetings was to inform the stakeholders of the study, outline the study goals and process, describe existing and projected transportation deficiencies and issues, describe the alternatives being considered, and present the findings to date. Meetings were structured to provide for feedback and suggestions.

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What the Stakeholders Said...

During the first Stakeholders meetings, participants were encouraged to express their opinions regarding the major issues facing I-40 travelers and to suggest approaches for improving commuter travel. Comments from the attendees included:

- Consider commuter development patterns within the Triangle Region, with many business centers in addition to RTP;
- Identify and concentrate on improving traffic bottlenecks;
- Consider more than just home-to-work trips;
- Be realistic about the impacts of Travel Demand Management (TDM) and transit;
- Educate the public about the causes of and possible improvements to traffic congestion;
- Reduce traffic volume during peak travel hours;
- Transit service is inadequate;
- Lack of coordination between public agencies; and
- Incident management on I-40 is inadequate.

During the second stakeholders meeting participants were requested to comment on the findings of the first phase of the study and recommended goals for Phase II. Key recommendations for Phase II were:

- Coordinate new development with roadway improvements;
- Identify specific projects, costs, and funding sources;
- Phase immediate improvements into future plans;
- Model future transit alternatives; and
- Communicate the vision with the public.

3.2 Triangle Regional Initiatives

There are many ongoing efforts to address congestion in the Triangle Region, particularly on I-40 in the AM and PM peak periods. These efforts include ways to add highway capacity, to better manage existing and future highways, and to provide alternative modes of travel.

As part of the I-40 HOV/CMS, the various on-going and past transportation planning studies and projects were reviewed for applicability to the objectives of the I-40 study. The most relevant projects are summarized below.

- **Regional Transit** – The Triangle Transit Authority (TTA) is planning and

implementing a regional rail service, express bus service, regional bus service, and coordinating each with local bus services and major destinations. It also operates van pool service.

- **MPO Plan Updates** – The Durham-Chapel Hill-Carrboro and Capital Area Metropolitan Planning Organizations (MPOs) have considered enhanced mobility in the development of their long-range transportation plans. Both MPOs have performed analyses on enhanced transit and managed lane facilities, as well as performed regional transportation modeling to determine land use impacts on their respective transportation systems. The Capital Area Metropolitan Planning Organization (CAMPO) approved its long-range transportation plan on April 17, 2002.
- **Intelligent Transportation Systems (ITS)** – The North Carolina Department of Transportation (NCDOT) has developed a statewide ITS program that identifies future ITS improvements in the Triangle Region. The purpose of the ITS program is to move traffic and people more efficiently and safely and to maximize the capacity of the existing roadways. ITS provides "real time" information to transportation professionals, the transportation system itself, and to transportation users.
- **Travel Demand Management (TDM)** – NCDOT, Durham County, and major Research Triangle Park employers have come together to develop and adopt programs and ordinances to reduce the amount of traffic attributable to commuters to the RTP. Carpools, vanpools and transit are important elements of their programs.
- **Regional Development and Mobility Principles** – The Triangle J Council of Governments is performing a study to illustrate the sustainability benefits (of which transportation is an integral part) of land development patterns other than conventional suburban expansion.
- **Regional Transportation Alliance** – Early in 1999 the Greater Raleigh Chamber of Commerce assembled a group of 35 government and business leaders to discuss transportation needs for the region. The focus was on accelerating roadway projects and increasing funding for roadway construction (particularly private funding and toll roads). The action plan includes policies for highways, transit, land use, and administrative and legislative changes to address traffic congestion. It also recommends a regional push for vanpooling, telecommuting and transit use. The report emphasizes the importance of regional cooperation.
- **Smart Growth Initiatives** – In April 1999, the General Assembly passed a bill to establish a Blue Ribbon Commission to address growth, infrastructure, and development issues. These issues include smarter infrastructure and transportation planning; more balanced economic development in rural and urban areas; fostering compatible land-use patterns; preserving and improving air quality; and preserving natural resources. The 37 Commission members represent a broad range of governmental, business, academic, and environmental groups. The Commission continued to meet throughout the year 2000 and made specific recommendations regarding Smart Growth legislation to the General Assembly.

- **Major Highway Projects** – Currently project development and environmental studies are underway for three major projects affecting I-40:
  - Widening of I-40 from I-85 to NC 147 in Durham County

- Western Wake Freeway
- Southern/Eastern Wake Freeway

Regional Transit, ITS and TDM are discussed in more detail in Chapter 5.

3.3 Attitudinal Survey

As part of Phase I, a statistically valid telephone survey was conducted to collect and quantify the attitudes and opinions of the users of I-40. This data provides NCDOT with a better understanding of how travelers in the region perceive congestion and the problems that cause that congestion, including an indication of the depth and breadth of user frustration.

The survey, not surprisingly, confirmed that the public is concerned about traffic congestion on I-40. Respondents also strongly indicated a public awareness and interest in alternative transportation improvements (in addition to highways) including transit, HOV lanes, traffic management strategies, and trip reduction measures. Key findings and specific observations include:

- The vast majority of commuters drive to and from work alone. Very few drive with at least one other person, and even fewer take public transportation.
- One third of the commuters feel they encounter major delays on I-40 on more than 50 percent of their trips.
- Most I-40 users and commuters perceive traffic to be a major or moderate problem on Triangle Region roads, and especially on I-40 during morning and evening peak hours.
- Key contributing factors to traffic congestion on I-40 were perceived to be (in order of seriousness):
  - The amount of traffic during peak travel hours;
  - Lack of sufficient public transit service;
  - Poor or inconsiderate driving habits;
  - Unmanaged regional development and growth;
  - Lack of reasonable alternative routes;
  - Back-ups on I-40 entrance and exit ramps;
  - Crashes and mechanical breakdowns;
  - Congestion on roads adjacent to I-40 exits and entrances; and
  - Lack of coordination between various government agencies or departments for improvements.
- Reactions to potential congestion management strategies were:
  - A high priority should be assigned to providing commuter rail and connecting bus service along I-40 corridor. (53 percent)
  - A high priority should be given to improving crash response and removal. (48 percent)

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  - While adding more highway lanes was considered a high priority, providing HOV lanes for buses and cars with two or more occupants was considered to be as important as adding general purpose lanes.
- Other alternatives that were considered to be a high priority by one-third of respondents, and at least a moderate priority by two-thirds include:
  - Increase employer-sponsored incentives to carpool and use public transit;
  - Increase bus service along the I-40 corridor; and
  - Improve signal timing at intersections adjacent to I-40 entrances/exits.
- Almost fifty percent of those interviewed did not support toll lanes. Few would use the toll lanes, even at a cost of only 25 cents.

3.4 Community Outreach

Improvements to the I-40 Corridor will impact citizens in Orange, Durham, and Wake Counties. Therefore, it was important to provide citizens throughout the Triangle Region with information on the proposed project, as well as an opportunity to comment. Though not required as part of the study, a community outreach program meeting Federal, State, and other requirements for public involvement was conducted, including National Environmental Policy Act (NEPA), Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Transportation Efficiency Act for the 21st Century (TEA 21), and rules promulgated by the NCDOT and the local metropolitan planning organizations.

3.4.1 Objectives

The objectives of the I-40 HOV/CMS public involvement activities were to:

- Disseminate information about the I-40 HOV/CMS to the general public and to directly affected communities.
- Identify stakeholder groups most affected by and interested in possible I-40 improvements and actively solicit their input.
- Provide a variety of opportunities for public participation and involvement throughout the study.
- Present study findings that are sensitive to and adequately address issues raised by the projects' multiple stakeholders.

3.4.2 Public Involvement Activities

Each of the public involvement tools discussed below was used to achieve these objectives. In addition, to be effective, outreach efforts were tailored to the needs and concerns of specific constituent groups in a manner conducive to their involvement. Some communications met the diverse needs of all stakeholders, such as newsletters and fact sheets. At other times, strategies tailored to specific groups were a more effective means to accomplish project objectives.

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- **Open Houses** – A series of three open houses was held from December 10 to 12, 2001 to provide the public an opportunity to learn more about and provide comments on the study early in the study process. The public was given the opportunity to view display boards with information on HOV lanes in general, as well as specific information on the study progress. Citizens were also able to discuss the project with representatives from the NCDOT and to give feedback verbally or in writing.
- **Speakers Bureau** – Opportunities to present information about the project were provided on an ongoing basis. These presentations were held in order to obtain feedback from and build consensus within the Triangle Region political base and among key decision makers. Presentations were also given to other interested organizations in the Triangle Region. Presentations were continually updated to reflect the current status of the project.
- **Project Displays** – A project display consisting of sixteen display boards showing information about the study was developed for the purpose of presenting project information in public places. The project display was "manned" in order to receive feedback from the public and answer questions.
- **Project Brochure** – A project brochure was developed and distributed at all public involvement activities throughout the study.
- **Project Newsletters** – Three project newsletters were distributed at specific milestones in the project to provide specific information to the public.
- **Project Hotline** – The toll-free project hotline (866-527-7715) provided 24-hour access to I-40 HOV/CMS information.
- **Project Website** – The project website (www.I40HOV.com) also provided 24-hour access to I-40 HOV/CMS information.

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4. STRATEGIES AND RECOMMENDATIONS

Numerous congestion management strategies were examined as part of this study and are shown in Table 4-1. This section reports the findings for these strategies. The findings are grouped under the headings of:

- High Occupancy Vehicle (HOV) Facilities
- Traditional Capacity Improvements
- Express Lanes
- Transit
- Intelligent Transportation Systems (ITS)
- Ramp Metering
- Transportation Systems Management
- Travel Demand Management (TDM)

High Occupancy Vehicle (HOV) Facilities were identified as feasible for the Triangle Region and were examined in greater detail than the other strategies. This analysis is included in Chapter 5.

In addition to the strategies studied in detail, some congestion management strategies, after preliminary evaluation, were eliminated from the study and are shown in Table 4-2. These include:

- Toll Roads
- Truck Lanes
- High Occupancy Toll (HOT) Facilities
- Ramp Restrictions/Closures
- Congestion Pricing

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Table 4-1 Summary of Strategies Recommended for Study in Phase II

Strategy	Potential Application for I-40	Benefits	Comments	Coordination with Other Projects
High Occupancy Vehicle (HOV) Facilities	Approximately 100 miles on I-40, I-540, US 1, and US 64 technically feasible. Approximately 60 miles on I-40 and I-540 financially feasible by 2025.	Could reduce SOV commute trips by up to 2%, and overall peak period VMT by 3%. Provides incentive and benefits for ridesharing and transit.	Phasing of segments varies over the next 25 years. Continuity is a consideration In developing an HOV network.	Provide findings to MPOs for adoption into long-range plans. Coordinate and evaluate with regional transit plans.
Traditional Capacity Improvements (beyond those currently included in the adopted 2025 Plans)	NC 147 Extension (Triangle Parkway). Widening and improving I-40 between NC 147 and I-540. Widening I-40 between Wade Ave and US 1/ US 64. Key interchange projects.	NC 147 Extension reduces congestion on I-40 bottleneck section between I-540 and NC147. Reduces overall peak period VMT by 3%. Reduces delays for RTP commuters by 15%.	Arterial improvements should be considered. I-540 interchange significantly impacts congestion in future.	Coordinate with MPO plan updates and potential TSM improvements.
Express Lanes	Modified express lane/collector distributor may be applicable on I-40 at RTP in future.	Can improve safety and capacity if high percentage of long distance trips.	Best applied in areas with numerous long distance trips.	Coordinate with HOV design through RTP.
Transit	Regional rail, express bus, busways, park-and-ride, direct connections to I-40, other supporting facilities.	TTA studies have determined regional transit is justified and provides an important alternative means of transportation.	Regional transit plans were developed and adopted, but need to be reviewed to take advantage of HOV lanes. Future high volume bus corridors coincide with several HOV corridors.	Develop and evaluate in coordination with TTA.

Table 4-1 (continued)

Strategy	Potential Application for I-40	Benefits	Comments	Coordination with Other Projects
Intelligent Transportation Systems (ITS)	Incident management and traveler information systems for I-40 and other facilities.	Can reduce mainline travel time and crashes by between 10% and 20%.	Can be implemented and extended as part of roadway construction.	Coordinate with Statewide ITS Study.
Ramp Metering	I-40 on-ramps to regulate flow onto mainline I-40.	Can reduce mainline I-40 travel time and crashes by between 20% and 30%. Easy to construct. HOV bypasses can be installed in short term.	Ramp characteristics allow for ramp metering to be installed. Requires specific studies for candidate I-40 interchange locations. For maximum benefit, should be installed as part of a system.	Coordinate with Statewide ITS Study in evaluating individual strategies.
Transportation Systems Management (TSM)	Auxiliary lanes, interchange improvements and arterial roads. Upgrade existing and install new signal systems.	Relatively low cost of improvements with high benefits. Arterial road system provides alternatives to freeways in event of incidents and for shorter trips.	Bottleneck Report evaluated three specific interchanges.	Coordinate with NCDOT and MPOs.

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Table 4-1 (continued)

Strategy St	Potential Application for I-40	Benefits	Comments	Coordination with Other Projects
Travel Demand Management (TDM)	Trip reduction programs and measures at key employment zones. Includes on-site coordinators, address matching, preferred parking, emergency ride home, transit subsidies, telecommuting, and on-site ticket sales.	Benefits depend on level of employer involvement and aggressiveness of program. Affects work trips only. 20% reduction in RTP work trips would have approximately a 4-5% reduction in peak hour trips on I-40 near RTP.	TDM can support and is an essential element of an HOV program.	Coordinate with RTP and Durham TDM studies and evaluate potential impacts of adopted measures.

Table 4-2 Summary of Strategies Not Recommended for Study in Phase II

Strategy	Potential Application for I-40	Benefits	Comments	Coordination with Other Projects
Toll Roads	None identified.	Can accelerate construction of needed roadway projects.	May be considered in Phase II if major new freeways considered (beyond 2025 Plan).	N/A
Truck Lanes	None identified.	Can improve safety and capacity if high percentage of heavy trucks.	I-40 is not a major corridor for through trucks.	N/A
High Occupancy Toll (HOT) Facilities	Tolls must be low to attract enough users. Revenues do not justify cost.	Allows users that value time highly to utilize HOV lanes	Probably practical only with HOV 3+ by 2025. Would probably require higher-cost barrier-separated HOV lanes.	N/A
Ramp Restrictions/ Closures	None identified.	Can improve safety by eliminating unsafe merges/weaves.	Ramps on I-40 corridor have relatively high design standards.	N/A
Congestion Pricing	Not recommended.	Can spread peak periods.	Insufficient congestion projected, and limited number of hours during the day.	N/A

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4.1 Traditional Capacity Improvements

Traditional capacity improvements involve both upgrading existing roadways and constructing new roadways. In addition, interchange improvements and other major projects, such as a bridge widening, are classified as traditional capacity improvements.

Over the next 25 years, the Triangle Region is planning to undertake an ambitious roadway improvement program. In addition to widening miles of existing roadway, numerous new freeways are planned for construction. Key elements of the program include the I-540 Raleigh Outer Loop and bypasses of Knightdale, Holly Springs, and Clayton.

In addition to these freeway improvements, numerous new arterials are planned for construction. Interchange improvements, and other minor projects are proposed to upgrade existing facilities.

To understand the impact of traditional capacity improvements on congestion, an assessment of the improvements included in the regional network was made. As shown in Table 4-3, the current transportation plan anticipates that the total number of lane-miles of freeways and major arterials in the Triangle Region will increase by 45 percent over the next 25 years. Put in other terms, for every two lane-miles of roadway today, there is estimated to be three lane-miles in 2025.

Table 4-3 Planned Growth in Lane-Miles for the Triangle Regional Model

Type of Roadway	1995 lane-miles	2025 lane-miles	Percent Increase
Freeway/Expressway	870	1,773	104%
Arterial	2,292	2,822	23%
Total	**3,162**	**4,595**	**45%**

Despite this significant investment in highways, the planned increases in the roadway network will not keep pace with the projected increases in population and employment of greater than 100 percent. Therefore, it is reasonable to expect that congestion would worsen on the Triangle Region's roadway network.

Another reason for congestion on I-40 is the lack of viable alternate routes. One project that could provide an alternate route would be the extension of NC 147 south of I-40 to I-540, i.e., the Triangle Parkway. Preliminary analyses indicated it could provide up to a three percent reduction in vehicle-miles traveled (VMT) through the region and up to a 15 percent reduction in delays within the Research Triangle Park itself. Therefore, the Triangle Parkway would be a very viable and desirable addition to the 2025 roadway network.

Based on this analysis, it can be concluded that traditional capacity improvements are an essential element for any transportation plan for the Triangle Region. As ambitious as the

current traditional capacity plan for the Triangle Region may seem, it is actually quite modest when compared to growth that is projected to occur.

4.2 Express Lanes

Express lanes were examined as potential treatments on I-40 in the Triangle Region. In general, this treatment provides dedicated through lanes in the center of the freeway to serve longer distance traffic. Ingress and egress to express lanes are limited to a few locations, so that shorter (local) trips are prevented from using them.

While extensive analysis is required before implementing express lanes, two general rules of thumb are generally applied:

- For express lanes, the roadway must have a directional split of 60/40 and a minimum of 25 percent of the forecasted traffic needs to travel five miles or further on the corridor.
- The express lane concept requires a median width that will accommodate a two-lane, two-way roadway (typically 40 foot minimum).

In general, it was determined that express lanes would not be applicable for the I-40 corridor due to the high number of short, local trips. On I-40 between NC 147 and I-540, however, express lanes in combination with HOV lanes may be an option. Because of the very high volumes on this section of roadway (both HOV and non-HOV), roadway modifications that include express lanes or a collector-distributor system may be necessary to provide adequate capacity for the anticipated future ADT of approximately 230,000 vehicles per day (vpd). The three RTP exit ramps and two freeway ramps through this section suggest that the collector-distributor volumes would likely exceed the freeway volumes resulting in a de-facto express lane treatment.

4.3 Regional Transit Systems

4.3.1 The Need for Regional Transit

Transit is an essential element of a congestion management plan, and efforts to improve and enhance the regional transit system should be supported. Regional transit is vital to improving mobility for all segments of the population and for providing an alternative to a congested highway system.

A comprehensive regional transit system is a critical element of the transportation system for almost all major metropolitan areas. As regions grow and opportunities to add highway capacity become limited, transit, particularly fixed guideway (or rapid) transit, offers the ability to move more people without adversely impacting the performance of the system. For example, once the initial investment has been made in rail or a busway, increasing demand can be satisfied by running more trains or buses, or increasing the size of the train or bus. In North Carolina, the Charlotte-Mecklenburg Region has determined that a rapid transit system that guides development into identified growth corridors is essential to maintaining quality of life and the economic vitality the region now enjoys. The region has financially committed to implementing an extensive region-wide system.

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The Triangle Region's highway system is not adequate to accommodate today's demand for travel. Analysis has demonstrated that the conditions will worsen over time with the growth projected for the Triangle Region. Overall travel times in the region will increase even with significant investment in new or improved highways. The transit alternative will become attractive to more and more people as mobility and trip reliability decreases on the roadway network. Land use initiatives (as part of smart growth policies) that focus more intensive, transit-oriented development around transit stops could enhance the convenience of transit and the attractiveness of transit travel.

4.3.2 The Regional Transit Plan

In 1989 the Triangle Transit Authority (TTA) was established to develop plans for and operate regional public transportation in the three-county Triangle Region. In the mid 90's the Regional Transit Plan was developed that included rail service, expanded regional bus service, shuttles, park-and-ride and enhanced pedestrian and bicycle access to transit stations as shown in Figure 4-1.

Statistics compiled by the TTA show that in 1995 there were 36,400 transit trips in the Triangle Region. Forecasts by the TTA using the Triangle Regional Model indicate that with current transit expansion plans, including new routes and increased service, the number of transit trips in the region is anticipated to reach 58,000 by 2025, a 60 percent increase. Adding the regional rail system to the Triangle's transit system would increase the number of transit trips to between 80,000 and 83,000 by 2025, a 120 to 128 percent increase over the 30-year period.

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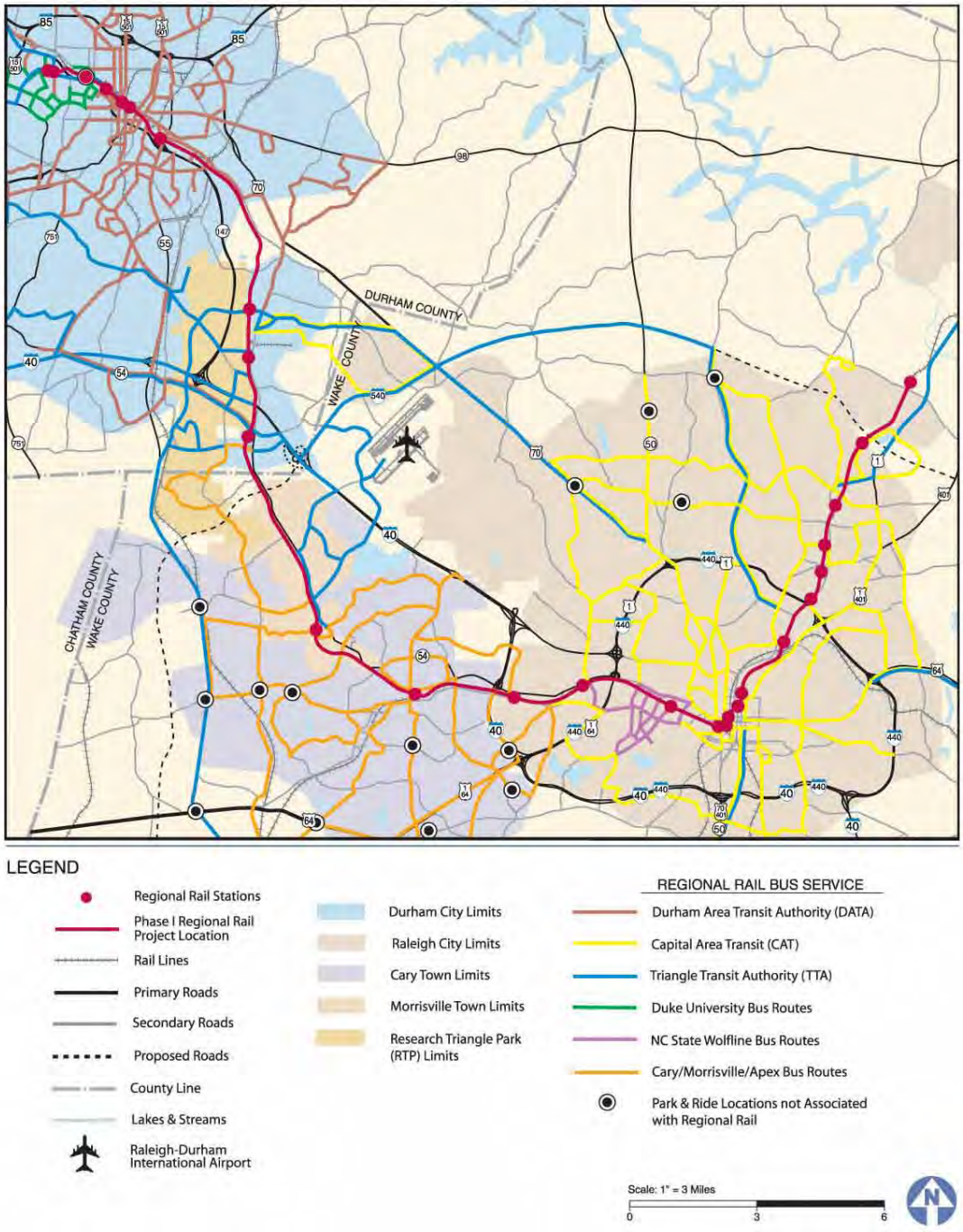
Figure 4-1 TTA Regional Rail System DEIS 2025 Transit Network



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Fixed Guideway Transit

Phase I of the TTA Plan provides for a 35-mile rail system connecting Durham, Chapel Hill, RTP, Morrisville, Cary, downtown Raleigh, and North Raleigh. Service is anticipated to commence around 2008. The proposed route is displayed in Figure 4-1.

Diesel Multiple Unit (DMU) Vehicle

The regional rail alignment intersects with I-40 in two places: in the RTP near Davis Drive, and near Exit 290 (NC 54—Hillsborough Street). In the latter case, there may be opportunities for bus service to feed into the rail station to support the Raleigh-to-RTP and Durham rail service.

The Draft Environmental Impact Statement for the proposed regional rail line assumes the existence of the rail line (but does not assume the existence of the proposed HOV lanes in the I-40 corridor) and orients some of its bus service to supporting the rail line.

Expanded Bus Service

The other major component of this plan is a robust local bus network serving the Cary and Apex areas, with much more extensive service than the existing TTA system. Subsequent phases will consider fixed guideway transit in existing rail corridors to outlying communities. Currently, regional service connects Raleigh, Durham and Chapel Hill, with a major transfer hub in RTP. The regional service also enables transferring between the local transit systems in each of the three communities.

Bus Rapid Transit

Bus Rapid Transit (BRT) is not included in the current regional plan. However, an HOV network can provide the backbone for a high-speed, regional express bus service that includes busways (roadways or lanes that are used exclusively by buses), HOV facilities, and buses operating in mixed traffic on streets in areas where the construction of HOV lanes or busways is infeasible or unreasonable.

A system of bus routes operating on HOV lanes on I-40 between NC 86 and I-440 would provide greater coverage for the mass transit system and, in so doing, provide greater opportunities for mass transit use by residents and workers in the Triangle Region. It also could provide a catalyst for an integrated transit and park-and-ride network serving the region.

Bus routes operating on HOV lanes would experience speed benefits that would reduce travel time for those routes. This travel time reduction would make the buses more attractive relative to driving, which should have the effect of increasing transit's mode share and market penetration in the Triangle Region.

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HOV can enhance opportunities for the existing mass transit service operating on or near I-40. It offers options for modifying the existing services to take advantage of the proposed HOV lanes, and to develop a network of park-and-ride lots and bus routes oriented around the I-40 HOV lanes and the interchanges served by I-40.

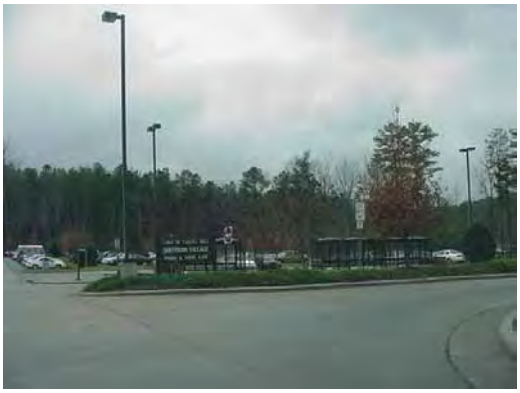
BRT is particularly compatible with the low-density suburban land uses that characterize the Triangle Region. BRT technology offers the opportunity to establish rapid transit in corridors that cannot justify the cost of rail transit. While a BRT system includes the traditional feeder buses and park-and-ride lots found on rail rapid transit, its key attribute is the buses that combine the feeder, line-haul and distribution functions. With a BRT system, the same bus can loop through a neighborhood picking up passengers within convenient walking distance of their homes before entering a high-speed HOV or bus lane.

The TTA has identified a number of corridors where relatively high volumes of buses are projected in the future. Those that coincide with corridors where HOV lanes are potentially feasible are shown in Figure 4-2 and include:

- I-40 from NC 54 (Exit 273) to Miami Boulevard (Exit 281)
- Northern Wake Freeway from Wake Forest Road to I-40
- Western Wake Freeway from the Holly Springs Bypass to I-40
- Knightdale Bypass (from US 64 to I-440)
- US 1/US 64/I-40 to connect passengers to a future West Raleigh rail station (near I-40)

Park-and-Ride Facilities

Park and ride lots can enhance transit usage and HOV usage on I-40. The lots would serve as transit hubs or collector points for vehicles to access transit, including express bus service, which could use the HOV facilities. In addition, the lots could serve as collector points for carpool riders.



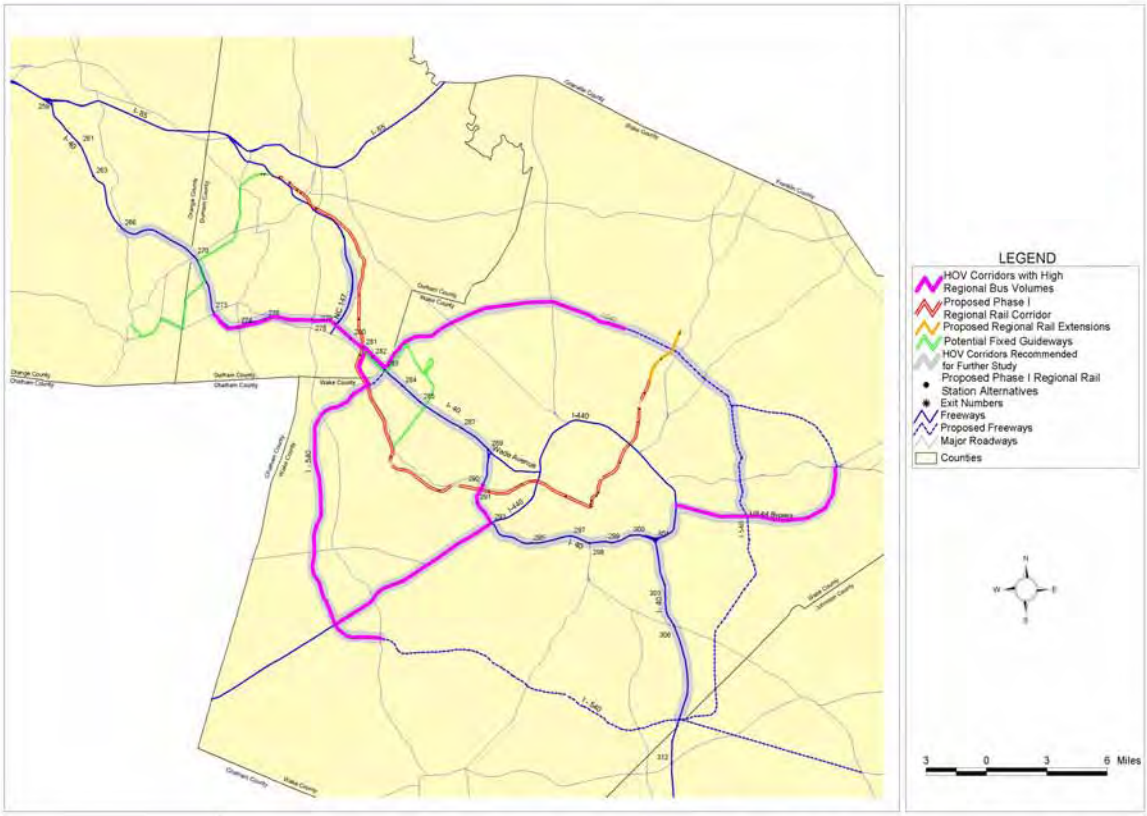
The Raleigh-Durham-Chapel Hill region has a number of park-and-ride facilities for use by bus passengers as well as by car- and van-pools. TTA serves ten park-and-ride lots located throughout the area, mainly east of RTP. Additional lots maintained by local transit agencies are in place within Raleigh and Chapel Hill. Most of these locations are joint- or shared-use sites, meaning that the park-and-ride lot is

secondary or auxiliary to the primary use of the site, such as parking for shopping, entertainment, recreation or other land uses.

Since park-and-ride facilities along I-40 could increase bus transit and HOV volumes, an analysis of potential lots on the I-40 corridor was undertaken. For all the interchanges outside the RTP area that are considered primarily destination interchanges, potential shared-use park-and-ride lots were identified. The analysis considered potential transit routes and identified 35 potential park-and-ride lots.

The development of the park-and-ride system could be refined in the context of a regional strategic park-and-ride study, with the Department of Transportation, the MPOs and the transit agencies in the region working together as partners. An integrated system could provide the region with a uniform standard of coverage and service, and properly sized facilities where they are needed most.

Figure 4-2 2025 HOV Corridors with High Regional Bus Volumes



2025 HOV Corridors with High Regional Bus Volumes

4.4 Freeway Management/Intelligent Transportation Systems

Freeway Management is the application of a variety of strategies aimed at improving the efficiency and safety of a highway. The deployment of Intelligent Transportation Systems (ITS) is a central element of a modern, efficient freeway management plan. Freeway Management strategies use advanced technology, such as detection through cameras or radar, telecommunications, computing and control software to:

- Collect accurate, real-time data on actual traffic flows and roadway conditions;
- Detect changes in traffic flows, due to stalled vehicles, crashes, debris in roadway, or other occurrences that affect system efficiency and capacity;
- Verify the nature of any detected incidents;
- Respond to incidents and quickly restore normal traffic flows; and
- Inform the driving public of current traffic conditions and provide information on alternative routes and/or modes.

4.4.1 ITS Techniques

Video Wall at TTMC

Each element is necessary to operate the system. Any individual element has very little benefit in isolation. However, all the elements operating as a system have a substantial impact on the transportation network and can improve daily operations by providing users with the "real-time" information needed to make "on-the-spot" travel decisions. Traffic control centers serve as the main component of most freeway traffic management systems. In the Triangle Region, NCDOT operates the Triangle Transportation Management Center (TTMC). The TTMC and its associated systems collect and disseminate real-time traffic and transportation information and data, verify the location of incidents and place information regarding delays, severity, longevity, etc., on the system's variable message signs (VMS) and other media. The TTMC provides data and information feeds to other outlets, including the North Carolina State Highway Patrol and local media outlets, primarily television stations.

Some examples of ITS and freeway management strategies include:

- Video surveillance to verify the location, severity and appropriate response for an incident. Surveillance of traffic is most commonly conducted with cable TV cameras remotely operated from a traffic control center. The NCDOT currently has 18 cameras on I-40 throughout the Triangle Region.

Camera View of I-40 at Aviation Parkway
Online Updates Courtesy of WRAL TV

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- Detection of changes in traffic flow, using several technologies available such as video imaging, in-pavement loops, radar, and microwave.

VMS Sign - Westbound I-40 Prior to Aviation Parkway Exit

- Variable Message Signs (VMS) to provide travelers with en-route travel and incident information. VMS are large signs mounted over the roadway with programmable messages detailing current traffic conditions. The sign messages are developed through information provided by the ITS. Several VMS are currently in operation on I-40.

Incident Management Assistance Program (IMAP) Response Vehicle

- Freeway service patrols, a common incident management technique used in most major U.S. cities, provide vehicles equipped with gasoline, tire repair kits, emergency equipment, portable changeable message signs, and trained drivers. These vehicles patrol freeways, respond to incidents, and assist stranded motorists. The service patrol operators have cellular phones so they can be alerted when an incident is detected. NCDOT currently operates such a program on I-40 called the Incident Management Assistance Program (IMAP).
- Coordination of jurisdictions and emergency response agencies (local and state law enforcement, local fire and rescue agencies, ambulance and emergency medical agencies, and hazardous materials emergency response agencies) to cooperatively produce a response plan. This plan should define all coverage areas and emergency responsibilities for each agency.
- Highway Advisory Radio (HAR) to provide travelers with en-route travel and incident information. HAR is one or more low power radio transmitters placed along roadways that broadcast travel and incident related messages along travel corridors. Real-time information is obtained from the freeway management system and is rebroadcast in near real-time.

Edwards Mill Road Reversible Lanes

- Lane control systems can be used to maximize roadway capacity for reversible or peak hour operations. In the Triangle Region, the TTMC operates the five-lane reversible lane system on Edwards Mill Road near Carter Finley Stadium to allow greater ingress and egress to the sports complex. Overhead signs display either a red "X" or a green "arrow" indicating direction of travel.
- The communication system for the TTMC and other various field devices utilizes a fiber optic communications backbone located along I-40. The fiber optic cable is installed in the highway right-of-way along the sides of the roadways and is tied to the various field devices.

4.4.2 Planned Upgrades to ITS Infrastructure

NCDOT has recently finalized a statewide ITS Strategic Deployment Plan for implementing ITS throughout the state, including the Triangle Region. This guided deployment of ITS is intended to result in an integrated, cost-effective plan that will increase motorist safety and security, preserve infrastructure and services, ensure transportation system efficiency, and increase economic development opportunities throughout the state.

In the short-term, the NCDOT plans to increase the size and scope of the TTMC by placing more infrastructure and equipment in the field. This will allow for the expansion of the existing ITS infrastructure into specific market packages and areas. Short-term, funded plans call for the expansion of Closed Circuit Television (CCTV) surveillance along I-40 including more CCTV equipment and VMS.

Soon, the TTMC will be linked with the Durham Transportation Operations Center (TOC) as well as the Raleigh TOC. These interfaces will provide integrated surveillance coverage of the Triangle Region, multi-partner incident management and, to some degree, monitoring of local traffic signals. These new information components will provide traveler alerts via VMS, HAR and media partners.

4.4.3 Potential ITS Improvements in Conjunction with HOV Lanes

Improving the existing ITS infrastructure would take advantage of NCDOT's previous investments in the ITS infrastructure. The improvements listed below are compatible with and complementary to HOV lanes and to the proposed expansion of the ITS system prescribed by the Strategic Deployment Plan. These improvements, in combination with the more obvious improvements such as expanding the system with more CCTV cameras, more VMS locations, and an expanded fiber optic backbone, would leverage the programmed investment(s) in the ITS system.

Implementing a Statewide Transportation Operations Center (STOC)

The current Triangle Region TTMC could be migrated into a STOC. This migration would allow the TTMC to move its current 12-hour span of operation to one that is 24 hours a day, 7 days a week. The new Triangle-based STOC could be the center of ITS control and operation throughout the state and could share data feeds and/or control with other Regional Operational Control Centers (ROCCs).

Expanding Advanced Traveler Information System (ATIS)

Expanding traveler information will allow the TTMC to fully embrace other detection, information and communications market packages associated with ATIS. Some of these systems and market packages are often provided in a cooperative venture between the public and private sectors. The data is provided by the public sector via freeway management and other systems, and the private sector develops this data into traveler information and disseminates it through a variety of mechanisms.

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An array of ATIS market packages applicable to the RTP region include:

- **Driver Advisory Information** - Provide comprehensive real-time driver advisory information, such as traffic, transit, and roadway conditions, both before and during trips.
- **Broadcast Traveler Information** – Provide basic, non-interactive (static) traveler information, such as travel advisories and reports, general transit information, and public service announcements, over a wider area than HAR through existing infrastructure via lower-cost user equipment.
- **Interactive Traveler Information** – Provide a higher-level, tailored information stream in response to a traveler's request using interactive equipment such as mobile telephone, interactive kiosks, personal data devices, and in-vehicle devices.
- **Route Guidance Systems** – Provide travelers assistance during a trip by suggesting primary and/or secondary or alternative routes and providing detailed directions to desired destinations using either static or dynamic systems.
- **Ridematching** – Provide ridematching information to users that match the preferences and demands of trip requesters with providers and expands the market for TDM and shared-ride transportation.

4.4.4 Key Findings

Freeway management using ITS is one of the most effective strategies for managing congestion on freeways. Studies done around the nation show that ITS and incident management programs can reduce freeway travel time between 10 and 20 percent, and crashes by 10 to 15 percent during congested periods. The state's current efforts include implementing ITS and freeway management on all of the region's major freeways and many of the major arterials over the next 25 years. These techniques can be applicable to general purpose traffic as well as improve the effectiveness of HOV lanes.

The NCDOT has made strides in establishing a comprehensive ITS system in the Triangle Region. The basic infrastructure is in place. Surveillance, detection, communication and other hardware and software are fairly modern and widespread throughout the study area. The region needs to coordinate the collection and dissemination of real-time traveler information through a convenient platform that reaches a broader audience, more than just travelers who see the VMS displays on I-40.

The Strategic Deployment Plan identifies the benefits of further developing the region's ITS system and provides a framework for it's future expansion. The Plan calls for added infrastructure and expanded deployment of ITS devices. Attempts to develop the current and future system into an advanced system such as ATIS will need improved coordination and partnerships of the NCDOT, regional Transit Providers, MPOs, local governments, fire, police, EMS, and the private sector, including local media and telecommunications providers.

Another critical need is the identification of dedicated sources of capital for the purchase of equipment and for a dedicated operations and maintenance staff. The current system

lacks dedicated funding and has developed gradually. Financing issues with regard to direct allocations at the statewide level need to be resolved to provide this dedicated funding source.

4.5 Ramp Metering

Ramp metering is a low-cost, freeway management/ ITS strategy for controlling vehicle flow onto freeways, thereby improving flow on the freeway's mainline. It is used on freeways that are at or near a reduced flow condition (such as I-40). Ramp metering is presented as an independent strategy since ITS can be implemented with or without it.

4.5.1 Considerations in Applying Ramp Metering

Ramp metering is accomplished by placing a modified traffic signal at the end of a freeway entrance ramp. The signal allows individual vehicles to access the freeway at pre-timed intervals, based on traffic conditions on the freeway or on the queue length on the ramp itself. An additional lane can be added on the ramp to allow buses and HOVs to bypass the ramp meter signal (referred to as HOV bypass lanes). Nationally, there are many examples of successful ramp metering installations.

Ramp metering is primarily a method to reduce crashes and increase traffic throughput on the freeway system. Ramp metering discourages drivers from using the freeway for very short trips and, by the addition of bypass lanes, provides incentives for transit and HOV use.

Ramp Metering Application in Atlanta, GA

For metering to be effective, the delay experienced on the ramp would need to be compensated by improved speed on the freeway. The freeway speed could be improved by reducing turbulence in the traffic flow as well as reducing crashes and crash-related delays. In order to be most effective, ramp metering is typically implemented as a series of metered interchanges. Isolated metered locations primarily offer safety and capacity benefits at the ramp merge, while the effects for mainline freeway flow are more limited.

Ramp metering is often considered in the development of a freeway management system in order to take advantage of video cameras and in-pavement sensors that are installed for other purposes (e.g., incident detection and management).

Aside from the typical engineering considerations, the introduction of ramp metering faces three key issues:

- **Public acceptance** - Experience has demonstrated that public acceptance will require more effort in areas where the technology is less prevalent or absent entirely.
- **Policy** – The first installations need to be successful and provide measurable benefits in order to garner political support. Just as in other proposed improvements, those benefits must be weighed against total cost.

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- **Enforcement** - Enforcement is necessary to ensure the meters have the intended effect of stopping vehicles. In some cases, the use of video cameras may alleviate the long-term burden on law enforcement. The best enforcement is the perception that the ramp meters are working as intended with reasonable compromises on cross-streets and improved freeway mainline flow. Regardless, with well-designed and actively managed ramp metering systems, violation rates are very low and enforcement is not an issue.

4.5.2 Potential Benefits

Ramp metering reduces the number and frequency of interruptions on the mainline, thereby facilitating smoother and more efficient mainline flow. It also reduces the number of crashes, especially rear-end collisions and crashes in the ramp merge areas. The crash reduction is typically in the 30 percent range when metering is in operation.

A survey of traffic management centers nationwide using ramp metering reports speed increases of 16 to 62 percent, travel time improvements up to 48 percent and volume increases from 17 to 25 percent. In addition, traffic-responsive ramp metering often produces results that are 5 to 10 percent greater than those of pre-timed metering.

Table 4-4 summarizes some cases of the impacts of ramp metering as cited in the Atlanta Region CMS Task 7 Report (PB-Farradyne, December 1996).

Table 4-4 Ramp Metering Impacts

Location	Before Speed	After Speed	Change In...		
			Travel Time	Crashes	Volume
Portland, OR	16 mph	41 mph	-61%	-43%	N/A
Minneapolis	34 mph	46 mph	N/A	-27%	+32%
Seattle	N/A	N/A	-48%	-39%	+62%
Denver	43 mph	50 mph	-37%	-5%	+19%
Long Island, NY	29 mph	35 mph	-20%	N/A	N/A

4.5.3 Key Findings

Ramp metering is a strategy that could reduce delay and crashes on the I-40 corridor. NCDOT is currently examining the implementation of this technique at isolated locations on I-40 in the Triangle Region. While isolated ramp metering installations can reduce accidents, a system-wide approach is required in order to reach the full benefit in reduced congestion and travel time.

HOV bypass lanes can be installed quickly at all locations where ramp meters are proposed. These simple improvements would lay the ground work for a regional HOV system.

4.6 Transportation Systems Management (TSM)

Transportation Systems Management is defined as modest physical and operational improvements to traffic performance, safety and management. While these improvements are often installed as parts of larger projects, they can be implemented quickly as independent, short-term improvements. These projects typically do not involve large capital outlays; as a result most (but not all) projects with substantial bridge construction or right-of-way acquisition are not considered TSM improvements.

Potential applications of TSM solutions depend upon the specific problem addressed. Examples are listed in Table 4-5.

