

# Crabtree Valley Transportation Study



Prepared for



Prepared by



The Louis Berger Group, Inc.

March 3, 2011

# Table of Contents



## Table of Contents

Table of Contents.....	i
Executive Summary.....	1
People and Ideas.....	11
Accident Analysis .....	17
Streets and Highways.....	37
Traffic Analysis .....	42
Public Transportation.....	78
Appendix A: Developing Land Use Scenarios and Traffic Generation Forecasts .....	A-1
Appendix B: Survey and Results.....	B-1
Appendix C: Post-Holiday Survey Responses to Open-Ended Questions .....	C-1
Appendix D: Cost Estimate Analysis.....	D-1
Appendix E: Existing Traffic Counts and Travel Time Data .....	E-1
Appendix F: Traffic Signal Plans and Timing Schedules .....	F-1
Appendix G: Traffic Volume Diagrams .....	G-1
Appendix H: HCS Reports.....	H-1
Appendix I: Synchro and Simtraffic Analysis Reports .....	I-1
Appendix J: Accident Analysis.....	J-1
Appendix K: Design Alternative Maps.....	K-1
Appendix L: Citizen Comments & Consultant Responses .....	L-1

## List of Figures

Figure 1. Study Area of Crabtree Valley.....	2
Figure 2. Mall kiosk for public involvement surveys.....	3
Figure 3. Perspective rendering of preferred transportation improvements by 2035.....	7
Figure 4. City of Raleigh Greenway Entrance.....	9
Figure 5. Mode of travel used to arrive at mall. ....	12
Figure 6. Alternative Mode of Travel used at least once a week.....	12
Figure 7. Respondent car ownership. ....	12
Figure 8. Typical Method of Accessing the Study Area.....	12
Figure 9. Number of People in Car (Occupancy) .....	13
Figure 10. Average Age of Respondents (Total = 273).....	13
Figure 11. Are Traffic Delays Unacceptable? .....	13
Figure 12. Accident Analysis Intersections in Study Area .....	17
Figure 13. Monthly Accident Summary .....	19
Figure 14. Daily Accident Summary .....	20
Figure 15. Hourly Accident Summary .....	20
Figure 16. Glenwood Avenue and Creedmoor Road Crash Diagram.....	25
Figure 17. Glenwood Avenue and Mall Entrance/Marriott Drive Crash Diagram .....	26
Figure 18. Glenwood Avenue and Lead Mine Road/Blue Ridge Road Crash Diagram .....	27
Figure 19. Glenwood Avenue and I-440 WB Ramp Crash Diagram .....	28
Figure 20. Glenwood Avenue and I-440 EB Ramp Crash Diagram.....	29
Figure 21. Lead Mine Road and North Hills Drive .....	30
Figure 22. Creedmoor Road and Crabtree Valley Avenue Crash Diagram.....	31
Figure 23. Blue Ridge Road & Crabtree Valley Avenue Intersection .....	32
Figure 24. Traffic Analysis Process .....	43
Figure 25. 2009 Morning Peak Hour Traffic Volumes.....	48
Figure 26. 2009 Evening Peak Hour Traffic Volumes.....	49
Figure 27. Crabtree Valley Traffic Growth Projections .....	52
Figure 28. Existing Transit Hub Modifications .....	82

## List of Tables

Table 1. 2009 Baseline Traffic Conditions.....	4
Table 2. 2035 No Improvement Traffic Conditions. ....	4
Table 3. Level of Service in 2035 with preferred transportation improvements implemented.....	8
Table 4. Time savings comparing no improvements to preferred alternative improvements.....	8
Table 5. Opinion of Probable Construction Cost. ....	9
Table 6. Accident Type Summary, 1/1/2007 - 12/31/2009 .....	18
Table 7. Accident Cost Analysis.....	21
Table 8. Annual Accident Frequency .....	22
Table 9. Severity Index.....	22
Table 10. Equivalent Property Damage Only (EPDO) Index.....	23
Table 11. Intersection Crash Rate.....	24
Table 12. Glenwood Avenue/Creedmoor Road Intersection Accident Data Summary .....	25
Table 13. Glenwood Avenue and Mall Entrance / Marriott Drive Intersection Accident Data Summary .....	26
Table 14. Glenwood Avenue and Lead Mine Road/ Blue Ridge Road Accident Data Summary.....	27
Table 15. Glenwood Avenue and I-440 WB Ramp Accident Data Summary .....	28
Table 16. Glenwood Avenue and I-440 EB Ramp Accident Data Summary .....	29
Table 17. Lead Mine Road and North Hills Drive Accident Data Summary .....	30
Table 18. Creedmoor Road and Crabtree Valley Avenue Accident Data Summary.....	31
Table 19. Blue Ridge Road and Crabtree Valley Avenue Accident Data Summary.....	32
Table 20. Additional Right-of-Way Requirements .....	40
Table 21. Construction Cost.....	41
Table 22. 2009 Baseline Traffic Condition .....	47
Table 23. Crabtree Valley Area with No Improvements Performance Index (2035) .....	54
Table 24. 2035 Creedmoor Road Interchange System Performance .....	58
Table 25. 2035 Lead Mine Road Flyover System Performance .....	60
Table 26. 2035 Crabtree Valley Avenue Extensions System Performance .....	62
Table 27. 2035 Crabtree Valley Avenue Extension to I-440 System Performance .....	64
Table 28. Crabtree Valley Avenue Improvements Performance Index(2009). ....	67
Table 29. Crabtree Valley Avenue Extension to I-440 System Performance (2035).....	69
Table 30. Crabtree Valley Avenue Extension and Creedmoor Road SPUI (2035).....	71
Table 31. Crabtree Valley Avenue Extension and Westbound Glenwood Avenue (2035) .....	74
Table 32. Crabtree Valley Avenue Extension with Glenwood Avenue Overpass and Creedmoor Road Improvements (2035).....	76
Table A-33. Crabtree Valley Automobile Trip Reduction Measures .....	A-3
Table B-34. Top Issues and Solutions .....	B-7

# Executive Summary



The Crabtree Valley Transportation Study is a comprehensive transportation engineering and land use investigation for the defined study area. Based on projected land use scenarios, the Study includes an in-depth analysis of existing and future travel demand in the area and an evaluation of transportation needs to accommodate future growth. The long-range strategy for the area and details of the study with key issues related to public involvement, traffic projections, and alternative methods for relieving traffic are provided within the report. Data related to traffic forecasting, traffic generation, public surveys, analyses, and alternatives are provided in the appendices of this report. A copy of the full report is contained on a compact disc at the end of this document.