Table 4-5 General TSM Solutions

Candidate Problem	Potential Applications
High accident site	• Improve lighting • Improve signing and pavement markings
Erratic weaving between sites	• Re-orient ramp alignments • Braid ramps (grade separate) • Extend acceleration length • Add auxiliary lane
Isolated congestion between on and off ramps	• Add auxiliary lane • Meter on-ramp (isolated treatment)
Queuing from intersection onto freeway	• Add intersection approach lanes • Re-time signal

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4.6.1 Considerations in Applying TSM

TSM applications offer the following advantages and disadvantages:

Advantages

- Proven track record,
- Cost effectiveness,
- Can be applied as part of an incremental improvement,
- Can be implemented in short timeframe,
- Can be applied to both freeways and arterial roadways, which either cross or parallel the freeway,
- Amenable for any size urban area,
- Usually the first means of addressing simple problems, and
- Usually applied to optimize higher investment strategies once improvements are implemented.

Disadvantages

- Cannot solve major capacity problems associated with corridor congestion, and
- High level benefits require a higher level of investment.

4.6.2 The Bottleneck Study

A bottleneck study was undertaken to identify specific TSM improvements as part of the I-40 HOV/CMS. Instead of focusing on the long-term (year 2025) needs of the I-40 corridor, the purpose of these analyses was to identify possible short-term, relatively low cost improvements that could relieve existing congestion at these “bottleneck” locations.

The initial analysis included examining 47 potential bottleneck locations along the existing I-40 corridor between NC 86 in Orange County and NC 42 in Johnston County. Some of the issues examined included:

- General Issues,
- Potential Improvements,
- Priority,
- Conceptual Construction Cost,
- Traffic Volumes and Congestion,
- Potential Improvement to I-40 Operations, and
- Potential Improvement to Cross Street Operations.

Using this information, a matrix was developed which prioritized potential bottleneck locations for additional study based upon a systematic evaluation methodology. The cost of potential improvements was not considered within this ranking system. Instead, costs were included as separate variables to assist in the balancing of projects with the highest impacts on traffic flow against construction costs.

Based upon an examination of the data, two major findings were noted. First, most of the locations with severe traffic bottleneck problems were located within RTP between NC 147 and I-540 or between I-540 and US 1/US 64, i.e., the areas with the highest traffic volumes. Second, very few "classic" bottleneck locations were found for which smaller, less expensive improvements could be implemented. Instead, most of the improvements required moderate to substantial improvements such as widening bridges and ramp approaches.

Given this situation, the Technical Committee decided that it would prefer to address some of the locations with high levels of traffic congestion even if potential solutions for these locations require considerably more capital investment and time to implement than originally intended for the bottleneck study.

The three project locations identified for further study were the interchanges of I-40 with:

- NC 54 near Chapel Hill
- Aviation Parkway
- Airport Boulevard

For each of the interchange locations, numerous TSM strategies were considered, including lengthening and widening freeway on/off ramps. On the arterial crossroads, bridge widening, intersection widening, and the application of access management techniques were identified as viable techniques. A specific recommended alternative was developed for each of the three locations. The Raleigh Durham Airport Authority is currently constructing the recommended improvement at the Aviation Parkway (an improved diamond interchange with widened bridge, widened approaches and a loop on-ramp from southbound Aviation Parkway to northbound I-40).

A summary of the study is included in the Bottleneck Analysis Report dated February 2002.

4.7 Travel Demand Management (TDM)

Travel Demand Management (TDM) is a general term for a set of tools, programs and actions that encourage travelers to consider alternatives to driving during peak travel periods. TDM strategies promote travel alternatives, particularly for Single Occupant Vehicle (SOV) commuters, that reduce the travel demand during peak periods. By reducing demand, TDM increases the people-carrying capacity of the transportation system. Generally speaking, TDM consists of three types of actions:

- Improved alternatives to driving alone, especially higher-occupancy modes such as ridesharing (vanpooling and carpooling), transit services, and ancillary infrastructure such as transit centers, carpool / park-and-ride lots, HOV lanes, etc.

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- Incentives, supporting actions and disincentives to encourage use of alternatives such as transit-friendly zoning, trip reduction ordinances, guaranteed ride home programs, transit discount programs, and parking space "cash outs."
- Measures to shift the time at which a vehicle trip occurs or measures to reduce the number of weekly trips such as flexible and staggered work hours, compressed work weeks, and telecommuting.

National experience shows that the potential for vehicle trip reductions for work trips range from one to two percent for information-based, modest, and voluntary TDM programs to upwards of thirty percent for mandatory programs that provide significant time and/or financial savings for those who choose to rideshare. Because TDM is directed primarily at work trips, it mainly impacts peak period travel.

4.7.1 Existing TDM Programs in the Triangle Region

Over the last year there have been major advances in TDM efforts in the Triangle Region, specifically in the Research Triangle Park (RTP) and in Durham. The University of North Carolina at Chapel Hill and North Carolina State University are also encouraging TDM practices. These efforts represent key essential elements of a regional transportation demand management strategy for the future.

The current TDM programs in the Triangle Region are primarily voluntary and include:

- Triangle Transit Authority TDM Initiatives,
- Durham County TDM Initiatives,
- RTP Smart Commute Program, and
- University Initiatives.

Triangle Transit Authority TDM Initiative

TTA Vanpool Service

The Triangle Transit Authority (TTA) is the only inter-regional public transportation provider in the Triangle Region and offers fixed route transit and shuttle services. In addition, TTA offers TDM-specific services, including:

- Vanpool matching and administration service for bringing commuters into the major work centers,
- Rideshare matching service, and
- Administering the Durham TDM ordinance

TTA currently maintains approximately 49 vanpool routes with additional routes under continuous development. TTA provides the 15-passenger van, pays for gas, and arranges, oversees, and pays for all preventative maintenance.

Durham County TDM Ordinance

In 1999, Durham County began studying travel demand management strategies that would reduce traffic congestion and be compatible with earlier efforts by the Town of Chapel Hill and the Research Triangle Park's Smart Commute program.

By February 2000, Durham County adopted an ordinance requiring all employers with more than 100 employees to develop trip reduction plans and set targets for traffic reduction. The TDM plan and action strategies were developed through a joint initiative with the City of Durham, NCDOT, the Town of Chapel Hill, the Durham Chamber of Commerce, local developers, employers, neighborhood leaders, and other interested parties. Penalties are provided for those employers failing to submit a plan.

The main objectives of the Durham County plan are to:

- Create an education and awareness program focusing on transportation alternatives;
- Reduce the number and length of commute trips;
- Shift additional commute travel to off-peak hours;
- Encourage walking, cycling, public transit and carpooling as alternatives to driving;
- Promote better integration of land use and transportation planning;
- Improve air quality and reduce the number of ozone alert days; and
- Emphasize the need for a stable funding source for a transit expansion program.

Employers that are required to participate must do the following:

- Conduct annual transportation surveys of their employees;
- Set goals to reduce single occupant vehicle use among their employees and reduce the overall number of vehicle miles traveled;
- Prepare and submit a travel reduction plan each year;
- Motivate their employees to reduce single occupant vehicle travel and inform them of their transportation options; and
- Pay an annual $200 processing fee.

The RTP Smart Commute Program

The RTP Smart Commute Program is an initiative of the Research Triangle Owners & Tenants Association in conjunction with NCDOT to reduce the number of SOVs commuting to and from RTP. Participants include the major employers within and adjacent to RTP, the Research Triangle Foundation, Triangle Transit Authority, and NCDOT.

The program was adopted and launched in April 2000. The program is planned to unfold in three phases.

- **Phase 1 – Company-Based Programs** – Phase 1 includes requiring RTP companies to help get cars off the road by employing travel demand management techniques. The package focuses initially on primary commuting alternatives such as carpool, vanpool, public transit, cycling and telecommuting.

  Potential commuters are assisted in their selection of an alternative through the use of on-site travel coordinators, TDM web sites, rideshare matching program, preferential parking, emergency ride home, and transit subsidies. A number of RTP-based companies currently employ these travel demand management strategies.

- **Phase 2 - Service Provider Enhancements** –- During Phase 2, the area transit authorities (particularly the TTA), MPO's, and NCDOT will work to improve services to RTP. A committee will focus on the travel demand techniques and initiatives currently employed by RTP companies to assess their applicability for sharing with other companies involved with the TDM initiative. "Best practice" initiatives will be studied and pursued.
- **Phase 3 - Continuous Improvement** –- Phase 3 involves on-going and continuous improvement of the program to keep it effective.

University Initiatives

Both North Carolina State University (NCSU) and the University of North Carolina at Chapel Hill (UNC) operate carpool matching services and promote vanpooling in partnership with TTA. In addition, they offer guaranteed ride home programs.

4.7.2 Relationship of TDM to HOV Lanes and I-40 Congestion

TDM efforts are usually most effective when focused on employment sites where actions can be coordinated and the travelers have a common destination. However, a major incentive for travelers to rideshare or use transit is the travel time advantages and trip time reliability offered by improved highway access provided by HOV lanes. HOV lanes allow carpool, vanpool and transit vehicles an exclusive travel lane avoiding congestion and delays, decreasing travel time and increasing trip reliability. As such, TDM actions and HOV lanes are complementary, and the success of an HOV program is enhanced with strong and committed TDM programs.

The potential impact of TDM measures was assessed for the Triangle Region using the United States Department of Transportation (USDOT) Travel Demand Management Evaluation Model. The TDM model evaluates the impacts of TDM strategies either individually or grouped into packages as a percent reduction in peak period home-based work vehicle trips, vehicle miles of travel and changes in mode shift. The impacts are based on national TDM experience. The impacts of low level, voluntary efforts to aggressive, mandatory efforts can be assessed. The following strategies were assessed with the model:

- Transit, carpool or vanpool support and informational programs (including on-site services, transportation coordinators, emergency ride home, etc.);

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- Incentives (including parking management and subsidies); and
- Alternative work schedules (including flexible and staggered work hours, compressed work weeks and telecommuting).

The model was used to estimate order-of-magnitude impacts of TDM strategies on major employment centers in the region, including the RTP. The following is the range of potential reductions in drive-alone work trips for various levels of TDM efforts:

- One percent with a modest, voluntary program;
- Eight percent with a medium/strong program (mandatory for all new employers);
- 10 percent with a medium/strong program with subsidies for those choosing alternatives;
- 20 percent with an aggressive, mandatory program; and
- 23 percent with an aggressive, mandatory program with subsidies.

The impacts of a moderate-aggressive TDM program in the RTP on I-40 traffic, in conjunction with a region-wide HOV system, were also assessed. It was estimated that morning peak hour traffic could decrease by approximately four to five percent on I-40 within RTP. This is a significant reduction, but one that would take a serious and ongoing commitment. Without a regional HOV system, the impact of TDM on I-40 traffic within RTP would be less than two percent. Even with a regional HOV system, the impact of TDM on I-40 traffic approximately 5 miles outside RTP falls to less than a one percent reduction in traffic volumes.

4.7.3 Key Findings

TDM programs are in place in the region and there is a growing recognition of their importance in addressing mobility and accessibility in general and in stemming the growth of congestion in particular.

A vision for TDM in the entire Triangle Region is needed, however. The vision needs to articulate the goals and objectives of the program and receive support from a spectrum of interests; NCDOT, local governments, private industry and other institutions. Specific suggestions to be examined and undertaken are:

- Establish a region-wide focus for TDM;
- Establish formal organization / partnerships with employers, agencies and others;
- Consider the expansion of TDM regulation to a more regional initiative;
- Improve ridematching capability;
- Enhance employer/university programs;
- Promote and stage community events; and
- Consider employer-based financial incentive programs.

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To implement the vision and the program, dedicated funding sources need to be explored and established. For on-going operations, Congestion Management Air Quality (CMAQ), Surface Transportation Program (STP) or other transportation funds can be leveraged to establish and sustain programs. Member dues for the Transportation Management Associations can serve as a source of funds if the private sector feels that value is added to the services they and their employees receive. Likewise, grant money for innovative research, perhaps funneled by or through the Institute for Transportation Research and Education (ITRE) can fund research and development.

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5. HIGH OCCUPANCY VEHICLE (HOV) FACILITIES

HOV lanes are managed lanes reserved for carpools, vanpools and/or buses. They are usually located next to the general purpose (GP), or unrestricted, lanes in the center of a freeway or major highway. They can be separated from GP lanes by a physical barrier, a wide painted pavement area or buffer, or simply a painted line. These managed lanes enable those who carpool or ride the bus to bypass the congested traffic in the adjacent, unrestricted, GP lanes.

The eligibility requirements (the minimum number of persons who must be in the vehicle) are set to ensure that the amount of traffic in the HOV lane does not exceed the capacity of the lane thereby ensuring free-flowing speed (typically 55 mph). Therefore, HOV lanes provide both a travel-time savings and a predictable travel time to HOV users in the peak travel periods. Understandably, this HOV advantage only occurs when the adjacent GP lanes are congested.

Guaranteeing carpoolers and bus riders a reliable and congestion-free ride during rush hour serves as a strong incentive for ridesharing. Additionally, by facilitating the movement of transit, carpools and vanpools, HOV lanes promote more efficient use of the limited freeway capacity available.

Some HOV lanes are restricted to use only during peak hours of the day, while others operate 24-hours a day. Because congestion or incidents can occur at any time, the 24-hour designation provides HOVs with travel-time savings and reliability throughout the day and night.

The objectives of HOV priority treatments are to:

- Provide a faster, more reliable trip for people ridesharing or using transit;
- Encourage motorists who would otherwise drive alone to choose to rideshare or use transit;
- Increase the person-carrying capacity of highway corridors;
- Reduce or defer the need for roadway widening;
- Improve efficiency and economy of transit operations; and
- Reduce fuel consumption.

Most HOV lanes throughout the country are operating at higher speeds and carrying more people than the GP lanes. Typical GP lanes rarely carry more than 2,500 people per lane during the peak hour, while HOV lanes can and do carry many more. For example, in Houston, Texas the North Freeway (I-45N) HOV facility carries about 5,600 persons during the morning peak period. HOV lanes that are used extensively by buses carry even more people. The New Jersey Route 495 HOV lane facility was recorded as carrying more than 725 buses and 35,000 people during the peak period.

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5.1 Types of HOV Lanes

Several types of HOV lanes could be considered for the freeways in the Triangle Region:

5.1.1 Concurrent Flow HOV Facilities

Concurrent flow HOV lanes are defined as freeway lanes in the same direction of travel, not physically separated from the general purpose lanes, designated for exclusive use by HOVs for all or a portion of the day. Concurrent flow lanes are usually located on the inside lane or shoulder, although not always. Paint striping is a common means used to delineate these lanes. Concurrent flow lanes are typically divided into two general types:

- **Buffer separated:** With this treatment, the HOV lane is separated from adjacent general purpose freeway lanes by a buffer width of one foot or more. A four-foot wide painted median is very common. Ingress and egress to the HOV lane can occur by driving across the barrier at designated access points or by crossing the buffer at random locations.

Buffer separated HOV

Non-buffer separated HOV lane

- **Non-buffer separated:** With this treatment, the HOV and general purpose lanes are separated by a single paint stripe. In most cases, HOV traffic is allowed to freely cross the stripe either into or out of the HOV lane, thereby eliminating the need for specific ingress and egress points.

Studies on the advantages and disadvantages of buffer separated and non-buffer separated facilities have yielded varying results. Buffer separated facilities separate HOV traffic from congested mainline traffic and allow lane changes to be concentrated at ingress and egress points. Buffer separated facilities also have enforcement advantages. Of course, the additional buffer width requires additional right-of-way.

5.1.2 Two-Way Barrier Separated

Two-way barrier separated HOV facilities are similar to concurrent flow facilities. The HOV lane, however, is separated from the GP lanes by a physical barrier instead of a buffer or paint stripe. The HOV traffic flows in the same direction of travel as the GP lanes. The primary advantages are that HOV traffic is free-flowing, enforcement is simpler, and access can be restricted to specific locations. Ramps or interchanges can be provided at access locations to serve HOV traffic.

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5.1.3 Reversible HOV Facilities

Reversible HOV

Another type of exclusive HOV treatment is the reversible lane. This approach involves a lane or lanes within the freeway right-of-way that are physically separated from the GP freeway lanes and used exclusively by HOVs for all or a portion of the day. Exclusive reversible HOV facilities usually operate inbound toward the central business district (CBD) or other major activity center in the morning and outbound during the afternoon.

Reversible HOV lanes typically are separated from the general purpose lanes by concrete barriers. Specialized equipment such as electronic gates, monitoring devices, and electronic message boards are required to reverse the direction of traffic flow in the lane.

I-40 serves numerous trip types – not just commuters going to or from RTP. A large percentage of the traffic is also bound for Chapel Hill, Durham, Cary, Garner, or Raleigh. In addition, I-40 is a regional freeway serving long-distance through traffic. These flow patterns result in directional split of 60/40 percent on I-40, which is not served well by reversible lanes because there is no clear distinction in peak flow. For these reasons, reversible flow HOV operations are not applicable for I-40.

5.2 Feasibility Criteria for HOV Lanes

Basic criteria or rules of thumb are available for the operation and planning of successful HOV facilities. Specific criteria based on the experience of the Federal Highway Administration and numerous state Departments of Transportation from across the nation are applicable in the feasibility of an I-40 HOV facility. The rules of thumb are:

- There typically must be six or more general purpose lanes in the corridor.
- Users must save five or more minutes per average commute trip on the HOV lane.
- There must be 500 or more HOVs per peak hour per lane in the opening year (to avoid the “empty lane” syndrome which can lead to criticism from motorists sitting in traffic in the adjacent lanes).
- There must be 2,000 or more persons per hour per lane in the design year in the peak direction.
- There should be potential for express transit on the HOV lanes.

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5.2.1 Determining Ultimate HOV Network (Phase I)

In Phase I, the Triangle Regional Model (TRM) was applied to estimate the usage of HOV facilities for the year 2025. HOV facilities were coded as additional lanes in each direction without reducing the number of GP lanes. The AM peak period was used as the basic design period since it more accurately reflects HOV usage on I-40.

At this initial testing phase, HOV facilities were assumed to be in place on all the freeways (existing and planned) in the Triangle Region. While it is probably unrealistic for all corridors in the region to have HOV lanes, at least by 2025, this assumption provides an evaluation that maximizes HOV use and ensures no potentially feasible corridors are omitted during the early screening phase. Then the model was run through a series of iterations that eliminated any unfeasible segments.

After a series of nine model runs, a 100-mile base network was developed using 2025 projected HOV demand. This network was the basis for the Phase II analysis. The Phase I (feasible) network included the following roadway sections:

- I-40 between NC 86 in Orange County to the future I-540 south of Raleigh
- I-540, Northern Wake Freeway between I-40 and US 64, Knightdale Bypass
- I-540, Western Wake Freeway between I-40 and US 64, West of Cary
- US 1 between I-540, Western Wake Freeway and I-40 at Crossroads
- US 64, Knightdale Bypass
- I-440 between US 64, Knightdale Bypass and I-40 south of Raleigh, Eastern Wake Freeway

In addition to the preliminary findings for the HOV/CM study, the Phase I analysis recommended specific changes to the TRM which were subsequently incorporated into the model. An example is converting the TRM model AM peak model from a 2-hour to a 4-hour model. Other recommendations from the Phase I modeling effort included recalibrating ridership assumptions and HOV utilization factors. These tasks were completed as part of the recalibration effort prior to the beginning of Phase II.

5.2.2 Determining Feasible HOV Network (Phase II)

Using the updated TRM model and the findings of Phase I, a more detailed analysis was conducted for Phase II.

As in Phase I, the primary measure for feasibility of a corridor was the AM peak hour. Using existing field data and an evaluation of potential peak period spreading, it was estimated that the AM peak hour represented 28 percent of the TRM's 4-hour AM peak period. For the analysis, it was assumed that an HOV lane would need to carry 500 vehicles per hour to warrant future analysis.

The Phase II analysis was altered from the Phase I analysis by providing one less GP lane per direction throughout the length of I-40 in the study area to reduce right-of-way impacts. This reduction in the typical section significantly increased GP lane congestion and the

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propensity of vehicles to utilize HOV facilities.

The Policy and Technical Committees considered the reasonableness of evaluating an HOV facility that is 100 miles long and recognized that the costs for such an extensive system would be prohibitive in the 2025 horizon. Therefore, the Committees advised the study team to evaluate the demand for HOV on a reduced network. This reduced HOV network represents approximately 60 miles of HOV lanes. The following sections of the Full Implementation HOV network were eliminated:

- I-540, Western Wake Freeway between NC 55 and US 64
- I-540, Northern Wake Freeway between Creedmoor Road and US 64, Knightdale Bypass
- US 1 between I-540 Western Wake Freeway and I-40 at Crossroads
- US 64, Knightdale Bypass
- I-440 between US 64, Knightdale Bypass and I-40 south of Raleigh, Eastern Wake Freeway

5.2.3 HOV Traffic Projections – 2005, 2015, 2025

A series of interim years was also required (as opposed to straight line analysis) because trip patterns in Wake County will progressively change over the next 25 years with the extension and completion of the I-540 Wake Freeway. Some traffic that now uses I-40 to access RTP will use I-540 in the future. In addition, as Wake County increases in population and employment, future growth patterns will be more focused on future transportation facilities than existing facilities.

In addition to 2025, two interim years were analyzed – 2005 and 2015. Both models were run with the updated Triangle Regional Model to reflect the forecast network improvements and land use growth for each time period. These interim volumes were utilized in the phasing analysis for the implementation of HOV. The volumes are included in Table 5-1.

Note that the intention of these volumes was to estimate the phasing of the reduced HOV network and, therefore, were somewhat conservative. In contrast, the capacity analysis uses higher volumes to examine operational issues.

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Table 5-1 Projected I-40 HOV Volumes for 2005, 2015, and 2025 AM Peak Hour

HOV Section	2005	2015	2025
NC 86 to US 15/US 501	500	700	900
US 15/US 501 to NC 147	700	900	1,400
NC 147 to I-540	1,100	1,600	2,600
I-540 to Wade Avenue	1,000	1,100	1,400
Wade Avenue to US 1/US 64	700	900	1,200
US 1/US 64 to I-440 Split	700	1,200	1,500
I-440 Split to US 70	800	1,000	800

Note: volumes are in vehicles per hour (vph).

5.3 HOV Phasing Analysis

A critical component of a successful HOV system is developing an effective phasing plan for implementing the system. The earliest HOV sections implemented must be successful or else the concept of HOV lanes will lose public support and become politically unacceptable. In addition, an HOV section should not be implemented too quickly. A segment with high projected future volumes must be supported by adequate traffic volumes even in the first years of operation.

Recognizing that the actual phasing of an HOV implementation plan is critical to the ultimate success of an HOV system, the I-40 HOV/CMS looked at a series of interim years to determine which sections should be implemented first. This plan is especially critical for the I-40 analysis given that the 2025 traffic forecasts indicate strong justification for HOV on most routes in 2025.

As discussed in Section 5.2, the minimum threshold for operation of an HOV facility is 500 vph per direction. In general, however, this represents the minimum operational threshold for an HOV facility in order to reduce public perceptions that the lane is being underutilized, i.e., the "empty lane syndrome." While 500 vph may be acceptable at the entrances into an HOV system, a higher threshold should be utilized for justifying the construction of a HOV system.

For the Phase II analysis, thresholds were developed to indicate the level of justification for specific sections of the HOV system. These are approximately the same as Phase I, but vary somewhat. The thresholds used for this study and included in Table 5-2 are:

- Very high demand – greater than 2000 vph
- High to very high demand – 1500 - 2000 vph
- High demand – 1000 - 1500 vph
- Moderate demand – 500 - 1000 vph
- Low demand – less than 500 vph

Using these thresholds, each of the potential HOV sections were evaluated to determine

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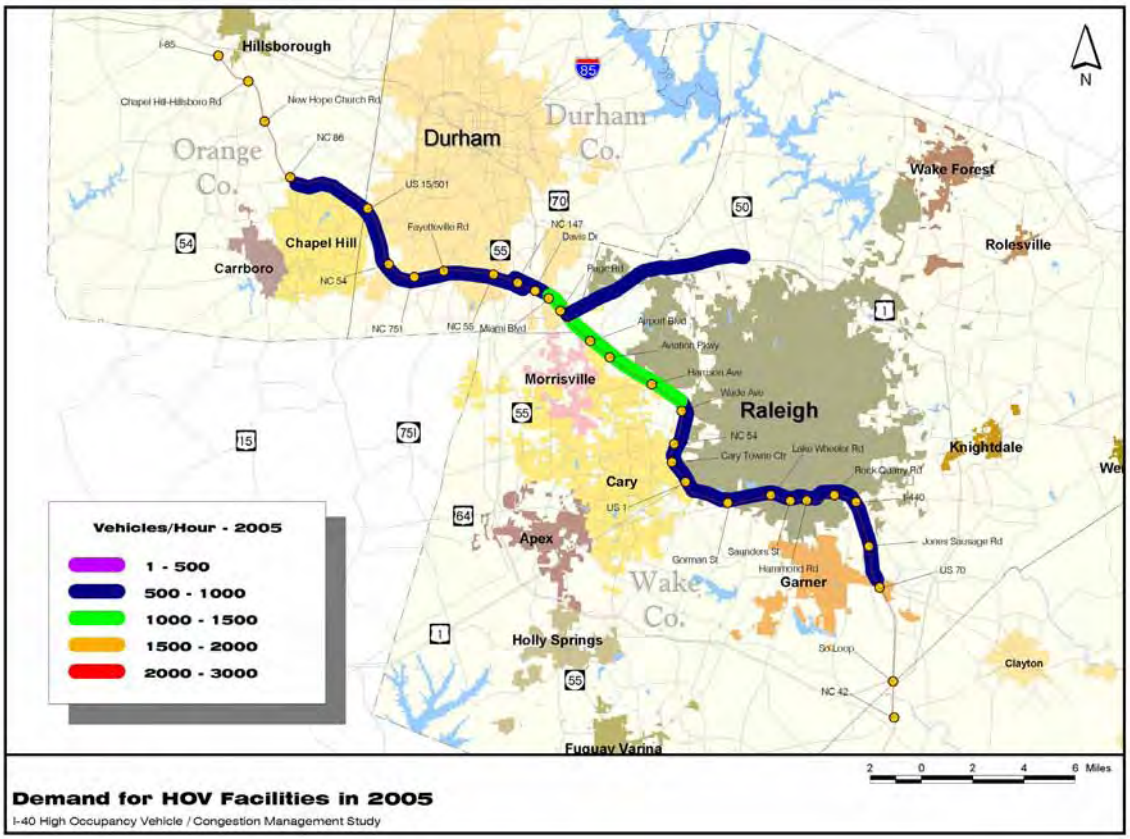
when and to what degree HOV is justified for the network. The phasing analysis for 2005, 2015, and 2025 is shown in Table 5-2. Figure 5-1, Figure 5-2, and Figure 5-3 present maps showing 2005, 2015, and 2025 peak hour HOV demand, respectively.

Table 5-2 Phase II I-40 and I-540 HOV Demand Analysis

HOV Section	2005	2015	2025
NC 86 to US 15/ US 501	Low	Moderate	Moderate
US 15/US 501 to Durham Freeway	Moderate	Moderate	High
NC 147 Durham Freeway to I-540	High	High to Very High	Very High
I-540 to Wade Avenue	High	High	High
Wade Avenue to US 1/US 64	Moderate	Moderate	High
US 1/US 64 to I-440 Split	Moderate	High	High
I-440 Split to US 70	Moderate	Moderate	Moderate
I-540 North – I-40 to Creedmoor Road	Moderate	High	High to Very High
I-540 West – I-40 to US 64	Not Constructed	Low	High

Figure 5-1 Demand for HOV Facilities in 2005



Demand for HOV Facilities in 2005
I-40 High Occupancy Vehicle / Congestion Management Study

Figure 5-2 Demand for HOV Facilities in 2015

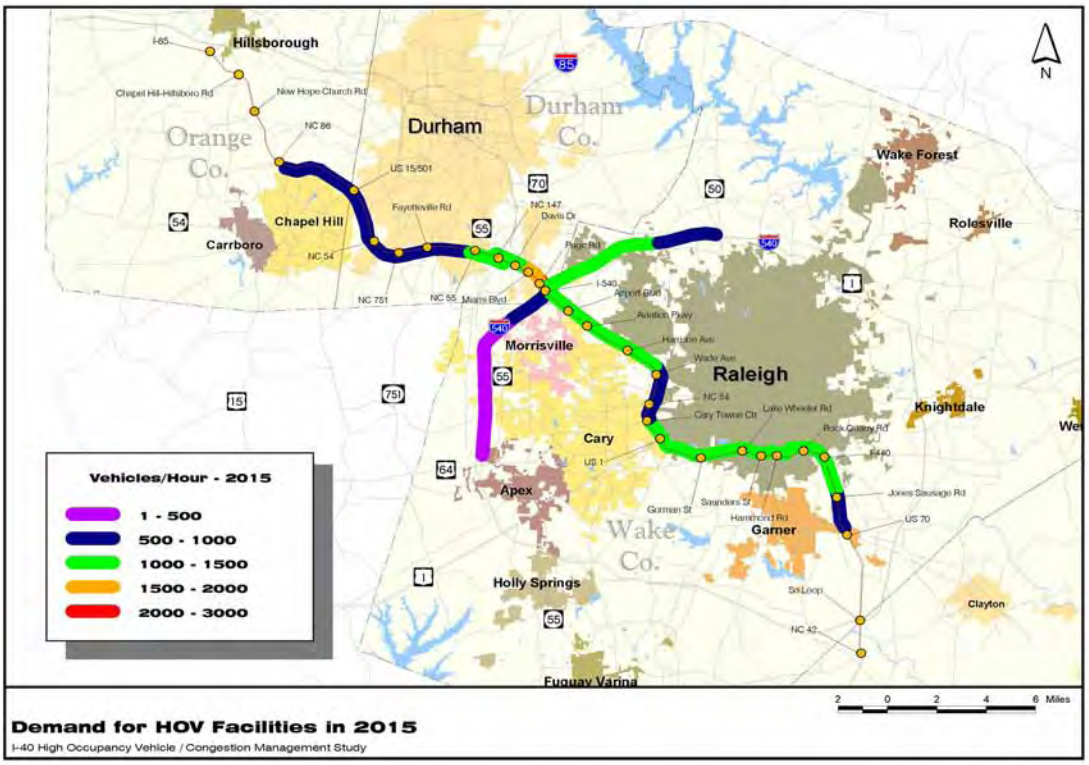
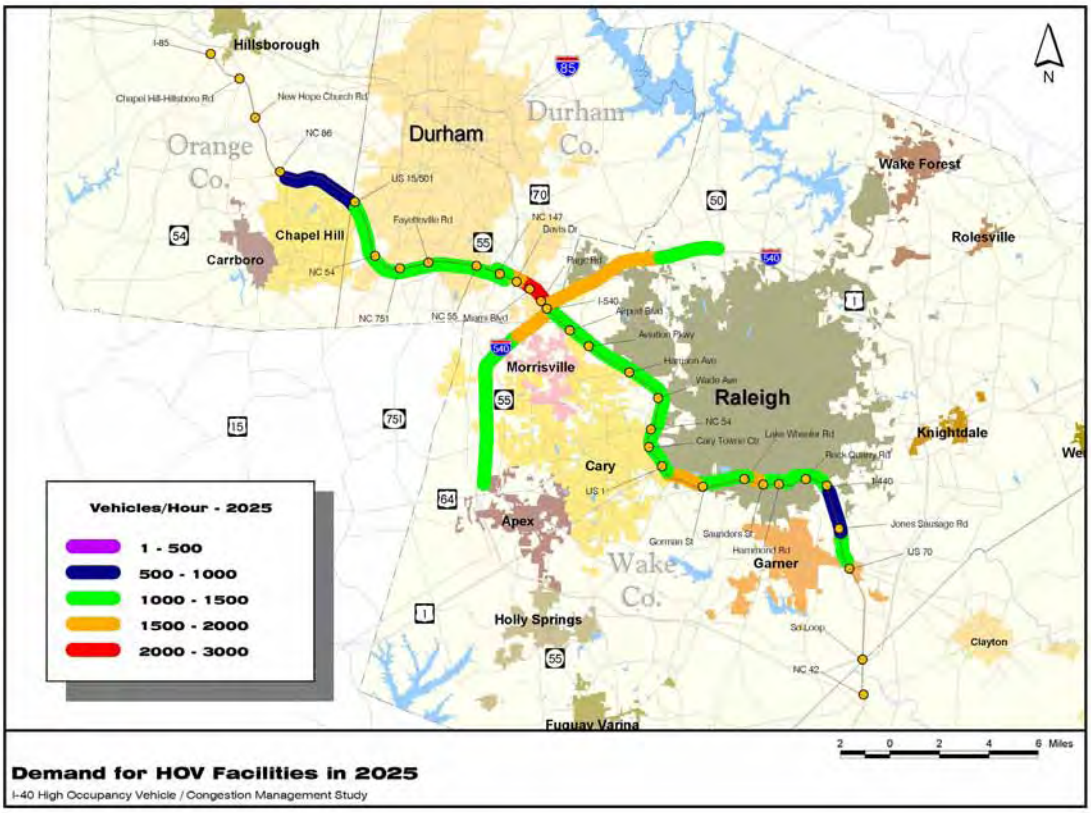


Figure 5-3 Demand for HOV Facilities in 2025



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Using Table 5-2, the time periods when each segment in the reduced HOV network reaches a certain level of justification can be determined. By examining which segments are justified earlier than others, a phasing plan can be developed. Segments that have a higher justification than others can be given a higher priority. This plan, in addition to technical and operational constraints, can consider financial and other constraints such as the need for specific planning, design, and construction schedules.

The feasibility analysis indicates that the planning, design, and construction could exceed ten years for each segment accentuating the need to include the priority segments in the TIP process as soon as possible. Specific high priority projects are listed below:

Highest Priority

- I-40 between NC 147 to I-540 has the highest demand of HOV volumes of any segment of I-40 for the 2005, 2015, and 2025 scenarios. Since RTP is the destination for a majority of HOV vehicles, this link is critical for minimizing delays between RTP and points east. It would be the important first piece in an HOV system for the Triangle Region. This segment serves the work end of the home-based work trips.
- I-40 from I-540 to Wade Avenue also has high demand for HOV facilities by 2005. It is a critical link connecting the residential areas of Cary, Raleigh, and Garner with RTP. It would allow HOV vehicles along I-40 to bypass the recurring backups in the GP lanes at the interchange with I-540.
- I-40 between Wade Avenue and US 1/US 64 would extend the travel time benefits realized with the two sections noted above. It would double the effective length of the HOV commute and would provide a connection for traffic from Cary, Apex, Holly Springs, and Fuquay Varina using US 1 to access I-40.

Second Priority

- I-540 north of I-40 to Creedmoor Road (NC 50) has a higher projected 2025 HOV volume than any section of I-40 except the section between NC 147 and I-540 in RTP. As traffic increases on I-540 with the opening of future sections of the Northern Wake Freeway, the justification for HOV will rapidly increase. These observations could justify constructing HOV on this segment as the second priority in a successful HOV phasing plan.

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Other Priorities

- The section of I-40 between US 1/US 64 and the I-440 split has high demand by 2015. Construction of this section would increase HOV traffic on I-40 between US 1/US 64 and I-540. HOV operations would be optimized since the longer HOV trips (I-440 to RTP) would result in greater time-savings for users of the system.
- The section of I-40 west of RTP does not have high demand until 2025. In the section from US 15/US 501 to NC 86, only moderate demand is anticipated by 2025. This section could be supported by park and ride connections or by tying into the US 15/US 501 corridor transit plan.
- The section of I-540 south of I-40 to US 64 is anticipated to have high demand by 2025. Since this section is not yet constructed, allowance will be made in the planning process to reserve right of way for future HOV facilities. However, it is unlikely that HOV demand would warrant HOV lanes as part of the initial construction. In addition, HOV volumes could be reduced by future planning decisions. Because of this uncertainty, more detailed analysis will be required before HOV is implemented. Note that future planning has significant cost and impact implications on the I-540 / I-40 interchange, the most critical juncture in the HOV network. Two projects would affect HOV volumes on this segment of I-540:
  - The I-540 Southern Wake Freeway will connect I-40 south of Raleigh to I-40 just east of RTP. If this section of the Raleigh Outer Loop is not constructed, HOV traffic from southern Wake County and Johnston County would likely use I-40, thereby increasing HOV demand on this segment.
  - The Triangle Parkway, which would connect the NC 147 Durham Freeway to I-540 south of I-40, could shift traffic volumes on I-40 between NC 147 and I-540 and provide an alternate route for incident management near RTP. Similarly, it could shift traffic volumes on I-540 south of I-40 between the Triangle Parkway interchange and I-40.
- The section of I-40 south of Raleigh between the I-40/I-440 split and US 70 has moderate demand for HOV by 2025. If the I-540 Southern Wake Freeway is not constructed, HOV volumes would increase slightly on this segment. Since the freeway includes a proposed interchange within this section, SOV and HOV traffic would be diverted from this congested area.

Regardless, building the reduced HOV network may not be feasible by 2025 due to financial constraints as well as permitting and processing requirements. Further information on the benefits and the characteristics of the facility will be needed in order to clearly define and prioritize the implementation strategy. The phasing plan is a valuable roadmap in evaluating future HOV needs and priorities for the region.

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5.4 Key Findings

This study has determined that HOV facilities could contribute to managing traffic congestion in the Triangle Region. Major findings and recommendations include:

- Most importantly, HOV lanes can provide a faster and more reliable trip time and provide a mobility option for those choosing to rideshare or use transit.
- Preliminary analysis indicates that providing a fully implemented 100-mile HOV system could provide significant system-wide benefits including:
  - A three percent reduction in overall vehicle miles traveled (VMT)
  - A two percent reduction in overall travel time delay
  - A two percent reduction in peak hour drive alone trips on I-40
- A 60-mile reduced network including sections of I-40 in Orange, Durham, and Wake Counties as well as portions of the I-540 Northern and Western Wake Freeways is justified by 2025.
- The section with the highest justification for immediate implementation is the section between NC 147 in RTP and US 1/US 64 at Crossroads. A secondary priority is extending HOV to the north on I-540. Note that these observations are not intended to serve as a recommendation of a particular phasing schedule since numerous other factors should be considered. From a pure HOV demand analysis, however, the demand for various projects does dictate a potential strategy for developing an HOV system.
- TDM efforts can be greatly enhanced if transportation facilities are available to offer a faster and more reliable commute to those choosing to rideshare or use transit rather than driving alone in GP lanes.

Even with the investment in an extensive HOV network and additional highway capacity, congestion in the GP lanes will increase over time because of the high growth expected in the Triangle Region.

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6. HIGH OCCUPANCY VEHICLE (HOV) TECHNICAL ANALYSIS

A primary objective of this study was to determine if HOV facilities on I-40 are feasible, where they are feasible, and when they become feasible. Based on policy, funding and implementation considerations, the Policy Committee of the I-40 HOV/CM Study decided to focus on a shorter and critical I-40 corridor, which runs between NC 86 near Chapel Hill and US 1/US 64 near Cary. This chapter presents a detailed comparative evaluation of this critical corridor. The evaluation included an analysis of travel demand, traffic operations, functional design, and construction costs of different HOV configurations. In addition, the evaluation included a few system-wide metrics to assess overall impacts. This chapter also describes the methodology of this HOV feasibility analysis.

6.1 Analysis Assumptions

6.1.1 HOV Roadway Configurations

In this study, four HOV configurations were developed and evaluated. The four configurations have been defined below. Sections 6.2 through 6.5 provide more detailed design criteria and description of the functional design. Note that the ultimate HOV network could include a combination or "hybrid" of the various HOV configurations.

Simple HOV Configuration

The Simple configuration is the least expensive method and can be implemented most quickly. The HOV lane (one in each direction) is separated from the general purpose (GP) lanes with a four-foot painted buffer. Access to the HOV lane is continuous (i.e., no physical barrier) and HOV lane users share GP ramps at interchanges. HOV's must weave across GP lanes at both trip ends to gain access to the left-side HOV lane.

Complex Configuration

The Complex configuration includes barrier-separated HOV lanes and HOV-only access interchanges. The HOV lanes are separated from the general purpose lanes by a physical barrier, prohibiting access to the lane except at the dedicated access points. This configuration eliminates the need for HOVs to weave across general purpose lanes to reach the HOV facilities.

In total, 18 exclusive HOV-only access interchanges are considered. Of these, four HOV-only access interchanges are located where there is currently no access for general purpose traffic (Sunrise Road, Barbee Road, Old Page Road, and Trinity Road). Because of the short distance between the Page Road and Miami Boulevard interchanges in RTP, no HOV-only access would be provided at either interchange. Instead, the new HOV-only ramps at Old Page Road would serve both existing interchanges.

This configuration also includes an Express lane from just west of NC 147 to just east of I-540. The Express lane allows single occupant vehicles to travel through the RTP corridor in the HOV lanes without accessing the HOV ramps in RTP. This provides improved time savings for through vehicles in the corridor and removes their impact to weaving traffic in the GP lanes, particularly where there are closely spaced intersections through RTP.

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Modified Complex Configuration

The Modified Complex configuration is a variation of the Complex configuration, and includes the same barrier-separated HOV lanes but with six HOV-only access interchanges instead of 18 access points, as identified in the Complex configuration. These HOV-only access points were provided at the locations with the highest demand, at NC 86, NC 54, NC 147, I-540, Wade Avenue and US 1/ US 64. Similar to the Complex, this configuration includes an Express lane from just west of NC 147 to just east of I-540 as well as an HOV-only interchange at Old Page Road.

Elevated Configuration

The Elevated configuration includes a two-lane viaduct on both sides of the I-40 freeway from NC 86 near Chapel Hill to US 1/ US 64 in Cary. The viaduct would have two lanes separated by a barrier – one lane for HOV and one for the express lane. The scenario maintains the same number and location of HOV-only access interchanges as the Modified Complex configuration. It should be noted here that the HOV plus express lanes introduced in the Elevated concept made this configuration capacity-rich for both GP and HOV traffic.

6.1.2 Sections of Roadway

For the purpose of comparative evaluation, the study corridor was segmented into five (5) sections. These sections provide a geographic distinction between major roadways accessing I-40. Segmenting the roadway helps to categorize the demand for specific segments of I-40 and provides insight into prioritization and phasing of potential improvements. The sections are discussed below and illustrated in Figure 6-1.

- **Western Corridor:** I-40 between NC 86 and NC 54 – This section is the western most approach into the Triangle region. It serves primarily longer distance commuter traffic approaching RTP from the rural suburban areas to the west.
- **RTP Corridor – West:** I-40 between NC 54 and NC 147 – This corridor serves as the primary commuter link between Chapel Hill and the Research Triangle Park. It also serves heavy retail development at the NC 751, Fayetteville Road and NC 55 interchanges.
- **RTP Corridor – East:** I-40 between NC 147 and Aviation Parkway – This section serves as the primary access point to the Research Triangle Park. It includes RTP access interchanges at Page Road, Miami Boulevard and Davis Drive in addition to the freeway interchanges with NC 147 and I-540 on the western and eastern limits of Research Triangle Park. This link between NC 147 and I-540 is the critical regional bottleneck both for commuter and longer distance through traffic. In addition, this section serves as the principal access to Raleigh-Durham International Airport from Chapel Hill and Durham via I-40 at the I-540, Airport Boulevard, and Aviation Parkway interchanges.
- **Airport Corridor** – I-40 between Aviation Parkway and Wade Avenue – East of RTP, this section includes the Aviation Parkway and Harrison Avenue interchanges that serve Cary and Morrisville. The Wade Avenue interchange serves as the merging point for commuter traffic from north and south Raleigh.