## Introduction

The Crabtree Valley Transportation Study centers along Glenwood Avenue from 1.5 miles west of the I-440 Interchange to 0.5 mile east of the Interchange. The study limits are approximately 0.5 miles north of Glenwood Avenue and 0.75 miles south of Glenwood Avenue. This area is approximately 2.5 square miles in area, or about 1,600 acres. Located in northwest Raleigh, the study area is generally defined along Glenwood Avenue between I-440 and Moorehead Drive including Crabtree Valley Avenue, Blue Ridge, Edwards Mill, Creedmoor and Lead Mine Roads. Crabtree Valley Mall, a major regional shopping destination, opened in 1972 and has since been remodeled and expanded to include many upscale specialty stores and a food court. The area is a growth center in the City's Comprehensive Plan. Crabtree Valley is a major regional activity center for retail, office, hotels, and housing which can be interconnected as an urban, mixed-use within a pedestrian and transit environment.

## Project Description

The Crabtree Valley Study Area is bisected by US 70/NC 50 (Glenwood Avenue) approximately 4.5 miles from downtown Raleigh. The main traffic corridor is Glenwood Avenue to the north of the property, with a majority of traffic coming from I-440 to the east of the mall. Edwards Mill Road/Creedmoor Road provides the western border, with residential and small commercial properties composing the southern border of the subject property. Heavy traffic volumes are experienced along Glenwood Avenue during peak commuting times (6 am to 9 am and 3 pm to 7 pm) and seasonally during the holiday shopping months between November and January.

Limited right-of-way and current traffic patterns provide unique challenges for improving the Crabtree Valley traffic conditions. Residents, employees, business owners, and commuters all share the need for improving the transportation system surrounding the mall. With plans for expansion, additional traffic generation will only cause the currently stressed transportation corridor to fail if no improvements or changes are made. Roadway and transit improvements will require the involvement of the City of Raleigh, the North Carolina Department of Transportation (NCDOT), Crabtree Valley Mall stakeholders, Capital Area Transit, the Triangle Transit Authority, surrounding business owners, and residents.



### **On Crabtree Valley Mall**

*At 1.3 million square feet, the Mall contains over 220 stores. Less well known is the fact the Crabtree Valley Mall is one of the few independently owned malls in the country. While other malls have struggled during the current economic recession, Crabtree Valley Mall enjoyed a 100% occupancy rate over the December 2009 holidays.*

## Objective

The objective of the Crabtree Valley Transportation Study is to assess current and future transportation conditions inside of a study area, shown in Figure 1. The study is primarily directed at providing future private vehicle, bus transit, pedestrian, and bicycling accommodations by making assumptions about internal development patterns and internal and external increases in traffic demand.

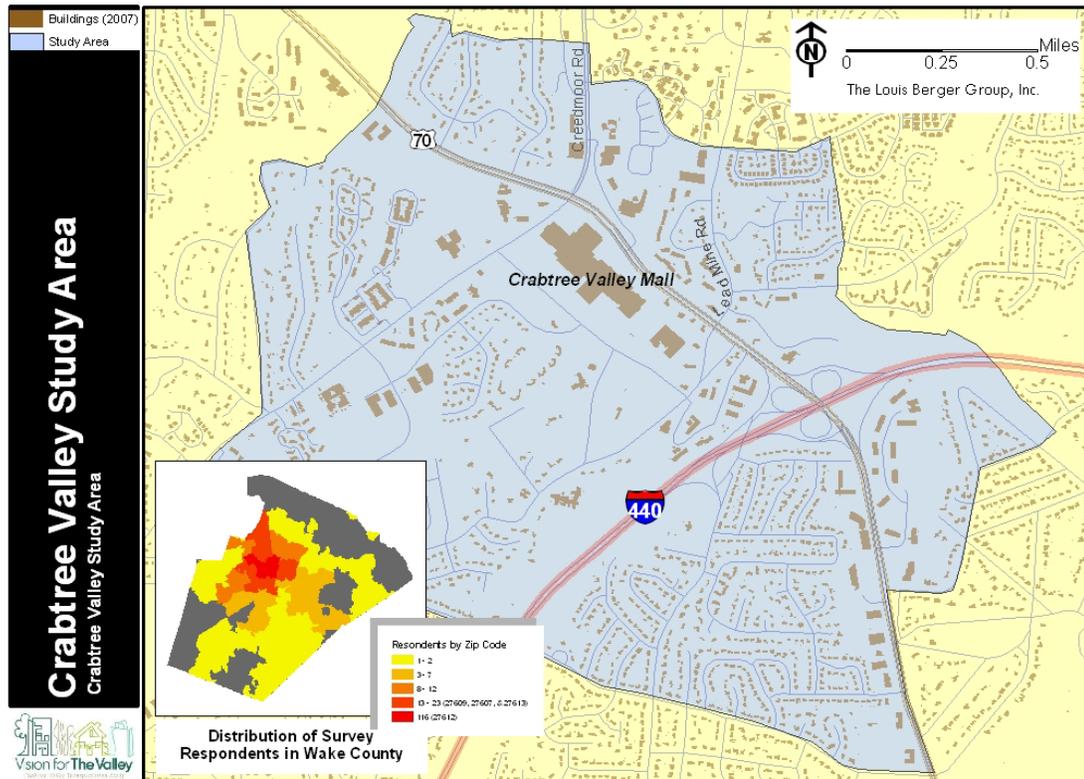


Figure 1. Study Area of Crabtree Valley

Maintaining reasonable mobility was a key factor in developing the preferred alternative that is best suited to meet the study area's future transportation needs while minimizing impacts to the surrounding environment. The following objectives were accomplished as a result of the study:

1. Established a clear "Vision for the Valley" by planning for congestion relief, and reasonable mobility even with the likely significant increase in vehicle trips in and through the study area.
2. Engaged interested citizens, mall patrons, and mall managers, developers and property owners to develop improvements that address their concerns and needs for mobility.
3. Analyzed current roadways and traffic to determine current level of service and create comparative analysis based on expected future traffic levels.
4. Evaluated various alternative traffic patterns to determine a preferred pattern for congestion relief and reasonable mobility at an attainable construction and right-of-way cost.

## Public Involvement

Several opportunities were provided for public participation study. The public involvement process included surveys, presentations to three Raleigh Citizen Advisory Councils, two house events, and an e-mail campaign to over 3,000 people on list. The study team met with specific groups with interest in Crabtree Valley study area. The input from the various efforts information for the preferred alternative.

Surveys were used to identify the travel market area, modes of transportation utilized, population demographics, and perceptions of traffic delays. Surveys were conducted during the holiday season among patrons walking through the mall.