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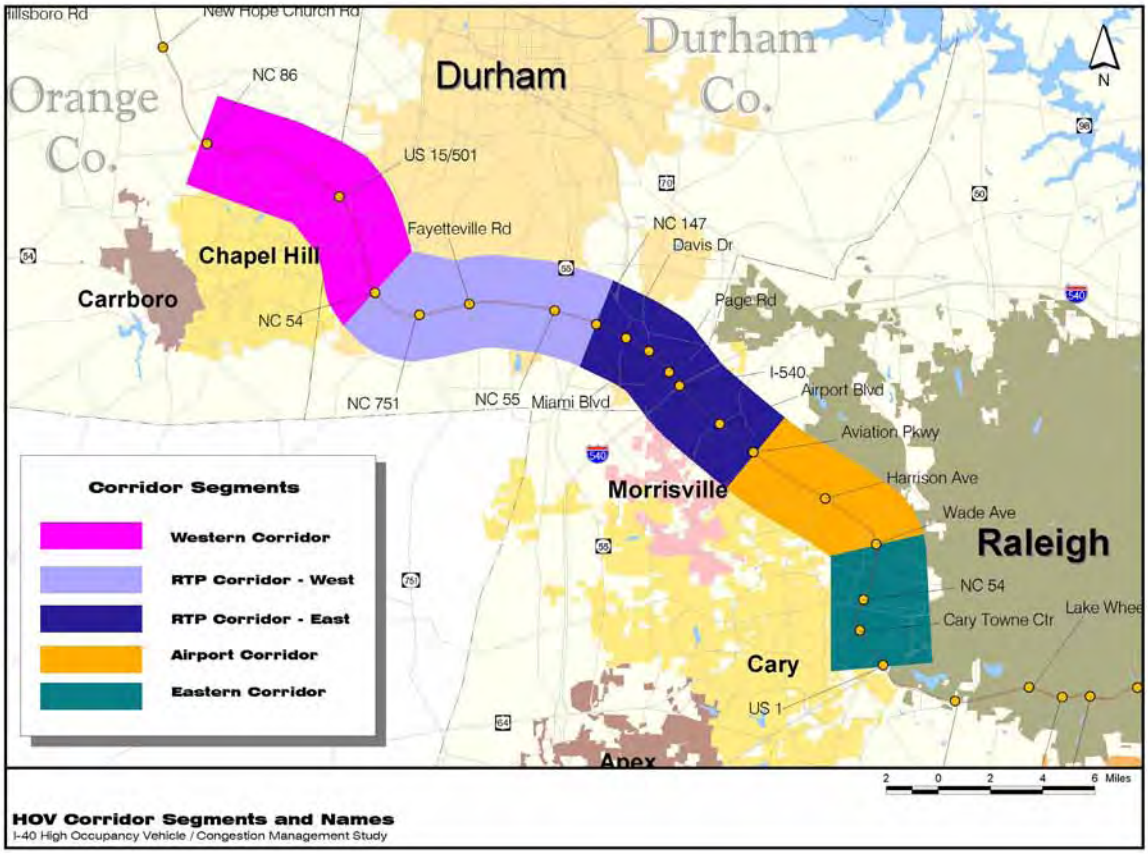
- **Eastern Corridor** – I-40 between Wade Avenue and US 1/ US 64 – East of Wade Avenue, this section provides access to south Raleigh and Cary. Traffic at the NC 54 and Cary Town Center Boulevard interchanges is a mix of residential and commercial traffic. The next section to the east, I-40 south of Raleigh, services a high volume of traffic generated by the urban/ suburban development in south Raleigh and Garner.

Figure 6-1 HOV Corridor Segments and Names



For each of these corridors, the potential impacts, costs, and travel benefits of providing the four HOV configurations were estimated and compared. In addition to identifying design and operational characteristics, a phasing analysis was developed. This analysis includes an examination of functional design as well as traffic demand, capacity and operations for each section.

6.1.3 Typical Sections and Design Criteria

Roadway and HOV design criteria were established and functional roadway designs were developed for all HOV configurations between NC 86 and US 1/US 64, as well as for an I-40 widening concept between Wade Avenue and US 1/US 64. The typical sections developed for each HOV configuration would accommodate projected traffic demand and are in compliance with the established project design criteria.

Historic Perspective

I-40 from NC 86 to US 1/US 64 was constructed in three intervals as described below. All sections have a design speed of 70 mph. The two corridors west of NC 147 (the Western and RTP-West Corridors) were completed in the mid-1980's as a four-lane divided section with a 46-foot median which is currently being widened to six lanes separated by concrete barrier (TIP Project I-3306). Both the RTP-East and the Airport Corridors were completed in the late 1960's / early 1970's as a four-lane divided section with a 68-foot median and have since been widened, or are in the process of being widened, to eight lanes with a 22-foot median. The Eastern Corridor from Wade Avenue to US 1/US 64 was finished in the late 1970's / early 1980's as a four-lane divided section with a 92-foot median.

HOV lanes cannot be considered for the Eastern Corridor without widening the existing roadway to a minimum of six lanes to accommodate three general purpose lanes in each direction. Similarly, the current widening of I-40 west of NC 147 will allow for the future provision of HOV lanes on the RTP Corridor-West.

Design Criteria

Design criteria for the HOV configurations and widening concept are in accordance with North Carolina Department of Transportation (NCDOT) and American Association of State Highway and Transportation Officials (AASHTO) standards. The HOV design criteria are based on AASHTO guidelines and the *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual* (Chuck Fuhs, 1989) along with recommendations developed in consultation with NCDOT. Design criteria were established based on the functional classification of an interstate over rolling terrain and are summarized in Table 6-1.

Table 6-1 Design Criteria

Alignment	Design Speed (Max.)	Superelevation (Max.)
I-40 (Existing)	70 mph	0.08
HOV Lanes	70 mph	0.08
Ramps	50 mph	0.08
Loops	30 mph	0.08
Service Roads	50 mph	0.08

** Note: NCDOT Roadway Design Manual and Bridge Policy used.*

A detailed description of the design criteria can be found in the *Technical Memorandum – Functional Roadway Design.*

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6.1.4 Travel Demand Modeling

Travel demand analysis for the HOV configurations was performed for the planning year forecast of 2025 using the Triangle Regional Model (TRM) version 5-2001. Some modifications to the TRM were required in order to accommodate HOV as a mode in estimating the number of people who would carpool as well as assigning those HOVs to roadways. These changes are documented in *Technical Memorandum – Baseline Modeling*. Details and evaluation statistics for the HOV configuration models are documented in *Technical Memorandum – HOV Phasing and Modeling.*

Assumptions

Preliminary analysis indicated that the AM peak period estimates of the number of carpoolers on I-40 more closely replicated counted carpool volumes. Therefore, this analysis uses the AM peak period as the time period for evaluation of HOV feasibility. The model application assumed no use of the HOV facilities by transit buses. This was the conservative approach to evaluating the feasibility of HOV. It is likely that evaluation of transit use of the facilities would result in estimates of higher mobility than results shown here.

The analysis of the configurations assumed the completion of all network improvements programmed in the 2002-2008 NCDOT TIP and the addition of one lane in each direction on I-40 between Wade Avenue and US 1/US 64. While the functional design and traffic analysis looked only at I-40 from NC 86 to US 1/US 64, a larger network was evaluated for a few travel demand metrics. Demand for HOV was evaluated on I-40 from NC 86 to US 70 in Garner and on I-540 from US 64 west of Apex to NC 50 north of Raleigh. However, measures of effectiveness are reported for I-40 only.

Measures of Effectiveness

For each configuration the model runs generated system-wide measures of effectiveness and corridor-specific measures of effectiveness, which were compared to the No-Build measures. System-wide measures of effectiveness indicate the impact of implementation of an HOV configuration on the entire region's travel. The region covered by the TRM includes all of Wake, Durham, and Orange Counties and parts of Granville, Franklin, Chatham, Harnett and Johnston Counties. Because these measures are composites for the entire region, small changes are typical, even for major investments in infrastructure. System-wide measures used in this evaluation include:

- Lane-miles traveled by level of service (LOS) category,
- Vehicle-miles traveled,
- Person hours of delay, and
- Average speed.

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Corridor-specific measures of interest in this study include not only the number of vehicles using the HOV facilities, but the aggregate number of people utilizing the I-40 corridor. Specific measures reported here include:

- Absolute numbers of vehicles on the HOV facility,
- Changes in number of vehicles on the general purpose lanes,
- Changes in number of vehicles on adjacent roads, and
- Changes in number of people on I-40.

Additional statistics were generated for ramps and cross streets. See *Technical Memorandum – HOV Phasing - Modeling* for details on these statistics.

6.1.5 Traffic Operations Analysis

The traffic analysis involved extensive data collection and traffic modeling, using the Highway Capacity Manual (HCM), FREEVAL and FRESIM modeling software. These techniques are briefly described here, but more explicitly described in the *Technical Memorandum - Traffic Operations.*

Planning Level Analysis

A basic analysis of all freeway segments between interchanges was performed using the 2000 HCM methodology. This simplistic analysis tool gives a general indication of the overall operating level of service (LOS) and volume-to-capacity ratio (V/C) at which each freeway section is operating. The methodology does not consider capacity impacts of downstream queues, weaving, and/or interchange ramp influences; instead it is intended to be a quick and simple method to check basic segment capacity based on generic freeway conditions.

Freeway Operations Analysis

FREEVAL, a recent addition to the 2000 HCM, was developed to assist in the analysis of freeway facilities. The freeway facilities analysis was performed using collected traffic and highway data and following the procedure detailed in Chapter 22 of the 2000 HCM. A comparative analysis of the FREEVAL speed outputs and the speed data collected for existing conditions showed the model is reasonably calibrated to existing conditions using default FREEVAL values. Speed and count data collected for this study is documented in the *Technical Memorandum - Traffic Operations.*

Operations Simulation Analysis

Computer simulation is an important analytical tool for detailed freeway and arterial network operations analysis. Currently, the most widely used software package for such analysis is the FRESIM (FREeway SIMulation) model. FRESIM is a microscopic traffic analysis tool developed for the Federal Highway Administration (FHWA). It allows for a detailed microsimulation testing of the operational efficiency of multiple alternatives.

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In the FRESIM model, the behavior of each individual vehicle is represented through its given characteristics and interaction with the surrounding environment. Individual vehicle specifications include driver behavior (aggressive or passive lane changing), desired free-flow speeds, vehicle type, acceleration/deceleration capabilities, and vehicle origins and destinations. The surrounding environment includes interaction with other vehicles on the freeway and the physical freeway geometry including number of lanes, lane adds/drops, ramp/auxiliary lane lengths, and grades. The FRESIM model was initially run using all default value assumptions in the model and then calibrated to current counts and speed data.

6.1.6 Environmental Screening

An environmental screening was conducted as part of the HOV technical analysis to identify potential environmental impacts that could result from implementing each HOV configuration and any potential "fatal flaws" that would preclude implementing an HOV system. The environmental screening includes an assessment of:

- Topography and Geology
- Soils
- Wetland Sites and Stream Crossings
- Threatened and Endangered Species
- Protected/Public Lands
- Land Use and Land Cover
- Water Use and Quality
- Cultural Resources
- Community Impacts

Data for the environmental screening was compiled through background research of existing information. Field data collection was not included as part of the environmental screening. This analysis provided a useful comparison of the impacts of each configuration. No "fatal flaws" were identified as part of the analysis.

6.1.7 Roadway Design and Cost Estimate

A functional roadway design was developed for each of the four HOV configurations on I-40 between NC 86 near Chapel Hill and US 1/US 64 near Cary. The functional design drawings for the four HOV configurations as well as the widening between Wade Avenue and US 1/US 64 are provided as Appendix A to this document.

As part of this analysis, the functional design was used to develop a conceptual cost estimate for each of the four HOV roadway configurations. The costs, although conceptual, included numerous factors such as structures costs. Contingencies were also applied for numerous activities, but no right-of-way costs were included. By dividing the cost for each alternative into the five roadway sections noted above, the overall cost of a "hybrid" configuration combining different HOV configurations on different segments can be generated.

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Several design considerations were not included in the functional design study. They include the following:

- Geotechnical aspects
- Vertical alignment
- Utility conflicts
- Drainage and
- Lighting

Preliminary evaluation of utility conflicts indicated that no serious issues exist for any of the HOV configurations. Right-of-way issues are discussed in the *Technical Memorandum – Functional Roadway Design.*

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6.2 Simple Configuration

The following section describes in more detail the design assumptions of the Simple configuration. Section 6.2.2 describes the implications of this design for travel demand on the HOV facility as well as on GP lanes and adjacent roads. Section 6.2.3 describes the traffic operations conditions for the Simple configuration. Section 6.2.4 examines environmental issues. The construction implications are then described in Section 6.2.5.

6.2.1 Typical Sections

The Simple configuration provides for concurrent flow HOV lanes with continuous access to/from GP lanes across a striped buffer. The typical section includes GP lanes plus a 12-foot HOV lane with a 4-foot striped buffer and a minimum 14-foot enforcement median shoulder. The Simple configuration is considered to be the lower operational form of HOV treatment and does not include any dedicated HOV direct access at interchanges.

The design requires the widening of existing I-40 on each side, thus necessitating changes to the existing cut and fill slopes. Cut and fill slopes would be modified to remain within existing NCDOT right-of-way whenever possible. When slopes required to remain within right-of-way exceed the acceptable limits of 2:1, unless otherwise approved by geotechnical engineers, retaining walls would be used.

The five corridors outlined in Section 6.1.2 are designed to three different typical sections. These typical sections for the Simple HOV configuration are illustrated in Figure 6-2, Figure 6-3, and Figure 6-4.

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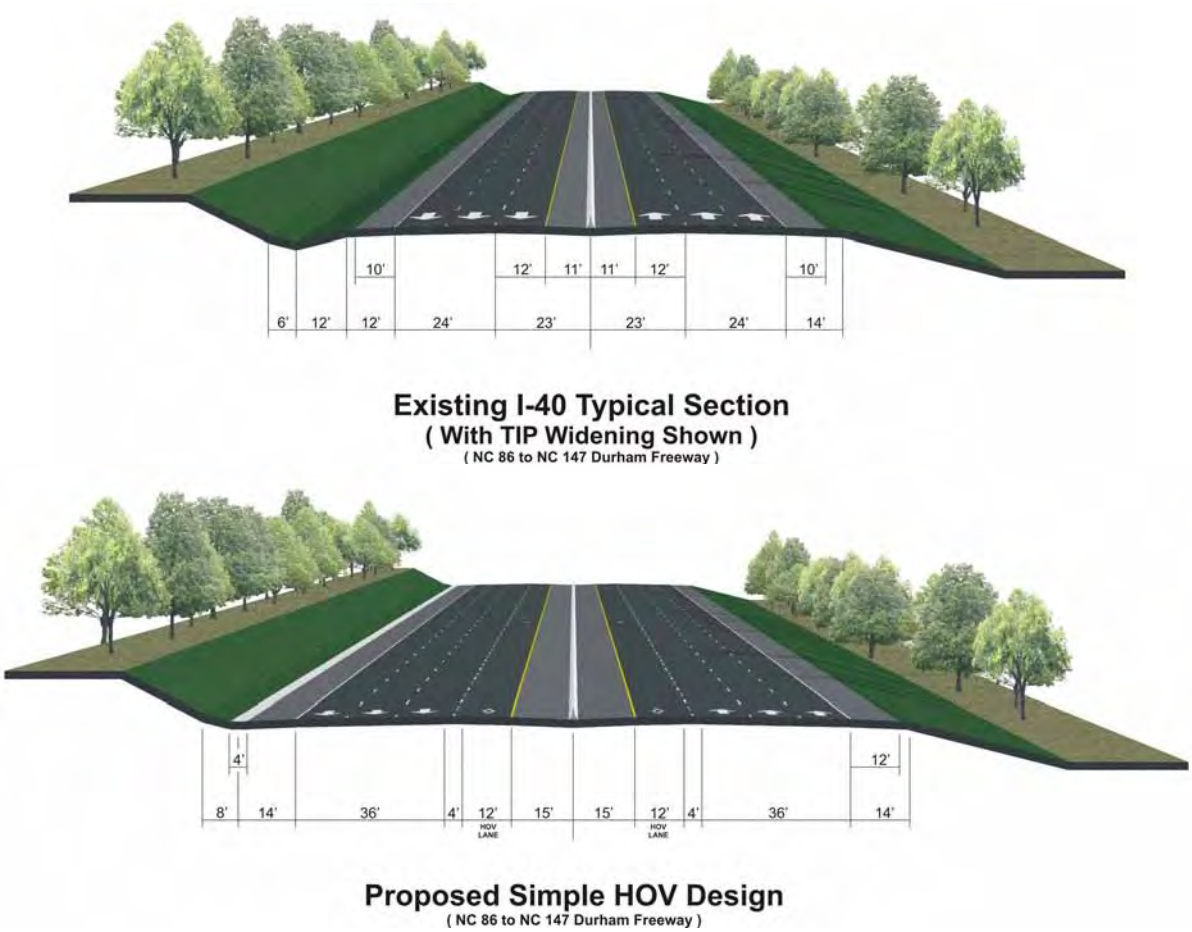
Western Corridor and RTP Corridor-West: NC 86 to NC 147

Figure 6-2 shows the typical section for the Simple configuration from NC 86 to NC 147. The proposed improvement calls for widening the existing three GP lanes to three GP lanes plus one concurrent flow HOV lane. It includes six 12-foot GP lanes plus two 12-foot HOV lanes with a 4-foot striped buffer and a 30-foot median with barrier providing 14-foot enforcement shoulders. On the outside, a 12-foot paved shoulder is provided.

Figure 6-2 Existing and Simple Configuration Typical Sections Between NC 86 and NC 147



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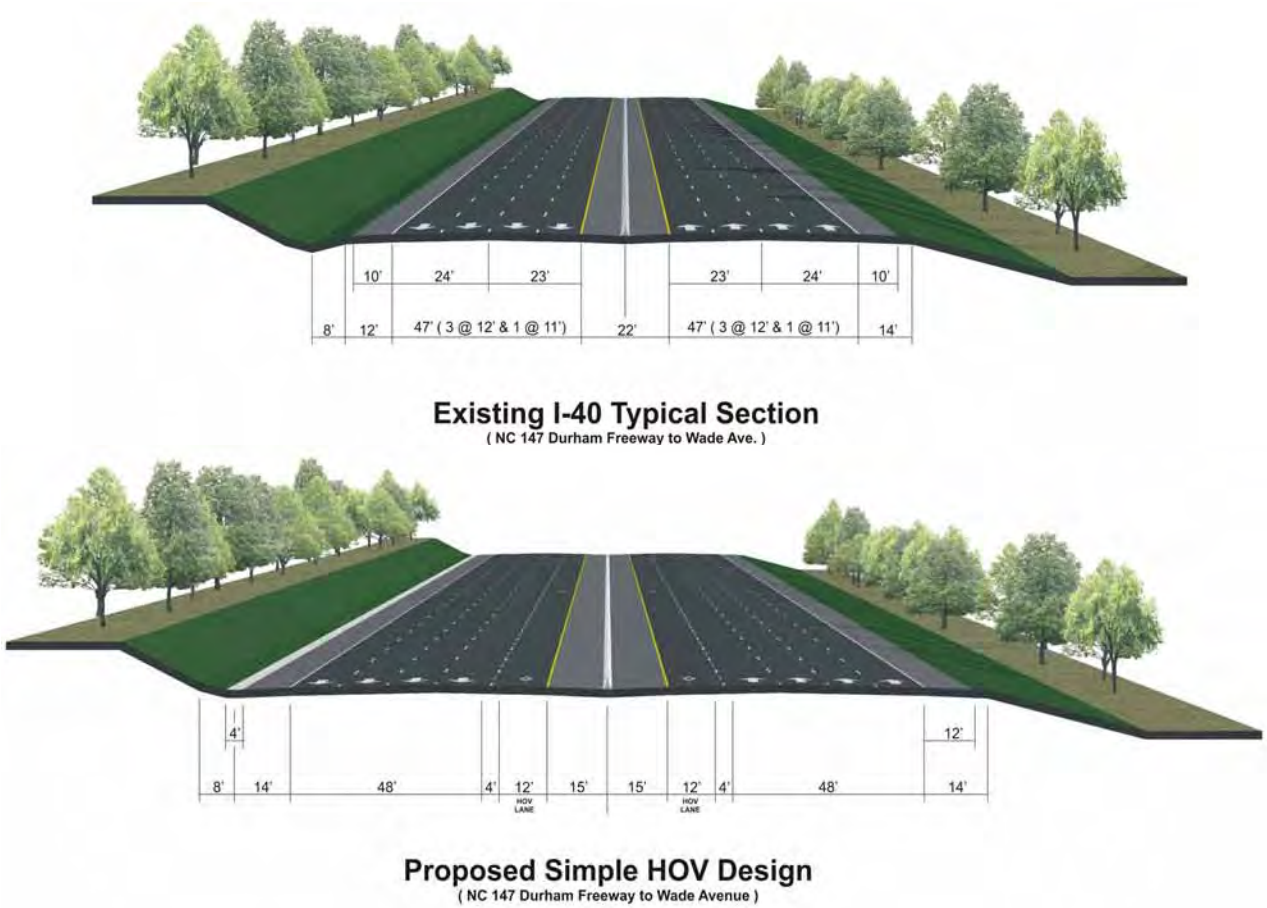
RTP Corridor-East and Airport Corridor: NC 147 to Wade Avenue

Figure 6-3 shows the typical section for the Simple configuration from NC 147 to Wade Avenue. The proposed improvement calls for widening the existing four GP lanes to four GP lanes plus one concurrent flow HOV lane. It includes eight 12-foot GP lanes plus two 12-foot HOV lanes with a 4-foot striped buffer and a 30-foot median with barrier providing 14-foot enforcement shoulders. On the outside, a 12-foot paved shoulder is provided.

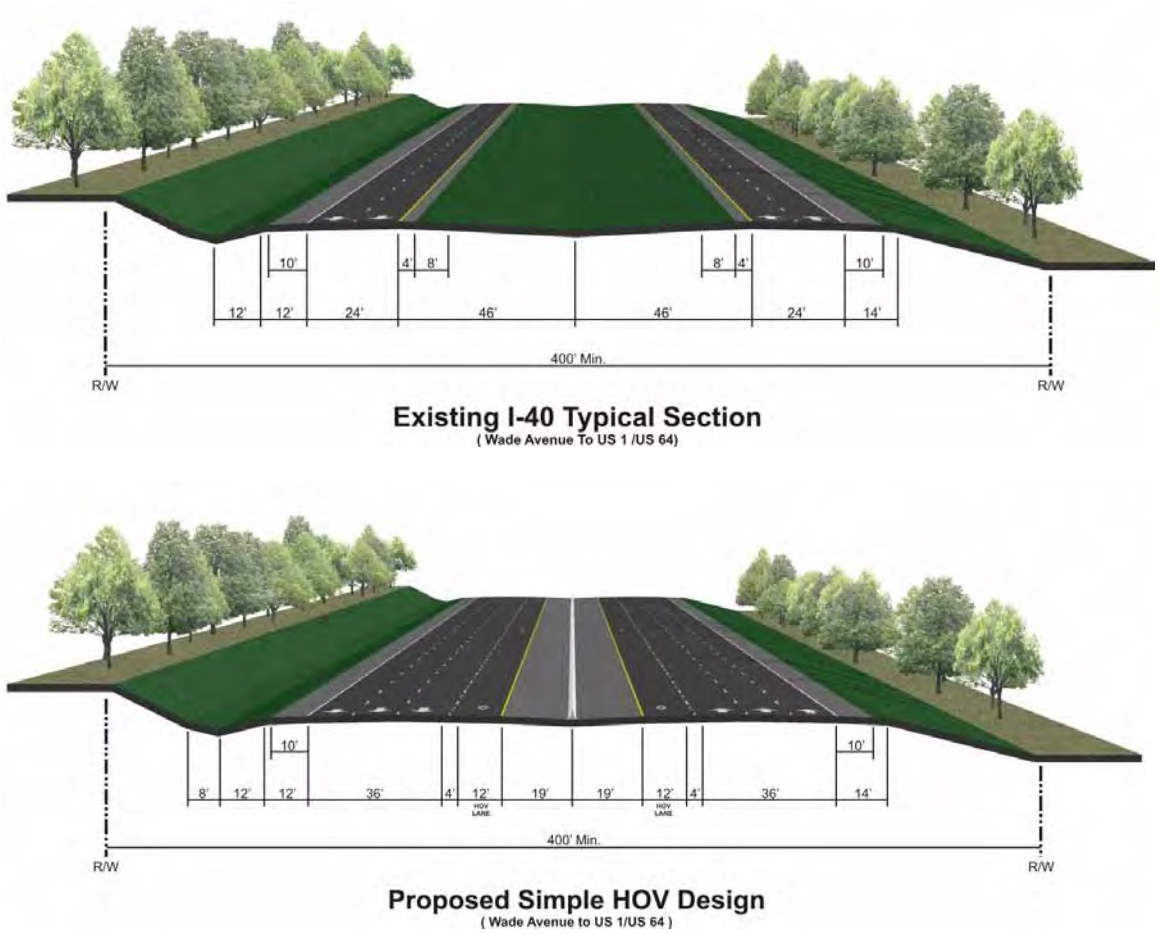
Figure 6-3 Existing and Simple Configuration Typical Sections Between NC 147 and Wade Avenue



Eastern Corridor: Wade Avenue to US 1/US 64

Figure 6-4 shows the typical section for the Simple HOV configuration from Wade Avenue to US 1/US 64. The proposed improvement calls for widening the existing two GP lanes to three GP lanes plus one concurrent flow HOV lane. It includes six 12-foot GP lanes plus two 12-foot HOV lanes, 4-foot striped buffer and a 38-foot median with barrier providing 18-foot enforcement shoulders. On the outside, a 10-foot paved shoulder is provided.

Figure 6-4 Existing and Simple Configuration Typical Sections Between Wade Avenue and US 1/US 64



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6.2.2 Travel Demand

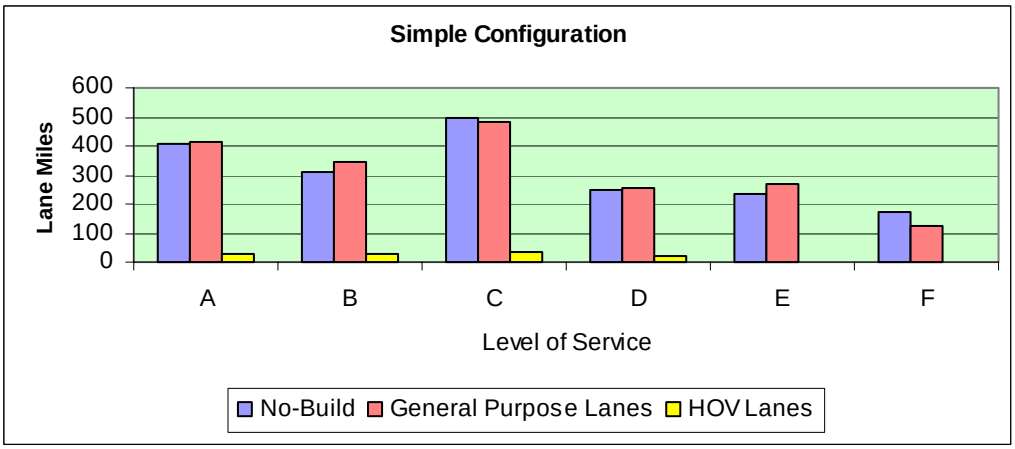
The following sections describe the system-wide and facility-specific measures of effectiveness as related to travel demand for the Simple configuration.

System-wide Level of Service

System-wide measures of effectiveness are utilized to measure impacts of specific projects on the regional roadway network. Since the regional network includes numerous roadways outside the I-40 corridor, implementing an HOV system may seem to have a small regional impact, although locally there is a much larger impact.

Figure 6-5 illustrates the distribution of freeway lane-miles traveled by LOS category during the AM four hour peak period in year 2025. LOS for the entire freeway network was analyzed for both the 2025 No-Build and Simple HOV configuration with planning level methods using the Triangle Regional Model. The results indicated that the implementation of HOV facilities would reduce the number of lane-miles operating at LOS F from 8 percent to 7 percent. Almost all of Simple HOV configuration is projected to operate at LOS D or better. It can be concluded that HOV provides an alternative that enhances mobility and increases reliability.

Figure 6-5 Freeway Lane-Miles Traveled by Level of Service



Systemwide Demand

Figure 6-6, Figure 6-7, and Figure 6-8 illustrate the vehicle-miles traveled (VMT), hours of person delay, and average speeds, respectively, for the Simple configuration compared to the No-Build. These measures represent the four-hour AM peak period conditions. Conclusions from the figures include:

- The total number of vehicle miles traveled increases by 0.2 percent, illustrating that vehicles are traveling farther in order to reach the new HOV facility.
- The vehicle-hours of delay are reduced by 11 percent for the Simple HOV configuration. This represents a savings of 87,000 person hours per day in the AM peak period. There is a 3 percent increase in the average, region-wide speed.

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Figure 6-6 Comparison of Simple Configuration Vehicle Miles Traveled (AM Peak)

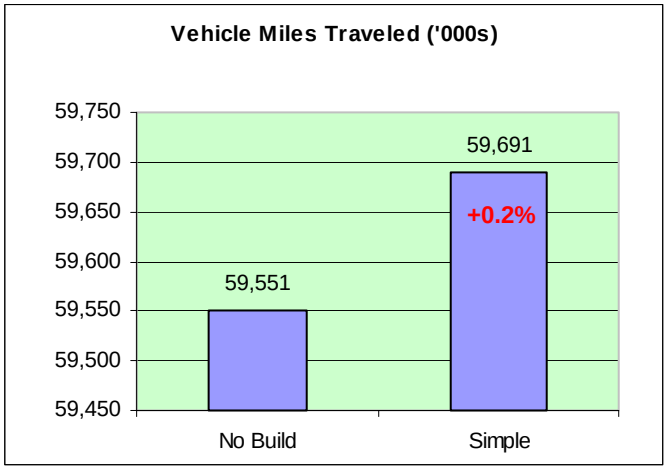


Figure 6-7 Comparison of Simple Configuration Hours of Delay (AM Peak)

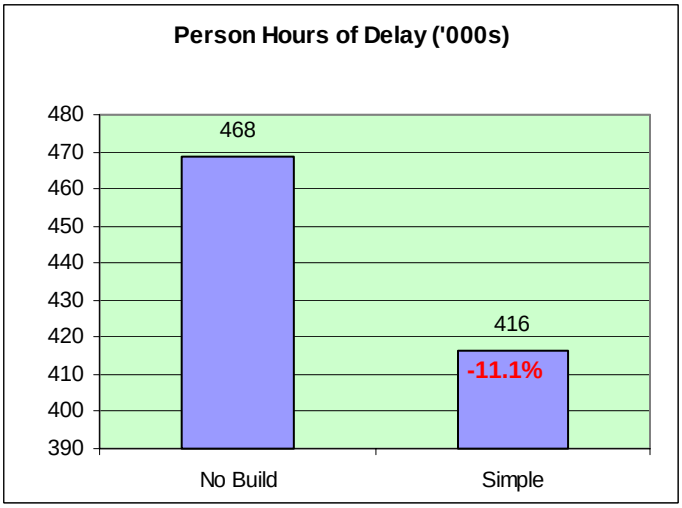
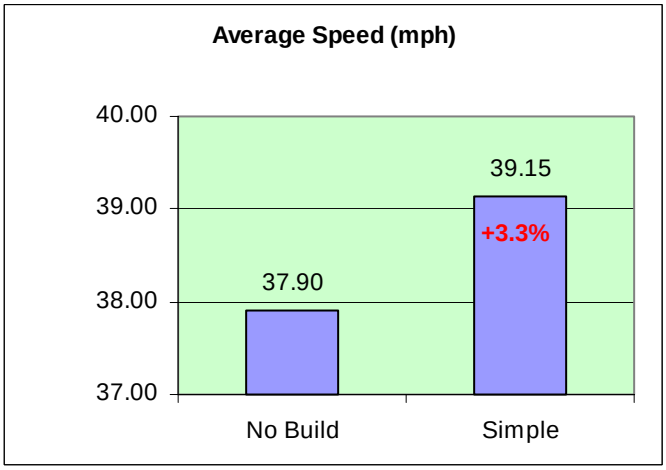


Figure 6-8 Comparison of Simple Configuration Average Speed (AM Peak)



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Shifts in Traffic Flows on the Local Roadway Network

In examining the effectiveness of the HOV facility, it is important to determine indicators of shifts of vehicles from the GP facilities to the HOV facilities and the impacts of the change on adjacent roads.

Shifts in volumes on adjacent streets are illustrated in Figure 6-9. On the map blue bandwidths indicate the absolute volumes on the HOV facilities. Red bandwidths indicate the amount of the increase in volumes on I-40 and I-540. Green bandwidths indicate the amount of decrease in volumes on I-40 and I-540. Bandwidths are offset to show volumes in both directions on opposite sides of the roadway.

The shift in vehicles to the HOV lanes results in an overall average reduction in volumes on adjacent roads of 2.6 percent. A closer examination of these links indicates that shifts on adjacent streets do not show a clear pattern. The shift in vehicles to the HOV lanes results in an overall average reduction in volumes on adjacent roads with no discernible pattern. Some of the observed shifts include:

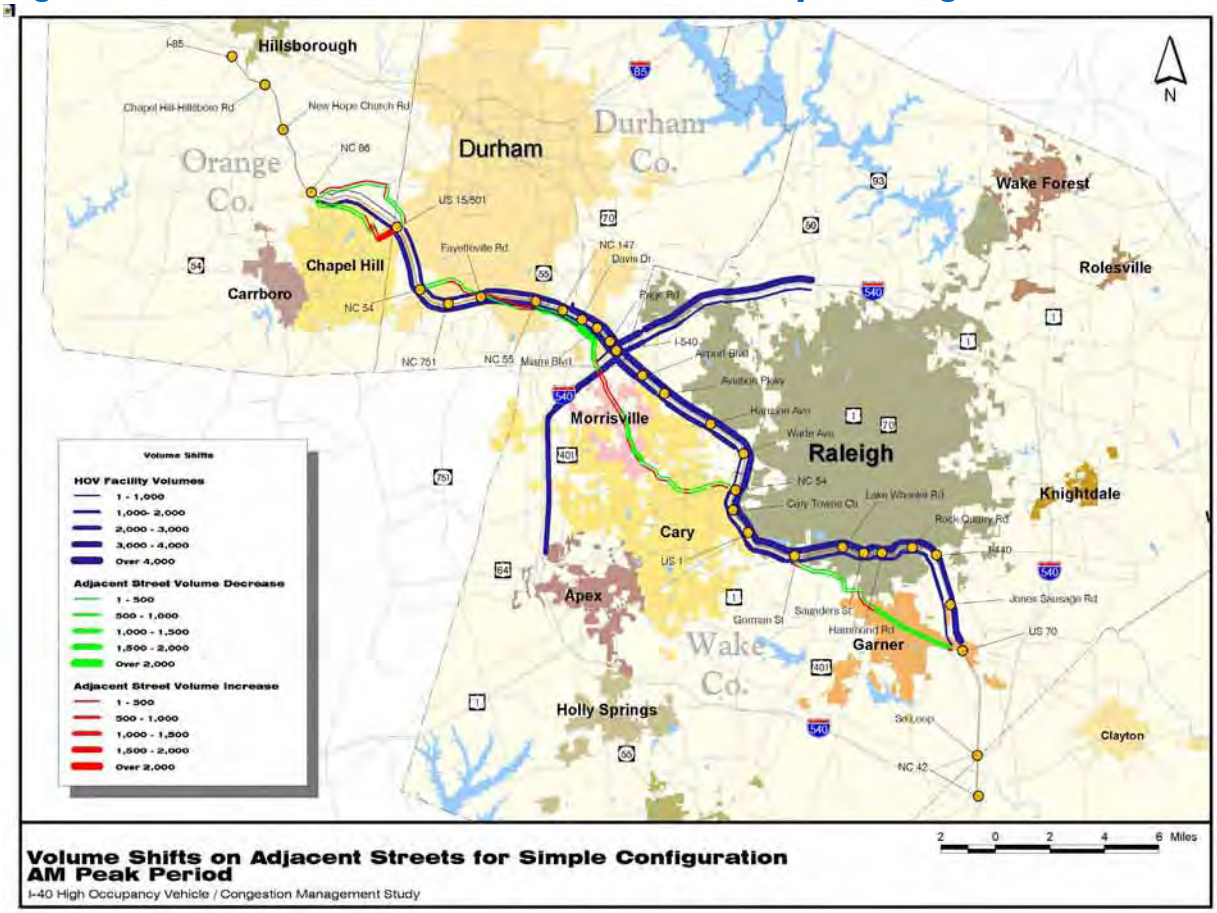
- The largest beneficiary of the shift in volumes to the HOV facility in the AM peak period is Tryon Road near Garner, which shows a 4.1 percent reduction in volumes.
- There is an increase in volumes in both directions on NC 54 in Morrisville but a counter-balancing decrease on NC 54 between I-540 and NC 55.
- There is a clear increase on Weaver Dairy Road on the approach to I-40 at the interchange of US 15/US 501. This increase is offset by a decrease on the western portions of Weaver Dairy Road.

Number of Vehicles Moved Through the Corridor

Table 6-2 shows the projected number of SOVs and HOVs on I-40 for the Simple configuration. The table is divided into two sections. First, a corridor summary of the projected vehicles is shown for each of the five study sections as well as I-40 south of the study area. A more detailed segment summary is then presented between each interchange. Specific observations from the table include:

- A significantly larger percentage of carpools is projected in the Simple configuration than in the No-Build (see Table 2-4). On average, the HOV share on I-40 increases in the Simple configuration by 65 percent over the No-Build scenario.
- Although the percentage of HOVs on I-40 increases, HOV shares do not increase significantly across the region. Examining the entire regional roadway network, the percent of HOV trips as compared with all vehicular trips remains essentially the same in the Simple configuration as in the No-Build condition.
- In 2025, HOV usage is projected to be highest in the RTP Corridor-East. The Airport and Eastern Corridor (as well as between US 1/US 64 and US 70) have higher peak period directional flows than the RTP-West or the Western Corridor.
- Both the RTP-East and the RTP-West Corridors have more balanced HOV flows (approximately 60-40 percent) as compared with sections further from Research Triangle Park (approximately 70–30 percent).
- Some HOV vehicles will continue to use the GP lanes. These vehicles do not realize sufficient time savings by using the HOV lanes and thus remain in the GP lanes.

Figure 6-9 Volume Shifts on Local Roads for Simple Configuration



Volume Shifts on Adjacent Streets for Simple Configuration
AM Peak Period
I-40 High Occupancy Vehicle / Congestion Management Study

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Table 6-2 Vehicles on I-40 by Link and % HOV -- Simple Configuration

SEGMENT	Eastbound				Westbound			
	General Purpose Lanes		HOV Lanes	% HOV	General Purpose Lanes		HOV Lanes	% HOV
	SOV	HOV			SOV	HOV		
Corridor Summary								
Western Corridor	5,010	160	860	14.3%	3,620	210	420	10.0%
RTP Corridor—West	6,550	420	1,140	14.0%	4,940	310	860	14.0%
RTP Corridor—East	6,980	480	1,250	14.3%	8,780	770	1,600	14.4%
Airport Corridor	5,840	430	930	12.9%	8,410	620	1,500	14.2%
Eastern Corridor	4,070	280	620	12.5%	5,490	390	1,270	17.8%
US 1/US 64 to US 70	4,570	440	750	13.0%	6,340	900	1,370	15.9%
Segment Summary								
NC 86 to US 15/US 501	5,110	270	740	12.1%	3,400	360	220	5.5%
US 15/US 501 to NC 54	4,860	0	1040	17.6%	3,930	0	720	15.5%
NC 54 to NC 751	6,310	400	1090	14.0%	4,780	310	750	12.8%
NC 751 to Fayetteville	6,390	430	990	12.7%	4,800	300	720	12.4%
Fayetteville to NC 55	6,880	450	980	11.8%	4,910	300	710	12.0%
NC 55 to NC 147	6,390	380	1,150	14.5%	5,350	340	840	12.9%
NC 147 to Davis	7,860	530	1,130	11.9%	7,410	1050	1,150	12.0%
Davis to Miami	7,750	550	1,380	14.3%	9,650	620	2,030	16.5%
Miami to Page	7,730	560	1,370	14.2%	11,460	670	2,400	16.5%
Page to I-540	8,080	580	1,350	13.5%	12,620	1620	1,870	11.6%
I-540 to Airport	6,450	400	1,170	14.6%	7,180	470	1,300	14.5%
Airport to Aviation	5,150	340	870	13.7%	6,700	450	1,320	15.6%
Aviation to Harrison	6,080	420	960	12.9%	8,510	620	1,500	14.1%
Harrison to Wade	5,510	450	890	13.0%	8,280	620	1,500	14.4%
Wade to NC 54	3,560	250	500	11.6%	4,920	330	1,210	18.7%
NC 54 to Cary Towne Ctr	4,000	280	620	12.7%	5,680	420	1,240	16.9%
Cary Towne Ctr to US 1/US 64	4,920	320	820	13.5%	6,240	450	1,390	17.2%
US 1/US 64 to Gorman	4,790	360	950	15.6%	6,470	420	1,550	18.4%
Gorman to Lake Wheeler	4,700	310	740	12.9%	6,410	440	1,430	17.3%
Lake Wheeler to South Saunders	5,300	370	820	12.6%	7,300	850	1,650	16.8%
South Saunders to Hammond	4,440	340	730	13.2%	6,850	1190	1,150	12.5%
Hammond to Rock Quarry	5,090	410	840	13.2%	7,650	1460	1,230	11.9%
Rock Quarry to I-440 split	4,840	420	790	13.1%	7,170	1160	1,650	16.5%
I-440 split to Jones Sausage	4,290	420	790	14.4%	5,320	1350	1,070	13.8%
Jones Sausage to US 70	3,760	770	370	7.6%	5,430	830	1,400	18.3%

Note: Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Number of People Moved Through the Corridor by Segment

A primary purpose of HOV is to increase the number of persons traveling through a roadway segment. Table 6-3 translates the number of vehicles on each segment of I-40 into number of people by applying the average auto occupancy for carpools to the HOV vehicles. Observations from the table include:

- There is a substantial increase in the number of people moved through the RTP-East Corridor under the Simple HOV configuration, especially between Miami Boulevard and I-540. The RTP Corridor-East is projected to carry 4,520 additional persons per hour, a 21 percent increase compared to the No-Build. The increase in person-flow on the segment between Miami Boulevard and the Page Road is approximately 26 percent.
- The Airport and Eastern Corridor (in addition to the section between US 1/US 64 and US 70) have higher peak period directional flows than the RTP-West or the Western Corridor.

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Table 6-3 Number of People Moved on I-40 - Simple Configuration

Segment	Eastbound			Westbound		
	No-Build	Simple	Increase	No-Build	Simple	Increase
Corridor Summary						
Western Corridor	6,570	7,540	970	4,730	5,200	460
RTP Corridor—West	8,900	10,410	1,510	6,750	7,820	1,070
RTP Corridor—East	9,730	11,240	1,510	11,630	14,650	3,020
Airport Corridor	8,320	9,210	900	11,680	13,660	1,980
Eastern Corridor	5,570	6,300	730	7,340	9,590	2,250
US 1/US 64 to US 70	6,840	7,510	660	9,640	11,970	2,320
Segment Summary						
NC 86 to US 15/US 501	6,820	7,610	790	4,440	4,840	400
US 15/US 501 to NC 54	6,210	7,430	1,220	5,160	5,710	550
NC 54 to NC 751	8,990	10,000	1,010	6,540	7,400	860
NC 751 to Fayetteville	8,910	10,150	1,240	6,580	7,500	920
Fayetteville to NC 55	9,090	10,840	1,750	6,790	7,730	940
NC 55 to NC 147	8,380	10,380	2,000	7,140	8,940	1,800
NC 147 to Davis	10,790	12,590	1,800	9,840	12,860	3,020
Davis to Miami	10,520	12,500	1,980	12,380	16,210	3,830
Miami to Page	10,770	12,680	1,910	14,370	19,060	4,690
Page to I-540	11,420	13,130	1,710	16,590	21,260	4,670
I-540 to Airport	9,250	10,340	1,090	9,990	11,560	1,570
Airport to Aviation	7,130	8,150	1,020	9,260	11,080	1,820
Aviation to Harrison	8,580	9,500	920	11,770	13,760	1,990
Harrison to Wade	7,960	8,830	870	11,560	13,530	1,970
Wade to NC 54	4,820	5,420	600	6,550	8,730	2,180
NC 54 to Cary Towne Center	5,450	6,230	780	7,540	9,790	2,250
Cary Towne Center to US 1/US 64	6,840	7,740	900	8,430	10,790	2,360
US 1/US 64 to Gorman	7,070	8,030	960	8,560	11,350	2,790
Gorman to Lake Wheeler	6,590	7,300	710	8,520	11,040	2,520
Lake Wheeler to South Saunders	7,540	8,250	710	11,250	13,490	2,240
South Saunders to Hammond	6,470	7,090	620	10,320	12,640	2,320
Hammond to Rock Quarry	7,530	8,180	650	11,430	14,310	2,880
Rock Quarry to I-440 split	7,230	7,840	610	11,510	14,130	2,620
I-440 split to Jones Sausage	6,800	7,290	490	9,330	11,310	1,980
Jones Sausage to US 70	6,080	6,580	500	9,430	10,950	1,520

Note: Volume in persons per hour.
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

6.2.3 Traffic and Operations

Level of Service Analysis

The FREEVAL model was run for the 2025 Simple HOV configuration to analyze freeway traffic operations during AM and PM peak hours. In contrast to all other build scenarios, the freeway analysis in the Simple configuration included the HOV lanes since concurrent flow lanes are not barrier-separated and traffic may change lanes freely at any location.

Table 6-4 provides a summary of the projected freeway traffic volume and capacity analysis results in terms of V/C ratios and LOS categories. Figure 6-10 and Figure 6-11 depict the V/C results of the freeway capacity analysis on color coded maps to highlight the congested corridor segments by time of day and by direction of travel. These maps and the LOS values indicate that the highest levels of congestion will occur on I-40 between NC 147 and I-540.

As projected V/C ratios increase, it can reasonably be expected that peak hour spreading will also occur. As a result, congestion would spread to more hours of the day. Under extreme conditions with very high V/C ratios or if an accident or other incident would occur, it is possible that congestion could extend throughout the day.

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Table 6-4 Simple Configuration LOS Analysis Results (FREEVAL)

Segment	2025 Simple AM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	6,120	0.73	C	3,980	0.50	B
US 15/US 501 to NC 54	5,900	0.70	C	4,650	0.58	C
NC 54 to NC 751	7,810	0.93	D	5,830	0.73	D
NC 751 to Fayetteville Road	7,910	0.94	D	5,880	0.73	D
Fayetteville Road to NC 55	8,470	1.01	F	6,050	0.75	C
NC 55 to NC 147	8,000	0.95	F	6,800	0.85	C
NC 147 to Davis Drive	9,770	0.92	F	9,610	1.46	D
Davis Drive to Miami Blvd	9,670	0.74	F	12,300	1.38	F
Miami Blvd to Page Road	9,730	0.80	F	14,530	1.27	F
Page Road to I-540	10,110	1.49	E	16,110	2.22	F
I-540 to Airport Blvd	8,010	0.55	C	8,950	0.87	F
Airport Blvd to Aviation Pkwy	6,360	0.62	C	8,470	0.83	F
Aviation Pkwy to Harrison Ave	7,470	0.73	D	10,640	1.04	F
Harrison Ave to Wade Avenue	6,850	0.64	C	10,410	0.80	D
Wade Avenue to NC 54	4,320	0.40	B	6,460	0.77	D
NC 54 to Cary Towne Boulevard	4,900	0.50	B	7,350	0.89	D
Cary Towne Blvd to US 1/US 64	6,070	0.91	C	8,080	0.75	D

Segment	2025 Simple PM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	4,580	0.57	C	5,830	0.70	C
US 15/US 501 to NC 54	4,970	0.62	C	5,910	0.70	D
NC 54 to NC 751	6,460	0.80	D	7,040	0.84	D
NC 751 to Fayetteville Road	6,550	0.81	D	7,700	0.92	E
Fayetteville Road to NC 55	6,610	0.82	F	7,900	0.94	E
NC 55 to NC 147	6,630	0.82	F	8,010	0.96	E
NC 147 to Davis Drive	9,680	0.94	F	8,980	1.04	D
Davis Drive to Miami Blvd	11,210	0.92	F	10,120	0.94	F
Miami Blvd to Page Road	13,270	1.21	F	10,870	0.94	D
Page Road to I-540	14,500	2.87	F	11,330	1.39	E
I-540 to Airport Blvd	8,630	0.57	C	8,490	0.83	F
Airport Blvd to Aviation Pkwy	7,570	0.71	D	6,760	0.66	F
Aviation Pkwy to Harrison Ave	9,650	0.90	E	8,050	0.78	F
Harrison Ave to Wade Avenue	9,580	0.89	E	7,740	0.72	D
Wade Avenue to NC 54	6,080	0.57	F	4,950	0.79	D
NC 54 to Cary Towne Boulevard	6,690	0.67	F	5,550	0.75	C
Cary Towne Blvd to US 1/US 64	8,050	1.06	D	6,550	0.76	D

Notes: V/C = volume to capacity ratio.
There is no direct correlation between V/C ratio and LOS.
Volumes in vehicles per hour (vph.)
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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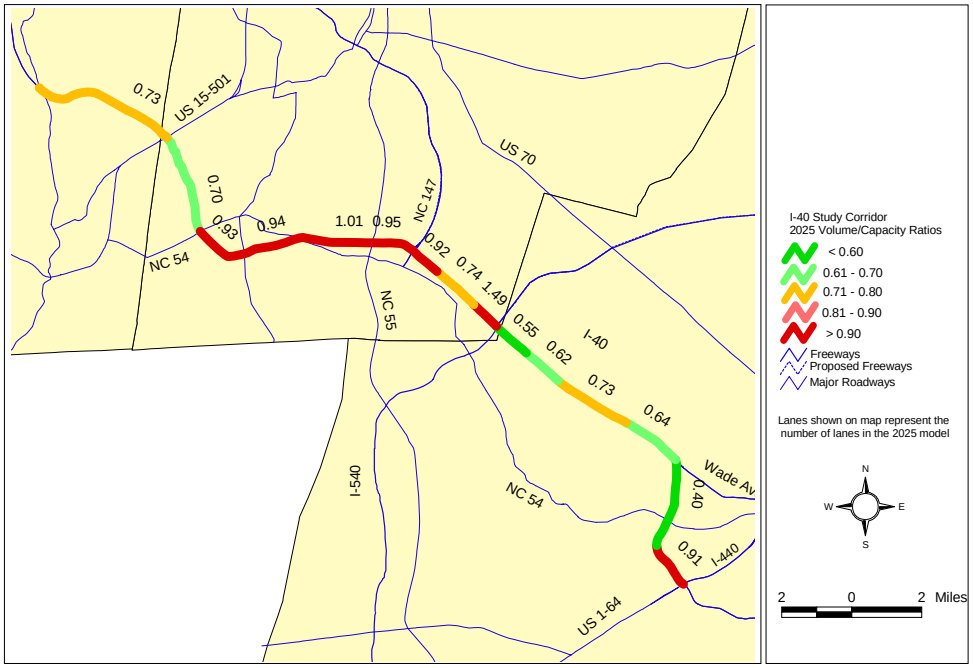
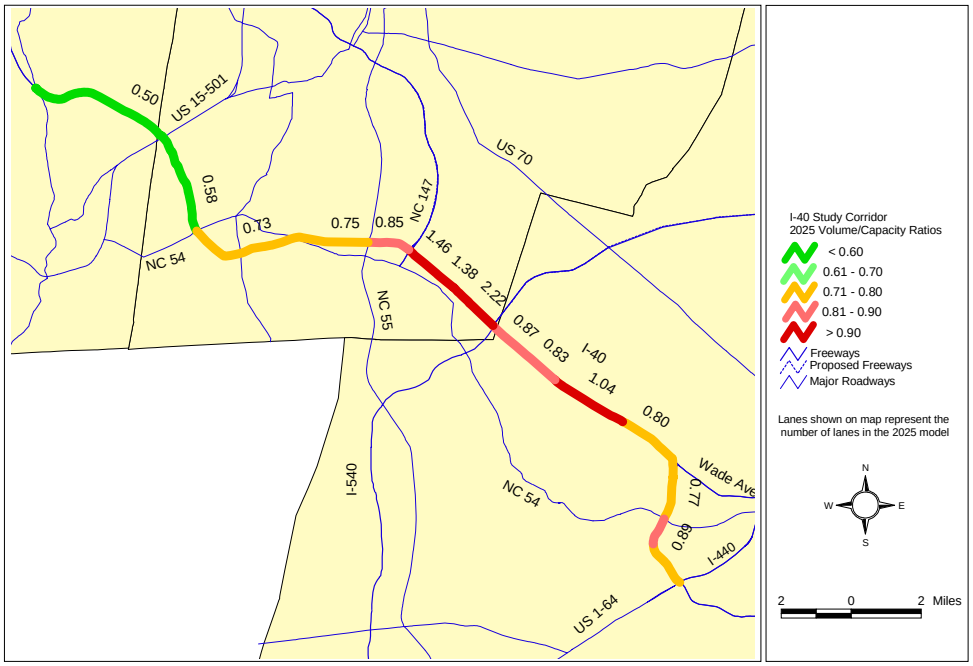
Figure 6-10 AM Peak Hour V/C Ratios – Simple Configuration



Simple Eastbound AM Volume/Capacity (V/C) Ratios



Simple Westbound AM Volume/Capacity (V/C) Ratios

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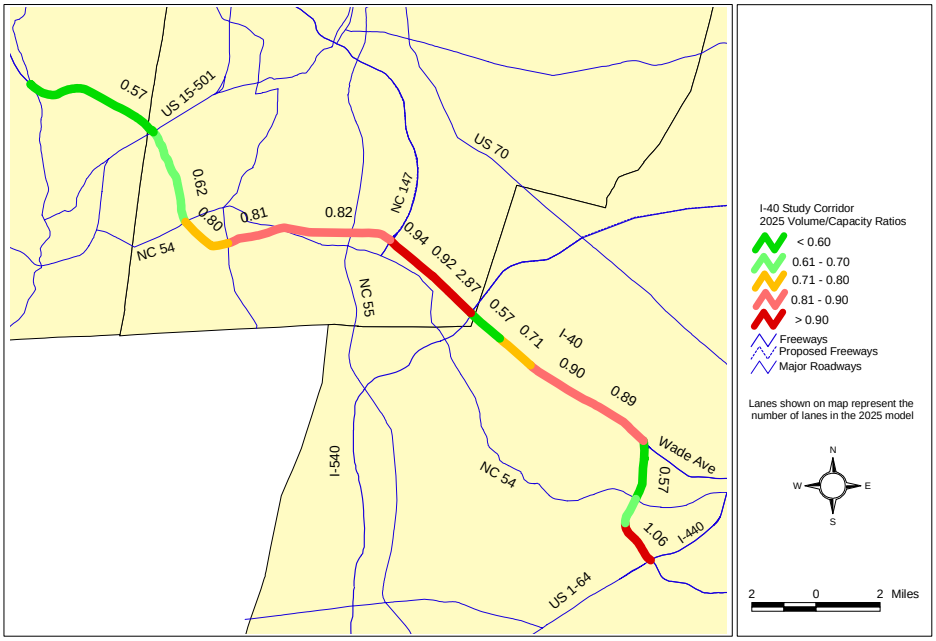
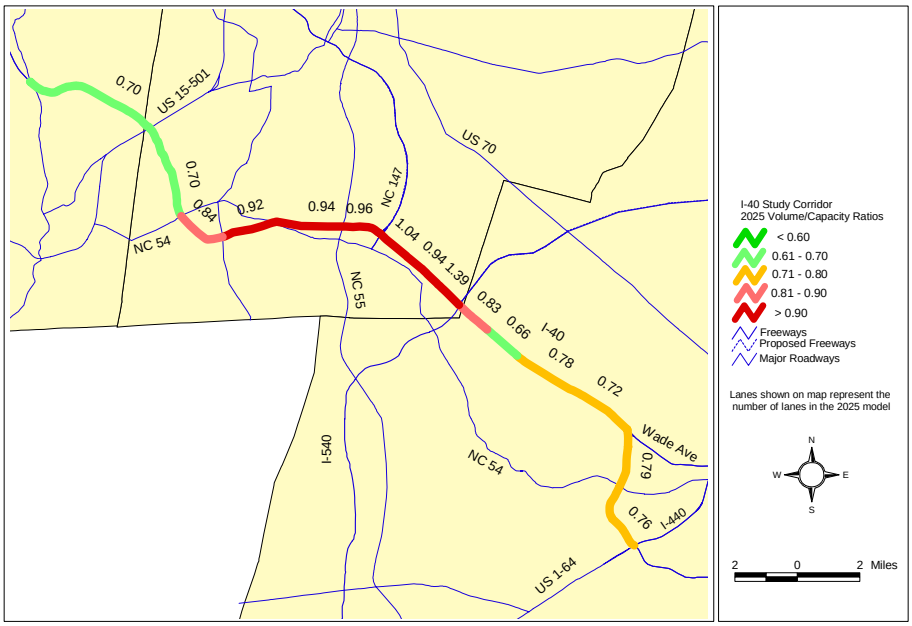
Figure 6-11 PM Peak Hour V/C Ratios – Simple Configuration



Simple Eastbound PM Volume/Capacity (V/C) Ratios



Simple Westbound PM Volume/Capacity (V/C) Ratios

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Travel Time Analysis

The FRESIM model was used to determine the net improvement, if any, for vehicles in the HOV lanes compared to the GP traffic. The FRESIM analysis results, including the bottleneck improvements identified in the No-Build network, show that significant congestion remains at the I-40 interchange with I-540. The Simple configuration HOV lane, however, had some time savings for users compared to the GP traffic. Table 6-5 illustrates the time savings along the corridor.

Table 6-5 Travel Time Savings in the HOV Lanes

Corridor	Trip Length (miles)	Travel Time savings (min:sec)	
		AM Peak	PM Peak
Eastbound I-40			
1. Western – NC 86 to NC 54	6.9	0:14	0:09
2. RTP West – NC 54 to NC 147	6.4	1:53	1:40
3. RTP East – NC 147 to Aviation Pkwy	5.6	0:01	13:36*
4. Airport – Aviation Pkwy to Wade Avenue	4.1	0	0
5. Eastern – Wade Avenue to US 1/US 64	3.8	0	0
EASTBOUND TOTAL	**26.8**	**2:08**	**15:25**
Westbound I-40			
1. Eastern – US 1/US 64 to Wade Avenue	3.8	0:07	0:01
2. Airport – Wade Avenue to Aviation Pkwy	4.1	1:48	0
3. RTP East – Aviation Pkwy to NC 147	5.6	1:08	0:02
4. RTP West – NC 147 to NC 54	6.4	0:02	0:57
5. Western – NC 54 to NC 86	6.9	0:04	0:09
WESTBOUND TOTAL	**26.8**	**3:10**	**1:09**

*Notes: * HOV time savings primarily results from extreme bottleneck conditions at the I-540 interchange for general purpose traffic.*
For HOV traffic using the I-540 interchange, time savings would be reduced.
Optimal concurrent HOV lane design (4-foot buffer and shoulder) assumed to provide optimal speeds when general purpose lanes are congested.

HOV Weaving Requirements

Recently researchers in Texas have utilized complex modeling techniques to determine the weave requirements of concurrent flow HOV lanes. The researchers identified several key issues that have bearing on managed lanes operation. These issues are:

- Freeway weaving from a freeway entrance to a managed (HOV) lane entrance,
- Freeway weaving from a managed lane exit to a freeway exit, and
- Intra-freeway vehicle stream separation of vehicles destined for managed lane access.

To describe the concept, intra-freeway weaving for accessing managed lanes is the "sorting" of vehicles destined for the managed lanes into the leftmost freeway lane. This maneuver can be viewed as the weaving distance required for a driver who has decided he/she is a candidate for using the managed lanes to reach the correct lane for a transition into the managed portion of the freeway facility. Using simulation modeling work, researchers were able to make the following recommendations concerning managed lanes operation:

- Typical generic managed lane design guidelines specify either minimum (500 feet) and desirable (1000 feet) weaving distances per lane, or a preferred minimum distance (2500 feet) between a freeway entrance or exit.
- For general managed lane planning purposes, the recommended minimum and desirable distances between a freeway entrance/exit ramp and a managed lanes entrance/exit are 2500 feet and 4000 feet, respectively. For high freeway volumes, especially in cases where an intermediate ramp is present between the freeway entrance/exit and the managed lanes entrance/exit, 4000 feet of cross-freeway weaving distance is appropriate.
- To preserve freeway quality of service in the vicinity of managed lanes entrance and exit ramps, it is recommended that for moderate freeway volumes, a transition distance of one mile be allowed for vehicles to selectively maneuver from their initial position in any freeway lane to the leftmost (or rightmost) freeway lane so that they can access a managed lane facility. Under high volume freeway conditions, a transition distance of 1.5 to 2 miles is appropriate.

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Delay Analysis

The Simple HOV configuration continues the single concurrent flow lane through the congested RTP Corridors between NC 147 and I-540. Table 6-6 compares various system-wide FRESIM measures of effectiveness for Simple HOV and No-Build traffic through I-40. The FRESIM model included I-40 exclusively from US 15/US 501 to US 1/US 64. The model could not be extended to include other freeways and arterials due to the fact that the FRESIM software has capacity constraints in terms of maximum number of links and vehicles that it can handle in a single roadway network.

Table 6-6 Simple Configuration Operations on I-40

I-40 Measures of Effectiveness	No-Build PM	Simple PM	Percentage Change
AM Peak Hour			
Vehicle-Miles Traveled (VMT)	323,461	336,764	+4.1%
Average Speed in Network, mph	38.9	32.9	-15.4%
Total Delay Time, vehicle-hours	3,298	5,269	+59.8%
Unit Delay Time, sec/veh-mile	36.6	51.6	+41.0%
PM Peak Hour			
Vehicle-Miles Traveled (VMT)	324,830	385,208	+18.6%
Average Speed in Network, mph	38.8	35.9	-7.4%
Total Delay Time, vehicle-hours	3,350	4,566	+36.3%
Unit Delay Time, sec/veh-mile	37.2	42.6	+14.5%

Note that the FRESIM model shows an increase in delays and decrease in travel speeds when comparing No-Build conditions to the Simple configuration. This is caused by three factors:

- The Simple configuration carries a higher number of HOV vehicles, particularly through the RTP, due to traffic diverting to I-40 from adjacent arterials.
- HOV and GP traffic cause significant weaving movements.
- Traffic bottlenecks occur at the I-540 interchange since no improvements in interchange capacity are assumed.

6.2.4 Environmental Screening

An environmental screening was conducted as part of the HOV study to identify potential environmental effects that could result from implementing the Simple HOV configuration. The environmental screening includes an assessment of numerous factors as outlined in Section 6.1.6.

Data for the environmental screening was compiled through background research of existing information. Field data collection was not included as part of the environmental screening. Table 6-7 summarizes the major findings of the environmental screening as they relate to the Simple HOV configuration.

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Table 6-7 I-40 HOV Improvements Impact Summary

Resource	Screening Results for the I-40 HOV Simple Configuration
Stream Crossings	40 crossings
Wetlands	Eight potential encroachments
Protected/Public Lands	No encroachments
Threatened & Endangered Species	No known impacts
Archaeological Sites	47 sites within one-half mile
Historic Sites	10 sites with some designation within one mile
Community Impacts	No property encroachments

6.2.5 Roadway Design and Cost Estimate

Functional roadway designs for the Simple configuration were developed and are shown in Appendix A. The following sections focus on the roadway design elements:

- Bridge Design and Construction
- Construction Phasing
- Cost Estimates

Bridge Design and Construction

The following structural design inputs were identified for the Simple configuration:

- Based on contour maps for the I-40 corridor, retaining walls may be necessary in several areas where existing slopes are 2:1 and extend to the right-of-way limits.
- Twenty existing bridges would be widened along I-40.
- Nine existing two-span bridges over I-40 would have their end bent slopes removed and replaced with retaining walls.
- Three existing bridges over I-40 would be replaced.
- One new bridge would be constructed.
- Several box culverts throughout the Western and RTP/Airport Corridors would likely require extension.
- Interchange entrance and exit ramps would require adjustment for widening beyond the existing cut and fill slopes.
- No new interchanges are proposed in the Simple HOV configuration.

Each of the five segments and the bridge construction impacts associated with the Simple HOV configuration are shown in Table 6-8.

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Table 6-8 Bridge Adjustments for Simple HOV Configuration

Location	Change End Bent	Widen Bridge	Reconstruct Bridge	New Bridge
Western Corridor	5	0	0	0
RTP Corridor-West	3	13	0	0
RTP Corridor-East	1	1	3	1
Airport Corridor	0	2	0	0
Eastern Corridor	0	4	0	0
TOTAL	**9**	**20**	**3**	**1**

Construction Phasing

A preliminary evaluation of the construction phasing for the Simple configuration indicates that it could be implemented in any phasing pattern because HOV traffic is free to move in and out of the HOV lanes at any time. However, the projected majority of use of the HOV lanes would be throughout the RTP/Airport Corridors during peak commuter hours and thus implementation of HOV lanes in these corridors first would be most logical.

The construction sequence for the I-40 Simple HOV configuration would begin by constructing the median improvements from NC 86 to US 1/US 64, as necessary. These improvements would include adding the median barrier, widening the existing structures along I-40, and adding a new structure at the NC 147 interchange. Upon completion of the median improvements, alternating lane closures would be employed to shift the I-40 eastbound and westbound traffic to the median. With the traffic shifted to a four-lane divided two way pattern, the 20-foot outside widening of I-40 up to, but not including, the grade tie-ins with existing ramps and loops would begin.

During the outside widening phase of I-40, construction of the proposed TTA railroad tracks and grade separation with I-40 just west of the Miami Boulevard interchange would begin also. Upon completion of the new rail alignment, trains would be relocated to the new rail, and removal and construction of the new railroad grade separation would begin. Concurrently, at the Aviation Parkway and I-40 grade separation and the Miami Boulevard and I-40 grade separation, the structures would be replaced in stages to construct half of the new bridge in each stage. This would allow two lanes of traffic to be maintained on Aviation Parkway and Miami Boulevard at all times. Upon completion of the outside widening of I-40 from NC 86 to Wade Avenue, alternating lane closures would be employed to shift traffic for eastbound and westbound ramp and loop grade tie-ins with existing. The final layer of surface course, including pavement marking and thermoplastic pavement markers, would be placed and all lanes would be open to traffic.

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Cost Estimates

Table 6-9 summarizes the cost estimates prepared for the Simple configuration. The cost estimates were based on the functional design rather than a per mile cost. Quantities for pavement and structures were estimated based on the geometric design. Unit costs were developed and applied in accordance with NCDOT procedures for preliminary design. Costs are first estimated in 2002 dollars and then inflated to year 2025 using an inflation rate of 2.7 percent per year. Estimates do not include right-of-way costs.

Specific costs that are included in the estimate are:

- Pavement removal and replacement
- Earthwork and grading
- Structures
- ITS techniques
- Signing, marking, and signals
- Drainage
- Retaining walls
- Miscellaneous items
- Engineering and design

Table 6-9 Simple Configuration Estimated Cost (in millions)

Project	Estimated 2002 Cost of Construction	Estimated 2025 Cost of Construction
Western Corridor (NC 86 to NC 54)	$ 29M	$ 54M
RTP Corridor – West (NC 54 to NC 147)	$ 68M	$ 126M
RTP Corridor – East (NC 147 to Aviation Pkwy)	$ 59M	$ 109M
Airport Corridor (Aviation Pkwy to Wade Ave)	$ 27M	$ 50M
Eastern Corridor (Wade Ave to US 1/US 64)	$ 54M	$ 100M
TOTAL	**$ 237M**	**$ 439M**

6.3 Complex Configuration

The following sections describe in more detail the design assumptions associated with the Complex configuration. Section 6.3.2 describes the implications of this design for travel demand on the HOV facility as well as on general purpose lanes and adjacent roads. Section 6.3.3 describes the traffic operations conditions for the Complex configuration. Section 6.3.4 examines environmental issues. The construction implications are described in Section 6.3.5.

6.3.1 Typical Sections

The Complex configuration is considered a higher operational form of HOV treatment. It provides exclusive HOV lanes with limited access along the corridor through HOV-only interchanges and direct access ramps. Barrier separation would require significant offsets for safety, enforcement, and sight distance, and weaves for ramp access. The Complex configuration defined for the I-40 corridor includes dedicated HOV direct access ramps at almost every existing interchange locations as well as dedicated interstate-to-interstate movements and Express lane access through the Regional Triangle Park.

Single T-Ramp

Most HOV access ramps are "T-Ramps" which rise out of the median with a 6 percent vertical grade over a 900-foot length to connect to an overpass. The Complex configuration also includes dual lanes for a combination of HOV and Express traffic through RTP. Overall, 18 HOV-only access locations are proposed in this configuration.

Dual T-Ramp

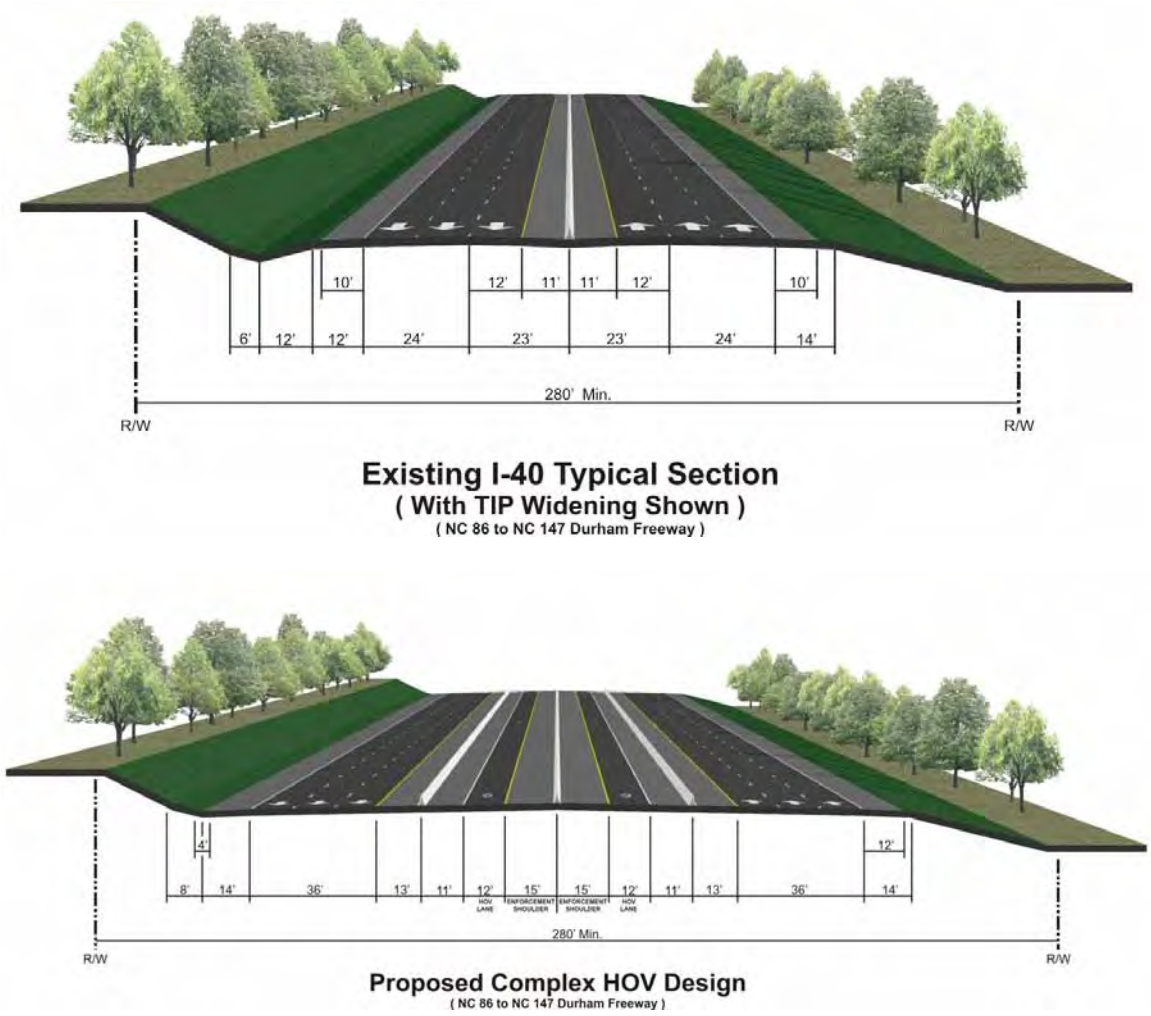
The Complex configuration typical section includes a 12-foot HOV lane with a minimum 10-foot lateral clearance for barrier separation and a minimum 14-foot enforcement shoulder. It requires the widening of existing I-40 on each side throughout the corridor, thus necessitating changes to the existing cut and fill slopes. Cut and fill slopes would be modified to remain within existing NCDOT right-of-way whenever possible. When slopes required to remain within right-of-way exceed acceptable limits, (2:1 unless otherwise approved by geotechnical engineers), retaining walls would be used.

Illustrated typical sections showing the Complex HOV configuration follow for each of the I-40 sections.

Western Corridor and RTP Corridor-West: NC 86 to NC 147

As shown in Figure 6-12, the Complex configuration from NC 86 to NC 147 expands the existing three general purpose (GP) lanes per direction to three GP lanes plus one HOV lane per direction. It includes six 12-foot GP lanes plus two 12-foot HOV lanes with a 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance). A 30-foot median with barrier will provide 14-foot enforcement shoulders. A 12-foot paved shoulder is provided on the outside.

Figure 6-12 Existing and Complex Configuration Typical Sections Between NC 86 and NC 147



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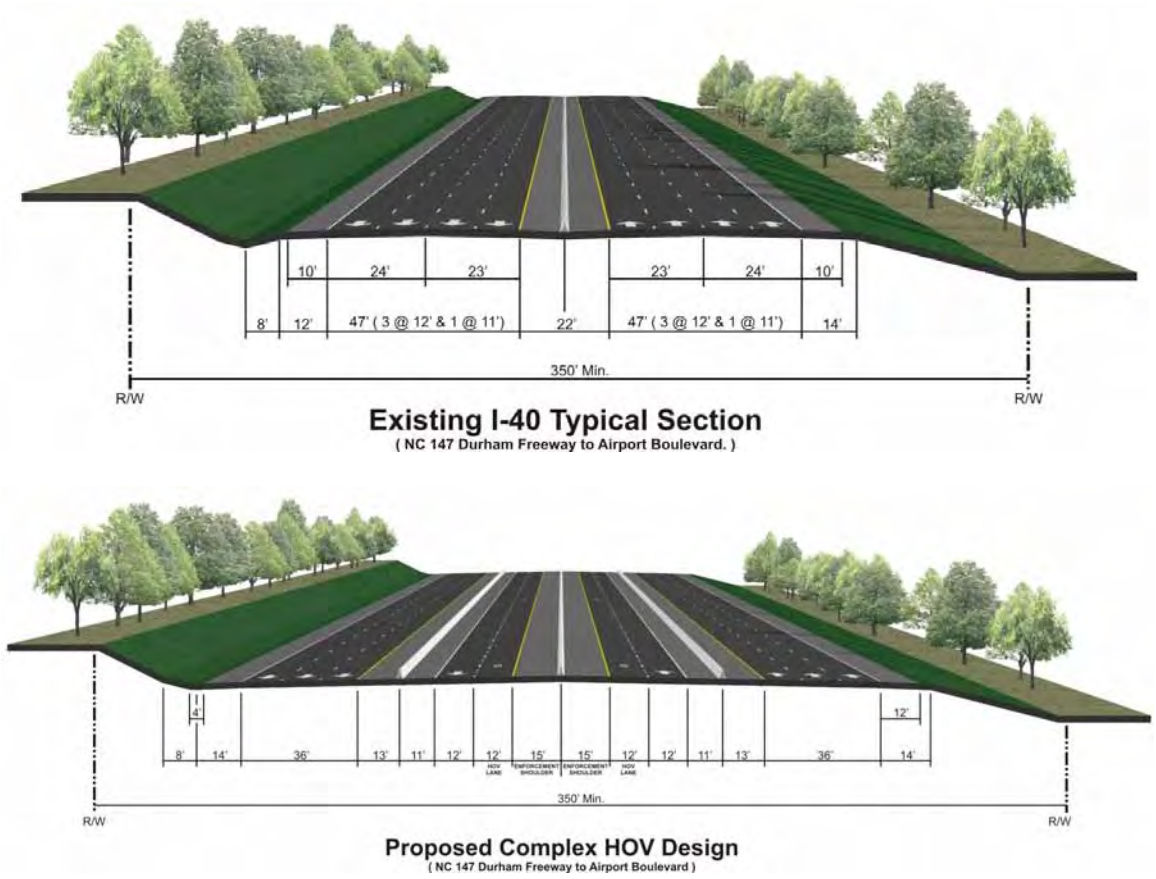
RTP Corridor-East and Airport Corridor: NC 147 to Wade Avenue

Two typical sections are provided between NC 147 and Wade Avenue – a shared HOV/ Express lane section between NC 147 and Airport Boulevard through RTP and an HOV-only section between Airport Boulevard and Wade Avenue.

As shown in Figure 6-13, the Complex configuration from NC 147 to Airport Boulevard expands the existing four GP lanes per direction to three GP lanes plus one HOV lane and one Express lane per direction. It includes six 12-foot general purpose lanes plus two 12-foot HOV lanes and two 12-foot express lanes with a 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance). A 30-foot median with barrier provides 14-foot enforcement shoulders. Outside shoulders are 12 feet wide.

East of RTP between Airport Boulevard and Wade Avenue, the Express lane is removed. The existing four GP lanes per direction are widened to include one HOV lane in addition to the four existing GP lanes. The section is similar to Figure 6-14 with four GP lanes.

Figure 6-13 Existing and Complex Configuration Typical Sections Between NC 147 and Airport Boulevard



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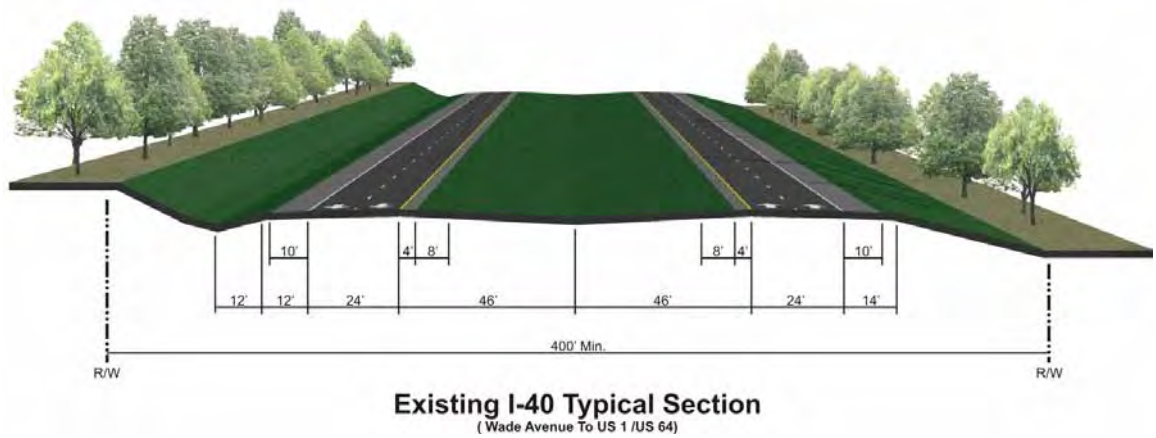
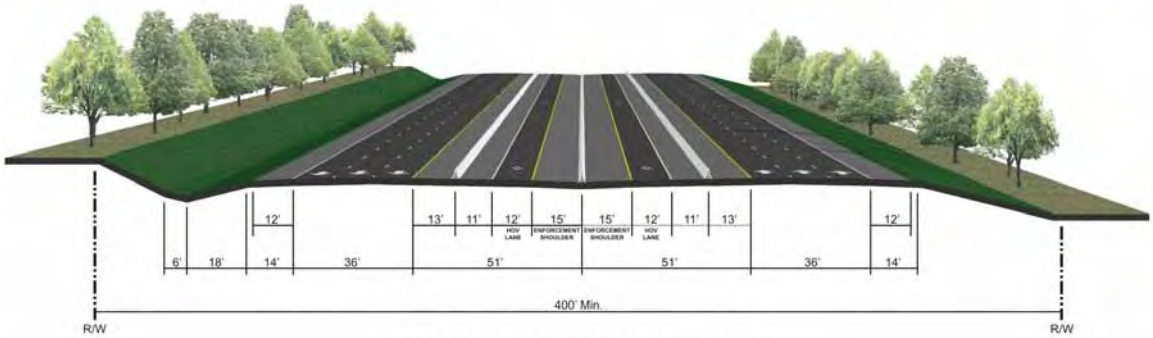
Eastern Corridor: Wade Avenue to US 1/US 64

As shown in Figure 6-14, the Complex configuration from Wade Avenue to US 1/US 64 proposes expanding the existing two GP lanes per direction to three GP lanes plus one separated HOV lane. It includes six 12-foot general purpose lanes plus two 12-foot HOV lanes. A 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance) and a 30-foot median with barrier to allow 14-foot enforcement shoulders are provided. Outside shoulders are 12 feet wide.

Figure 6-14 Existing and Complex Configuration Typical Sections Between Wade Avenue and US 1/US 64



Existing I-40 Typical Section
(Wade Avenue To US 1 /US 64)



Proposed Complex HOV Design
(Wade Avenue To US 1/US 64)

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6.3.2 Travel Demand

The following sections describe the system-wide and facility-specific measures of effectiveness as related to travel demand for the Complex configuration.

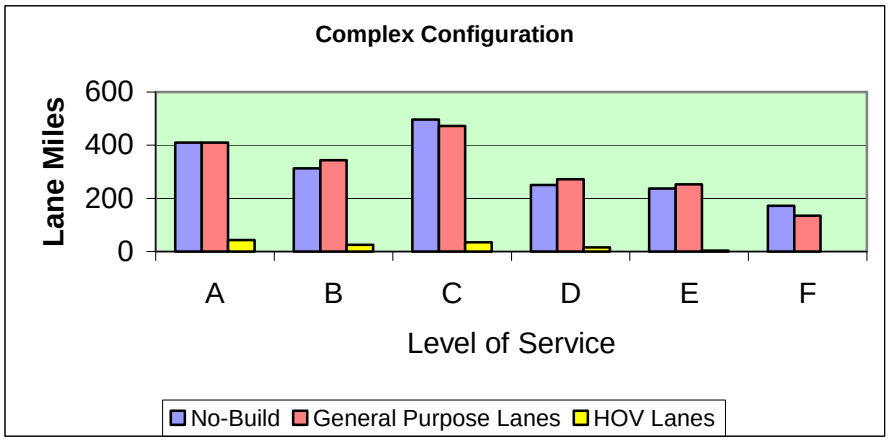
System-wide Level of Service

System-wide measures of effectiveness are utilized to measure impacts of specific projects on the regional roadway network. Since the regional network includes numerous roadways outside the I-40 corridor, implementing an HOV system may seem to have a small regional impact, although locally the impact is much larger.

Evaluating the system-wide characteristics, the Complex configuration provides improved access to the HOV facility, an increase in HOV vehicles in the I-40 corridor, and an increase in both average occupancy rate and the total number of people moved through the corridor. However, because there are more vehicles on the HOV facility, the model shows an increase in the volume/capacity ratios, and a corresponding degradation of some volume/capacity-based measures of effectiveness.

Figure 6-15 illustrates the distribution of lane-miles traveled by level of service (LOS) category during the AM four hour peak period in year 2025. LOS for the entire freeway network was analyzed for both the 2025 No-Build and Complex HOV configuration with planning level methods using the Triangle Regional Model. The results indicate that the provision of HOV lanes results in significant improvement in the congested freeway segments. Most significantly, the Complex configuration shows a 22 percent reduction in freeway lane-miles operating at LOS F. Similar to other build configurations, HOV lane-miles traveled are primarily in the LOS D or better categories.

Figure 6-15 Freeway Lane-Miles Traveled by Level of Service



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Systemwide Demand

Figure 6-16, Figure 6-17, and Figure 6-18 illustrate the performance of the Complex configuration, as compared to the No-Build, using three additional demand-model based indicators – VMT, hours of person delay, and average speed. Conclusions from the figures include:

- The Complex configuration is projected to increase VMT by 0.3 percent due to changes in trip origin-destination patterns resulting from the introduction of HOV.
- Despite the increase in VMT, network-wide delay would decrease (8 percent).
- Average travel speed for the entire roadway network would improve (1.6 percent) as a result of the added capacity in the HOV/Express lanes.

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Figure 6-16 Comparison of Complex Configuration Vehicle Miles Traveled (AM Peak)

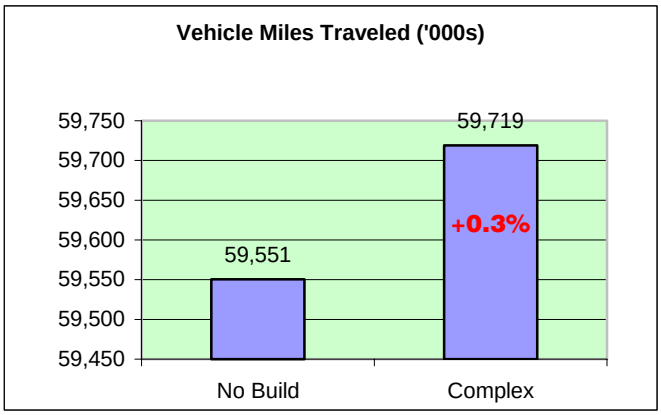


Figure 6-17 Comparison of Complex Configuration Hours of Delay (AM Peak)

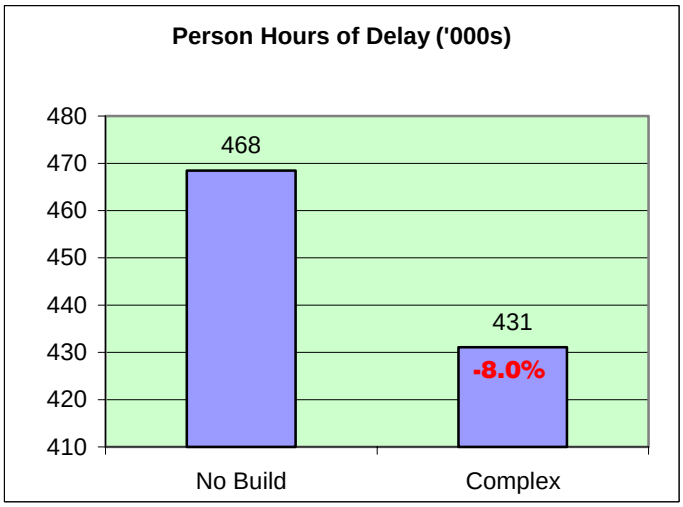
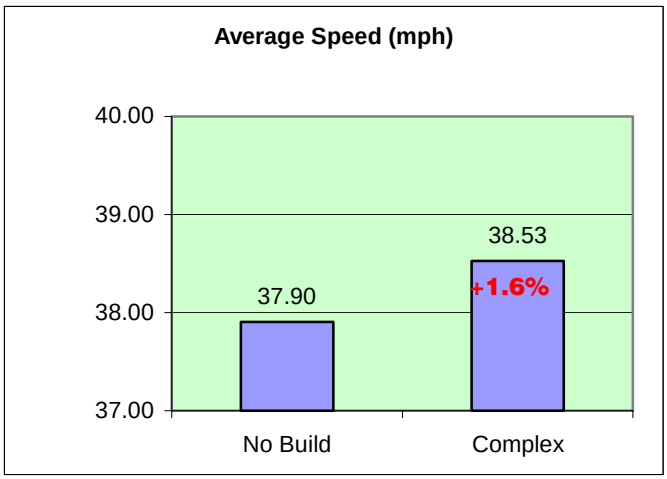


Figure 6-18 Comparison of Complex Configuration Average Speed (AM Peak)



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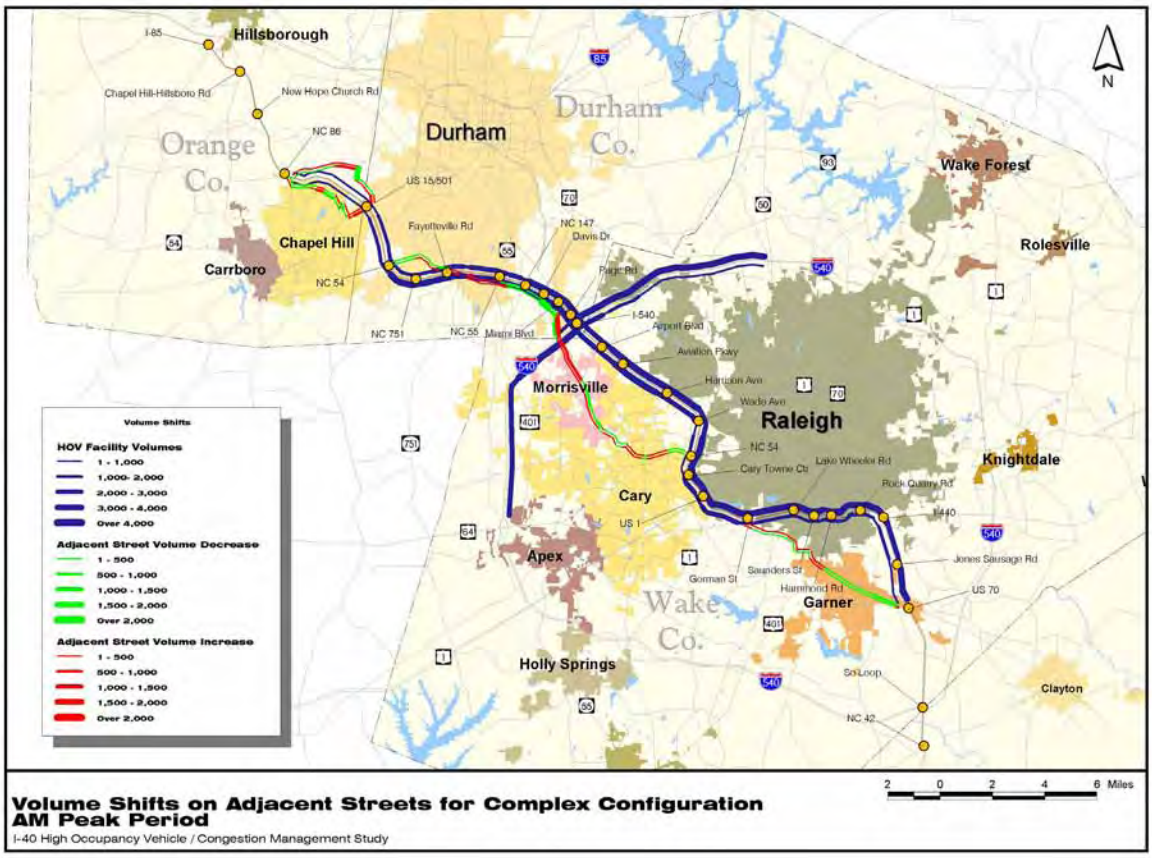
Shifts in Traffic Flows

In looking at the effectiveness of the HOV facility, it is important to look for indicators of shifts of vehicles from the general purpose facilities to the HOV facilities and the impacts of the change on adjacent roads. The shifts in volumes from the local roadway network can be seen in Figure 6-19. On the map, blue bandwidths indicate the absolute volumes on the HOV facility. Red bandwidths indicate the amount of increase in traffic volumes on I-40 and I-540. Green bandwidths indicate the amount of decrease in traffic volumes on I-40 and I-540. Bandwidths are offset to show volumes in both directions of the roadway.