Demographic characteristics of a majority of those who responded to the survey were 18 to 25 years of age, drove to the mall in their own car with no passengers and resided in the 27612 zip code. Most importantly, the respondents were asked three key questions regarding travel to Crabtree Valley Mall. These three questions were:

- Did you encounter any unusual delays before getting to the Mall that made the trip longer than usual?
- Please describe the most difficult part of the trip before you got onto the Mall property.
- If we make improvements to transportation in the Crabtree Valley Mall area, what should it be?

The overwhelming theme in the responses was traffic congestion and not being able to move through Glenwood Avenue intersections efficiently. Suggestions for improvements included synchronized signals and better access for transit, bicycle and pedestrian travel. The surveys provided a strong base for establishing public perception and justification for strategies to address congestion.



Additional public involvement included meetings with Citizen Advisory Councils, open house sessions, and preview meetings with Mall managers, developers and owners of large undeveloped property. This comprehensive approach to information gathering was developed to provide a meaningful cross section of inputs to the mobility solution for Crabtree Valley. Comments from these sessions provided data for addressing traffic, signals, transit, pedestrian access, bicycle safety, future development, and branding of Crabtree Valley. All groups are interested in the continued success of the Crabtree Valley Mall and are aware that mobility is a large component to this future success.

## Pedestrian and Bicycle Access and Safety Conditions – Present and Future

Although constrained somewhat by the topography of the Valley, access to the major destinations in Crabtree Valley is also constrained by perceptions of unsafe street crossings for pedestrians and unsafe streets for bicyclists. Many guests of hotels and motels in the study area consider destinations that are across the street, but choose to drive to avoid walking across busy streets. This challenge is explored and addressed in this study.



Figure 2. Mall kiosk for public involvement surveys.

during the open our mailing the provided

and after

responded

## Traffic Network Conditions – Present and Future

Current traffic volumes along Glenwood Avenue (US 70), the main thoroughfare of Crabtree Valley, total 40,000 to 70,000 vehicles per day. Overall, the roadway network is extremely well developed and constrained by existing land use, topography and floodplain/floodway restrictions. The current street system reaches maximum capacity of vehicular volume most days between Thanksgiving through the first week of January when additional commuters arrive from surrounding areas for holiday shopping. Future growth and development within Crabtree Valley and the surrounding areas will continue to impact traffic and stress a system that is already near capacity.

Over 20 intersections and freeway ramp junctions within Crabtree Valley were analyzed. Specific roadways considered in the study included Glenwood Avenue, Creedmoor Road, Lead Mine Road, North Hills Drive, Blue Ridge Road, Crabtree Valley Avenue, Edwards Mill Road, Homewood Banks Drive, Ridge Road and I-440. Traffic counts and supplementary historic traffic data were utilized to develop models and simulate baseline conditions for present day Level of Service (LOS). LOS is a performance measure used to evaluate the traffic operational conditions. A grade scale from A to F is used representing progressively worse traffic operations. LOS E or F are typically considered unacceptable by the City of Raleigh City Council when reviewing applications for new or intensifying redevelopment of land, although a LOS E may be accepted for adequate multimodal accommodations. Current LOS at the key intersections in Crabtree Valley are summarized below:

**Table 1. 2009 Baseline Traffic Conditions.**

Intersection	AM Traffic Average Delay (in seconds)	PM Traffic Average Delay (in seconds)
Glenwood Ave. and Creedmoor Rd.	66.3	89.5
Glenwood Ave. and Lead Mine Rd.	85.8	135.2
I-440 WB Offramp to Glenwood Ave.	14.7	144.3

Traffic projections are made for a design year of 2035 utilizing a combination of an annual growth factor (2.5%), the Trangle Regional Model, and land use analysis. The results of 2035 no improvement condition analysis are tabulated below:

**Table 2. 2035 No Improvement Traffic Conditions.**

Intersection	AM Traffic Average Delay (in seconds)	PM Traffic Average Delay (in seconds)
Glenwood Ave. and Creedmoor Rd.	259.5	422.8
Glenwood Ave. and Lead Mine Rd.	384.9	632.9
I-440 WB Offramp to Glenwood Ave.	193.6	360.2

Without increases in street capacity, mobility in Crabtree Valley will suffer, certainly by 2035 if not before. To preserve reasonable mobility in one of the most important centers in Raleigh, the need for mobility improvement is evident. Delays will get progressively worse as growth through the region continues, sales at existing businesses in Crabtree Valley increase, and land in the study area is developed. Mobility strategies are needed near-term (2010-2015), mid-term (2015-2020) and long-term (beyond 2020) in order to maintain reasonable mobility. Initial improvements would be focused on pedestrian and bicycle facility upgrades. Pedestrian refuge islands, reconstruction of I-440 ramps for traffic calming at pedestrian crossings,

construction of new sidewalks along Glenwood Avenue, and signage would improve pedestrian mobility and could be considered for near-term implementation.

- Near-Term Improvements
  - Narrow median and lane widths on Glenwood Avenue to build sidewalk on west side between Edwards Mill Road and Blue Ridge Road. Install pedestrian refuge islands at key crosswalks on Glenwood Avenue.
  - I-440 ramp geometry modifications to slow vehicular traffic as pedestrian crossings of ramps are improved for safety.
  - As development on adjacent parcels occurs, widen and relocate Crabtree Valley Avenue (See **Crabtree Valley Avenue B2 & B4** Maps)
- Mid-Term Improvements
  - Replace Ridge Road Bridge over I-440 and create new I-440 Interchange to direct traffic to Crabtree Valley Avenue (See **Crabtree Valley Avenue A3-B** Map)
  - Additional widening and signal improvements along Crabtree Valley Avenue
  - As development of adjacent parcels occurs, build enhanced CAT bus transfer center on site along Crabtree Valley Avenue with improved pedestrian access to nearest Mall building entrance
- Long-Term Improvements
  - Reduction of traffic signals for through traffic along Glenwood Avenue and directing Mall traffic to Crabtree Valley Avenue
    - Partial Grade Separation at Lead Mine Road (See **Crabtree Valley Avenue A4-B** Map)
    - Grade Separation Interchange at Creedmoor Road (See **Creedmoor Road** Map)
    - Provide pedestrian bridge from Marriott Drive over Glenwood Avenue
  - Fully developed transportation Master Plan by 2035 (See **Crabtree Valley Avenue A5-B** Map)

Alternative Description	Improvements	Reccomendations
Pedestrian & Bike Improvements	Improve connectivity of pedestrian and bicycle access in Crabtree Valley by adding sidewalks, installing pedestrian refuge areas at larger intersections, and providing traffic calming designs to improve pedestrian/vehicle interaction.	Implement pedestrian and bicycle improvements in the near term and continue to make improvements through the various traffic improvement measures.
A1 – Crabtree Valley Avenue/I-440 Interchange	Interchange for Crabtree Valley Avenue to I-440 includes an at grade crossing at Blue Ridge Road. This alternative also includes additional access for Arrow Drive and the replacement and reconfiguration of the Ridge Road Interchange.	The at grade configuration at Blue Ridge Road results in prohibitive grades for truck traffic due to the extreme elevation changes in the vicinity of Arrow Drive. Grades of 8% and greater would be required and would result in unsafe driving conditions.
A3 – Crabtree Valley Avenue/I-440 Interchange	Interchange for Crabtree Valley Avenue to I-440 provides a structure over Blue Ridge Road. The improvements also include use of the existing Ridge Road Offramp and includes improvements to access Glenwood Avenue. The existing Ridge Road Bridge is to be replaced.	Due to the existing geometric constraints, preferred design speeds could not be maintained for the entrance on to I-440.