Although the system-wide measures discussed above do not show significant differences between the No Build and Complex configurations, the specific analysis links indicate an average decrease in volumes on I-40 general purpose lanes of 3.5 percent. There is a small (0.1 percent average volume decrease) overall impact of these changes on adjacent roads. However, when looking at specific adjacent roads, observations include:

- Traffic on NC 86 decreases by 6.9 percent overall.
- Traffic on NC 54 increases by 1.5 percent overall, but varies throughout the network. Through RTP, traffic on NC 54 decreases in both directions. However, on either side of RTP, NC 54 increases in volumes.
- US 70 shows some clear advantages in terms of decreased volumes between the interchange with I-40 and the interchange with US 401 in Garner.

Figure 6-19 Volume Shifts on Local Roads for the Complex Configuration



Volume Shifts on Adjacent Streets for Complex Configuration
AM Peak Period
I-40 High Occupancy Vehicle / Congestion Management Study

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Number of Vehicles Moved Through the Corridor by Segment

Table 6-10 shows, by segment, the number of SOVs and HOVs on I-40 for the Complex configuration. The table is divided into two sections. First, a corridor summary of the projected vehicles is shown for each of the five study sections as well as I-40 south of the study area. A more detailed segment summary is then presented between each interchange. Specific observations from the table include:

- HOV demand is projected to increase considerably in the Complex configuration compared to the No-Build, approximately 46 percent in the morning peak hour.
- In 2025, HOV usage is projected to be highest in the RTP-East Corridor. With the Express lanes in place, approximately 3,000 vehicles per hour travel in each direction. HOV traffic makes up just under one-half of this traffic.
- The Airport and Eastern Corridor (in addition to the section between US 1/US 64 and US 70) have higher peak period directional flows than the RTP-West or the Western Corridor.
- Both the RTP-East and the RTP-West Corridors have more balanced HOV flows (approximately 60 - 40 percent splits) as compared with sections further from Research Triangle Park (approximately 70 – 30 percent splits).
- Some HOV vehicles will continue to use the general purpose lanes. These vehicles represent trips that do not realize sufficient time savings by using the HOV lanes and thus remain in the general purpose lanes. In addition, limited access points to the HOV lanes (as opposed to the Simple configuration) result in some HOV trips not using the HOV lanes.

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Table 6-10 Vehicles on I-40 by Segment and % HOV - Complex Configuration

Segment	Eastbound					Westbound				
	General Purpose Lanes		HOV Facility		% HOV	General Purpose Lanes		HOV Facility		% HOV
	SOV	HOV	SOV	HOV		SOV	HOV	SOV	HOV	
Corridor Summary										
Western Corridor	4,990	380	0	590	9.9%	3,590	340	0	300	7.2%
RTP Corridor--West	6,820	290	0	1,290	15.4%	4,950	360	0	850	13.8%
RTP Corridor—East	6,310	400	1,460	1,330	14.0%	7,090	820	1,620	1,430	13.1%
Airport Corridor	5,990	350	0	1,030	14.0%	8,180	520	0	1,510	14.8%
Eastern Corridor	4,080	290	0	650	12.9%	5,590	380	0	1,200	16.8%
US 1/US 64 to US 70	4,580	410	0	770	13.3%	6,300	840	0	1,400	16.4%
Segment Summary										
NC 86 to US 15/US 501	5,120	430	0	540	8.9%	3,380	330	0	230	5.8%
US 15/US 501 to NC 54	4,800	310	0	670	11.6%	3,890	350	0	410	8.8%
NC 54 to NC 751	6,690	310	0	1,210	14.7%	4,860	270	0	880	14.6%
NC 751 to Fayetteville	6,760	310	0	1,210	14.6%	4,780	280	0	880	14.8%
Fayetteville to NC 55	7,030	280	0	1,360	15.7%	4,890	370	0	830	13.6%
NC 55 to NC 147	6,650	270	0	1,360	16.4%	5,370	540	0	830	12.3%
NC 147 to Davis	6,610	310	1,460	1,600	16.0%	5,120	86	1,620	1,050	12.1%
Davis to Miami	6,380	340	1,460	1,500	15.5%	7,090	1,080	1,620	1,250	11.3%
Miami to Page	6,570	360	1,460	1,560	15.7%	8,120	1,090	1,620	2,090	16.2%
Page to I-540	6,740	430	1,460	1,560	15.3%	9,180	1,270	1,620	2,090	14.8%
I-540 to Airport	6,660	630	0	1010	12.2%	7,100	660	0	1,010	11.5%
Airport to Aviation	5,230	290	0	1,030	15.7%	6,600	320	0	1,400	16.8%
Aviation to Harrison	6,260	300	0	1,140	14.8%	8,250	480	0	1,580	15.3%
Harrison to Wade	5,630	410	0	880	12.7%	8,080	570	0	1,410	14.0%
Wade to NC 54	3,540	260	0	560	12.8%	5,130	340	0	1,150	17.4%
NC 54 to Cary Towne Center	4,070	370	0	540	10.8%	5,700	490	0	1,110	15.2%
Cary Towne Ctr to US 1/US 64	4,950	260	0	870	14.3%	6,210	370	0	1,360	17.1%
US 1/US 64 to Gorman	4,760	370	0	930	15.3%	6,410	440	0	1,480	17.8%
Gorman to Lake Wheeler	4,700	320	0	720	12.5%	6,410	460	0	1,370	16.6%
Lake Wheeler to South Saunders	5,280	380	0	790	12.2%	7,290	870	0	1,600	16.4%
South Saunders to Hammond	4,430	350	0	710	12.9%	6,760	750	0	1,550	17.1%
Hammond to Rock Quarry	5,090	430	0	820	12.9%	7,580	980	0	1,680	16.4%
Rock Quarry to I-440 split	4,820	430	0	770	12.8%	7,190	1190	0	1,590	15.9%
I-440 split to Jones Sausage	4,350	430	0	780	14.0%	5,280	1360	0	1,040	13.5%
Jones Sausage to US 70	3,780	550	0	590	12.0%	5,380	870	0	1,340	17.7%

Note: Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Number of People Moved Through The Corridor By Segment

Table 6-11 translates the number of vehicles on each segment of I-40 into number of people by applying the average auto occupancy for carpools to the HOV vehicles. A review of the analysis indicates:

- There is a substantial increase in the number of people moved through the RTP Corridor-East under the Complex configuration, especially between Miami Boulevard and I-540. The RTP Corridor-East is projected to carry 3,650 additional persons per hour, a 17 percent increase compared to the No-Build. The increase in person-flow on the segment between Miami Boulevard and the Page Road is approximately 21 percent.
- The Airport and Eastern Corridor (in addition to the section between US 1/US 64 and US 70) have higher peak period directional flows than the RTP-West or the Western Corridor.
- The Complex configuration results in greater increases in HOV volumes on the RTP Corridor-West than the Simple configuration.

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Table 6-11 Number of People Moved on I-40 Complex Configuration

Segment	Eastbound			Westbound		
	No Build	Complex	Increase	No Build	Complex	Increase
Corridor Summary						
Western Corridor	6,570	7,400	830	4,730	5,180	440
RTP Corridor—West	8,900	10,740	1,840	6,750	7,940	1,190
RTP Corridor—East	9,730	11,430	1,700	11,630	13,580	1,950
Airport Corridor	8,320	9,390	1,080	11,680	13,190	1,510
Eastern Corridor	5,570	6,400	830	7,340	9,510	2,170
US 1/US 64 to US 70	6,840	7,500	650	9,640	11,840	2,200
Segment Summary						
NC 86 to US 15/US 501	6,820	7,520	700	4,440	4,770	330
US 15/US 501 to NC 54	6,210	7,230	1,020	5,160	5,770	610
NC 54 to NC 751	8,990	10,450	1,460	6,540	7,710	1,170
NC 751 to Fayetteville	8,910	10,520	1,610	6,580	7,650	1,070
Fayetteville to NC 55	9,090	11,090	2,000	6,790	7,860	1,070
NC 55 to NC 147	8,380	10,680	2,300	7,140	8,760	1,620
NC 147 to Davis	10,790	12,800	2,010	9,840	11,470	1,630
Davis to Miami	10,520	12,390	1,870	12,380	14,480	2,100
Miami to Page	10,770	12,780	2,010	14,370	17,610	3,240
Page to I-540	11,420	13,130	1,710	16,590	19,120	2,530
I-540 to Airport	9,250	10,720	1,470	9,990	11,230	1,240
Airport to Aviation	7,130	8,500	1,370	9,260	10,860	1,600
Aviation to Harrison	8,580	9,820	1,240	11,770	13,350	1,580
Harrison to Wade	7,960	8,820	860	11,560	12,980	1,420
Wade to NC 54	4,820	5,570	750	6,550	8,820	2,270
NC 54 to Cary Towne Center	5,450	6,320	870	7,540	9,660	2,120
Cary Towne Center to US 1/US 64	6,840	7,750	910	8,430	10,490	2,060
US 1/US 64 to Gorman	6,070	7,980	910	8,560	11,160	2,600
Gorman to Lake Wheeler	6,590	7,270	680	8,520	10,940	2,420
Lake Wheeler to South Saunders	7,540	8,180	640	11,250	13,400	2,150
South Saunders to Hammond	6,470	7,050	580	10,320	12,450	2,130
Hammond to Rock Quarry	7,530	8,180	650	11,430	14,160	2,730
Rock Quarry to I-440 split	7,230	7,790	560	11,510	14,070	2,560
I-440 split to Jones Sausage	6,800	7,350	550	9,330	11,220	1,890
Jones Sausage to US 70	6,080	6,600	520	9,430	10,850	1,420

Note: Volumes in persons per hour.
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Access Points and HOV Ramp Volumes

The Complex configuration was designed to incorporate as many access points as possible in order to evaluate the traffic and functional design of the most complex and extensive HOV network. It is likely that a realistic implementation plan would involve a lesser number of HOV access ramps. In evaluating the Complex configuration it is important to review the access points to determine which are most effective from a demand point of view. Those access points that will not draw a substantial amount of HOV traffic should be considered for elimination from the HOV network, or possibly for implementation at a later phase when demand is higher.

Table 6-12 and Figure 6-20 show the average volume of HOV traffic on ramps accessing the HOV facilities in the AM peak hour in the peak direction. The volumes represent traffic moving onto the HOV facilities in the peak direction at the extreme ends of the network and an average of traffic entering the HOV facility in the RTP area.

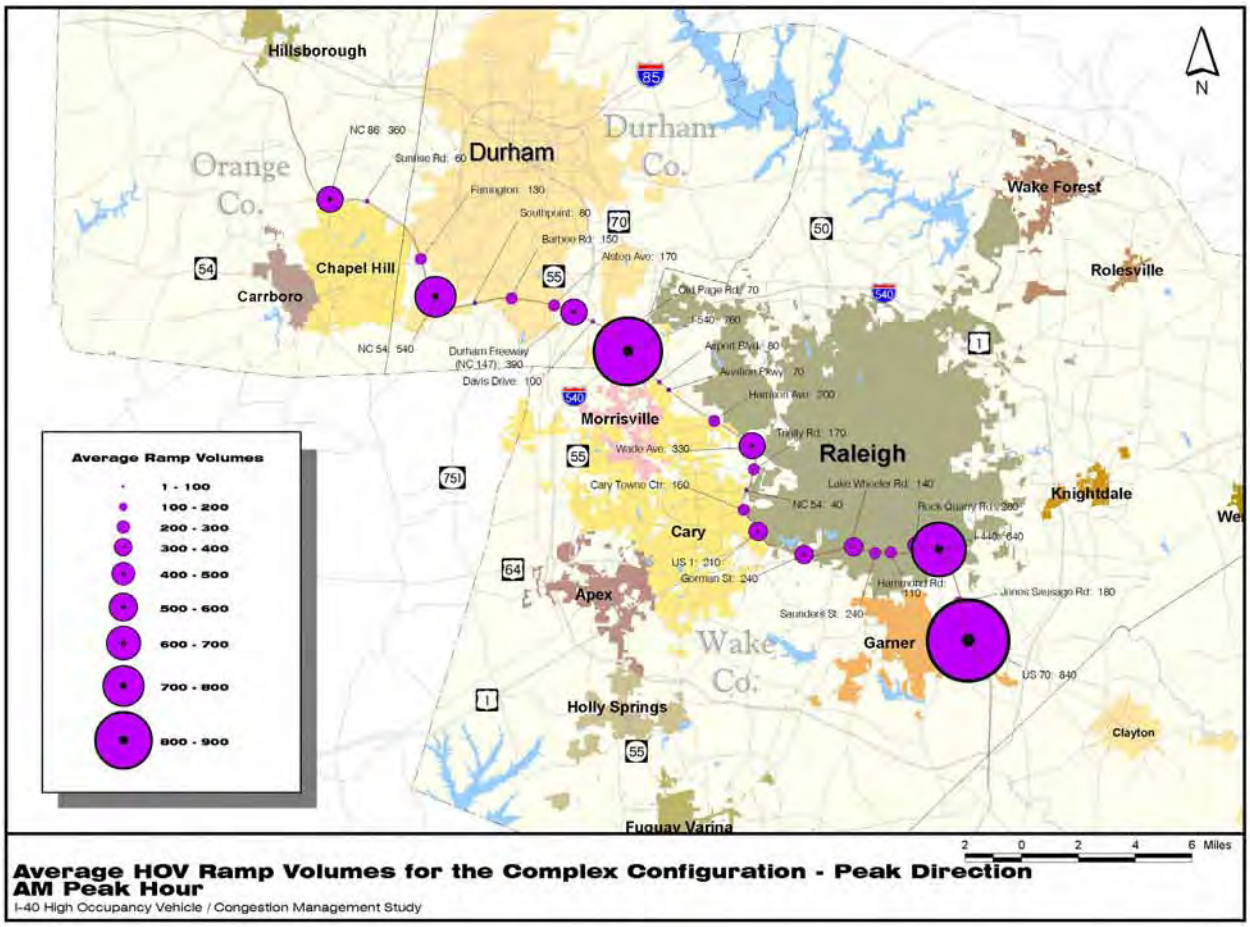
At some locations low demand ramps may not justify construction of an HOV access point. Specific points that could be considered for elimination might include Aviation Parkway, Airport Road, NC 54 in Cary, and the HOV-exclusive ramps that were added between existing interchanges (Sunrise Lane and Southpoint Road). The Modified Complex configuration (see Section 6.4) tests the impact of providing access at the six access points with the highest demand. These locations are shaded in Table 6-12.

Table 6-12 Complex HOV Ramp Volumes

HOV Access Location	Access type	AM Peak Hour Ramp Volume
Western access near NC 86	East only	480
Sunrise Lane	East only	60
South of US 15/US 501	East only	130
NC 54 at Farrington Road	East only	540
Southpoint Road (HOV only)	Both directions	80
NC 54 (HOV only) near Barbee Road	Both directions	150
Alston Avenue (HOV only)	Both directions	170
NC 147	Both directions	390
Davis Drive	Both directions	100
Old Page Road (HOV only)	Both directions	70
I-540	Both directions	760
Airport Road	Both directions	80
Aviation Parkway	Both directions	70
Harrison Avenue	Both directions	200
Wade Avenue	West only	330
Trinity Road	Both directions	170
NC 54 near Cary	West only	40
Cary Towne Parkway	West only	160
US 1/US 64	Both directions	210

As shown in Figure 6-20, HOV demand is not limited to I-40 between NC 86 and US 1/US 64. A high volume accesses the facility at the southeastern end of the study area (US 70). While the demand for HOV facilities is greatest in the RTP area, a substantial amount of that HOV traffic enters the I-40 corridor from the southeast. There are also high volumes accessing the facility between the I-440 split and Lake Wheeler Road. Note that the high volumes accessing the HOV facility in the westbound direction from the southeast end of the study area (US 70) primarily exit the facility before reaching RTP, reflecting a future need of HOV facilities east of US 1/ US 64.

Figure 6-20 AM Peak Hour HOV Ramp Volumes – Complex Configuration



Average HOV Ramp Volumes for the Complex Configuration - Peak Direction AM Peak Hour
I-40 High Occupancy Vehicle / Congestion Management Study

Visual Simulations of HOV Access Ramps

As shown in Appendix A, numerous interchange configurations were developed for the Complex configuration. These roadway drawings include multiple interchange concepts. For some concepts, visual simulations were developed to illustrate how specific access ramps and interchanges could appear in the future. Note that all simulations are preliminary and could change in final design. All sheet references apply to the Complex configuration interchange designs in Appendix A.

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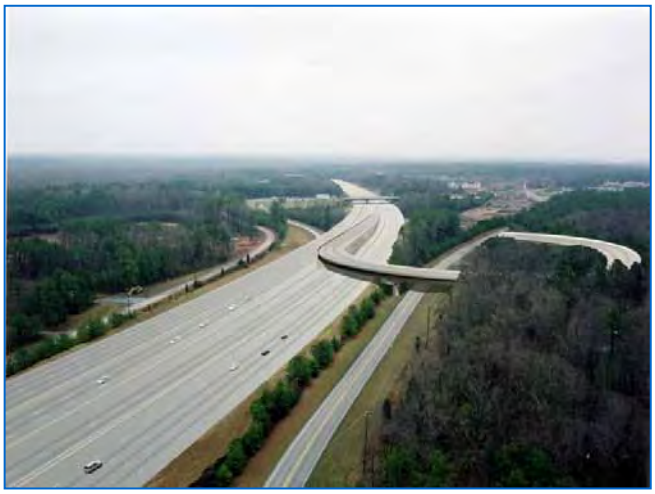
- Farrington Road (sheet 7A)



- NC 147 (sheet 14)

- I-540 (sheet 17)

- NC 54 near Cary (sheet 24)

6.3.3 Traffic and Operations

Level of Service Analysis

The FREEVAL model was run for the 2025 Complex HOV scenario to analyze freeway mainline traffic operations during AM and PM peak hours. Table 6-13 provides a summary of the projected mainline traffic volume and capacity analysis results in terms of V/C ratios and LOS categories. Figure 6-21 and Figure 6-22 depict the V/C results of the freeway mainline capacity analysis on color coded maps to highlight the congested corridor segments by time of day and by direction of travel.

These maps and the LOS values indicate that the highest levels of congestion will occur on I-40 between NC 147 and I-540. The Complex configuration does provide an additional general purpose/Express lane through this section to relieve congestion. Although it is not captured in the LOS rating, the HOV/Express lanes will provide significant relief in the future by reducing the flow density from highly unstable conditions to borderline unstable conditions, and thus reducing the frequency of flow breakdowns.

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Table 6-13 Complex Configuration LOS Analysis Results (FREEVAL)

Section Type	2025 Complex AM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	6,030	0.88	D	3,910	0.60	C
US 15/US 501 to NC 54	5,110	0.75	D	4,230	0.65	C
NC 54 to NC 751	7,000	1.02	D	5,130	0.78	D
NC 751 to Fayetteville Road	7,070	1.03	E	5,060	0.77	D
Fayetteville Road to NC 55	7,320	1.07	F	5,250	0.80	D
NC 55 to NC 147	6,920	1.11	F	5,910	1.17	F
NC 147 to Davis Drive	6,920	1.01	F	5,970	0.88	F
Davis Drive to Miami Blvd	6,720	0.74	F	8,170	1.09	F
Miami Blvd to Page Road	6,930	0.84	F	9,210	1.10	F
Page Road to I-540	7,170	1.22	F	10,450	1.33	F
I-540 to Airport Blvd	7,290	0.70	C	7,760	0.91	F
Airport Blvd to Aviation Pkwy	5,540	0.63	C	6,920	0.76	F
Aviation Pkwy to Harrison Ave	6,560	0.75	D	8,730	0.96	F
Harrison Ave to Wade Avenue	6,040	0.69	D	8,650	0.76	C
Wade Avenue to NC 54	3,740	0.43	B	5,460	0.80	D
NC 54 to Cary Towne Boulevard	4,450	0.57	C	6,180	0.80	D
Cary Towne Boulevard to US 1/US 64	5,430	0.85	D	6,990	0.77	F

Section Type	2025 Complex PM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	4,550	0.70	C	5,620	0.82	D
US 15/US 501 to NC 54	4,410	0.67	C	5,170	0.76	D
NC 54 to NC 751	5,750	0.88	D	6,100	0.89	E
NC 751 to Fayetteville Road	5,690	0.87	D	6,280	0.92	E
Fayetteville Road to NC 55	5,720	0.87	F	6,520	0.95	D
NC 55 to NC 147	5,890	1.00	F	6,800	1.27	F
NC 147 to Davis Drive	6,720	1.03	F	5,570	0.71	F
Davis Drive to Miami Blvd	7,360	0.84	F	6,750	0.84	F
Miami Blvd to Page Road	9,050	1.22	F	7,140	0.86	E
Page Road to I-540	10,200	1.99	F	7,320	0.96	F
I-540 to Airport Blvd	7,740	0.64	C	7,090	1.08	D
Airport Blvd to Aviation Pkwy	6,300	0.69	C	5,460	0.63	F
Aviation Pkwy to Harrison Ave	8,140	0.89	E	6,810	0.78	D
Harrison Ave to Wade Avenue	7,980	0.88	F	6,620	0.61	D
Wade Avenue to NC 54	5,090	0.56	C	4,210	0.64	C
NC 54 to Cary Towne Boulevard	5,940	0.73	D	4,770	0.65	C
Cary Towne Boulevard to US 1/US 64	6,730	0.91	E	5,720	0.65	C

Notes: V/C = volume to capacity ratio.
There is no direct correlation between V/C ratio and LOS.
Volumes are in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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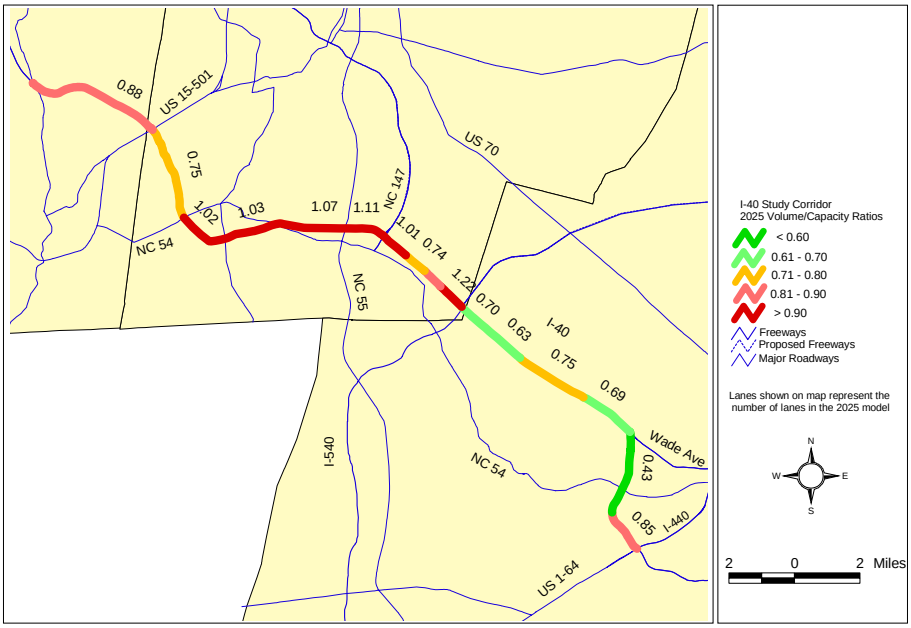
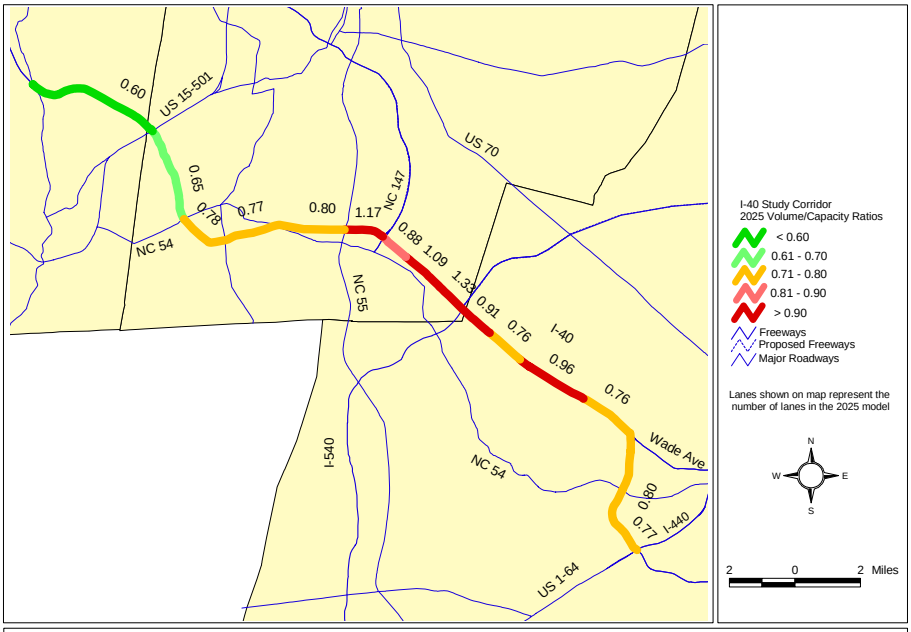
Figure 6-21 AM Peak Hour V/C Ratios – Complex Configuration



Complex Eastbound AM Volume/Capacity (V/C) Ratios



Complex Westbound AM Volume/Capacity (V/C) Ratios

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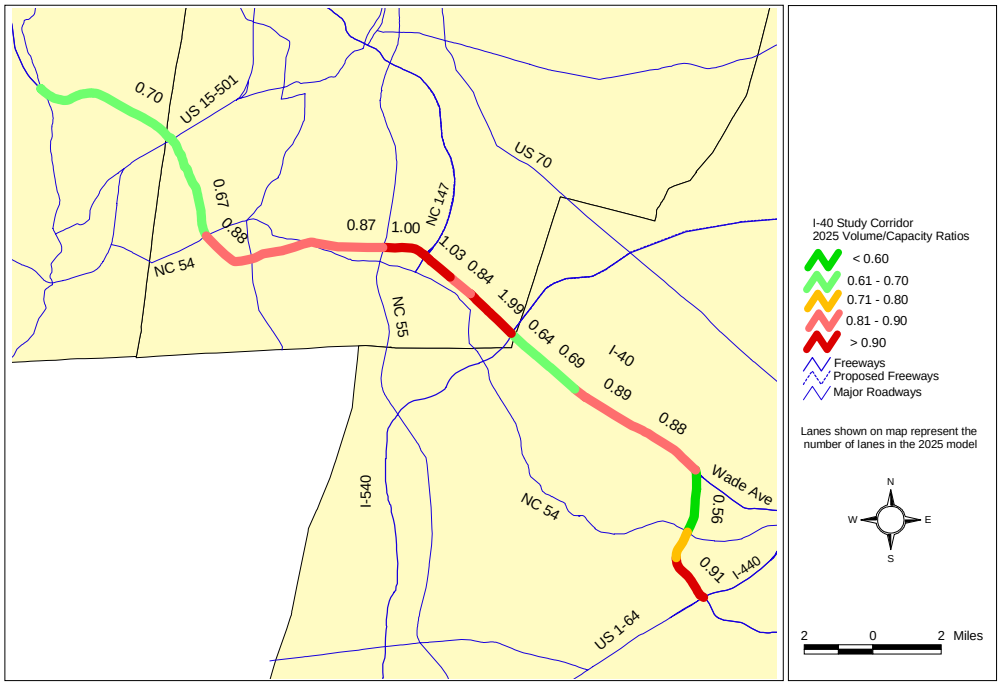
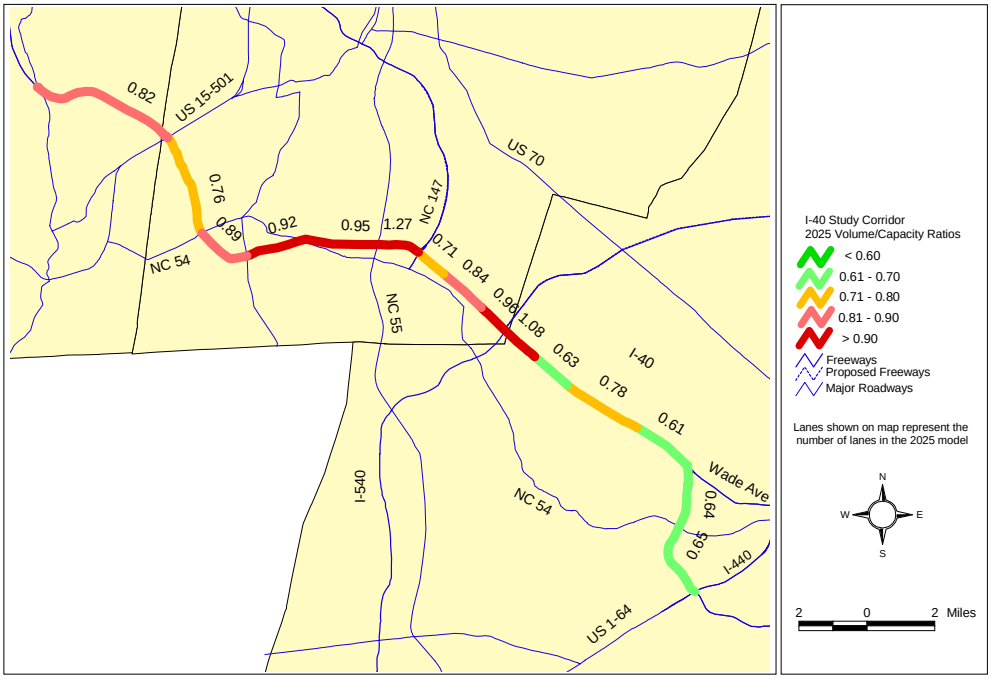
Figure 6-22 PM Peak Hour V/C Ratios – Complex Configuration



Complex Eastbound PM Volume/Capacity (V/C) Ratios



Complex Westbound PM Volume/Capacity (V/C) Ratios

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Travel Time Analysis

The introduction of direct access ramps between I-40 and I-540 in all directions would require the interchange to be significantly modified. This modification would allow the improvement of the general purpose ramp connections as well as the HOV access. One design scheme (included in the FRESIM analysis model) would add a flyover from westbound I-40 to southbound I-540, which would eliminate the weaves between loops and ramps on both the I-40 and I-540 mainlines.

The FRESIM analysis results, including the aforementioned I-540 interchange modifications and bottleneck improvements identified in the baseline network, showed improved general purpose lane travel time. Table 6-14 shows the travel time savings in the HOV lane compared to the mainline. It is evident that the HOV lane would provide a significant travel time advantage over the GP lanes in the peak directions of travel – inbound to RTP in the morning rush hour and outbound from RTP in the afternoon rush hour.

Table 6-14 Travel Time Savings in the HOV Lanes

Segment	Trip Length (miles)	Travel Time savings (min:sec)	
		AM Peak	PM Peak
Eastbound I-40			
1. Western – NC 86 to NC 54	6.9	1:31	0:23
2. Western RTP – NC 54 to Durham Fwy	6.4	3:50	3:40
3. Eastern RTP – Durham Fwy to Aviation Pkwy	5.6	3:14	9:12
4. Airport – Aviation Pkwy to Wade Ave	4.1	0:06	0:21
5. Eastern – Wade Ave to US 1/US 64	3.8	0:10	0:20
EASTBOUND TOTAL	**26.8**	**8:52**	**13:55**
Westbound I-40			
1. Eastern – US 1/US 64 to Wade Ave	3.8	0:08	0:09
2. Airport – Wade Ave to Aviation Pkwy	4.1	1:21	0:12
3. Eastern RTP – Aviation Pkwy to Durham Fwy	5.6	3:43	0:21
4. Western RTP – Durham Fwy to NC 54	6.4	0:06	0:02
5. Western – NC 54 to NC 86	6.9	0:15	0:18
WESTBOUND TOTAL	**26.8**	**5:32**	**1:02**

Delay Analysis

The FRESIM microsimulation model was used to analyze the traffic operations for the full I-40 corridor from NC 86 to US 1/US 64 and to understand how the Complex configuration would handle the projected demand. The goal was to simulate specific traffic bottlenecks

at higher levels of detail than the travel demand model in order to produce more realistic estimates of total delay, unit delay and average speed along the corridor. The results of this micro-simulation analysis are summarized and compared to the No-Build statistics in Table 6-15. The data is for I-40 exclusively and does not reflect other freeways, arterials or roadways in the region.

Table 6-15 Complex Configuration Operations on I-40

I-40 Measures of Effectiveness	Baseline	Complex	Percent Change
AM Peak Hour			
Vehicle-Miles Traveled (VMT)	323,461	345,287	6.7%
Average Speed in Network, mph	38.9	43.0	10.5%
Total Delay Time, vehicle-hours	3,298	2,517	-23.7%
Unit Delay Time, sec/veh-mile	36.6	26.4	-27.9%
PM Peak Hour			
Vehicle-Miles Traveled (VMT)	324,830	370,949	+14.2%
Average Speed in Network, mph	38.8	46.6	+20.3%
Total Delay Time, vehicle-hours	3,350	2,051	-38.8%
Unit Delay Time, sec/veh-mile	37.2	19.8	-46.8%

As illustrated in the table, the Complex configuration would reduce corridor delay and improve average speed during AM and PM peak hours, while accommodating a higher VMT demand. These operational benefits are more pronounced during the PM peak hour, as it shows 47 percent reduction in travel delay for each vehicle traveling one mile along the corridor.

6.3.4 Environmental Screening

An environmental screening for the Complex configuration was conducted to identify potential environmental effects that could result from the proposed improvements. Data for the environmental screening was compiled through background research of existing information. Field data collection was not included as part of the environmental screening. Table 6-16 summarizes the major findings of the environmental screening for the Complex HOV configuration.

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Table 6-16 Environmental Screening for the Complex Configuration

Resource	Screening Results for the I-40 HOV Complex Configuration
Stream Crossings	53 crossings
Wetlands	12 potential encroachments
Protected/Public Lands	No encroachments
Threatened & Endangered Species	No known impacts; encroachment in one Significant Natural Heritage Area
Archaeological Sites	54 sites within one-half mile
Historic Sites	10 sites with some designation within one mile
Community Impacts	Up to 19 property encroachments

6.3.5 Roadway Design and Cost Estimate

Roadway designs for the Complex configuration were developed and are shown in Appendix A. The following sections focus on these roadway elements:

- Bridge Design and Construction
- Construction Phasing
- Cost Estimates

Bridge Design and Construction

Using the typical sections for the Complex configuration that are presented in the previous section, the following bridge design impacts were identified:

- Based upon contour maps along the I-40 corridor, retaining walls may be necessary in several locations where existing slopes are 2:1 and where right-of-way boundaries are close to the toe of the slope.
- Eighteen existing bridges on I-40 would be widened.
- Twenty-four existing bridges over I-40 would be replaced.
- Twenty-four new bridges would be constructed.
- Several box culverts throughout the corridors would likely require extensions.
- Interchange entrance and exit ramps would require adjustment for widening beyond the existing cut and fill slopes.
- Several (18) new interchanges are proposed to provide direct access to the HOV lanes.

Each of the five corridor segments and the bridge construction impacts associated with the Complex HOV configuration are shown in Table 6-17.

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Table 6-17 Bridge Adjustments for Complex HOV Configuration

Location	Change End Bent	Widen Bridge	Reconstruct Bridge	New Bridge
Western Corridor	0	0	5	0
RTP Corridor - West	0	11	7	3
RTP Corridor - East	0	1	8	17
Airport Corridor	0	2	2	1
Eastern Corridor	0	4	2	3
TOTAL	**0**	**18**	**24**	**24**

Construction Phasing

A preliminary evaluation of construction phasing for the Complex configuration indicates that it could be implemented in a phasing pattern that allows building the middle portion first. Because there would be high HOV traffic on the RTP-East Corridor during peak commuter hours, building the HOV lanes in the RTP-East/Airport Corridor first would be desirable. This strategy avoids the situation of having any weaves in and out of the HOV lanes in the middle of the corridor and thus, would reduce the potential of creating traffic bottlenecks due to construction. In this phasing strategy the only entrance to the barrier separated HOV lanes would be at the ends of the RTP Corridor -East.

The Complex configuration would require rebuilding all existing grade separations between NC 86 and Harrison Avenue. Depending on the alternative design at or between interchanges; temporary detours would be needed to maintain traffic across grade separations and along I-40. The widening of I-40 from NC 86 to Wade Avenue would require median detours with alternating lane closures to tie-in ramps and loops to existing lanes. The complexity at the I-540 interchange would require the interchange to be built in two stages. The segment between Wade Avenue and Avent Ferry Road would result in the least traffic disturbance. Most of the existing grade separations would remain in place. The work would begin with the median improvements without interfering with traffic except at the Cary Towne Center Parkway interchange. This interchange would require a new grade separation with traffic being detoured on a temporary grade separation along Cary Towne Center Boulevard.

Cost Estimates

Functional design cost estimates were developed for five corridors as shown in Table 6-18. Cost estimates were based on functional design rather than a per mile cost. Quantities for pavement and structures were estimated based on geometric design from the 200 scale plans. Unit costs were developed and applied in accordance with NCDOT procedures for preliminary design. Costs are first estimated in 2002 dollars and then inflated to year 2025 using an inflation rate of 2.7 percent per year. The costs include engineering and other factors as outlined in Section 6.2 and do not include right-of-way costs.

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Table 6-18 Complex Configuration Estimated Cost (in millions)

Project	Estimated 2002 Cost of Construction	Estimated 2025 Cost of Construction
Western Corridor (NC 86 to NC 54)	$ 79M	$ 146M
RTP Corridor – West (NC 54 to NC 147)	$ 127M	$ 234M
RTP Corridor – East (NC 147 to Aviation Pkwy)	$ 293M	$ 541M
Airport Corridor (Aviation Pkwy to Wade Ave)	$ 53M	$ 98M
Eastern Corridor (Wade Ave to US 1/US 64)	$ 97M	$ 179M
TOTAL	**$ 649M**	**$1,198M**

6.4 Modified Complex Configuration

The Modified Complex configuration is a variation of the Complex configuration, and assumes barrier-separated HOV lanes with six HOV-only access points or interchanges. These six interchanges are a subset of the 18 access locations for the Complex configuration. The proposed access points are the I-40 access points with the highest projected HOV demand; NC 86, NC 54, NC 147, I-540, Wade Avenue and US 1/US 64. For traffic forecasting purposes, the HOV lanes were analyzed on a system-wide basis along I-40 from NC 86 (Mile post 266) to US 70 (Mile post 306) as well as on I-540 from US 64 to NC 50. The functional design and operational analysis was limited to I-40 between NC 86 and US 1/US 64.

The following section, 6.4.1, describes in more detail the typical sections applied in the Modified Complex configuration. Section 6.4.2 describes the implications of this design for travel demand on the HOV facility as well as on general purpose lanes and adjacent roads. Section 6.4.3 describes the traffic operations conditions for the Modified Complex configuration. Section 6.4.4 examines environmental issues. The construction implications are described in Section 6.4.5.

6.4.1 Typical Sections

Similar to the Complex, the Modified Complex configuration is also considered a higher operational form of HOV than the Simple configuration. It provides exclusive HOV lanes with limited access along the corridor through HOV-only interchanges and direct access ramps at high-demand areas. Barrier separation would require significant offsets for safety, enforcement, and sight distance, and weaves for ramp access.

Note that the six access points identified in the Modified Complex configuration are identical to the locations and interchange layouts as the Complex configuration. The Complex configuration contains 12 additional access locations. The six proposed interchanges common to both configurations are located at high volume access points and freeway-to-freeway connections. The interchanges include:

- NC 86 – Interstate approach from west
- NC 54 near Chapel Hill – High volume connection
- NC 147 – Freeway-to-freeway
- I-540 – Freeway-to-freeway
- Wade Avenue – Freeway-to-freeway
- US 1/US 64 – Interstate approach from east

All of these connections are of a higher design level than the single and dual “T-Ramps” that occur at the numerous arterial access interchanges common to the Complex configuration. The higher level of design accommodates dedicated HOV access at high volume interchange locations and provides dedicated freeway-to-freeway HOV movements, and Express lane access through RTP.

The Modified Complex typical section includes GP lanes plus a 12-foot HOV lane with a minimum 10-foot lateral clearance for barrier separation and a minimum 14-foot enforcement shoulder. The configuration requires widening of the existing I-40 footprint on

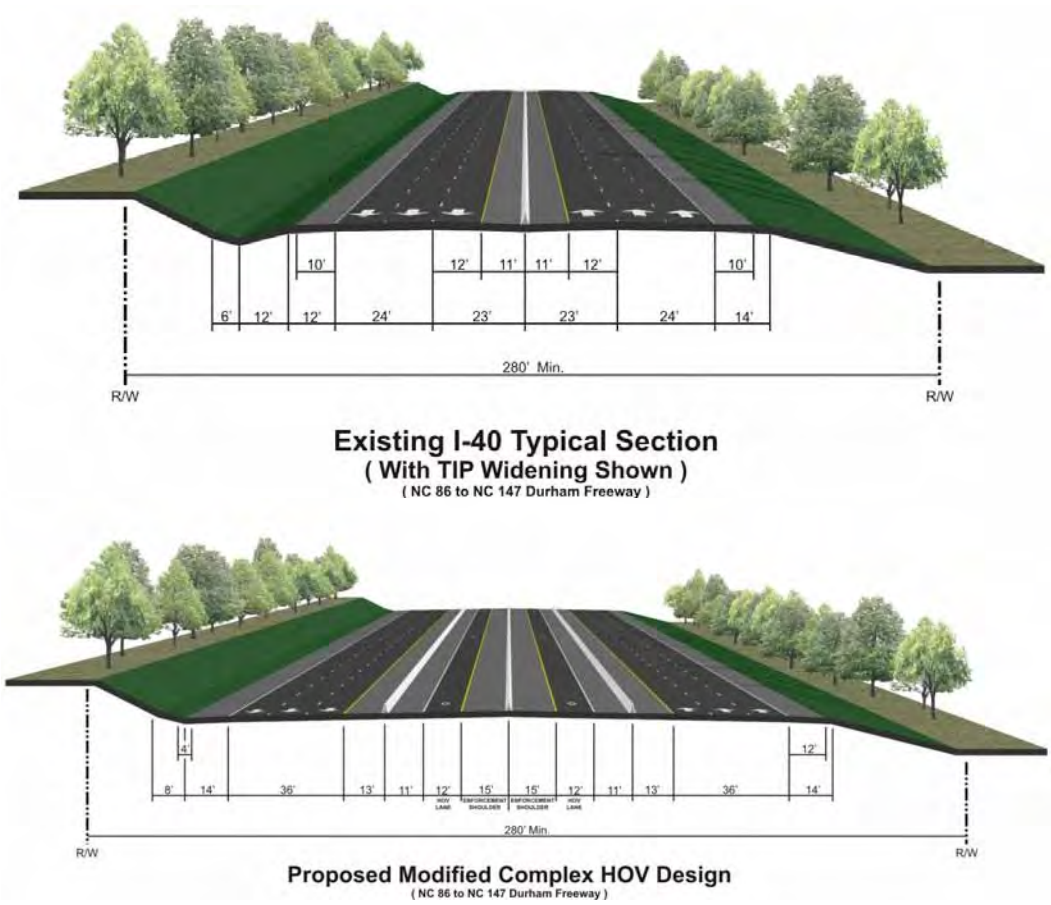
each side throughout the corridor, thus necessitating changes to the existing cut and fill slopes. Cut and fill slopes would be modified to remain within existing NCDOT right-of-way whenever possible. When slopes required to remain within right-of-way exceed acceptable limits, (2:1 unless otherwise approved by geotechnical engineers), retaining walls would be used.

The typical cross-sections of the Modified Complex HOV configuration are same as the Complex configuration for different I-40 corridor sections. These typical cross-sections are illustrated again in the following sections for the readers' convenience.