Alternative Description	Improvements	Reccomendations
A3-B Crabtree Valley Avenue/I-440 Interchange	Similar concept to A1 and A3 with geometry that meets current NCDOT guidelines in relation to design speeds on ramps. This alternative requires additional right-of-way take in order to provide the required geometry.	This is the preferred alternative for the study. This configuration provides the geometries that meet current NCDOT Design Policy Guidelines.
A4 – Lead Mine/I-440 Interchange	In an effort to alliviate the congestion caused due to the left hand movement from Lead Mine Road to I-440, structures were considered to provide direct access to I-440.	The structures required for this alternative in comparission to the traffic improvements were cost prohibitive and eliminated as a viable alternative.
A4-B – Glenwood Avenue/Lead Mine Road Elevated Section	Elevating Glenwood Avenue Westbound traffic to cross Lead Mine Road creates a free flow movement of traffic. West bound through traffic bypasses the currently congested intersection and provides right turn only movement on to Lead Mine Road. Lead Mine traffic passes under the raised structure.	This is part of the preferred alternative for the ultimate design build-out. The design would occur after improvements were completed on Crabtree Valley Avenue and I-440 Interchange modifications.
A5-B – Crabtree Valley Transportation Study Preferred Alternative	This alternative illustrates all of the component segments of construction fully developed for the final improvements to the project area.	
B1 – Glenwood Avenue to Crabtree Valley Avenue Bypass	Provide an intersection bypass west of Creedmoor Road directing mall and future I-440 traffic through the Crabtree Valley Avenue corridor.	Structures over Crabtree Creek floodway for the interchange make this a cost prohibitive alternative.
B2 – Crabtree Valley Avenue Improvements	Maintain existing grade on Crabtree Valley Avenue. Widen road to accommodate four lanes of traffic with a planted median and left hand turn pockets. Interim improvements for the Blue Ridge Road at grade alternative.	Due to grade restrictions for the future I-440 interchange, this alternative became obsolete. The widening of Crabtree Valley Avenue between Homewood Banks Drive and Blue Ridge Road is part of the recommended alternative.
B4 – Crabtree Valley Avenue Re-alignment	Relocation of Crabtree Valley Avenue to the south of the existing intersection. This alternative will provide a frontage road to a currently undeveloped commercial property and provide greater connectivity to the mall and surrounding residents as an alternative route to Crabtree Valley Mall.	This configuration is part of the preferred alternative. This improvement will likely be the second phase of the ultimate build-out for the Crabtree Valley Corridor.

Alternative Description	Improvements	Reccomendations
Creedmoor Road	Grade separation structure provided at Glenwood Avenue to allow free movement of East and West bound traffic on Glenwood Avenue. Left hand turns from Glenwood Avenue through the corridor are eliminated and replaced by "Texas U-turns". The pedestrian bridge at Marriott Drive is also part of this alternative.	This improvement is considered the final project for the preferred alternative.
Ridge Road	Traffic calming measures are provided at the I-440 ramps with improvements being made at Ridge Road and North Hills Drive.	Structure at North Hills Drive and overall traffic impacts to the existing Ridge Road configuration eliminated this alternative from the preferred improvements selection.



Figure 3. Perspective rendering of preferred transportation improvements by 2035.

The implementation of these improvements is projected to yield the following performance:

**Table 3. Level of Service in 2035 with preferred transportation improvements implemented.**

Intersection	2035 with Preferred Transportation Master Plan	
	AM Traffic Average Delay (in seconds)	PM Traffic Average Delay (in seconds)
Glenwood Avenue and Creedmoor Rd.	99.3	180.4
Glenwood Ave and Lead Mine Rd.	223.2	208.7
I-440 WB Offramp to Glenwood Ave.	15.2	57.3

**Table 4. Time savings comparing no improvements to preferred alternative improvements.**

Intersection	2035 No Improvements				2035 Proposed Improvements				
	AM		PM		AM		PM		
	Delays (Sec)	LOS	Delays (Sec)	LOS	Delays (Sec)	LOS	Delays (Sec)	LOS	
Glenwood Ave./ Creedmoor Rd.	259.5	F	422.8	F	99.3	F	180.4	F	
Glenwood Ave./ Marriott Dr.	39.2	D	220.6	F	--	--	--	--	
Glenwood Ave./ Lead Mine Rd.	384.9	F	632.9	F	223.2	F	208.7	F	
Glenwood Ave./ I-440 WB Ramp	193.6	F	360.2	F	15.2	B	57.3	E	
Glenwood Ave./ I-440 EB Ramp	148.4	F	185.0	F	57.5	E	54.4	D	
Lead Mine Rd./ North Hills Dr.	77.2	E	173.5	F	53.8	D	102.4	F	
Creedmoor Rd./ Mall Entrance	121.7	F	70.8	E	67.8	E	56.3	E	
Blue Ridge Rd./ Mall Entrance	139.7	F	133.4	F	--	--	--	--	
Creedmoor Rd./ Crabtree Valley Ave.	48.7	D	97.1	F	29.7	C	45.2	D	
Crabtree Valley Ave./ Blue Ridge Rd.	238.6	F	239.4	F	18.2	B	33.0	C	
Crabtree Valley Ave./ Mall Parking Deck	--	--	--	--	6.9	A	18.8	B	
Crabtree Valley Ave./ Homewood Banks Dr.	11.6	B	21.2	C	46.2	D	70.7	E	
Glenwood Ave Arterial	EB Speed (mph)	4 (4~4)	F	3 (3~3)	F	7 (5~8)	F	6 (4~6)	F
	WB Speed (mph)	7 (6~7)	F	5 (3~5)	F	34 (30~37)	B	28 (19~33)	B

## Improvement Impacts

Impacts to existing Right-of-Way and the environment played a significant role in the development of the preferred transportation alternatives for Crabtree Valley. Strategies and design concepts were created to compliment the surrounding environment and serve the ultimate purpose of maintaining mobility in the area. Constructability issues were also given consideration in anticipation of the physical improvements.