Western Corridor and RTP Corridor-West: NC 86 to NC 147

As shown in Figure 6-23, the Modified Complex configuration from NC 86 to NC 147 expands the existing three GP lanes per direction to three GP lanes plus one HOV lane per direction. It includes six 12-foot general purpose lanes plus two 12-foot HOV lanes with a 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance). A 30-foot median with barrier will provide 14-foot enforcement shoulders. A 12-foot paved shoulder is also provided on the outside.

Figure 6-23 Existing and Modified Complex Configuration Typical Sections Between NC 86 and NC 147



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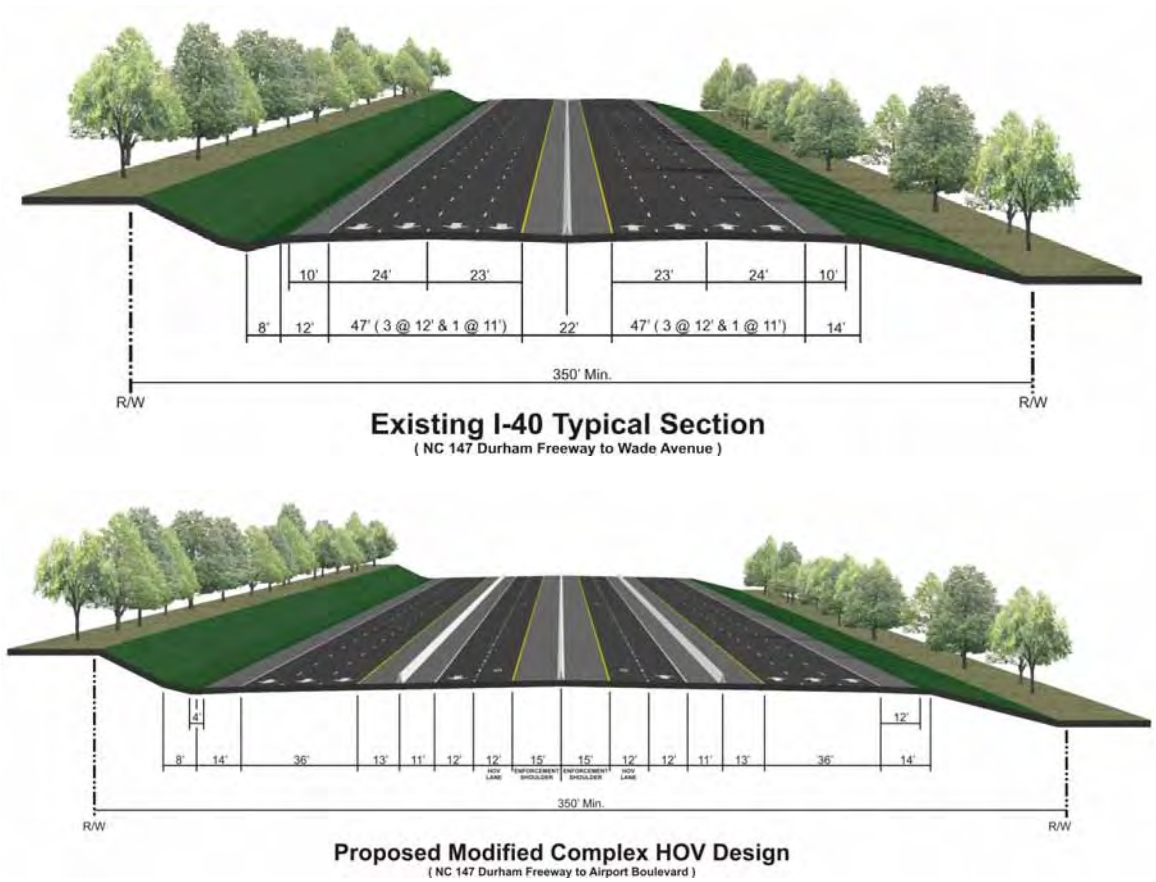
RTP Corridor-East and Airport Corridor: NC 147 to Wade Avenue

Two typical sections are provided between NC 147 and Wade Avenue – a shared HOV/ Express lane section between NC 147 and Airport Boulevard through RTP and an HOV-only section between I-540 and Wade Avenue.

As shown in Figure 6-24, the Modified Complex configuration from NC 147 to Airport Boulevard expands the existing four GP lanes per direction to three GP lanes plus one HOV lane and one Express lane per direction. It includes six 12-foot general purpose lanes plus two 12-foot HOV lanes and two 12-foot express lanes with a 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance). A 30-foot median with barrier provides 14-foot enforcement shoulders. A 12-foot paved shoulder is also provided on the outside.

East of RTP between Airport Boulevard and Wade Avenue, the Express lane is removed. The existing four GP lanes per direction are widened to include one HOV lane in addition to the four existing GP lanes. The section is similar to Figure 6-25 with four GP lanes.

Figure 6-24 Existing and Modified Complex Configuration Typical Sections Between NC 147 and Wade Avenue



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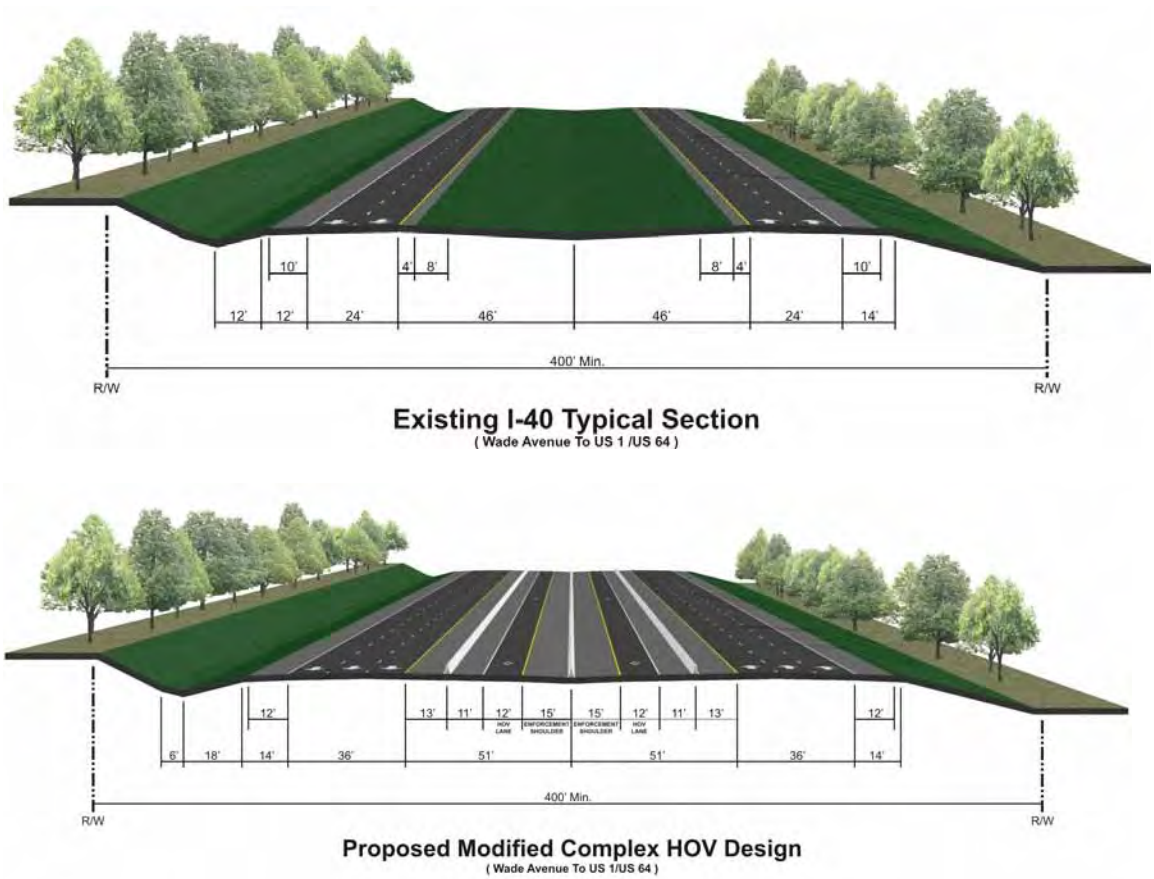
Eastern Corridor: Wade Avenue to US 1/ US 64

As shown in Figure 6-25, the Modified Complex configuration from Wade Avenue to US 1/ US 64 proposes expanding the existing two GP lanes per direction to three GP lanes plus one separated HOV lane. It includes six 12-foot general purpose lanes plus two 12-foot HOV lanes. A 24-foot barrier separation on each side (12-foot median shoulder, 2-foot barrier, and 10-foot lateral barrier clearance) and a 30-foot median with barrier to allow 14-foot enforcement shoulders are provided. A 12-foot paved shoulder is also provided on the outside.

Figure 6-25 Existing and Modified Complex Configuration Typical Sections Between Wade Avenue and US 1/US 64



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6.4.2 Travel Demand

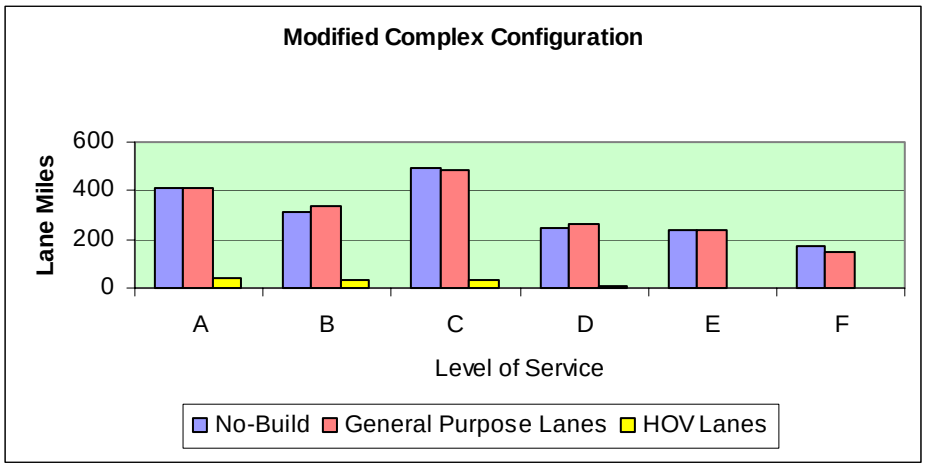
The following sections describe the system-wide and facility-specific measures of effectiveness as related to travel demand for the Modified Complex configuration.

System-wide Level of Service

The Modified Complex configuration provides improved access to the HOV facility at selected locations, which results in an increase in HOV vehicles and the total number of people moved through the I-40 corridor as compared to the No-Build conditions. However, these increases in demand are smaller than those for the Complex configuration due to reduced number of HOV access points.

Figure 6-26 illustrates the distribution of lane-miles traveled by LOS category (during AM four-hour peak period in year 2025) for the Modified Complex configuration when compared to the No-Build. The provision of HOV lanes results in a 16 percent reduction in freeway lane-miles operating at LOS F as compared with the No-Build configuration. Similar to other build configurations, HOV lane-miles traveled are primarily in the LOS D or better categories.

Figure 6-26 Freeway Lane-Miles Traveled by Level of Service



Systemwide Delays

Figure 6-27, Figure 6-28, and Figure 6-29 illustrate the performance of the Modified Complex configuration, as compared to the No-Build, using three additional travel demand-model based indicators – VMT, Hours of Person Delay and Average Speed. Primary conclusions from the figures include:

- The Modified Complex configuration is projected to increase VMT by 0.2 percent due to changes in trip origin-destination patterns resulting from the introduction of HOV.
- Despite the increase in VMT, network delay would decrease by 4.6 percent.
- Average travel speed for the entire roadway network would improve by 1.6 percent as a result of the added capacity in the managed lanes.

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In general, the system-wide travel demand measures for the Modified Complex reflect that this configuration has six access points, fewer than either the Simple (continuous access) or the Complex (18 access points) configurations. As a result, the travel demand is slightly lower than the Simple or the Complex configuration. However, these travel demand measures do not address the operational issues or specific bottlenecks that arise due to sharp spikes or heavy weaving causing breakdowns in traffic flow. The traffic operational issues are addressed in Section 6.4.3.

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Figure 6-27 Comparison of Modified Complex Configuration Vehicle Miles Traveled (AM Peak)

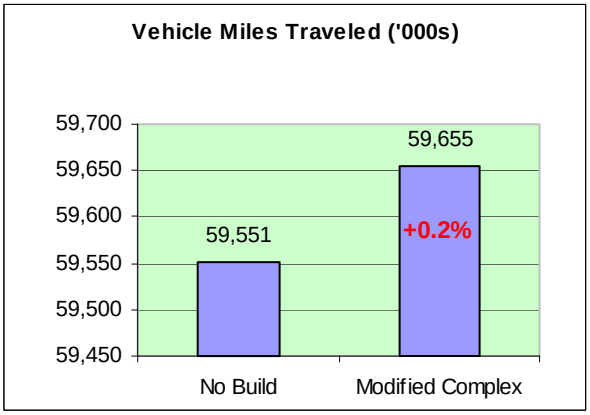


Figure 6-28 Comparison of Modified Complex Configuration Hours of Delay (AM Peak)

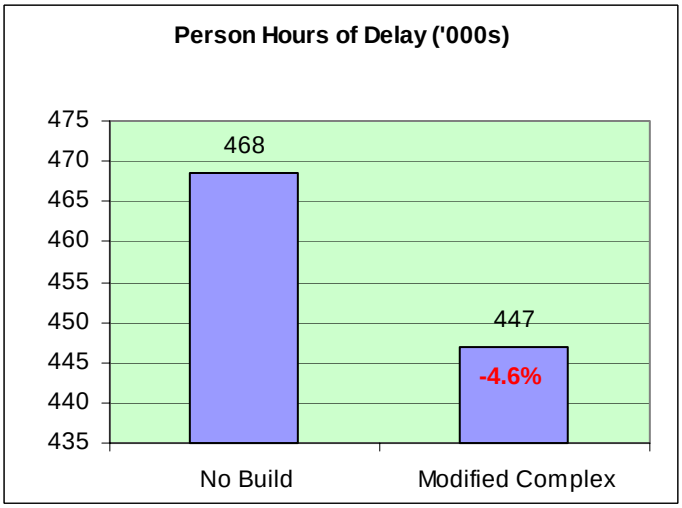
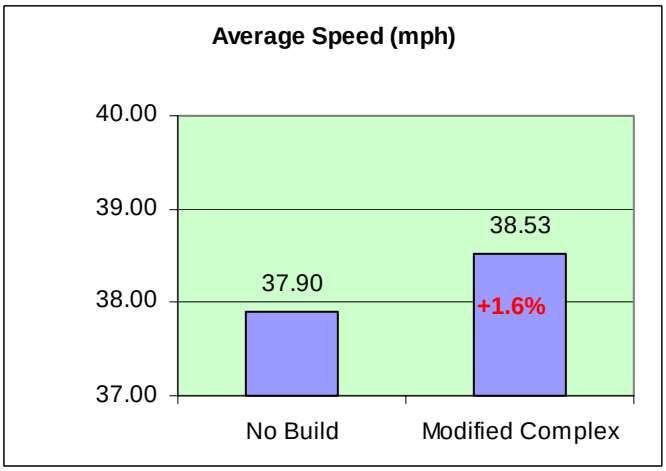


Figure 6-29 Comparison of Modified Complex Configuration Average Speed (AM Peak)



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Shifts in Traffic Flows on Local Roads

The provision of additional HOV and GP lane capacity will result in changes in travel flow patterns on the local roadway network. Specific roadway segments could show relatively high shifts in traffic volumes, especially around new or enhanced access points and along roadways parallel to the I-40 corridor. These traffic shifts tend to form a ripple-effect through the network, with higher impacts near the immediate vicinity of the new configuration.

The specific traffic shifts for the Modified Complex configuration were not analyzed and would need to be evaluated if this configuration is carried forward to the next phase of study. In general, however, the Modified Complex configuration could show a lower potential for traffic shifts from adjacent roads than the Complex configuration since there are fewer access points to the HOV lanes.

Number of Vehicles Moved Through the Corridor by Segment

Table 6-19 shows, by segment, the projected number of SOVs and HOVs on I-40 for the Modified Complex configuration. The table is divided into two sections. First, a corridor summary of the projected traffic volumes is shown for each of the five study sections as well as I-40 south of the study area. A more detailed segment summary is then presented between each interchange. Specific observations from the table include:

- HOV demand is projected to increase considerably in the Modified Complex configuration compared to the No-Build, approximately 35 percent in the morning peak hour. As expected, this is less than the 46 percent increase in the Complex configuration.
- In 2025, HOV usage is projected to be highest in the RTP Corridor-East. With the Express lanes in place, approximately 2,900 vehicles per hour travel in each direction. HOV traffic makes up approximately 40 percent of this traffic.
- The Airport and Eastern Corridor (in addition to the section between US 1/US 64 and US 70) have higher peak period directional flows than the RTP-West or the Western Corridor.
- Both the RTP-East and the RTP-West Corridors have more balanced HOV flows (approximately 60 - 40 percent splits) as compared with sections further from Research Triangle Park (approximately 70 – 30 percent splits).
- As in other configurations, some HOV vehicles will continue to use the GP lanes. These vehicles represent trips that do not realize sufficient time savings by using the HOV lanes and thus remain in the GP lanes. As a result of the increased spacing between access points, a lower percentage of HOV vehicles use the HOV lane as compared with the Simple or Complex configurations.

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Table 6-19 Vehicles on I-40 by Segment and % HOV -- Modified Complex Configuration

Segment	Eastbound					Westbound				
	General Purpose Lanes		HOV Facility		% HOV	General Purpose Lanes		HOV Facility		% HOV
	SOV	HOV	SOV	HOV		SOV	HOV	SOV	HOV	
Corridor Summary										
Western Corridor	5,000	480	0	430	7.3%	3,540	390	0	180	4.4%
RTP Corridor—West	6,810	450	0	1,010	12.2%	4,870	520	0	610	10.2%
RTP Corridor—East	6,410	690	1,140	900	9.8%	7,490	1,070	1,790	1,200	10.4%
Airport Corridor	5,790	660	0	670	9.4%	8,250	890	0	920	9.1%
Eastern Corridor	3,980	550	0	280	5.8%	5,410	620	0	710	10.5%
US 1/US 64 to US 70	4,560	450	0	710	12.3%	6,110	810	0	1,400	16.8%
Segment Summary										
NC 86 to US 15/US 501	5,200	520	0	430	7.0%	3,330	360	0	180	4.7%
US 15/US 501 to NC 54	4,720	430	0	430	7.7%	3,850	440	0	180	4.0%
NC 54 to NC 751	6,720	440	0	1,010	12.4%	4,770	430	0	610	10.5%
NC 751 to Fayetteville	6,830	420	0	1,010	12.2%	4,670	440	0	610	10.7%
Fayetteville to NC 55	6,960	470	0	1,010	12.0%	4,790	510	0	610	10.3%
NC 55 to NC 147	6,570	480	0	1,010	12.5%	5,410	750	0	610	9.0%
NC 147 to Davis	6,910	570	1,140	1,070	11.0%	5,090	990	1,790	1,410	15.2%
Davis to Miami	6,650	600	1,140	1,070	11.3%	7,520	1,270	1,790	1,410	11.8%
Miami to Page	6,740	660	1,140	1,070	11.1%	8,960	1,490	1,790	1,410	10.3%
Page to I-540	6,850	720	1,140	1,070	10.9%	10,120	1,680	1,790	1,410	9.4%
I-540 to Airport	6,600	950	0	670	8.2%	7,320	760	0	920	10.2%
Airport to Aviation	5,180	560	0	670	10.5%	6,850	640	0	920	10.9%
Aviation to Harrison	6,080	690	0	670	9.0%	8,290	910	0	920	9.1%
Harrison to Wade	5,410	620	0	670	10.0%	8,200	870	0	920	9.2%
Wade to NC 54	3,450	400	0	280	6.8%	4,980	490	0	710	11.5%
NC 54 to Cary Towne Center	3,940	540	0	280	5.9%	5,500	640	0	710	10.4%
Cary Towne Center to US 1/US 64	4,840	780	0	280	4.7%	6,010	810	0	710	9.4%
US 1/US 64 to Gorman	4,740	370	0	860	14.4%	6,130	440	0	1,390	17.5%
Gorman to Lake Wheeler	4,680	320	0	700	12.3%	5,970	450	0	1,310	16.9%
Lake Wheeler to South Saunders	5,260	380	0	770	12.0%	6,860	790	0	1,630	17.6%
South Saunders to Hammond	4,420	350	0	690	12.6%	6,600	1,180	0	1,080	12.2%
Hammond to Rock Quarry	5,100	430	0	800	12.6%	7,410	1,460	0	1,170	11.7%
Rock Quarry to I-440 split	4,870	430	0	750	12.4%	6,910	1,060	0	1,660	17.2%
I-440 split to Jones Sausage	4,290	430	0	760	13.9%	5,310	860	0	1,560	20.2%
Jones Sausage to US 70	3,770	780	0	360	7.3%	5,410	880	0	1,360	17.8%

Note: Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Number of People Moved Through The Corridor By Segment

Table 6-20 translates the number of vehicles on each segment of I-40 into number of people by applying the average auto occupancy for carpools to the HOV vehicles. A review of the analysis indicates:

- There is a substantial increase in the number of people moved through the RTP Corridor-East under the Modified Complex configuration, especially between Davis Drive and I-540. The RTP Corridor-East is projected to carry 3,740 additional persons per hour, an 18 percent increase compared to the No-Build. The increase in person-flow on the segment between Davis Drive and I-540 is approximately 22 percent.
- The Airport Corridor (in addition to the section between US 1/US 64 and US 70) has higher peak period directional flows than all corridors except the RTP Corridor-East.
- The Modified Complex configuration results in greater flows on the RTP Corridor- West than the Eastern Corridor. The primary reason is that the only HOV access from the Modified Complex configuration to an arterial occurs at NC 54. NC 54 directly loads onto the Western Corridor.

Access Points and HOV Ramp Volumes

The Modified Complex configuration incorporates HOV access points at only six major interchange locations in order to evaluate a more realistic concept of providing managed lanes through the congested I-40 corridor. Three are at freeway to freeway system interchanges, two are at the western and eastern termini of the HOV lanes, and one (NC 54 at Farrington Road) is at a high volume service interchange.

Table 6-21 shows the average volume of HOV traffic on ramps accessing the HOV lanes in the AM peak hour in the peak direction. The volumes represent traffic moving onto the HOV facilities in the peak direction at the extreme ends of the network and an average of traffic entering the HOV facility in the RTP area.

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Table 6-20 Number of People Moved on I-40 - Modified Complex Configuration

Segment	Eastbound			Westbound		
	No-Build	Modified Complex	Increase	No-Build	Modified Complex	Increase
Corridor Summary						
Western Corridor	6,570	7,270	690	4,730	4,960	230
RTP Corridor—West	8,900	10,430	1,530	6,750	7,670	920
RTP Corridor—East	9,730	10,990	1,260	11,630	14,120	2,490
Airport Corridor	8,320	9,090	770	11,680	12,740	1,060
Eastern Corridor	5,570	6,020	450	7,340	8,700	1,360
US 1/US 64 to US 70	6,840	7,420	570	9,640	11,570	1,930
Segment Summary						
NC 86 to US 15/US 501	6,820	7,550	730	4,440	4,670	230
US 15/US 501 to NC 54	6,210	7,850	640	5,160	5,380	220
NC 54 to NC 751	8,990	10,310	1,320	6,540	7,340	800
NC 751 to Fayetteville	8,910	10,370	1,460	6,580	7,270	690
Fayetteville to NC 55	9,090	10,620	1,530	6,790	7,560	770
NC 55 to NC 147	8,380	10,260	1,880	7,140	8,780	1,640
NC 147 to Davis	10,790	12,110	1,320	9,840	12,820	2,980
Davis to Miami	10,520	11,920	1,400	12,380	15,940	3,560
Miami to Page	10,770	12,160	1,390	14,370	17,930	3,560
Page to I-540	11,420	12,420	1,000	16,590	19,560	2,970
I-540 to Airport	9,250	10,610	1,360	9,990	11,480	1,490
Airport to Aviation	7,130	8,220	1,090	9,260	10,710	1,450
Aviation to Harrison	8,580	9,450	870	11,770	12,820	1,050
Harrison to Wade	7,960	8,600	640	11,560	12,630	1,070
Wade to NC 54	4,820	5,130	310	6,550	7,950	1,400
NC 54 to Cary Towne Center	5,450	5,970	520	7,540	8,840	1,300
Cary Towne Center to US 1/US 64	6,840	7,460	620	8,430	9,770	1,340
US 1/US 64 to Gorman	6,070	7,780	710	8,560	10,660	2,100
Gorman to Lake Wheeler	6,590	7,210	620	8,520	10,330	1,810
Lake Wheeler to South Saunders	7,540	8,110	570	11,250	12,690	1,600
South Saunders to Hammond	6,470	6,990	520	10,320	12,190	1,870
Hammond to Rock Quarry	7,530	8,140	610	11,430	13,920	2,490
Rock Quarry to I-440 split	7,230	7,790	560	11,510	13,640	2,130
I-440 split to Jones Sausage	6,800	7,240	440	9,330	11,300	1,970
Jones Sausage to US 70	6,080	6,590	510	9,430	10,960	1,530

Note: Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Table 6-21 Modified Complex HOV Ramp Volumes

HOV Access Location	Access type	AM Peak Hour Ramp Volume
Western access near NC 86	East only	430
NC 54 at Farrington Road	East only	580
NC 147	Both directions	310
I-540	Both directions	280
Wade Avenue	West only	210
US 1/US 64	Both directions	390

Visual Simulation of HOV Access Ramps

As stated earlier, the Modified Complex configuration is similar to the Complex configuration in terms of design criteria. Visual simulations for I-540 and NC 147 are presented in Section 6.3. In addition, a potential layout for an access point from NC 54 via Farrington Road is presented. Note that all simulations are preliminary and could change in final design.

Variations to Provide Additional HOV Access through the Corridor

This study analyzes only two scenarios for the Complex configuration: one that contained six access points (Modified Complex configuration) and one that contained eighteen access points (Complex configuration). Additional access points would result in additional trips on the HOV lanes. Based upon the analysis of the Complex configuration in Section 6.3, three locations for additional HOV-only access that would have a high potential for increasing HOV usage would include Harrison Avenue, Trinity Road, and Alston Avenue.

Strong consideration should also be given to providing an HOV-only access point between NC 147 and I-540 to serve RTP traffic. Otherwise, HOV traffic is forced to merge into mainline I-40 traffic from either the I-540 or NC 147 exits. The traffic must then immediately exit at one of the RTP exits (Page Road, Miami Boulevard, or Davis Drive). In addition to reducing impacts to mainline traffic, an RTP exit for HOV traffic could provide an effective HOV bypass that reduces travel time delay and encourages additional HOV usage.

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6.4.3 Traffic and Operations

Level of Service Analysis

The FREEVAL model was run for the 2025 Modified Complex HOV configuration to analyze freeway mainline traffic operations during AM and PM peak hours.

Table 6-22 provides a summary of the projected mainline traffic volume and capacity analysis results in terms of V/C ratios and LOS categories. Figure 6-30 and Figure 6-31 depict the V/C results of the freeway mainline capacity analysis on color coded maps to highlight the congested corridor segments by time of day and by direction of travel.

These maps and the LOS values indicate that the highest levels of congestion will occur on I-40 between NC 147 and I-540. The Modified Complex configuration does provide an additional GP/Express lane through this section to relieve congestion, but does not provide a local access interchange within RTP to provide a method for HOV traffic to bypass the mainline I-40 congestion. Although it is not captured in the LOS rating, the HOV/Express lanes will provide relief in the future by reducing the flow density from highly unstable conditions to borderline unstable conditions, and thus reducing the frequency of flow breakdowns.

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Table 6-22 Modified Complex LOS Analysis Results (FREEVAL)

Section Type	2025 Modified Complex AM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15/US 501	6,150	0.90	D	3,860	0.59	C
US 15/US 501 to NC 54	5,160	0.75	D	4,290	0.65	C
NC 54 to NC 751	7,170	1.05	D	5,200	0.79	D
NC 751 to Fayetteville Road	7,250	1.06	E	5,100	0.78	D
Fayetteville Road to NC 55	7,430	1.09	F	5,290	0.81	C
NC 55 to NC 147	7,060	1.12	F	6,160	1.25	F
NC 147 to Davis Drive	7,480	1.09	F	6,080	0.93	F
Davis Drive to Miami Blvd	7,250	0.80	F	8,800	1.29	F
Miami Blvd to Page Road	7,400	0.88	F	10,450	1.28	F
Page Road to I-540	7,570	1.26	F	11,810	1.52	F
I-540 to Airport Blvd	7,550	0.68	C	8,080	0.96	F
Airport Blvd to Aviation Pkwy	5,740	0.66	C	7,490	0.82	F
Aviation Pkwy to Harrison Ave	6,770	0.78	D	9,200	1.01	F
Harrison Ave to Wade Avenue	6,040	0.69	D	9,060	0.80	C
Wade Avenue to NC 54	3,850	0.44	B	5,470	0.80	D
NC 54 to Cary Towne Boulevard	4,490	0.57	C	6,140	0.79	D
Cary Towne Blvd to US 1/US 64	5,710	0.86	D	6,820	0.75	F

Section Type	2025 Modified Complex PM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15-501	4,510	0.69	C	5,750	0.84	D
US 15-501 to NC 54	4,460	0.68	C	5,380	0.79	D
NC 54 to NC 751	5,700	0.87	D	6,170	0.90	E
NC 751 to Fayetteville Road	5,630	0.86	D	6,500	0.95	E
Fayetteville Road to NC 55	5,730	0.87	F	6,610	0.97	D
NC 55 to NC 147	6,300	1.21	F	6,950	1.28	F
NC 147 to Davis Drive	6,590	1.01	F	5,770	0.76	F
Davis Drive to Miami Blvd	7,270	0.83	F	6,670	0.85	F
Miami Blvd to Page Road	8,900	1.20	F	7,230	0.89	E
Page Road to I-540	10,220	2.03	F	7,500	0.98	F
I-540 to Airport Blvd	7,700	0.65	C	7,440	1.10	E
Airport Blvd to Aviation Pkwy	6,380	0.70	D	6,150	0.70	F
Aviation Pkwy to Harrison Ave	8,370	0.92	E	7,160	0.82	F
Harrison Ave to Wade Avenue	8,190	0.90	F	6,710	0.61	D
Wade Avenue to NC 54	5,060	0.55	C	4,280	0.65	C
NC 54 to Cary Towne Boulevard	5,730	0.69	C	4,940	0.69	C
Cary Towne Blvd to US 1/US 64	7,070	0.92	E	5,770	0.66	C

Note: V/C = volume to capacity ratio.
There is no direct correlation between V/C ratio and LOS.
Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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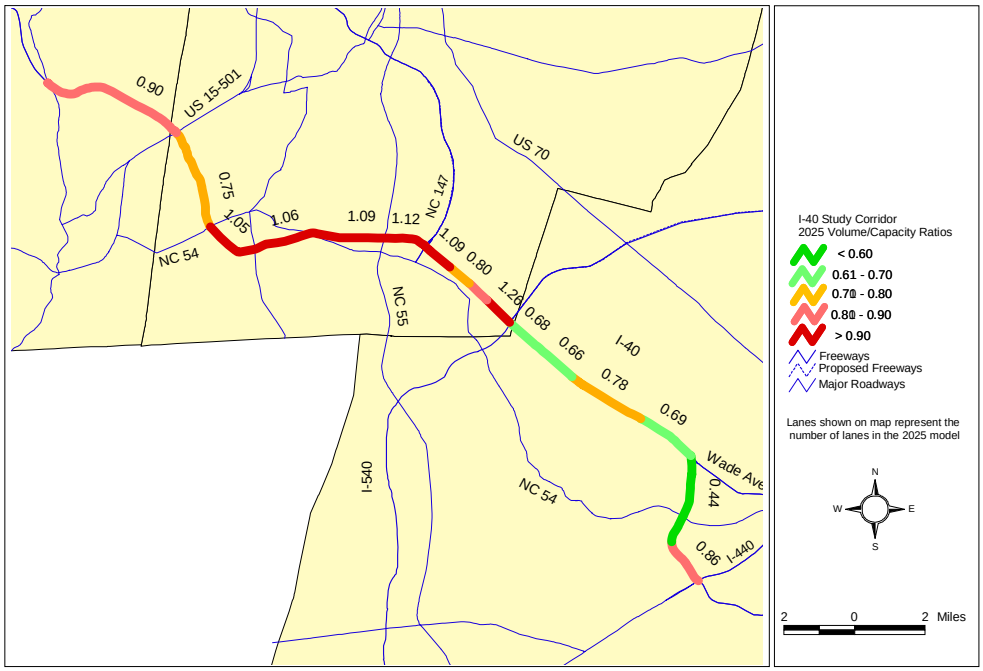
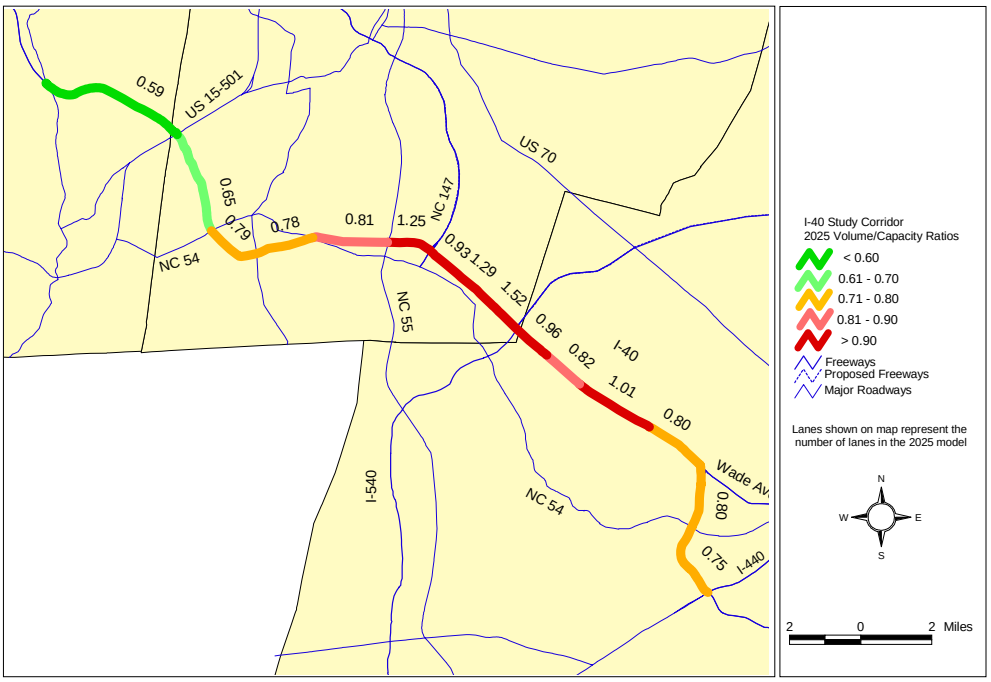
Figure 6-30 AM Peak Hour V/C Ratios – Modified Complex Configuration

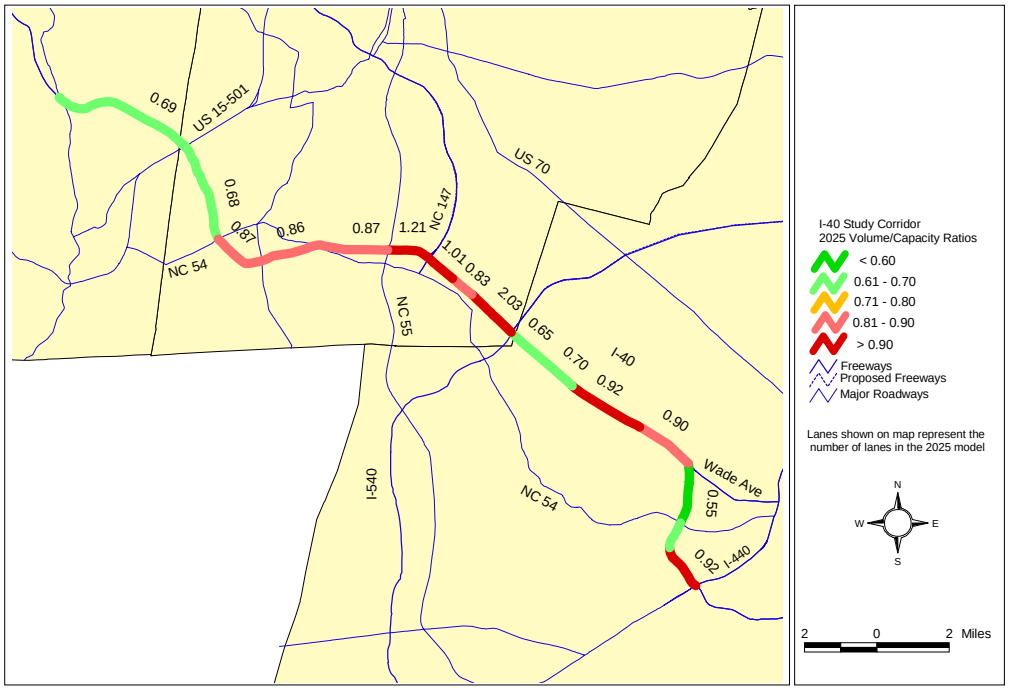


Modified Complex HOV Eastbound AM Volume/Capacity (V/C) Ratios

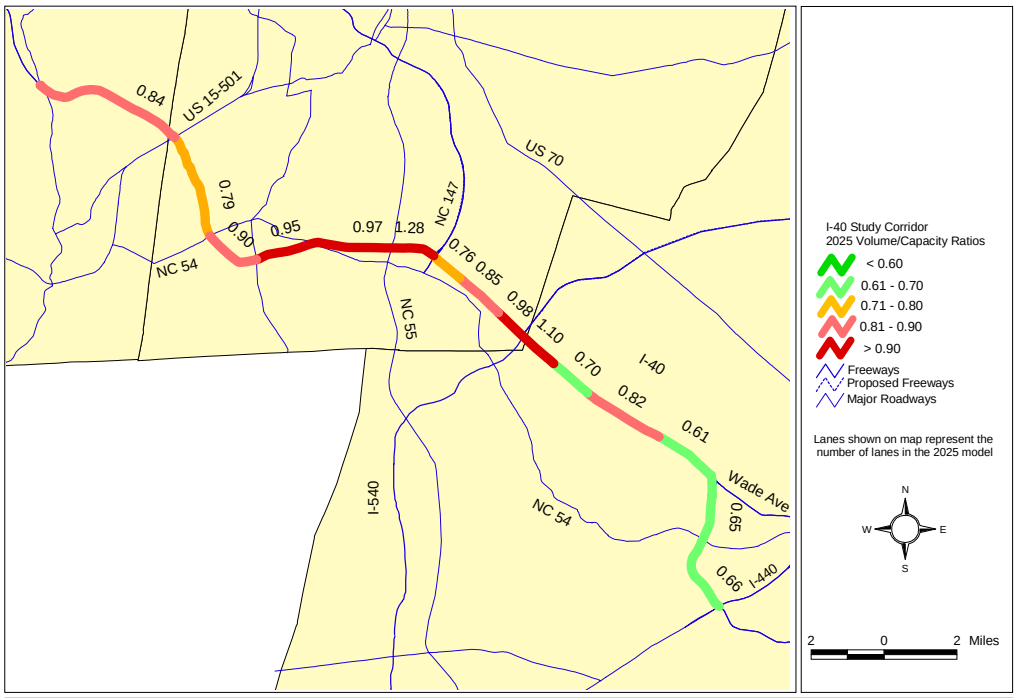


Modified Complex Westbound AM Volume/Capacity (V/C) Ratios

Figure 6-31 PM Peak Hour V/C Ratios – Modified Complex Configuration



Modified Complex Eastbound PM Volume/Capacity (V/C) Ratios



Modified Complex Westbound PM Volume/Capacity (V/C) Ratios

Travel Time Analysis

The introduction of direct access ramps between I-40 and I-540 in all directions would require the interchange to be significantly modified. This modification would allow the improvement of the GP ramp connections as well as the HOV access. One design scheme (included in the FRESIM analysis model) would add a flyover from westbound I-40 to southbound I-540, which would eliminate the weaves between loops and ramps on both the I-40 and I-540 mainlines.

The FRESIM analysis results show improved operational performance for traffic in the GP and the HOV lanes in the Modified Complex configuration. Table 6-23 shows the travel time savings in the HOV lanes compared to the mainline. It is evident that the HOV lanes would provide a significant travel time advantage over the GP lanes in the peak directions of travel – inbound to RTP in the morning rush hour and outbound from RTP in the afternoon rush hour.

Note that the Modified Complex configuration does not provide a local access interchange within RTP to allow HOV traffic to bypass the mainline I-40 congestion. The inclusion of an HOV access "T-ramp" between I-540 and NC 147 could allow for additional HOV time savings.

Table 6-23 Travel Time Savings in HOV Lanes

Corridor	Trip Length (miles)	Travel Time savings (min:sec)	
		AM Peak	PM Peak
Eastbound I-40			
1. Western – NC 86 to NC 54	6.9	1:20	0:27
2. RTP West – NC 54 to NC 147	6.4	1:23	2:38
3. RTP East – NC 147 to Aviation Pkwy	5.6	3:28	8:08
4. Airport – Aviation Pkwy to Wade Ave	4.1	0:21	0:17
5. Eastern – Wade Ave to US 1/US 64	3.8	0:06	0:08
EASTBOUND TOTAL	**26.8**	**6:38**	**11:39**
Westbound I-40			
1. Eastern – US 1/US 64 to Wade Ave.	3.8	0:10	0:13
2. Airport – Wade Ave to Aviation Pkwy	4.1	2:38	0:24
3. RTP East – Aviation Pkwy to NC 147	5.6	2:24	0
4. RTP West – NC 147 to NC 54	6.4	0:06	0:15
5. Western – NC 54 to NC 86	6.9	0:10	0:21
WESTBOUND TOTAL	**26.8**	**5:27**	**1:13**

Delay Analysis

The FRESIM micro-simulation model was used to analyze the traffic operations for the I-40 corridor from US 15/US 501 to US 1/US 64 and understand how the Modified Complex configuration would handle the projected demand. The goal was to simulate specific traffic bottlenecks at a higher level of detail than the travel demand model in order to produce more realistic estimates on total delay, unit delay and average speed along the corridor. The results of this micro-simulation analysis are summarized and compared to the No-Build statistics in Table 6-24.

Table 6-24 Modified Complex Delay Analysis Results

I-40 Measures of Effectiveness	No-Build	Modified Complex	Percent Change
AM Peak Hour			
Vehicle-Miles Traveled (VMT)	323,461	356,223	+10.1%
Average Speed in Network, mph	38.9	42.3	+8.7%
Total Delay Time, vehicle-hours	3,298	2,728	-17.3%
Unit Delay Time, sec/veh-mile	36.6	27.0	-26.2%
PM Peak Hour			
Vehicle-Miles Traveled (VMT)	324,830	371,239	+14.3%
Average Speed in Network, mph	38.8	44.4	+14.4%
Total Delay Time, vehicle-hours	3,350	2,488	- 25.7%
Unit Delay Time, sec/veh-mile	37.2	24.0	-35.5%

As illustrated in the table, the Modified Complex configuration would reduce corridor delay and improve average speed during AM and PM peak hours, while accommodating a higher VMT demand. These operational benefits are more pronounced during the PM peak hour, as it shows 36 percent reduction in travel delay for each vehicle traveling one mile along the corridor.

6.4.4 Environmental Screening

The Complex configuration and the Modified Complex configuration have identical footprints and estimated right-of-ways. Therefore, additional environmental screening was not performed for the Modified Complex configuration specifically. However, the Modified Complex configuration has fewer interchanges than the Complex configuration, and so it can be assumed that it would have a smaller overall impact on environmental resources.

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6.4.5 Roadway Design and Cost Estimate

Roadway design for the Modified Complex configuration was developed and is shown in Appendix A. The following sections focus on these roadway elements:

- Bridge Design and Construction
- Construction Phasing
- Cost Estimates

Bridge Design and Construction

Using the typical sections for the Modified Complex configuration that are presented in the previous section, the following bridge design impacts were identified for the Modified Complex configuration:

- Based upon contour maps along the I-40 corridor, retaining walls may be necessary in several locations where existing slopes are 2:1 and where right-of-way boundaries are close to the toe of the slope.
- Twenty existing bridges on I-40 would be widened.
- Twenty existing bridges over I-40 would be replaced.
- Fourteen new bridges would be constructed.
- Several box culverts throughout the corridors would likely require extension.
- Interchange entrance and exit ramps would require adjustment for widening beyond the existing cut and fill slopes.
- Several (six) new interchanges are proposed to provide direct access to the HOV lanes.

Each of the five corridor segments and the bridge construction impacts associated with the Modified Complex HOV configuration are shown in Table 6-25.

Table 6-25 Bridge Adjustments for Modified Complex Configuration

Location	Change End Bent	Widen Bridge	Reconstruct Bridge	New Bridge
Western Corridor	0	0	5	0
RTP Corridor - West	0	13	5	1
RTP Corridor – East	0	1	8	12
Airport Corridor	0	2	2	0
Eastern Corridor	0	4	0	1
TOTAL	**0**	**20**	**20**	**14**

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Construction Phasing

As in the case of Complex configuration, construction phasing for the Modified Complex configuration could be implemented in any phasing pattern by allowing the barrier separated HOV lanes to merge in and out of GP traffic at points where the HOV lanes are not complete. The implementation of HOV lanes in the RTP Corridors would be the most logical place to start. This is primarily due to high HOV demand and the potential to eliminate weaves in and out of the HOV lanes in the middle of the corridor, which would create traffic bottlenecks as cars from the HOV lanes tried to merge onto the most congested portion of I-40. Therefore, the only entrance to the barrier separated HOV lanes would be at the ends of the RTP Corridor-East.

The widening of I-40 between NC 86 and Wade Avenue would require median detours with alternating lane closures to tie-in ramps and loops to existing lanes. The complexity at the I-540 interchange would require the interchange to be built in two stages.

Cost Estimates

Functional design cost estimates were developed for five corridors as shown in Table 6-26. Cost estimates were based on functional design rather than a per mile cost. Quantities for pavement and structures were estimated based on geometric design from the 200 scale functional plans. Unit costs were developed and applied in accordance with NCDOT procedures for preliminary design. Costs are first estimated in 2002 dollars and then inflated to year 2025 using an inflation rate of 2.7 percent per year. The construction costs include engineering and other factors as outlined in Section 6.2, and do not include costs for right-of-way.

Table 6-26 Modified Complex Configuration Estimated Cost

Project	Estimated 2002 Cost of Construction	Estimated 2025 Cost of Construction
Western Corridor (NC 86 to NC 54)	$ 77M	$ 142M
RTP Corridor – West (NC 54 to NC 147)	$ 81M	$ 150M
RTP Corridor – East (NC 147 to Aviation Pkwy)	$ 225M	$ 415M
Airport Corridor (Aviation Pkwy to Wade Ave)	$ 52M	$ 96M
Eastern Corridor (Wade Ave to US 1/US 64)	$ 84M	$ 155M
TOTAL	**$ 519M**	**$ 958M**

6.5 Elevated Configuration

The Elevated configuration assumes that a two-lane viaduct will be constructed on both sides of the I-40 freeway from NC 86 near Chapel Hill to US 1/ US 64 in Cary. These two-lane elevated structures will provide additional travel lanes for HOV and Express traffic. The Express lanes on the elevated structures add GP "through movement" capacity.

For this configuration, six access locations were identified – the western approach near NC 86, NC 54 near Chapel Hill NC 147, I-540, Wade Avenue, and the eastern approach near US 1/US 64. These are the same access points identified for the Modified Complex configuration.

The following sections describe in more detail the design assumptions associated with the Elevated configuration. Section 6.5.2 describes the implications of this design for travel demand on the HOV facility as well as on GP lanes. Section 6.5.3 describes the traffic operations conditions for the Elevated configuration. Section 6.5.4 provides a brief comment about the environmental issues. The construction implications are summarized in Section 6.5.5.

6.5.1 Typical Sections

The functional design of the Elevated configuration followed consistent design criteria as defined for the other HOV configurations, but incorporated additional criteria that are unique to this configuration. The elevated structures pass over existing interchanges. As in the Modified Complex configuration, access points for HOV and Express traffic are provided at six interchange locations at or near NC 86, NC 54, NC 147, I-540, Wade Avenue and US 1/ US 64.

The typical section includes elevated structures consisting of two 12-foot lanes on each side of the existing GP lanes. The elevated structures will not require widening the existing I-40 roadway or changing the existing cut-and-fill slopes; thus the need for additional right-of-way is minimized.

Illustrated typical sections showing the Elevated HOV configuration follow for four I-40 sections.

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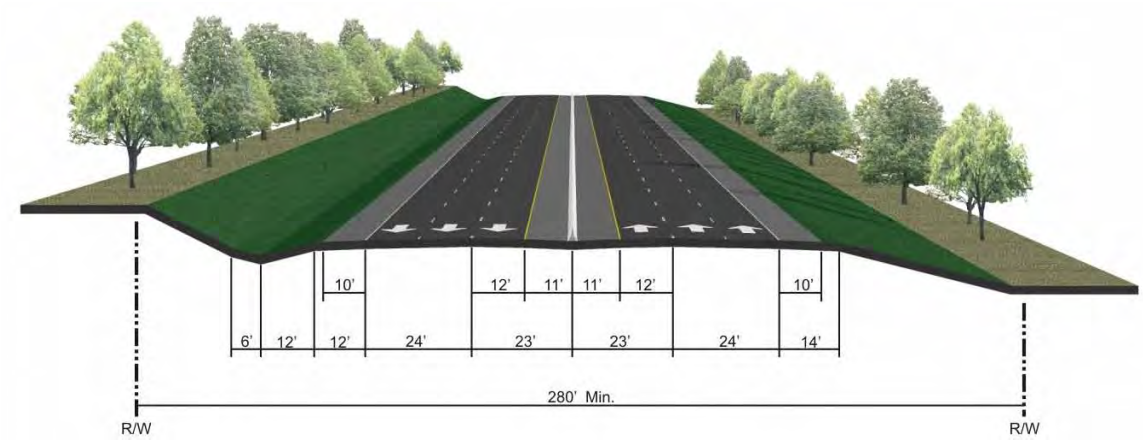
Western Corridor: NC 86 to NC 54

The Elevated configuration from NC 86 to NC 54 would include the existing three GP lanes plus two elevated bridges, or viaducts, along each side. The viaduct consists of two 12-foot shared HOV/ Express lanes with a 4-foot left shoulder and a 10-foot right shoulder. A typical cross-section of this design is shown in Figure 6-32.

Figure 6-32 Existing and Elevated Configuration Typical Sections Between NC 86 and NC 54



Existing Typical Section
(With TIP Widening Shown)
(NC 86 to NC 54)

Proposed Elevated HOV Design
(NC 86 to NC 54)

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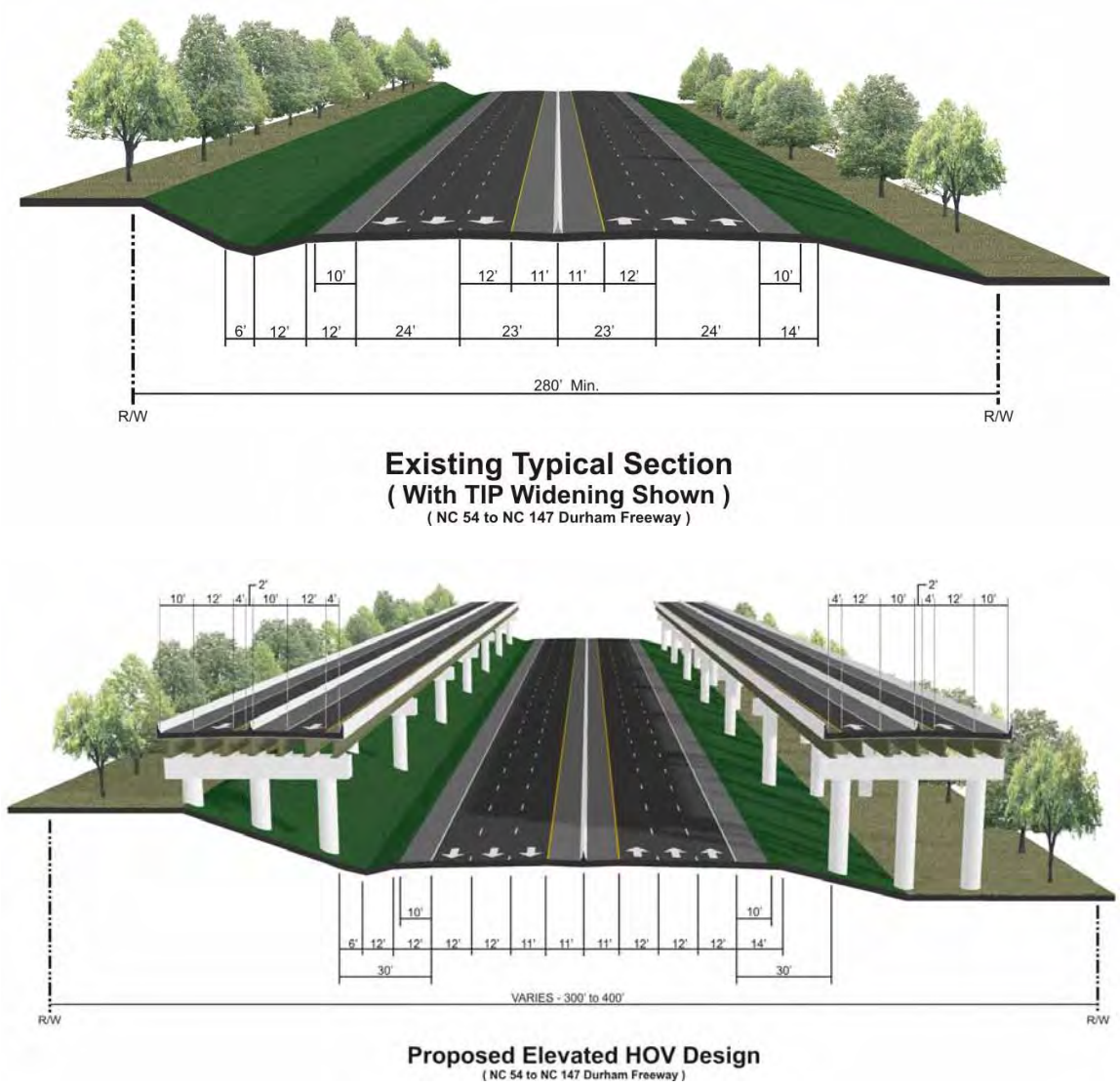
RTP Corridor – West: NC 54 to NC 147

The Elevated configuration from NC 54 to NC 147 west of RTP would include the existing three GP lanes plus two elevated bridges along each side. The typical section for each viaduct consists of one 12-foot HOV lane and one 12-foot Express lane separated by a barrier with a 4-foot left shoulder and a 10-foot right shoulder for each lane. Typical cross-sections of this design are shown in Figure 6-33.

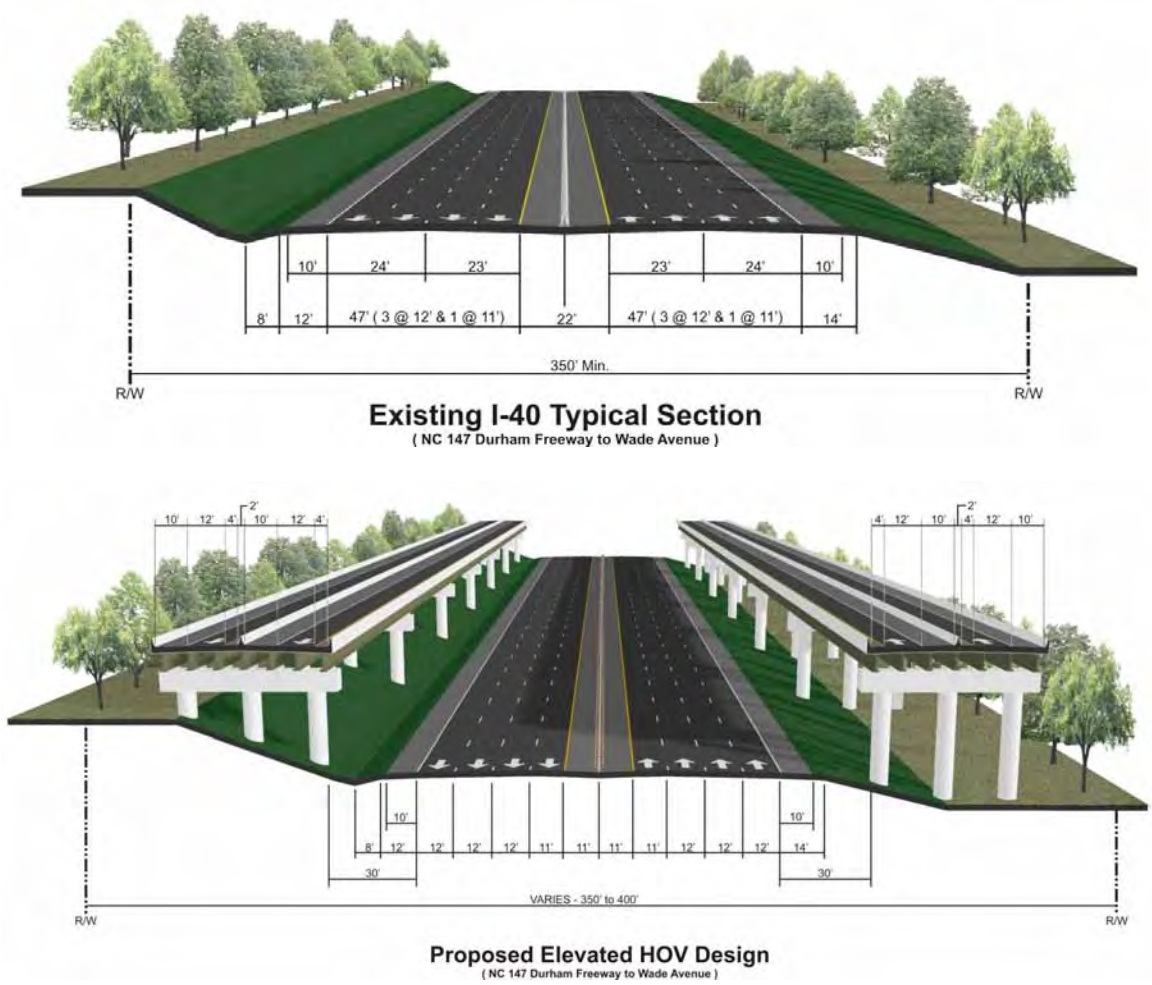
Figure 6-33 Existing and Elevated Configuration Typical Sections Between NC 54 and NC 147



RTP East and Airport Corridors: NC 147 to Wade Avenue

The Elevated configuration from NC 147 to Wade Avenue would include the existing four GP lanes plus two elevated bridges along each side. The typical section for each viaduct consists of one 12-foot HOV lane and one 12-foot Express lane separated by a barrier with a 4-foot left shoulder and a 10-foot right shoulder for each lane. Typical cross-sections of this design are shown in Figure 6-34.

Figure 6-34 Existing and Elevated Configuration Typical Sections Between NC 147 and Wade Avenue



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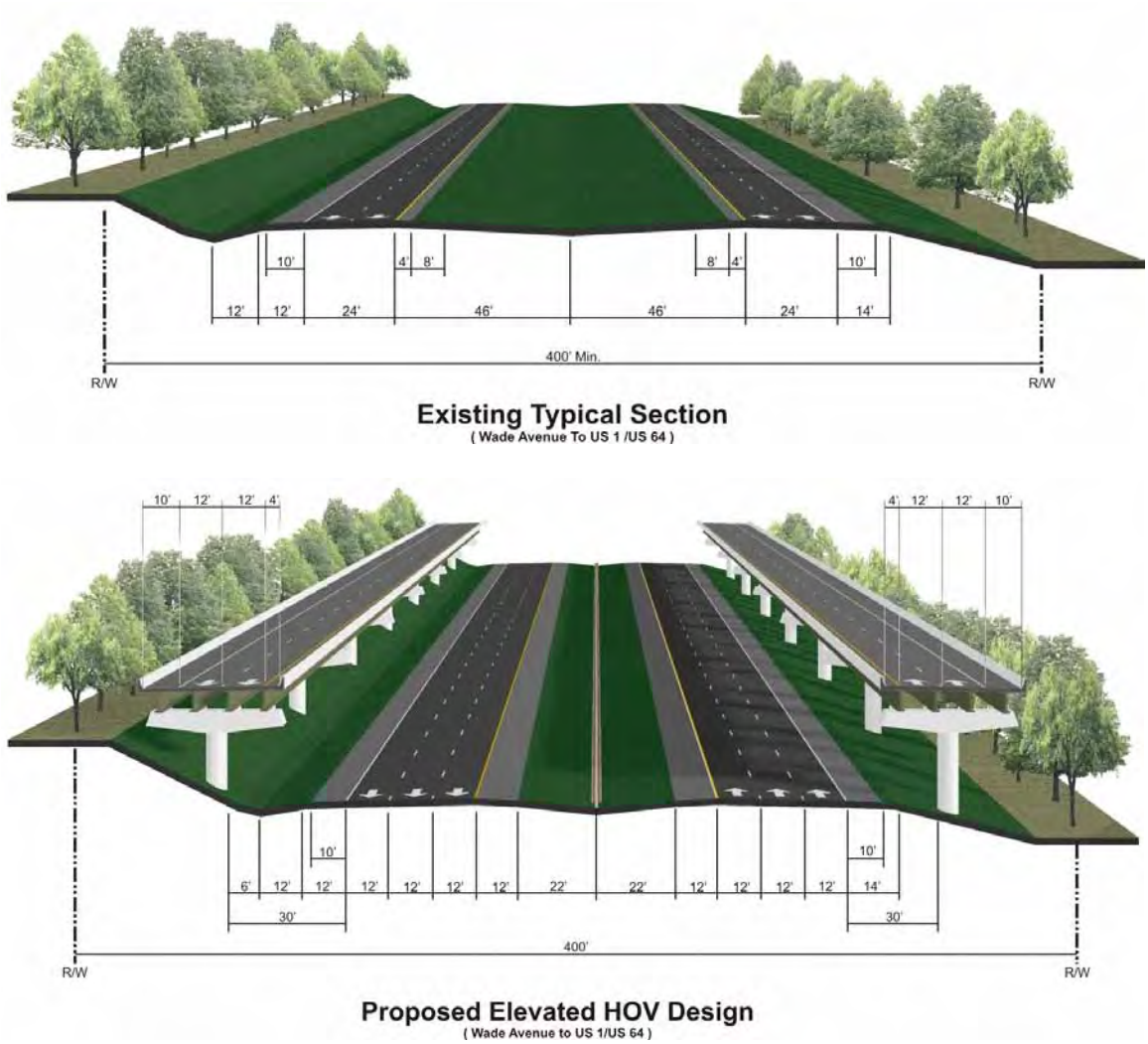
Eastern Corridor: Wade Avenue to US 1/ US 64

The Elevated HOV Design from Wade Avenue to US 1/US 64 would include widening the existing GP lanes from four 12-foot lanes to six 12-foot lanes plus adding two elevated bridges along each side of I-40. The typical section for the viaduct consists of two shared 12-foot HOV/ Express lanes with a four foot left shoulder and a 10-foot right shoulder. A 12-foot lane and 12-foot shoulder would be added in the existing median, narrowing the median from 92 feet to 68 feet. Adjustments to cut and fill slopes would not be required. A typical cross-section of this design is shown in Figure 6-35.

Figure 6-35 Existing and Elevated Configuration Typical Sections Between Wade Avenue and US 1/ US 64



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6.5.2 Travel Demand

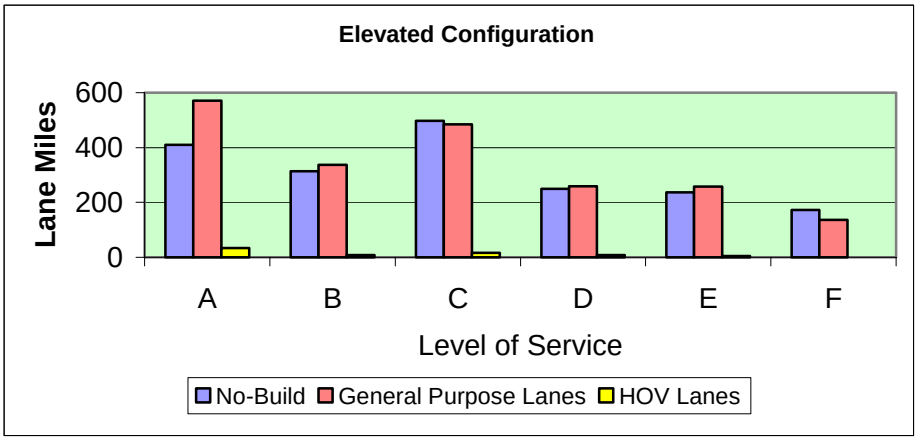
The following sections describe the system-wide and facility-specific measures of effectiveness as related to travel demand for the Elevated configuration.

System-wide Level of Service

The Elevated configuration shows an increase in HOV vehicles and the total number of people moved through the I-40 corridor as compared to the No-Build conditions. Because of the additional Express lanes, the Elevated configuration shows the highest number of people moved throughout the corridor when compared to all other HOV configurations. However, the increase in traffic demand on the exclusive HOV lane is smaller compared to the Simple or the Complex configuration due to the limited number of HOV access points of the Elevated configuration.

Figure 6-36 illustrates the distribution of lane-miles traveled by LOS category (during AM four-hour peak period in year 2025 projected land use conditions) for the Elevated configuration when compared to the No-Build. The provision of HOV and Express lanes results in significant improvements on the congested freeway segments, specifically a 20 percent reduction in freeway lane-miles operating at LOS F. Note that the Elevated configuration has more lane-miles than the No-Build. Similar to other build configurations, HOV lane-miles traveled are primarily in the LOS D or better categories, although more detailed analysis would be required to determine the impact of single-lane barrier separated operations in the Express and HOV lanes on the Elevated structure.

Figure 6-36 Freeway Lane-Miles Traveled by Level of Service



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System-wide Delays

Figure 6-37, Figure 6-38, and Figure 6-39 illustrate the performance of the Elevated configuration, as compared to the No-Build, using three additional demand-model based indicators – VMT, Hours of Person Delay and Average Speed. Primary conclusions from the figures include:

- The Elevated configuration is projected to increase VMT by 0.6 percent due to changes in trip origin-destination patterns resulting from the introduction of HOV and Express lanes.
- Network-wide delay would decrease (9.7 percent) and average travel speed would improve (3.3 percent) due to the added capacity in the Express lanes.

In general, the system-wide demand measures for the Elevated configuration are based upon a trip distribution pattern that reflects the highest level of capacity on I-40 tempered by limited access to the HOV lanes. Specifically, the configuration assumes a GP/Express lane in addition to the HOV lane along the entire corridor from NC 86 to US 1/US 64. As previously noted, six access points were proposed – the same number as for the Modified Complex configuration.

The overall result is a demand that is slightly lower than that for the Simple or the Complex configuration. As a result it can be concluded that access has a more significant impact than the added capacity.

However, these demand measures do not address the operational issues or specific bottlenecks that arise due to sharp spikes in the demand causing breakdowns in traffic flow. The traffic operational issues are addressed in Section 6.5.3.

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Figure 6-37 Comparison of Elevated Configuration Vehicle Miles Traveled (AM Peak)

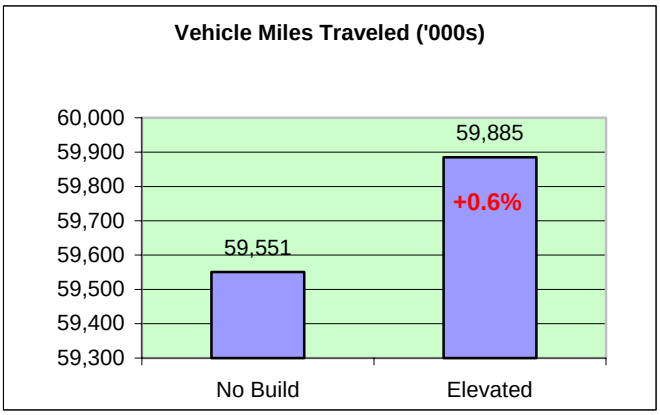


Figure 6-38 Comparison of Elevated Configuration Hours of Delay (AM Peak)

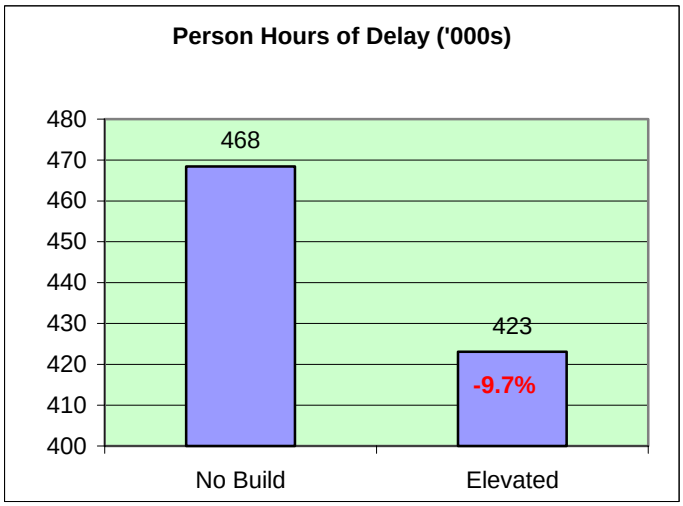
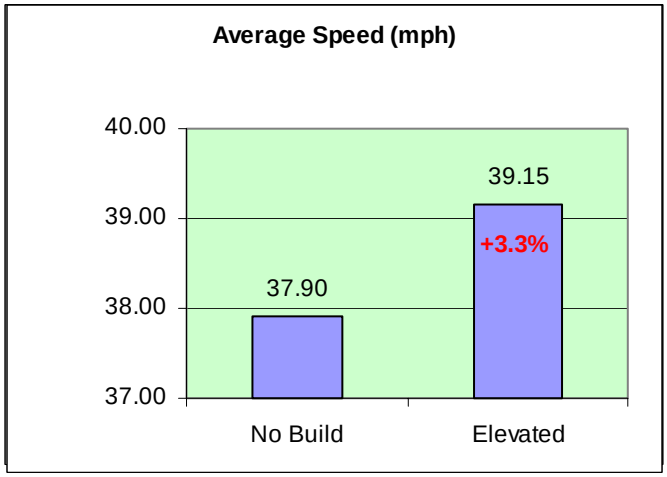


Figure 6-39 Comparison of Elevated Configuration Average Speed (AM Peak)



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Shifts in Traffic Flows on Local Roads

The provision of additional HOV and GP lane capacity will result in changes in travel flow patterns on the local roadway network. Specific roadway segments could show relatively high shifts in traffic volumes, especially around new or enhanced access points and along roadways parallel to the I-40 corridor. These traffic shifts tend to form a ripple-effect through the network, with higher impacts near the immediate vicinity of the new configuration.

The specific traffic shifts for the Elevated configurations were not analyzed and would need to be evaluated if this configuration is carried forward to the next phase of study. In general, however, the Elevated configuration could show a higher potential for traffic shifts from adjacent roads since it adds GP lane capacity for the entire corridor.

Number of Vehicles Moved Through the Corridor by Segment

Table 6-27 shows the number of SOVs and HOVs on I-40 for the Elevated configuration. The table is divided into two sections. First, a corridor summary of the projected vehicles is shown for each of the five study sections as well as I-40 south of the study area. A more detailed segment summary is then presented between each interchange. Specific observations from the table include:

- HOV demand is projected to increase considerably in the Elevated configuration compared to the No-Build, approximately 36 percent in the morning peak period. As expected, this is approximately the same as the 35 percent increase in the Modified Complex configuration.
- In 2025, HOV usage is projected to be highest in the RTP Corridor-East. With the Express lanes in place, approximately 4,200 vehicles per hour travel in each direction. HOV traffic makes up approximately 40 percent of this traffic.
- The RTP-West and RTP-East Corridors have higher peak period HOV directional flows than the Airport, Eastern, or Western Corridor.
- Both the RTP-East and the RTP-West Corridors have more balanced HOV flows (approximately 60 - 40 percent splits) as compared with sections further from Research Triangle Park (approximately 70 – 30 percent splits).
- As in other configurations, some HOV vehicles will continue to use the GP. These vehicles represent trips that do not realize sufficient time savings by using the HOV lanes and thus remain in the GP lanes. As a result of the increased spacing between access points, a lower percentage of HOV vehicles use the HOV lane as compared with the Simple or Complex configurations.
- Access to and from the Express lanes from GP lanes is not provided at the I-540 and NC 147 interchanges. The primary reason was to limit construction impacts, maintain geometric standards, and minimize interchange costs. The demand impact of this was to reduce GP traffic to a projected level that can be served at an acceptable LOS.

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Table 6-27 Vehicles on I-40 by Segment and % HOV -- Elevated Configuration

Segment	Eastbound					Westbound				
	General Purpose Lanes		HOV Facility		% HOV	General Purpose Lanes		HOV Facility		% HOV
	SOV	HOV	SOV	HOV		SOV	HOV	SOV	HOV	
Corridor Summary										
Western Corridor	4,660	490	580	440	7.1%	3,390	410	370	200	4.6%
RTP Corridor-West	6,230	420	1,350	1,030	11.4%	4,360	610	1,190	640	9.4%
RTP Corridor-East	6,330	780	1,350	860	9.2%	8,120	750	1,190	1,590	13.6%
Airport Corridor	5,060	730	1,350	600	7.7%	7,620	810	1,190	880	8.4%
Eastern Corridor	3,800	530	420	220	4.4%	5,380	550	740	600	8.3%
US 1/US 64 to US 70	4,520	1,000	0	0	0.0%	6,440	1,480	0	0	0.0%
Segment Summary										
NC 86 to US 15/US 501	4,710	510	580	440	7.1%	3,170	370	370	200	4.9%
US 15/US 501 to NC 54	4,590	450	580	440	7.3%	3,720	470	370	200	4.2%
NC 54 to NC 751	5,830	410	1,350	1,030	11.9%	4,300	490	1,190	640	9.7%
NC 751 to Fayetteville	6,070	400	1,350	1,030	11.6%	4,210	500	1,190	640	9.8%
Fayetteville to NC 55	6,690	430	1,350	1,030	10.8%	4,330	590	1,190	640	9.5%
NC 55 to NC 147	6,030	440	1,350	1,030	11.6%	4,700	930	1,190	640	8.6%
NC 147 to Davis	7,410	660	1,350	1,050	10.0%	6,680	340	1,190	2,110	20.4%
Davis to Miami	7,230	680	1,350	1,050	10.2%	8,830	700	1,190	2,110	16.4%
Miami to Page	7,220	750	1,350	1,050	10.1%	10,550	950	1,190	2,110	14.3%
Page to I-540	7,490	850	1,350	1,050	9.8%	12,100	1,260	1,190	2,110	12.7%
I-540 to Airport	5,690	1,050	1,350	600	6.9%	6,400	780	1,190	880	9.5%
Airport to Aviation	4,240	650	1,350	600	8.8%	6,400	610	1,190	880	9.7%
Aviation to Harrison	5,310	760	1,350	600	7.5%	7,780	840	1,190	880	8.2%
Harrison to Wade	4,730	700	1,350	600	8.1%	7,400	760	1,190	880	8.6%
Wade to NC 54	3,250	410	420	220	5.1%	4,940	440	740	600	8.9%
NC 54 to Cary Towne Center	3,790	530	420	220	4.4%	5,490	570	740	600	8.1%
Cary Towne Center to US 1/US 64	4,660	730	420	220	3.6%	5,970	700	740	600	7.5%
US 1/ US 64 to Gorman	4,730	1,040	0	0	0.0%	6,610	1,110	0	0	0.0%
Gorman to Lake Wheeler	4,620	860	0	0	0.0%	6,450	1,060	0	0	0.0%
Lake Wheeler to South Saunders	5,170	1,030	0	0	0.0%	7,540	1,790	0	0	0.0%
South Saunders to Hammond	4,360	920	0	0	0.0%	6,960	1,610	0	0	0.0%
Hammond to Rock Quarry	4,980	1,090	0	0	0.0%	7,720	1,750	0	0	0.0%
Rock Quarry to I-440 split	4,730	1,040	0	0	0.0%	7,410	1,860	0	0	0.0%
I-440 split to Jones Sausage	4,310	1,050	0	0	0.0%	5,400	1,620	0	0	0.0%
Jones Sausage to US 70	3,750	1,000	0	0	0.0%	5,480	1,610	0	0	0.0%

Note: Volumes in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Number of People Moved Through The Corridor By Segment

Table 6-28 translates the number of vehicles on each segment of I-40 into number of people by applying the average auto occupancy for carpools to the HOV vehicles. The Elevated configuration shows a substantial increase in the number of people moved through the two RTP Corridors (East and West), especially between Davis Drive and I-540. The RTP Corridor-East is projected to carry 5,460 additional persons per hour, a 26 percent increase compared to the No-Build. Similarly, the RTP Corridor-West is projected to move an additional 4,180 persons, a 27 percent increase. The segment between Davis Drive and I-540 shows an even higher increase, as high as 30 percent.

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Table 6-28 Number of People Moved on I-40 -- Elevated Configuration

Segment	Eastbound			Westbound		
	No-Build	Elevated	Increase	No-Build	Elevated	Increase
Corridor Summary						
Western Corridor	6,570	7,530	960	4,730	5,280	540
RTP Corridor—West	8,900	11,170	2,280	6,750	8,650	1,900
RTP Corridor—East	9,730	11,740	2,010	11,630	15,080	3,450
Airport Corridor	8,320	9,720	1,400	11,680	12,980	1,300
Eastern Corridor	5,570	6,080	510	7,340	8,960	1,620
US 1/US 64 to US 70	6,840	7,000	160	9,640	10,100	450
Segment Summary						
NC 86 to US 15/US 501	6,820	7,640	820	4,440	4,950	510
US 15/US 501 to NC 54	6,210	7,370	1,160	5,160	5,750	590
NC 54 to NC 751	8,990	10,740	1,750	6,540	8,290	1,750
NC 751 to Fayetteville	8,910	10,960	2,050	6,580	8,220	1,640
Fayetteville to NC 55	9,090	11,650	2,560	6,790	8,560	1,770
NC 55 to NC 147	8,380	11,020	2,640	7,140	9,780	2,640
NC 147 to Davis	10,790	12,990	2,200	9,840	13,930	4,090
Davis to Miami	10,520	12,860	2,340	12,380	16,980	4,600
Miami to Page	10,770	13,030	2,260	14,370	19,310	4,940
Page to I-540	11,420	13,540	2,120	16,590	21,630	5,040
I-540 to Airport	9,250	11,120	1,870	9,990	11,700	1,710
Airport to Aviation	7,130	8,680	1,550	9,260	11,280	2,020
Aviation to Harrison	8,580	10,030	1,450	11,770	13,230	1,460
Harrison to Wade	7,960	9,300	1,340	11,560	12,650	1,090
Wade to NC 54	4,820	5,230	410	6,550	8,250	1,700
NC 54 to Cary Towne Center	5,450	6,070	620	7,540	9,130	1,590
Cary Towne Center to US 1/US 64	6,840	7,430	590	8,430	9,930	1,500
US 1/US 64 to Gorman	7,070	7,300	230	8,560	9,360	800
Gorman to Lake Wheeler	6,590	6,750	160	8,520	9,070	550
Lake Wheeler to South Saunders	7,540	7,720	180	11,250	11,970	720
South Saunders to Hammond	6,470	6,640	170	10,320	10,950	630
Hammond to Rock Quarry	7,530	7,680	150	11,430	12,050	620
Rock Quarry to I-440 split	7,230	7,300	70	11,510	12,010	500
I-440 split to Jones Sausage	6,800	6,910	110	9,330	9,410	80
Jones Sausage to US 70	6,080	6,230	150	9,430	9,470	40

Note: Volumes in persons per hour.
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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Access Points and HOV Ramp Volumes

The Elevated configuration was designed to incorporate HOV access points at major destination points or interchange locations and evaluate a viaduct concept of providing Express lanes through the congested I-40 corridor. GP traffic can access the Express lane at only four of the six proposed access points (i.e., GP traffic cannot exit or enter at NC 197 and I-580.

Table 6-29 shows the average volume of HOV traffic on ramps accessing the HOV facilities in the AM peak hour in the peak direction. The volumes represent traffic moving onto the HOV facilities in the peak direction at the extreme ends of the network and an average of traffic entering the HOV facility in the RTP area.

Table 6-29 Elevated HOV Ramp Volumes

HOV Access Location	Access Type	AM EB Peak Hour Ramp Volume	AM WB Peak Hour Ramp Volume
Western Approach near NC 86	East only (SOV & HOV)	580 (440)	—
NC 54 at Farrington Road	East only (SOV & HOV)	1,360 (590)	—
NC 147	Both directions (HOV only)	0 (360)	0 (350)
I-540	Both directions (HOV only)	0 (210)	0 (1600)
Wade Avenue	West only (SOV & HOV)	—	730 (270)
US 1/US 64	West only (SOV & HOV)	—	680 (280)

xx – Express volumes entering HOV facility.
(xx) – HOV volumes entering HOV facility.

Visual Simulation of HOV Access Ramps

No photo simulations of the Elevated configuration design were developed for this report. The configuration was evaluated on a cursory basis to identify any conflicts with RDU airport flight paths due to elevated structures over the current I-40 / I-540 interchange. The analysis showed no such conflicts.

Variations to Provide Additional HOV Access through the Corridor

As with the Modified Complex, additional access points could increase HOV usage on the corridor. Based upon the analysis of the Complex configuration in Section 6.3, three locations for additional HOV-only access that would have a high potential for increasing HOV usage would include Harrison Avenue, Trinity Road, and Alston Avenue.

Similarly, strong consideration should also be given to providing an HOV-only access point between NC 147 and I-540 to serve RTP traffic. Otherwise, HOV traffic is forced to merge into mainline I-40 traffic from either the I-540 or NC 147 exits. The traffic must then immediately exit at one of the RTP exits (Page Road, Miami Boulevard, or Davis Drive). In addition to reducing impacts to mainline traffic, an RTP exit for HOV traffic could provide an effective HOV bypass that reduces travel time delay and encourages additional HOV usage.

There are some major constraints in providing these additional access points with the Elevated configuration, however. First, the geometric requirements of any interchange access must be met. Cost and right-of-way considerations are also very high. Finally, the advantages of additional HOV and GP access must be balanced with the limitations of roadway capacity on the Elevated structure, particularly if the structure is divided into single lane highways.

6.5.3 Traffic and Operations

Level of Service Analysis

The FREEVAL model was run for the 2025 Elevated configuration to analyze mainline freeway traffic operations during AM and PM peak hours.

Table 6-30 provides a summary of the projected mainline traffic volume and capacity analysis results in terms of V/C ratios and LOS categories. Figure 6-40 and Figure 6-41 depict the V/C results of the freeway mainline capacity analysis on color coded maps to highlight the congested corridor segments by time of day and by direction of travel.

These maps and the LOS values indicate that I-40 thorough the RTP area will experience very high levels of congestion in the GP lanes. Although it is not captured in the LOS rating, the HOV/Express lanes are forecast to provide relief in the future by reducing the flow density from highly unstable conditions to borderline unstable conditions, and thus reducing the frequency of flow breakdowns. Unfortunately, the FREEVAL model does not directly examine the impact of driver perceptions and expectations for long distance operations on a single lane freeway.

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Table 6-30 Elevated Configuration LOS Analysis Results (FREEVAL)

Section Type	2025 Elevated AM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15-501	6,250	0.91	D	4,130	0.63	C
US 15-501 to NC 54	5,050	0.74	D	4,200	0.64	C
NC 54 to NC 751	6,240	0.91	D	4,790	0.73	D
NC 751 to Fayetteville Road	6,470	0.95	F	4,710	0.72	C
Fayetteville Road to NC 55	7,130	1.04	F	4,920	0.75	C
NC 55 to NC 147	6,470	0.95	E	5,630	0.86	D
NC 147 to Davis Drive	8,080	0.92	F	7,020	1.07	D
Davis Drive to Miami Blvd	7,910	0.72	F	9,530	1.22	E
Miami Blvd to Page Road	7,970	0.79	F	11,500	1.17	F
Page Road to I-540	8,340	1.33	E	13,350	1.93	F
I-540 to Airport Blvd	6,740	0.51	B	7,190	0.82	F
Airport Blvd to Aviation Pkwy	4,890	0.56	B	7,010	0.80	F
Aviation Pkwy to Harrison Ave	6,070	0.69	C	8,610	0.99	F
Harrison Ave to Wade Avenue	5,420	0.62	C	8,170	0.72	C
Wade Avenue to NC 54	3,670	0.42	B	5,380	0.79	D
NC 54 to Cary Towne Boulevard	4,330	0.55	C	6,060	0.80	D
Cary Towne Boulevard to US 1/US 64	5,390	0.86	D	6,670	0.73	D

Section Type	2025 Elevated PM					
	Eastbound			Westbound		
	Volume	V/C	LOS	Volume	V/C	LOS
NC 86 to US 15-501	4,650	0.68	C	5,920	0.90	E
US 15-501 to NC 54	4,460	0.65	C	5,210	0.80	D
NC 54 to NC 751	5,290	0.77	D	5,820	0.89	E
NC 751 to Fayetteville Road	5,230	0.76	D	6,200	0.95	E
Fayetteville Road to NC 55	5,220	0.76	D	6,430	0.98	E
NC 55 to NC 147	5,480	0.80	D	6,350	0.97	E
NC 147 to Davis Drive	7,310	0.84	F	7,130	0.92	D
Davis Drive to Miami Blvd	8,900	0.88	F	8,100	0.89	D
Miami Blvd to Page Road	9,820	0.98	F	8,810	0.89	E
Page Road to I-540	10,990	2.08	F	9,190	1.12	E
I-540 to Airport Blvd	7,050	0.54	B	7,150	0.82	F
Airport Blvd to Aviation Pkwy	5,930	0.68	B	5,480	0.63	C
Aviation Pkwy to Harrison Ave	7,830	0.90	F	6,640	0.76	D
Harrison Ave to Wade Avenue	7,620	0.87	F	6,200	0.54	C
Wade Avenue to NC 54	4,810	0.55	C	4,080	0.60	C
NC 54 to Cary Towne Boulevard	5,490	0.69	C	4,620	0.62	C
Cary Towne Boulevard to US 1/US 64	6,580	0.90	E	5,330	0.59	C

Note: V/C = volume to capacity ratio,
There is not a direct correlation between V/C ratio and LOS.
Volumes are in vehicles per hour (vph).
Shading represents the various segments associated with each corridor element (Western, RTP West, RTP East, Airport, Eastern, etc.).