**Right-of-Way** impact minimization was an objective in creating design concepts. Many of the impacts considered are complimented with the opportunity for mobility improvement. Less than three (3) acres of additional right-of-way is required for any of the eleven (11) alternatives considered. Six (6) of the alternatives require less than two (2) acres of additional right-of-way. The preferred alternative would require approximately three (3) acres.

An important attribute of Crabtree Valley is Crabtree Creek, running along the southern border of the mall property. Segments of roadway projects will occur within the Crabtree Creek floodplain. While the transportation study did not specifically identify environmental impacts, the National Environmental Policy Act (NEPA) requires federal agencies to integrate environmental impact avoidance and minimization into the decision-making process. NEPA documentation may include Categorical Exclusion, Environmental Assessment, or an Environmental Impact Statement. Avoidance, minimization, and mitigation will be key items to be discussed as the environmental permitting process evolves. As funds are secured and specific roadway projects are designed, extensive environmental studies will be conducted and coordinated with federal and state natural resource agencies regarding potential environmental impacts and permitting.



Figure 4. City of Raleigh Greenway Entrance.

Maintenance of traffic during construction will be a major challenge for all of the alternatives provided. Detours, temporary signals, and extensive signage will be utilized to maintain access to businesses and residents in Crabtree Valley. Coordination with the City of Raleigh, NCDOT, and the contractor will be critical in the development of a staged construction or construction phasing plan. The completion of new street capacity construction prior to major reconstruction of existing streets is a centerpiece of the preferred alternative, so that existing travelers will have a viable alternate route to avoid delay on streets that are under construction.

### Opinion of Probable Construction Cost for Proposed Alternatives

The following table identifies the alternatives considered for the transportation study, and an opinion of probable cost for construction using current year dollars. The likely cost in the year of construction will likely be higher, due to inflation, escalation of the cost of construction materials, the cost to finance construction, design costs, right-of-way acquisition, and utility impacts. The preferred alternative cost shown is the total project construction in a single construction phase. Detailed cost breakouts are provided in **Appendix D** of this report.

Table 5. Opinion of Probable Construction Cost.

Alternative	Description of Alternative	Construction Cost (millions)
B-4	Widening and Relocation of Crabtree Valley Avenue	\$ 10.0
A3-B	Blue Ridge Rd. to I-440 (Crabtree Valley Avenue extension with grade separation at Blue Ridge Road)	\$ 40.1
A4-B	Blue Ridge Rd. to I-440 with Lead Mine Partial Grade Separation	\$ 52.8
CR	Grade Separation Structure at Creedmoor Road	\$ 26.1
<b>A5-B</b>	<b>Preferred Alternative – Master Transportation Plan 2035</b>	<b>\$ 90.7</b>

### Implementation of the Preferred Alternative

The Crabtree Valley Transportation Study is focussed on accommodating multiple modes of transportation, projected land use, and maintaining reasonable mobility levels in the study area. The preferred alternative is displayed in the **Crabtree Valley Avenue A5-B** map and the perspective drawing shown previously in Figure 3. The implementation sequence for the plan has been outlined as follows:

- Acceptance of the Transportation Study Report and Opening Public Comment Period
- Acceptance of the Study Report and the Preferred Alternative by the Raleigh City Council for the Crabtree Valley Transportation Study
- Amendments to the Raleigh Comprehensive Plan
- City of Raleigh schematic design of Near-Term, Mid-Term, and Long-Term Improvements
- Environmental studies, documentation and permitting
- Programming of funds
- Transit planning with CAT and NCDOT
- NCDOT planning for Ridge Road bridge improvements
- Plans, specifications and estimates
- Right-of-way acquisition
- Utility relocation
- Construction

### Whom to Contact for More Information on this Report

Eric Lamb, PE, Manager  
Transportation Services Division  
One Exchange Plaza, Suite 727  
P.O. Box 590  
Raleigh, NC 27602  
Office (919)516-2161  
[Eric.Lamb@raleighnc.gov](mailto:Eric.Lamb@raleighnc.gov)

Fleming A. El-Amin II, AICP  
Transportation Services Division  
One Exchange Plaza, Suite 727  
P.O. Box 590  
Raleigh, NC 27602  
Office (919)516-2158  
[Fleming.El-Amin@raleighnc.gov](mailto:Fleming.El-Amin@raleighnc.gov)

Dean Hatfield, PE, Director of Engineering  
The Louis Berger Group, Inc.  
1001 Wade Avenue, Suite 400  
Raleigh, NC 27605  
Office 919.866.4425  
[dhatfield@louisberger.com](mailto:dhatfield@louisberger.com)



#### **Acknowledgements**

*The Louis Berger Group, Inc. would like to thank the City of Raleigh and its citizens, business owners and elected officials for their visions and leadership contributions. Our study team also consisted of WSP-Sells, Henderson Consulting, Springboard Eydo, and BREE & Associates.*

# *People and Ideas*



## **The Challenge**

The study area is particularly heavily travelled during the peak holiday season, beginning at Thanksgiving and continuing throughout the month of December and the first week of January. This posed a particular challenge in gathering information, since the most obvious shortcomings in transportation accommodations are more evident during these periods, and also in that many people who are not regular visitors would be responding to surveys. During the holidays, more people from farther away, and potentially with less familiarity with the study area, would overwhelm the survey results submitted by regular customers of the Mall and surrounding neighborhoods who are more knowledgeable about local traffic conditions. Nevertheless, public input is absolutely crucial to understanding traffic patterns and in particular, small-scale concerns that can be easily addressed in shorter-term scenarios.

## **The Response**

A four-pronged approach was thus undertaken to develop meaningful input to the study design.

1. Execute public surveys inside Crabtree Valley Mall before, during, and after the December holidays;
2. Engage the Raleigh Citizen Advisory Committees (CAC) that represent this Study Area;
3. Conduct Two Open House events to refine issues and recommendations; and
4. Reach out to specific interested parties in the hotel industry, Crabtree Valley Mall, private developers, and City of Raleigh staff, particularly those responsible for traffic, land planning, and public transit/bicycle/pedestrian transportation.

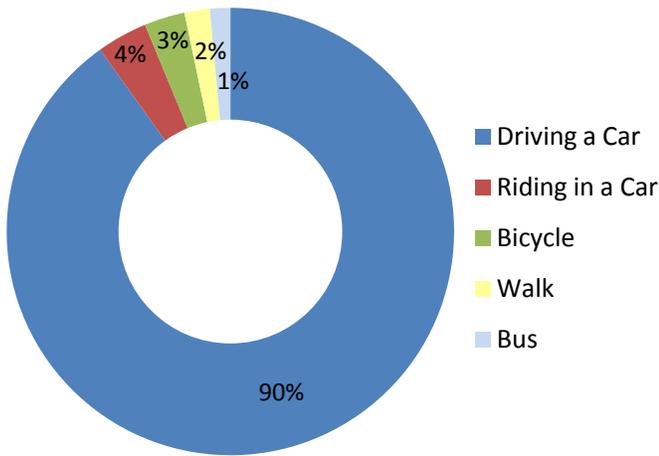


Figure 5. Mode of travel used to arrive at mall.

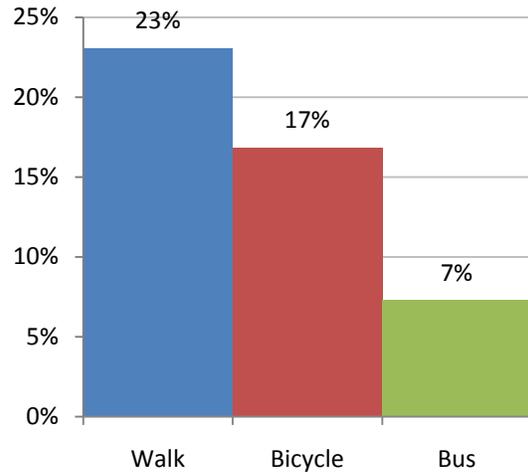


Figure 6. Alternative Mode of Travel used at least once a week.

A three-tiered survey effort took place to capture holiday season and post-holiday season Crabtree Valley Mall patrons; and a third effort conducted to assess other residents and area travelers. A survey consisting entirely of a mall-walking group preceded these surveys, and was generally used as a pilot study to identify any issues with the survey instrument. The holiday and post-holiday in-mall survey methodologies and results are entirely contained in Appendix B of this document, as well as an example of the actual survey instrument.

The third tier of surveying was directed toward general citizens and travelers through the study area. The input was accomplished through both an on-line and paper-based survey, which was completed by 273 people between the beginning of February and end of March, 2010. The survey results show a heavy reliance on personal automobiles for accessing the study area, as well as significant amounts of carpooling, biking, walking, and transit usage (Figure 5 and Figure 6). The result is not surprising since many more people ride together to go to retail establishments than for other trip types such as work, and because the area's car ownership rate is over 98% for all survey respondents (Figure 7 and 13).

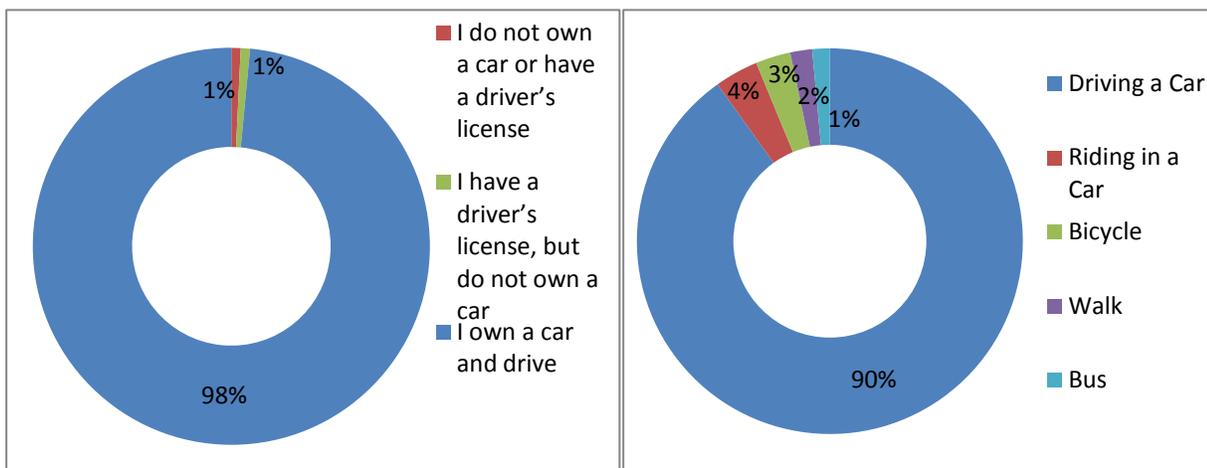


Figure 7. Respondent car ownership.

Figure 8. Typical Method of Accessing the Study Area.

The automobile occupancy rate in fact is nearly 1.67 persons per vehicle (for all respondents that rode or drove in a car), well above typical occupancy rates of 1.2 – 1.4. However, nearly half of all car riders still ride alone through the study area (Figure 9).

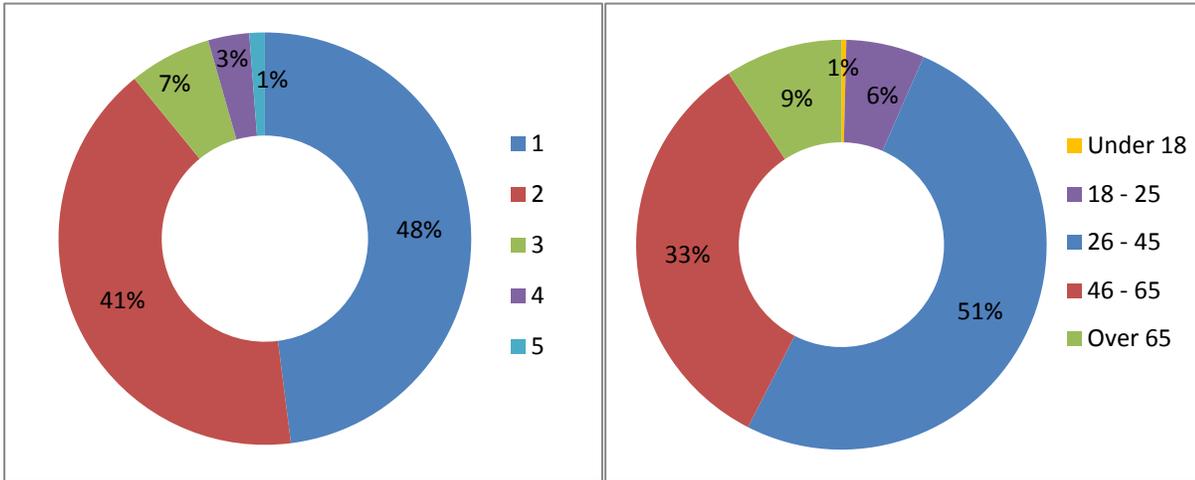


Figure 9. Number of People in Car (Occupancy)

Figure 10. Average age of Respondents (Total = 273)

Half of the survey respondents were between 26 to 45 years old (Figure 10). The distribution of respondents is identified in Figure 3 showing Wake County as an inset in the study area map. Generally, the distribution of the respondents were focused tightly around the study area; the holiday season respondents exhibited a somewhat greater spread of origins (refer to Appendix B).