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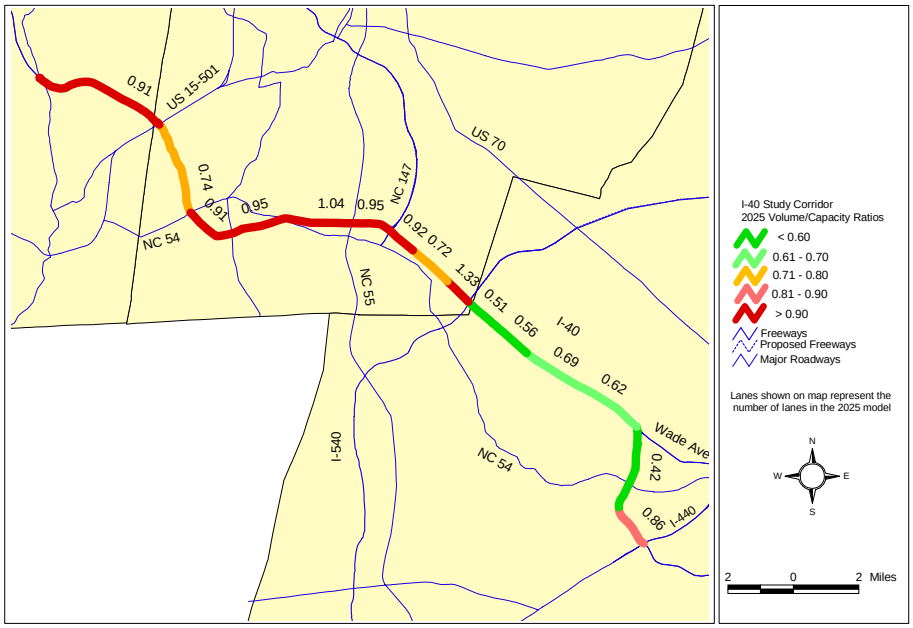
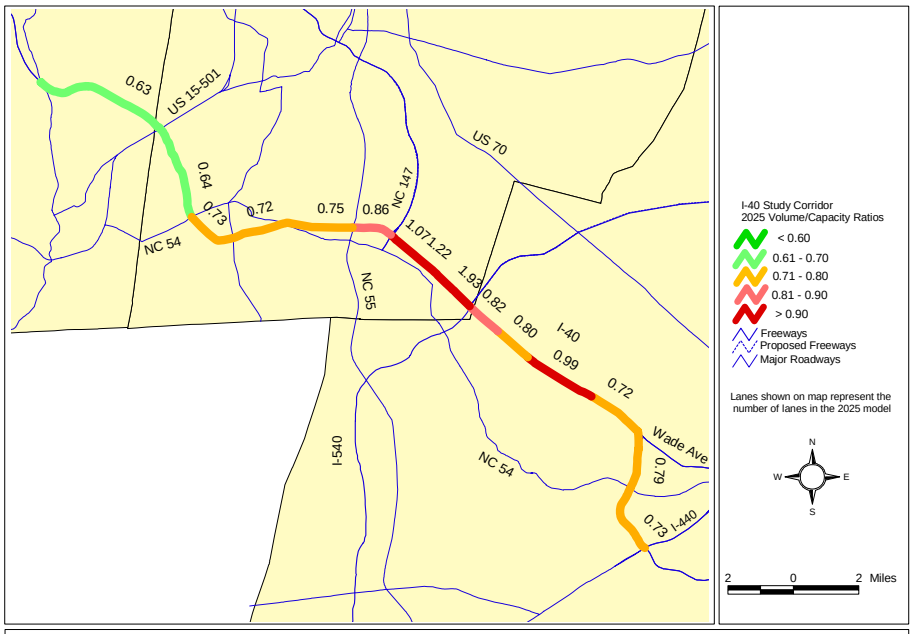
Figure 6-40 AM Peak Hour V/C Ratios – Elevated Configuration



Elevated Eastbound AM Volume/Capacity (V/C) Ratios



Elevated Westbound AM Volume/Capacity (V/C) Ratios

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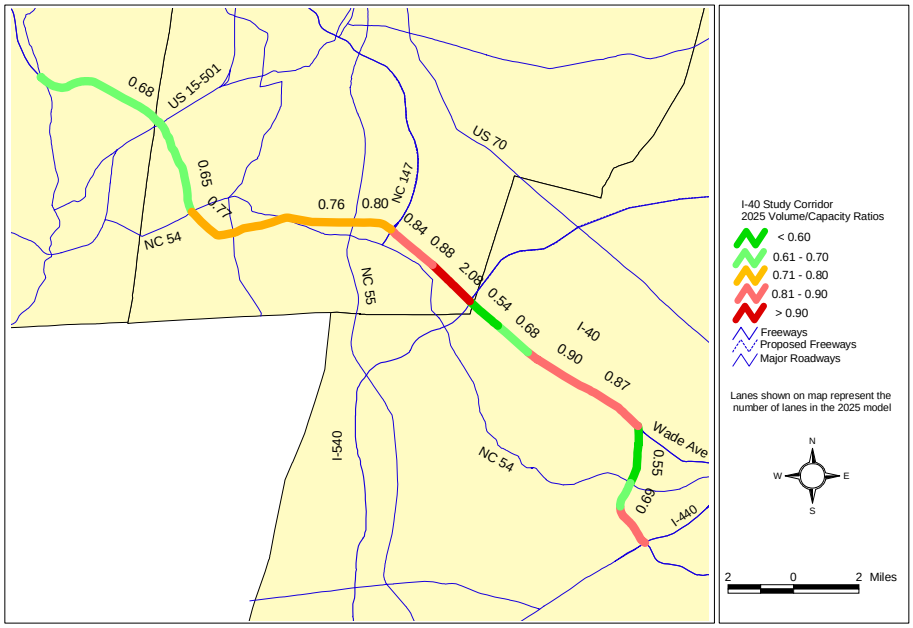
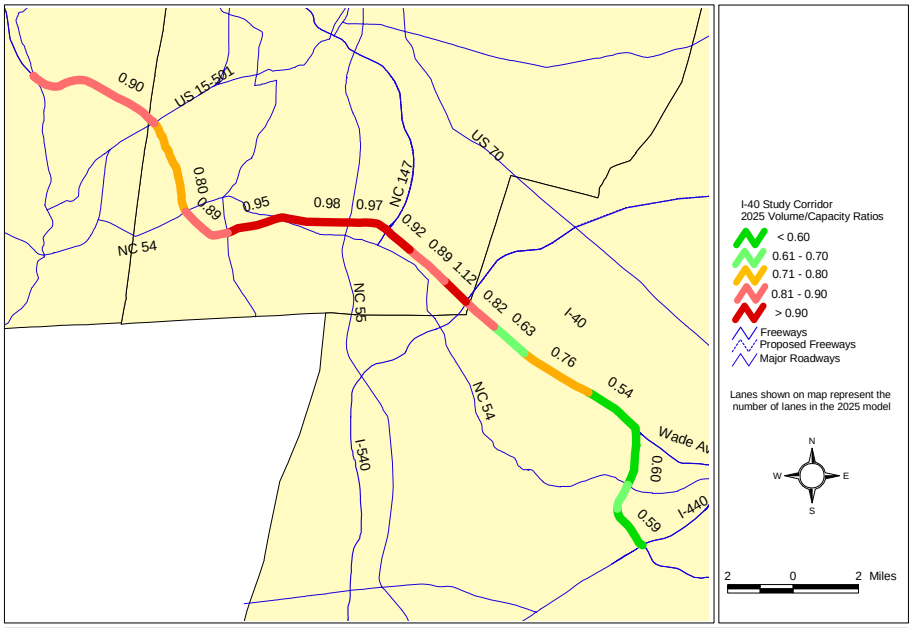
Figure 6-41 PM Peak Hour V/C Ratios – Elevated Configuration



Elevated Eastbound PM Volume/Capacity (V/C) Ratios



Elevated Westbound PM Volume/Capacity (V/C) Ratios

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Travel Time Analysis

The FRESIM analysis results show improved operational performance for traffic in the GP and the HOV lanes in the Elevated configuration. Table 6-31 shows the travel time savings in the HOV lane compared to the GP lanes. It is evident that HOV lanes would provide a significant travel time advantage over the GP in the peak directions of travel – inbound to RTP in the morning rush hour and outbound from RTP in the afternoon rush hour.

Table 6-31 Travel Time Savings in HOV Lanes

Corridor	Trip Length (miles)	Travel Time Savings (min:sec)	
		AM Peak	PM Peak
Eastbound I-40			
1. Western – NC 86 to NC 54	6.9	0:41	0:33
2. Western RTP – NC 54 to NC 147	6.4	5:44	1:43
3. Eastern RTP – NC 147 to Aviation Pkwy	5.6	0:29	9:28
4. Airport – Aviation Pkwy to Wade Ave	4.1	0:24	0:35
5. Eastern – Wade Ave to US 1/US 64	3.8	0:20	0:44
EASTBOUND TOTAL	**26.8**	**7:38**	**13:03**
Westbound I-40			
1. Eastern – US 1/US 64 to Wade Ave	3.8	0:37	0:26
2. Airport Corridor – Wade Ave to Aviation Pkwy	4.1	2:33	0:27
3. Eastern RTP – Aviation Pkwy to NC 147	5.6	3:58	0:35
4. Western RTP – NC 147 to NC 54	6.4	0:02	0:06
5. Western Corridor – NC 54 to NC 86	6.9	0:25	0:28
WESTBOUND TOTAL	**26.8**	**7:34**	**2:02**

Delay Analysis

The FRESIM micro-simulation model was used to analyze the traffic operations for the I-40 corridor from NC 86 to US 1/US 64 and understand how the Elevated configuration would handle the projected traffic demand. The goal was to simulate specific traffic bottlenecks at higher level of detail than the demand model in order to produce more realistic estimates of total delay, unit delay and average speed along the corridor. The results of this micro-simulation analysis are summarized and compared to the No-Build statistics in Table 6-32.

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Table 6-32 Elevated Configuration Delay Analysis Results

I-40 Measures of Effectiveness	No-Build	Elevated	Percent Change
AM Peak Hour			
Vehicle-Miles Traveled (VMT)	323,461	405,843	25.5%
Average Speed in Network, mph	38.9	41.8	7.4%
Total Delay Time, vehicle-hours	3,298	3,352	1.6%
Unit Delay Time, sec/veh-mile	36.6	30.0	-18%
PM Peak Hour			
Vehicle-Miles Traveled (VMT)	324,830	405,392	24.8%
Average Speed in Network, mph	38.8	48.2	24.4%
Total Delay Time, vehicle-hours	3,350	2,047	-38.9%
Unit Delay Time, sec/veh-mile	37.2	18.0	-51.6%

As illustrated in the table, the Elevated configuration would reduce unit delay by 18 to 52 percent, and improve average speed by 7 to 24 percent during AM and PM peak hours, while accommodating a 25 percent increase in the VMT demand. These operational benefits are more pronounced during the PM peak hour, as it shows 52 percent reduction in travel delay for each vehicle traveling one mile along the corridor. However, this configuration shows a two percent increase in delay in the AM peak hour due to high increase in VMT.

6.5.4 Environmental Screening

Environmental Screening was not performed for the Elevated configuration. It was originally anticipated that the elevated structure could be fit entirely within the median of the existing roadway, and therefore the impact on the environment would be negligible. As the analysis progressed it became apparent that the two-lane viaducts would need to be placed outside of the existing roadway. This finding resulted in expanding the required right-of-way slightly wider than that for the Complex configuration. Although not analyzed, this right-of-way expansion is expected to cause similar but somewhat greater environmental impacts than the Complex configuration.

6.5.5 Roadway Design and Cost Estimate

Functional roadway design for the Elevated configuration was developed and is shown in Appendix A. The following sections focus on these roadway elements:

- Bridge Design and Construction
- Construction Phasing
- Cost Estimates

Bridge Design and Construction

The elevated structures pass over existing interchanges and provide exclusive access at only a few key locations. Consequently, no changes would be necessary to the existing

cut-and-fill slopes, retaining walls, box culverts and bridges along the corridor. The only change would occur at the I-40/NC 147 interchange for the existing ramps.

Construction Phasing

The construction sequence for the Elevated design would consist of constructing elevated structures along both sides of I-40, spanning over top of existing interchanges, and connecting the elevated structures to appropriate access points. This construction could be accomplished with very minimal impacts to existing general purpose traffic patterns as all of the construction would be adding bridges to the outside of the existing travel lanes.

The elevated design could be implemented in any phasing pattern as long as two access points are open. Use of this configuration is concentrated in the RTP and Airport Corridors during peak hours and thus implementation of HOV lanes at this part of the I-40 corridor first would be most logical. The construction would then need to be completed from the middle of the corridor and out. As one section is completed to the next access point, the elevated structure could be opened. To allow for express service, most of the elevated structure along I-40 would need to be opened because the access points to the I-40 GP lanes are at the beginning and end of the corridor.

Cost Estimates

Functional design cost estimates were developed for five corridors as shown in Table 6-33. Cost estimates were based on functional design rather than a per mile cost. Quantities for pavement and structures were estimated based on geometric design from the 200 scale plans. Unit costs were developed and applied in accordance with NCDOT procedures for preliminary design. Costs are first estimated in 2002 dollars and then inflated to year 2025 using an inflation rate of 2.7 percent per year. The costs include engineering and other factors as outlined in Section 6.2, but do not include right-of-way costs.

Table 6-33 Elevated Configuration Estimated Cost (in millions)

Project	Estimated 2002 Cost of Construction	Estimated 2025 Cost of Construction
Western Corridor (NC 86 to NC 54)	$ 232M	$ 428M
RTP Corridor – West (NC 54 to NC 147)	$ 465M	$ 858M
RTP Corridor – East (NC 147 to Aviation Pkwy)	$ 617M	$1,139M
Airport Corridor (Aviation Pkwy to Wade Ave)	$ 323M	$ 596M
Eastern Corridor (Wade Ave to US 1/US 64)	$ 324M	$ 598M
TOTAL	**$1,961M**	**$3,619M**

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7. SUMMARY OF THE I-40 HIGH OCCUPANCY VEHICLE/CONGESTION MANAGEMENT STUDY

The I-40 High Occupancy Vehicle/Congestion Management study was conducted to investigate methods to better manage congestion on the I-40 corridor based on the projected rapid growth in the Triangle Region for the next twenty years. Several congestion management strategies were investigated for application to I-40.

High Occupancy Vehicle (HOV) facilities provide an opportunity to better manage congestion by offering an alternative for commuter traffic. HOV lanes would provide fast and reliable trip times for those individuals willing to take advantage of an additional mobility option – driving or riding in a carpool, vanpool, or transit vehicle.

In conducting the study, extensive data collection, technical analysis, and functional design were performed. All findings were presented to a technical committee and a policy committee composed of members from NCDOT and local agencies. In addition, a public involvement plan, geared toward educating and soliciting input from the general public, was implemented.

The results of the overall study are summarized in the following sections. These general conclusions are divided into four sections:

- Congestion Management Strategies,
- Phasing of HOV Facilities,
- Comparison of Initial HOV Configurations, and
- Combining Configurations.

7.1 Congestion Management Strategies

Although this study focused on HOV lanes, numerous other congestion management techniques could be applied to help reduce future congestion on I-40. These strategies include, but are not limited to:

- Traditional roadway capacity improvements,
- Express lanes,
- Transit,
- Intelligent Transportation Systems (ITS),
- Ramp metering,
- Transportation Systems Management (TSM), and
- Travel Demand Management (TDM).

7.2 Phasing of HOV Facilities

This study analyzes the feasibility of a 60-mile HOV network. The roadway sections that make up this core HOV network include:

- I-40 from NC 86 near Chapel Hill to US 1/ US 64 in Cary

- I-40 from US 1/ US 64 in Cary to US 70 near Garner
- I-540 from US 64 near Apex to Creedmoor Road in North Raleigh

The I-40 HOV/Congestion Management Study focuses on one part of this core HOV network, I-40 from NC 86 to US 1/ US 64. This section was chosen due to the high concentration of employment in the Research Triangle Park (RTP) area and the projected trip demand.

This HOV section was further segmented into five corridors for analysis, cost estimation and reporting purposes. These five corridors are labeled as follows in this report:

- **Western Corridor:** I-40 between NC 86 and NC 54
- **RTP Corridor – West:** I-40 between NC 54 and NC 147
- **RTP Corridor – East:** I-40 between NC 147 and Aviation Parkway
- **Airport Corridor:** I-40 between Aviation Parkway and Wade Avenue
- **Eastern Corridor:** I-40 between Wade Avenue and US 1/ US 64

Demand for HOV facilities varies significantly between these five corridors, depending on the peak direction of traffic flow and the overall traffic demand in GP lanes. The highest HOV demand occurs on the RTP Corridor – East and generally peaks between NC 147 and I-540, especially in the westbound direction during the morning commute hours and in the eastbound direction during the afternoon commute hours.

In the Triangle Region, the amount of HOV demand on I-40 is expected to increase in the future. The amount and rate of the increase in HOV demand will vary, however, due to differences in land use growth patterns and the planned roadway network, affecting each of the five corridor segments as shown in Table 7-1.

Table 7-1 Projected HOV Demand Comparison

Roadway Section	2005	2025
Western Corridor	Low	Moderate
RTP Corridor -- West	Moderate	High
RTP Corridor -- East	High	Very High
Airport Corridor	High	High
Eastern Corridor	Moderate	High

Based upon this analysis and other factors outlined in Section 5.3, the three eastern-most sections – i.e., the RTP Corridor East, the Airport Corridor, and the Eastern Corridor were ranked as the highest priority for implementation of HOV in the region. The analysis also shows moderate to very high HOV demand along I-540 segments in North Raleigh and I-40 segments in South Raleigh. This analysis can provide a framework for an overall implementation program of the core HOV system.

Note that these observations are not intended to serve as a recommendation of a particular phasing schedule since numerous other factors should be considered. From a pure HOV demand analysis, however, the demand for various projects does dictate a potential strategy for developing an HOV system.

Successful implementation of a new HOV system in a region requires a carefully developed phasing plan that identifies those corridors with the highest near-term and long-term HOV traffic demand. The construction and expansion of an HOV system must be planned to maintain adequate HOV demand to minimize the risk of losing public support of HOV facilities throughout the region.

7.3 Comparison of HOV Configurations

In determining the type of configuration which may be more appropriate for the Triangle Region as well as specific sections of the HOV network, an investigation of four configurations and their impacts on measures of effectiveness were developed. These four HOV configurations are summarized below.

- **Simple** – This configuration consist of one concurrent flow HOV lane in each direction separated by a pavement stripe buffer. The demand analysis for this HOV lane configuration was calculated for I-40 from NC 86 (Mile post 266) to US 70 (Mile post 306) and I-540 from US 64 to NC 50. No HOV-only access interchanges were included.
- **Complex** – This configuration consist of one barrier-separated HOV lane in each direction and HOV-only access interchanges. An Express lane for general purpose traffic would be added to the HOV lane on I-40 between NC 147 and I-540. The demand analysis for this type of HOV lane was calculated for I-40 from NC 86 (Mile post 266) to US 70 (Mile post 306) and I-540 from US 64 to NC 50. In addition, eighteen new HOV-only access interchanges were included at or near existing interchange locations.
- **Modified Complex** – This configuration is a variation of the Complex scenario, and consist of the same barrier-separated HOV and Express lanes. It includes six HOV-only access interchanges at the following high demand locations: NC 86, NC 54, NC 147, I-540, Wade Avenue and US 1/ US 64. Note that future environmental analysis could examine additional access locations for the Modified Complex configuration.
- **Elevated** – This configuration includes two two-lane viaducts (one on each side of the I-40 freeway) from NC 86 near Chapel Hill to US 1/ US 64 in Cary. This configuration required an extra GP lane along the entire length of the viaducts due to safety and operational considerations. The configuration includes the same six access points as the Modified Complex configuration. Managed lane access at NC 147 and I-540 is provided for HOV vehicles only while the other four locations provide access to HOV and Express lane traffic. Note that the design variations made the Elevated configuration somewhat difficult to compare with other configurations based on traffic demand and operational characteristics. In addition, the geometric requirements of the viaduct limit the possibilities for providing additional HOV interchanges in the future.

Table 7-2 summarizes the number of GP, HOV and Express lanes included for each configuration by study corridor.

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Table 7-2 Lane Geometrics for HOV Configurations

Corridor	Simple			Complex			Modified Complex			Elevated		
	GP	HOV	Exp	GP	HOV	Exp	GP	HOV	Exp	GP	HOV	Exp
Western Corridor	3	1	0	3	1	0	3	1	0	3	1*	1*
RTP Corridor – West	3	1	0	3	1	0	3	1	0	3	1	1
RTP Corridor – East	4	1	0	3	1*	1*	3	1	1	4	1	1
Airport Corridor	4	1	0	4	1	0	4	1	0	4	1	1
Eastern Corridor	3	1	0	3	1	0	3	1	0	3	1*	1*

Notes: Number of lanes per direction.
** HOV and Express lanes use shared two-lane freeway section.*

The overall analysis and comparison of configurations is summarized in the following sections:

- Travel Demand Modeling
- Traffic and Operations
- Environmental Screening
- Construction and Costs

7.3.1 Travel Demand Modeling

An extensive travel demand modeling effort was performed for this study applying the Triangle Regional Model (TRM). It served to develop future traffic projections for analysis of both HOV and general purpose traffic. In addition, the TRM demand model was used to evaluate the potential impact of an HOV system on overall network operation and efficiency for the entire region.

Capacity and Access Analysis

The demand modeling effort required numerous analytical considerations that affected the trip distribution pattern for each configuration. Some of the analysis included:

- The results in this section are reported from the TRM (Triangle Regional Model, 2025 AM Peak Scenario). Therefore, delay or level of service (LOS) metrics are at the planning level and do not consider specific operational bottlenecks.
- The 2025 No-Build network is used as a baseline to compare the potential impact of

HOV facilities. The No-Build network includes all improvements funded in the NCDOT 2002-2008 Transportation Improvement Program (TIP) as well as the 2025 fiscally constrained regional transportation model. As described in Chapter 2, Interstate projects along the I-40 corridor included in the TRM are as follows:

- I-40 widened to six lanes between the Durham Freeway and I-85 in Hillsborough,
- I-40 widened to eight lanes between the Durham Freeway and I-540 in RTP,
- I-540 extended as a six-lane freeway from I-40 south to US 1 in Apex, and.
- I-40 widened to six lanes between Wade Avenue and US 1/ US 64

- In contrast to the Simple configuration, the Complex, Modified Complex and Elevated configurations add Express lane or GP lane capacity in addition to HOV capacity. For the Complex and Modified Complex configurations, this additional capacity is limited to the section of I-40 through Research Triangle Park between NC 147 and I-540. For the Elevated configuration, additional GP lane capacity is provided through the I-40 corridor study area from NC 86 to US 1/US 64. This additional capacity causes significant changes in traffic distribution patterns in the study area and attracts additional trips to the I-40 corridor from other routes and parts of the region.
- In addition to general purpose capacity, the number and type of access points directly impact the trip distribution patterns as well as the type of trips using the I-40 mainline, HOV, and Express lanes. In general, more access points would be anticipated to attract additional trips to I-40. Differences in overall capacity and access locations will provide variations, however. Table 7-3 summarizes the access points in the analysis.

Table 7-3 Number of Access Points

Comparison to No-Build Conditions	Simple	Complex	Modified Complex	Elevated
Number of Access points:				
HOV lane access points	Continuous	18	6	6
Express lane access points	N/A	2	2	4
I-40 Mainline interchanges	18	18	18	18

Demand Model Findings

Table 7-4 illustrates the network-wide and corridor-specific access impacts of the Build HOV configurations (i.e., Simple, Complex, Modified Complex & Elevated) as compared with the 2025 No-Build condition during the morning commute time. The results show no clear-cut preferences since no configuration consistently performed better for all the demand metrics considered in the study.

Table 7-4 Comparison of Demand Measures of Effectiveness (MOEs)

Comparison to No-Build Conditions	Simple	Complex	Modified Complex	Elevated
Network-wide indicators:				
Roadways operating at LOS F	-13.4%	-8.3%	-7.9%	-8.9%
Network Vehicle Miles Traveled (VMT)	+0.2%	+0.3%	+0.2%	+0.6%
Network Hours of Delay	-11.1%	-8.0%	-4.6%	-9.7%
Average Network Speed	+3.3%	+1.6%	+1.6%	+3.3%
I-40 indicators:				
VMT on I-40 (NC86 to US 1/ 64)	+15.3%	+15.3%	+14.6%	+22.3%
Average HOV volume on I-40	+65.4%	+45.5%	+35.1%	35.6%
Average People Moved on I-40	+17.5%	+16.5%	+13.4%	+20.3%
Average People Moved on I-40 through RTP (NC 55 to Aviation)	+19%	+18%	+16%	+26%

Some observations and conclusions that can be made from the results of the analysis include:

- The Simple configuration can be viewed as a marginally better solution as it shows the best performance in three out of the eight selected demand-model based indicators and ties in two indicators. The Simple configuration involves adding only HOV-capacity to the system, which causes small shifts to the traffic origin-destination pattern. As a net result, we observe higher capacity for essentially the same number of trips with similar origin-destination patterns. This results in a substantial increase in HOV volumes on I-40 and a reduction in both overall congested lane-miles and vehicle hours of delay.
- The Complex and the Modified Complex configurations show similar middle-of-the-chart type performance values in most of the demand measures. However, the Complex configuration shows a marginal edge over the Modified Complex in terms of number of people moved on I-40 and network delay reduction, since there are more frequent HOV-only access points. Specifically, the Complex configuration has eighteen HOV access interchanges as compared with six HOV access interchanges with the Modified Complex configuration.
- The Elevated configuration has the highest number of people moved on I-40 because of the additional general purpose capacity, and consequently the highest increase in VMT throughout the network and along I-40.
- In contrast to the Simple configuration, the Complex, the Modified Complex and the Elevated configurations are projected to accommodate significant Express lane traffic going through the RTP Corridor – East section of the study corridor. Express lanes provide improved operations for mainline traffic through this critical regional bottleneck.

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7.3.2 Traffic and Operations

Using the traffic projections from the TRM demand model, a thorough analysis of traffic operations through the I-40 corridor was undertaken. This included a level of service (LOS) analysis and a micro-simulation modeling for travel time analysis.

Traffic Operations

Table 7-5 presents a summary comparison of the LOS along I-40 corridors for morning (AM) and afternoon (PM) 2025 peak period traffic conditions. The LOS is reported for the peak direction of flow and average traffic volumes on each corridor section.

The Simple configuration includes the additional HOV lane, but for all other build configurations, the HOV and Express lanes are separated from the GP lanes. As a result, the LOS designation for the Simple configuration is generally better than all other configurations.

Barrier separated HOV operations on the Complex, Modified Complex and the Elevated configurations are not presented but are expected to operate at LOS D or better for most of the segments. In general, a two-lane freeway serving a combination of Express lane and HOV traffic (i.e., the Complex configurations) would have higher capacity than two barrier separated lanes serving Express lane and HOV traffic separately (i.e., the Elevated configuration).

The mainline analysis reveals that the I-40 GP lanes will continue to experience the highest level of congestion in the RTP Corridor – East segment, regardless of the direction of travel or time of day. In other words, I-40 through the RTP area would operate at- or over-capacity conditions in both directions during peak periods, resulting in unstable flow and frequent breakdown conditions. The Airport Corridor is also projected to experience high levels of congestion, especially in the westbound direction in AM and in the eastbound direction in the PM.

Although the configurations show only minimal improvement in the operations and LOS of the GP lanes, they are projected to accommodate higher peak period traffic volumes than the No-Build scenario. In addition, the impacts of peak period spreading should be minimized with additional capacity. Finally, this analysis does not examine the potential benefits of providing the proposed scenarios on off-peak operations, either with or without HOV restrictions.

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Table 7-5 2025 Traffic Operation Level of Service

AM PEAK PERIOD

Study Corridor and Direction of Peak Flow	No-Build	Simple	Complex	Modified Complex	Elevated
Western Corridor (EB)	D	C	D	D	D
RTP Corridor – West (EB)	F	E	E	E	E
RTP Corridor – East (WB)	F	F	F	F	F
Airport Corridor (WB)	F	E	E	E	E
Eastern Corridor (WB)	D	D	E	E	D

PM PEAK PERIOD

Study Corridor and Direction of Peak Flow	No-Build	Simple	Complex	Modified Complex	Elevated
Western Corridor (WB)	D	D	D	D	E
RTP Corridor – West (WB)	F	E	E	E	E
RTP Corridor – East (WB)	F	E	F	F	E
Airport Corridor (EB)	E	E	F	F	F
Eastern Corridor (EB)	D	E	D	D	D

Notes: LOS letter grades indicate a range of traffic conditions from free-flow (LOS A) to stop-and-go traffic (LOS D), to breakdown conditions (LOS F). Theoretical capacity has been exceeded when LOS E is reached.
Corridor LOS estimates reflect average traffic volumes and mask any bottlenecks.
Corridor LOS estimates are for general purpose lanes and do not include HOV/Express traffic except for the Simple configuration.

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Travel Time Savings and Delay Comparisons

Table 7-6 presents part of the results of micro-simulation modeling, which estimated travel times along GP lanes and the HOV facility and investigated the effects of specific traffic bottlenecks. The analysis shows that the majority of travel time savings on the corridor occurs within the RTP section of I-40. This primarily results from a critical bottleneck at the I-540 interchange that results in excessive delays for GP lane traffic.

Table 7-6 2025 Travel Time Advantage of HOV Lanes over GP lanes for RTP Commuters (Minutes)

	Simple	Complex	Modified Complex	Elevated
AM Peak Period				
1. EB I-40 from NC 86(Chapel Hill) to Aviation Pkwy (RTP)	2.1	8.6	6.2	6.9
2. WB I-40 from US 1/US 64 (Cary) to NC 147 (RTP)	3.1	5.2	5.2	7.1
PM Peak Period				
1. WB I-40 from Aviation Pkwy (RTP) to NC 86 (Chapel Hill)	1.1	0.7	0.6	1.2
2. EB I-40 from NC 147 (RTP) to US 1/US 64 (Cary)	13.6*	9.9*	8.6*	10.8*

**Time savings are primarily due to the bottleneck west of Aviation Pkwy and at the I-540 interchange in the GP lanes.*

Using the CORSIM micro-simulation tool, the total delays encountered by all vehicles, both in the GP and the HOV lanes, was estimated. Since this delay comparison is based on microsimulation analysis, it factors in delays due to traffic bottlenecks, weaving movements, and flow breakdowns along the I-40 corridor. The comparison is focused on the delay in the I-40 corridor between NC 86 to US 1/US 64, exclusively. It does not examine changes in regional delay that may occur on adjacent roads or access points to the network.

Delay for each HOV configuration was compared on a percentage basis with the 2025 No-Build condition.

Figure 7-1 summarizes the projected delay per unit vehicle miles traveled (VMT) for each HOV configuration. Figure 7-2 summarizes projected changes in total vehicle hours of delay for each HOV configuration. In examining the figures, a positive percentage change indicates that the HOV configuration is expected to increase delays as compared to the No-Build condition. In contrast, a negative change shows a reduction in vehicle hours of delay with the proposed configuration and indicates improved operations.

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Figure 7-1 Comparison of Unit Delay

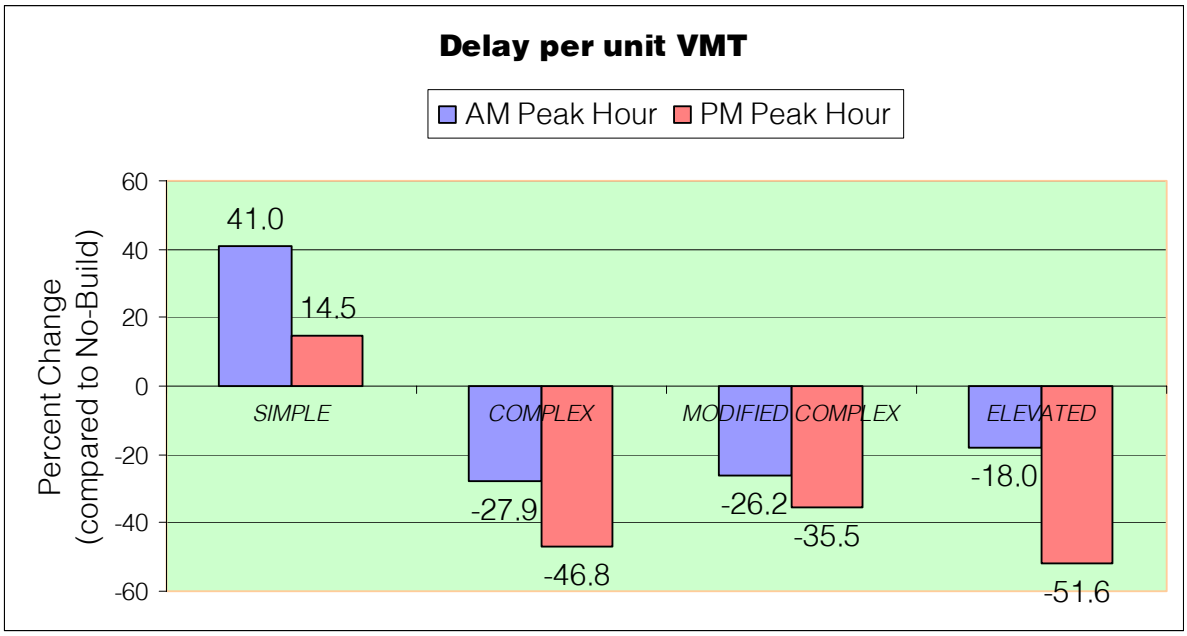
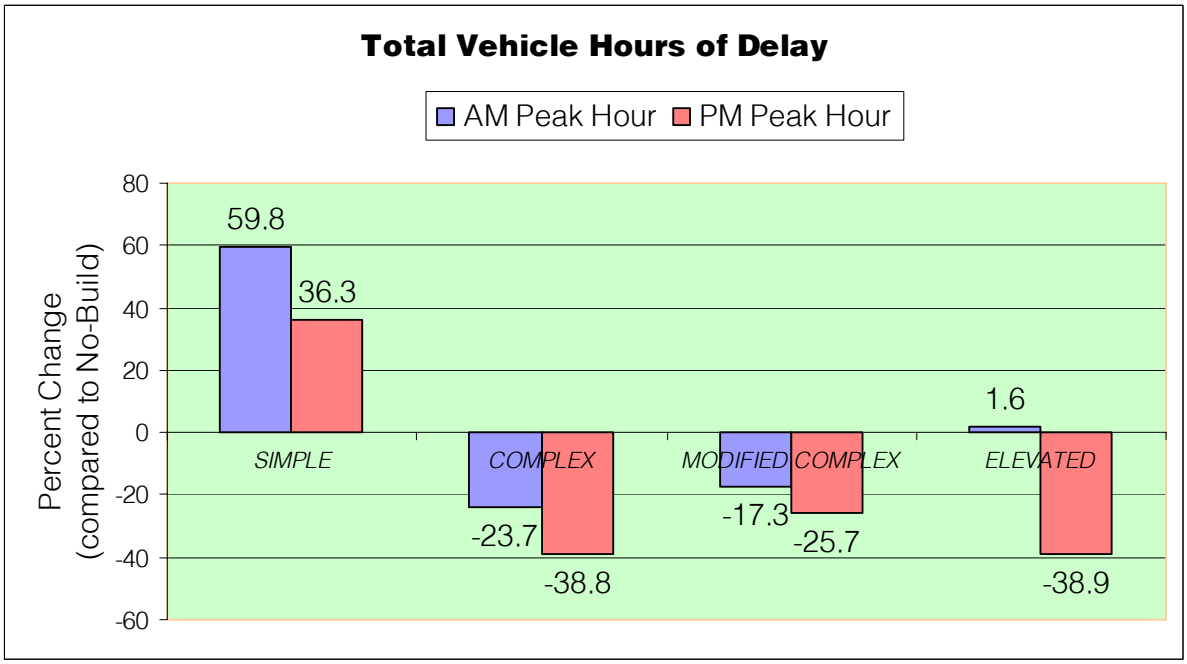


Figure 7-2 Comparison of Total Corridor Delay



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The two figures indicate the following:

- The Simple configuration shows significant weakness in reducing peak period travel delays. The Simple configuration is projected to make delay longer than the No-Build condition because of additional delay that results from weaving operations between the general purpose traffic and the HOV traffic near interchange locations.
- The Complex and the Modified Complex configurations show the best performance in reducing delay during the AM peak period, either on the basis of per unit VMT or total delay. These two configurations also show consistent results in reducing PM peak period delay. They provide an additional Express lane (resulting in additional general purpose lane capacity) on I-40 between NC 147 and I-540.
- The Elevated configuration shows the best performance in reducing delay in the PM peak period but is less consistent in reducing AM delay. Note that additional general purpose traffic capacity is provided through the entire corridor with this configuration.

An evaluation of the traffic operations analysis indicates that the Complex configuration shows the best performance in handling future projected traffic conditions during both AM and PM peak periods. The Modified Complex configuration also shows good operational performance. While the Elevated configuration works the best during PM peak condition, it fails to adequately handle the projected AM peak period demand. The Simple Configuration shows poor operational performance overall as would be expected since it does not include the provision for additional general purpose capacity in the RTP East Corridor section and the high HOV demand creates weaving-related bottlenecks on the GP lanes.

7.3.3 Environmental Screening

An environmental screening was conducted for two of the four build configurations, the Simple and the Complex, based on research of existing information. This environmental screening did not include any field data collection. The intention of the environmental screening at this juncture was to determine if there are any significant fatal flaws. If this project moves forward, a more detailed environmental assessment of configurations will more accurately account for specific environmental impacts. At this level of analysis, no fatal flaws were identified for any of the configurations.

Table 7-7 provides a comparison of potential environmental impacts of the Simple and Complex HOV configurations.

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Table 7-7 Environmental Impact Comparison

Resource	Simple Configuration	Complex Configuration
Stream Crossings	40 crossings	53 crossings
Wetlands	8 potential encroachments	12 potential encroachments
Protected/Public Lands	No encroachments	No encroachments
Threatened & Endangered Species	No known impacts	No known impacts; encroachment in one Significant Natural Heritage Area
Archaeological Sites	47 sites within one-half mile	54 sites within one-half mile
Historic Sites	10 sites with some designation within one mile	10 sites with some designation within one mile
Community Impacts	No property encroachments	Up to 19 property encroachments

The Complex Configuration and the Modified Complex configuration have identical footprints and estimated right-of-ways. Therefore, environmental screening was not performed for the Modified Complex Configuration specifically. However, the Modified Complex configuration has fewer interchanges than the Complex configuration, and so it can be assumed that it would have a reduced impact on environmental resources than the Complex configuration.

Environmental screening was also not performed for the Elevated configuration. At the time that the work was scoped for the Elevated configuration analysis, NCDOT anticipated that the elevated structure could be fit entirely within the median of the existing roadway, and that the impact on the environment would be negligible. As the analysis progressed it became apparent that going to the outside of the existing roadway was necessary. This resulted in expanding the required right of way. Without an environmental screening exercise it is not possible to determine the magnitude of possible impacts. Since the right of way is wider than that for the Complex Configuration it can be assumed that the impacts would be somewhat greater.

7.3.4 Construction and Costs

A conceptual roadway design for I-40 between NC 86 near Chapel Hill and US 1/US 64 was developed and is shown in Appendix A. They include the Simple, Complex, Modified Complex and Elevated HOV configuration as well as a design for a standard widening of I-40 between Wade Avenue and US 1/ US 64.

Based upon this analysis, comparisons between the four configurations were developed. Table 7-8 examines the basic width for each typical section, excluding cut/fill slopes and right of way offsets. In general, the Simple configuration requires the narrowest typical section, the Complex and Modified Complex configuration have the same width, and the elevated section has the greatest width.

Table 7-8 Typical Section Comparison

Typical Section Width*	Simple	Complex	Modified Complex	Elevated
Western Corridor	170’	210’	210’	199’
RTP Corridor -- West	170’	210’	210’	255’
RTP Corridor -- East	194’	234’	234’	283’
Airport Corridor	194’	234’	234’	283’
Eastern Corridor	186’	226’	226’	247’

**Excluding construction easements, right of way offsets, and cut/fill slopes*

Table 7-9 examines the impact of widening I-40 to provide for HOV facilities on bridge structures through the corridor. The Simple configuration requires approximately half the bridge replacements/new bridges as the Complex alternative because it has both a narrower typical section and no HOV-exclusive interchanges in the Simple configuration. The Modified Complex, as analyzed, has fewer HOV-only interchanges (6) than the Complex configuration (18) resulting in fewer bridges. The Elevated configuration requires two two-lane structures on each side of the existing I-40. In addition, structures will be required for six HOV interchanges.

Table 7-9 Bridge Requirements Comparison

Reconstruct & Provide New Bridges	Simple	Complex	Modified Complex	Elevated
Western Corridor	5	5	5	CNES
RTP Corridor -- West	16	21	19	CNES
RTP Corridor – East	6	26	21	CNES
Airport Corridor	2	5	4	CNES
Eastern Corridor	4	9	5	CNES
TOTAL	**33**	**66**	**54**	CNES

Notes: Some of the bridge reconstruction activities in Simple will entail only changing the bent slopes to retaining walls.
CNES = Construct New Elevated Structures with minimal impact to existing general purpose traffic by adding bridges outside the existing travel lanes.

Table 7-10 provides preliminary construction cost estimates for the four HOV configurations analyzed in this study. These figures do not include right-of-way costs. As would be expected, the Simple configuration is the least expensive with the Elevated structure having the greatest cost. The Modified Complex is less expensive than the Complex as a result of having fewer HOV-exclusive interchanges.

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Table 7-10 Cost Estimates Comparison (in millions)

	Simple	Complex	Modified Complex	Elevated	Simple	Complex	Modified Complex	Elevated
	2002				2025			
Western Corridor	29	79	77	232	54	146	142	428
RTP Corridor -- West	68	127	81	465	126	234	150	858
RTP Corridor – East	59	293	225	617	109	541	415	1,139
Airport Corridor	27	53	52	323	50	98	96	596
Eastern Corridor	54	97	84	324	100	179	155	598
TOTAL	**$237**	**$649**	**$519**	**$1,961**	**$439**	**$1,198**	**$958**	**$ 3,619**

In comparing Tables 7-8, 7-9, and 7-10, it should be noted that the section with the widest typical section, the highest bridge requirements, and the highest cost is the RTP Corridor – East between NC 147 and I-540. This section also carries the highest traffic volumes in the entire region and is a daily bottleneck on the I-40 corridor today and into the future.

7.4 Combining Configurations

The analysis in this study focuses on several issues and measures of effectiveness for each of the four configurations. These four configurations represented different concepts in providing HOV mobility and accessibility. Although these four configurations were applied uniformly throughout the study corridor, it is possible that a combination of these configurations could be applied in different sections of the HOV network producing a "hybrid" configuration. This would allow a regional solution that best addresses the unique requirements of each segment of I-40. Of course, any specific "hybrid" configuration would require more detailed analysis as part of a NEPA process to determine a preferred alternative.

On I-40 through the RTP, a configuration that addresses both local and through movement congestion would be required. The area is a major employment center destination attracting thousands of commuters, thereby generating daily traffic congestion. Not only does this congestion affect those commuters destined to RTP, it affects both commuters and Interstate trips passing through RTP to other destinations.

An example of a hybrid combination concept would be combining a higher capacity alternative, such as the Elevated configuration, through the high demand RTP East Corridor with a less expensive alternative configuration in adjacent corridors. For the Airport corridor, the Modified Complex configuration may be desirable due to the wide section of GP lanes and major interchange splits that complicate highway flow. In contrast, the Simple configuration may be most applicable in the Western, RTP West, and Eastern corridors that have lower HOV demand as well as a planned typical section of six GP lanes.

In addition to varying the specific configurations under study, potential hybrid configurations could examine the potential of adding additional access points. An example would be to utilize the Modified Complex configuration and add a few local access HOV service interchanges at high demand locations. Potential opportunities that were identified as part of the demand analysis include Harrison Avenue, Alston Avenue, and possibly Trinity Road. In addition, an HOV interchange serving the Research Triangle Park could provide an HOV bypass for commuter trips.

By varying cross sections, access locations, and phasing plans, various "hybrid" configurations can be tested in the NEPA process. Analyzing "hybrid" configurations offers the potential for minimizing costs for construction on lower demand corridors. As a result, there may be opportunities for accelerated implementation of HOV facilities on a project level basis while ultimately allowing for development of a regional system.

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8. FINDINGS AND NEXT STEPS

The I-40 High Occupancy Vehicle/Congestion Management Study has determined that there is enough HOV demand by the year 2025 to support a 100-mile HOV network. While it may not be realistic to believe that the cities of Raleigh, Durham and Chapel Hill can implement an extensive HOV lane system in such a relatively short time, it is important to develop the planning framework and funding plans for this strategic congestion management effort.

Given the strong projected demand and the continuing growth in regional traffic congestion anticipated in the Triangle Region, this 100-mile network should serve as the "blue-print" for a long-range future HOV system. The plan also recognizes the needed regional components of a major highway and arterial improvement program, a TDM program and the high capacity transit investment. The study has determined a high HOV demand in some sections of I-40 for interim years 2005 and 2015. This demand exists in spite of a number of new highway projects targeted to come on line in the near future. The network needed to handle this interim HOV demand is smaller and indicates where the more immediate needs exist. These are the HOV segments that should move forward first.

The first step towards implementation is to include all or portions of the HOV network in short-, mid- and long-range transportation programs. The NCDOT along with CAMPO, DCHC, TTA and other transportation planning agencies should work together to confirm the overall congestion management "blue print," including it in master plans and transportation improvement plans. It is imperative that each agency within the region champion the HOV "cause" now. HOV treatment has been proven itself as an appropriate tool for addressing current and forecasted congested conditions in numerous other locations across the country. This study indicates that HOV facilities are an appropriate strategy for managing congestion in this region as well.

It is very important that the first I-40 HOV project to move forward is considered a success by the public. This project has to be seen as an immediate success; otherwise future investments in extensions could be questioned for effectiveness and thus be lost as a transportation tool for some time to come.

Not surprisingly, the study determined that the highest priority segment for HOV on I-40 is in Research Triangle Park between NC 147 and I-540 and implementing this segment can generate a project success. However, the study also concluded that the need is not simply to serve RTP but to serve trips passing through RTP. Therefore, it is recommended that more detailed environmental analysis be conducted for HOV facilities between NC 86 near Chapel Hill and US 1/US 64 near Cary. The proposed study corridor limits allow for a more focused evaluation of trips destined to and through the RTP. These limits also provide for reasonable NEPA coverage that addresses logical termini and segmentation issues.

The HOV concept should not be studied in isolation. Other elements can contribute to the potential success of HOV and should be studied in conjunction with it. At a minimum, these studies should include park-and-ride lots that support the proposed HOV lanes and bus service that could take advantage of HOV lane travel-time savings.

The HOV concept can also potentially "buy time" for the NCDOT. By improving the efficiency of a facility, some transportation improvements could be delayed or eliminated

altogether.

As the saying goes, “You cannot build your way out of congestion.” It is important to look at options that better manage the transportation resources that exist. HOV is a tool that meets that objective. By moving more people in fewer cars, the overall transportation system can become more efficient. Moving forward with the next steps to implementation can make HOV lane a reality for the region.

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