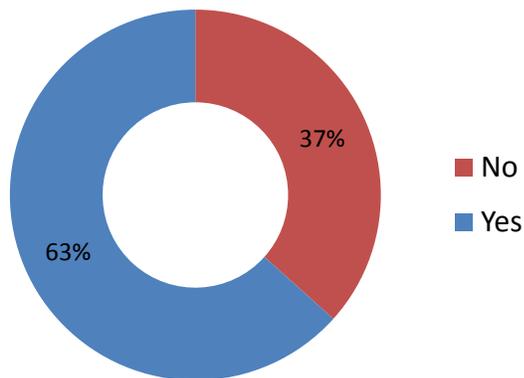


Figure 11. Are Traffic Delays Unacceptable?

All survey respondents were asked if they felt the vehicular travel delays that they encounter in the Crabtree Valley study area were “unacceptable.” Figure 11 indicates the results; approximately two-thirds of the respondents to this question answered “Yes.”

Finally, all survey respondents were asked three questions to gather further information about their experiences, ideas, and general comments on the Crabtree Valley area. Appendix C provides the complete set of responses to all three questions.

Three Raleigh Citizens Advisory Councils (Glenwood, Northwest, and Six Forks) were contacted and invited to participate in the public engagement process. Study team members attended regularly-scheduled CAC meetings to introduce the study process and distribute surveys. Attendance at each CAC meeting ranged from 20 - 50 people. Questions from citizens centered on

asking for more details on the problem to be addressed and requests for more pedestrian, bicycle, and transit facilities and service.

Two open house events were held, one on March 1<sup>st</sup> and the other on May 3<sup>rd</sup>, 2010. Attendance on March 1<sup>st</sup> exceeded 75 people. Surveys were distributed at the March 1 event, but the survey period closed before the May 3<sup>rd</sup> open house. Attendance on May 3<sup>rd</sup> was approximately 20 people. Most of the questions asked of staff during the May 3 open house related to process and next steps. The only written comment form submitted on May 3<sup>rd</sup> indicated support for changes that would facilitate traffic moving smoothly.

### Synthesis of Public Comments

Interested citizens have responded to a detailed questionnaire distributed in the early phase of the study with information about “the most difficult part of their trip to or through Crabtree Valley” and suggested improvements. Comment were also received at two open house meetings and via an e-mail address provided to over 1,300 citizens on an e-mail list. The following is a synthesis of the most prevalent comments and a response from the consulting team as to how each comment is addressed in the Draft Report.

**Comment 1:** Synchronize traffic signals on Glenwood Avenue in Crabtree Valley.

**Response 1:** The traffic signals on Glenwood Avenue are already synchronized. Traffic congestion on Glenwood Avenue may be the reason for driver’s perception of unsynchronized traffic signals, since they may see green lights ahead, but are unable to get through an intersection due to vehicle queues. High traffic volume from side streets reduce the traffic signal green time available to Glenwood Avenue, thus shortening the amount of time that Glenwood Avenue green lights are in synch.

**Comment 1:** Synchronize traffic signals on Glenwood Avenue in Crabtree Valley.

**Response 1:** The traffic signals on Glenwood Avenue are already synchronized. Traffic congestion on Glenwood Avenue may be the reason for driver’s perception of unsynchronized traffic signals, since they may see green lights ahead, but are unable to get through an intersection due to vehicle queues. High traffic volume from side streets reduce the traffic signal green time available to Glenwood Avenue, thus shortening the amount of time that Glenwood Avenue green lights are in synch.

**Comment 2:** When were traffic signals last retimed?

**Response 2:** The signals in the valley were last retimed in October/November 2009.

**Comment 3:** Reduce or eliminate traffic signals along Glenwood Avenue.

**Response 3:** Each traffic signal provides important access and right-of-way control. Only through the construction of bridges called grade separations or other methods of providing alternate access would the City of Raleigh and NCDOT consider removing a traffic signal. In this study report, all of the alternatives will either reduce the amount of traffic signals or improve the signal operations on Glenwood Avenue. One specific example of a concept to eliminate signals for through traffic on Glenwood Avenue is Alternative A5, whereby grade separations would be built so that westbound through traffic on Glenwood Avenue would have no signals between I-440 and the Pleasant Valley area. In Alternative A5, eastbound through traffic on Glenwood Avenue would encounter just two signalized intersections, at Lead Mine Road/ Blue Ridge Road and also at the I-440 eastbound ramp.

**Comment 4:** Reduce turning movement onto and off of Glenwood Avenue.

**Response 4:** Two of the proposed alternatives restrict turning movements on and off Glenwood Avenue. The movement restrictions are proposed in two stages. As shown in alternative A4-B, stage 1 involves constructing grade separation for Glenwood westbound traffic over the Lead Mine Road / Blue Ridge Road intersection, which would eliminate left turns from westbound Glenwood Avenue to Blue Ridge Road. Alternative A4-B includes converting Marriot Drive to a right-in/ right-out only driveway, and converting the Mall Entrance at Glenwood Avenue to a right-in/ right-out /left-in only driveway. In stage 2, as shown in alternative A5-B, the existing median on Glenwood Avenue would be extended through the Marriott Drive / Mall Entrance intersection to eliminate left-turn movements from Glenwood Avenue including those inbound to the Mall. Instead, traffic would make a U-turn at the Creedmoor/Glenwood Avenue intersection.

**Comment 5:** Separate Crabtree Valley Mall traffic from through traffic on Glenwood Avenue.

**Response 5:** Most of the alternatives developed by the study team would, in varying degrees, separate some Mall traffic from through traffic on Glenwood Ave. Alternative A3 would create a new interchange on I-440 to Crabtree Valley Avenue, connecting Mall traffic to and from I-440 without using Glenwood Avenue.

**Comment 6:** Reduce or eliminate Crabtree Valley Mall access from Glenwood Avenue.

**Response 6:** Right turns have little effect on the capacity of a roadway compared with left turns that diminish capacity and add conflict points that often result in crashes. So the consulting team interpreted this public comment as specifically suggesting that left turns be reduced or eliminated. Several alternatives would restrict left-turn movements from Glenwood Avenue to the Mall entrance at Marriott Drive. Alternative A4-B would eliminate left turns from westbound Glenwood Avenue to Blue Ridge Road, diverting this traffic to a new interchange on I-440 at Crabtree Valley Avenue. Alternative A5-B would extend the existing median on Glenwood Avenue through the Mall Entrance/ Marriott Drive intersection, eliminating left-turn movements at this intersection.

**Comment 7:** Construct flyover ramp to Crabtree Valley mall from Glenwood Avenue or I-440.

**Response 7:** The study team has developed three alternatives (A1, A3, and B1) that would provide direct ramp connections between Crabtree Valley Avenue and I-440. Alternative A1 and A3 would extend Crabtree Valley Avenue to I-440 on the east side of the valley, while Alternative B1 would extend Crabtree Valley Avenue to Glenwood Avenue on the west side of the valley. In Alternative A3, which is the recommended alternative, Mall traffic can access I-440 from Crabtree Valley Avenue via Blue Ridge Road and via Homewood Banks Drive / Mall Entrance intersection. The latter intersection would be signalized to increase capacity in and out of the Mall.

**Comment 8:** Construct an additional interchange to and from I-440 at Crabtree Valley Avenue.

**Response 8:** With Glenwood Avenue reaching its capacity, the study team realizes the importance of providing an alternate route for traffic trying to access I-440. Alternatives A1, A3, A4-B and A5-B would all provide access to and from I-440 via an extension of Crabtree Valley Avenue. Signage on the freeway would be labeled as "Crabtree Valley" or "Crabtree Valley Avenue" to reinforce the use of the new interchange for local traffic, thus freeing up capacity on Glenwood Avenue.

## Outreach to Stakeholders

Outreach to specific stakeholders, and stakeholder groups, included managers of Crabtree Valley Mall, hotel operators, property managers, and Weingarten Realty who own the former Kidds Hill Plaza site at Crabtree Valley Avenue and Edwards Mill Road. Early outreach with Crabtree Valley Mall management occurred in September 2009 as a form of advance planning prior to the busy holiday shopping period. In November and December 2009, study team members attended regularly scheduled Mall Walkers Club meetings to raise awareness of the study and to distribute surveys. In February 2010, a study team member distributed open house invitations door-to-door throughout the study area including office, hotel, retail, service,

and multi-family residential properties. The study team member discussed the study with people at each office who asked for more information. This approach is believed to have contributed to the large attendance at the March open house event.

The following comments were provided by Mall managers during the study:

- **Traffic:** Interstate 440 and Glenwood Avenue traffic is “not that bad” compared with prior years. Partly due to the economy, but construction of Interstate 540 has helped by creating an alternate route.
- **Signals:** Coordination of Glenwood Avenue traffic signals will help reduce traffic delay; funding is secure, designs complete and implementation is coming soon according to the City of Raleigh. The City of Raleigh asserts that signal timing is already optimal on Glenwood Avenue although the heavy cross street volumes of Creedmoor Road and Lead Mine Road cause significant delay on Glenwood Avenue.
- **Transit:** The on-site bus hub operates as a transfer center for several CAT bus routes. This is a bigger operation than originally envisioned, which was simply to serve the Mall and other destinations within walking distance. Mall operators asked the City to relocate the CAT bus hub to another site owned by the Mall, located on Crabtree Valley Avenue.
- **Pedestrians:** The crossing at the intersection of Glenwood Avenue and Marriott Drive is often dangerous and difficult for pedestrians. NCDOT has been reluctant to spend public funds to build a pedestrian overpass over Glenwood Avenue that would serve private properties. There are long term plans by the City to require developers to build pedestrian bridges over Crabtree Valley Avenue when development along the south side occurs.
- **Greenway Extensions:** The City has funding and design plans for the House Creek greenway extension connecting Crabtree Valley with the North Carolina Museum of Art.
- **Development:** Managers of Crabtree Valley Mall are looking forward to development on surrounding sites (for example Soleil Center, former Kidds Hill Plaza, Crabtree Village, and an undeveloped site on Arrow Drive) when the economy picks up again.
- **Branding:** Mall managers are working on a concept with other property owners and managers for “Uptown” Raleigh that would extend from Crabtree Valley Mall and hotels to Rex Hospital, NC Museum of Art, Carter Finley Stadium, RBC Center, and perhaps the State Fairgrounds. The commercial interest is to be the first choice for hotels, shopping, and eating for out-of-town visitors coming to an event at RBC Center, Carter Finley, etc.

Preview meetings were held with managers of Crabtree Valley Mall and separate meetings also with developers and large property owners before the March open house. The following are comments from those meetings:

- **Mall Access Intersection Restrictions:** Restricting Mall outbound movements to right-turn only on Blue Ridge Road is unacceptable to Mall managers unless the City simultaneously provides new access to I-440 via an extension of Crabtree Valley Avenue. Removing signals at the Mall access intersection on Creedmoor Rd is also unacceptable to Mall managers. The left-turn outbound from the Mall is not as critical as the left-turn inbound movement, but mall managers do not see the left-turn out move causing problems today. Changes here would put unacceptable traffic burdens on the intersection of Glenwood Avenue and Marriott Drive according to Mall managers.
- **Crabtree Valley Avenue Extensions:** Mall managers are very interested in these extensions, particularly if it shifts some through traffic away from Glenwood Avenue and provides some direct access from I-440 into Mall parking decks as is done from I-40 at Koury Center in Greensboro.
- **Lead Mine Road Flyover at Glenwood Avenue:** Mall managers suggested this become a secondary concept to consider only if the I-440 interchange with Crabtree Valley Avenue is not built. This flyover was also reviewed by the site owner / developer of the Trailwood office building on the southeast corner of the intersection of Lead Mine Road and North Hills Drive. The flyover concept as shown at the March open house was acceptable to this developer.
- **Interchange at Glenwood Avenue / Creedmoor Road:** The property leasing agent for the former Circuit City building at the northwest corner of the intersection of Glenwood Avenue and Creedmoor Road submitted a letter stating that company’s opposition to an interchange at this location, indicating perceived site access restrictions and diminished visibility by passing motorists. Crabtree Valley Mall managers, however, reviewed the concept illustrations and are supportive as long as all existing access driveways and intersections to the Mall are maintained.
- **Ridge Road Relocation to Intersect Glenwood Avenue:** Study team members attended the March 2010 Glenwood CAC meeting with several residents of neighborhoods along Ridge Road and Varnell Avenue. Residents of the Varnell Avenue neighborhood voiced opposition to relocating the western terminus of Ridge Road at Glenwood Avenue. Others in attendance were generally not displeased, and many expressed support for a more direct connection to the Mall via an extension of Ridge Road to Crabtree Valley Avenue even though this was not proposed or illustrated by study team members.

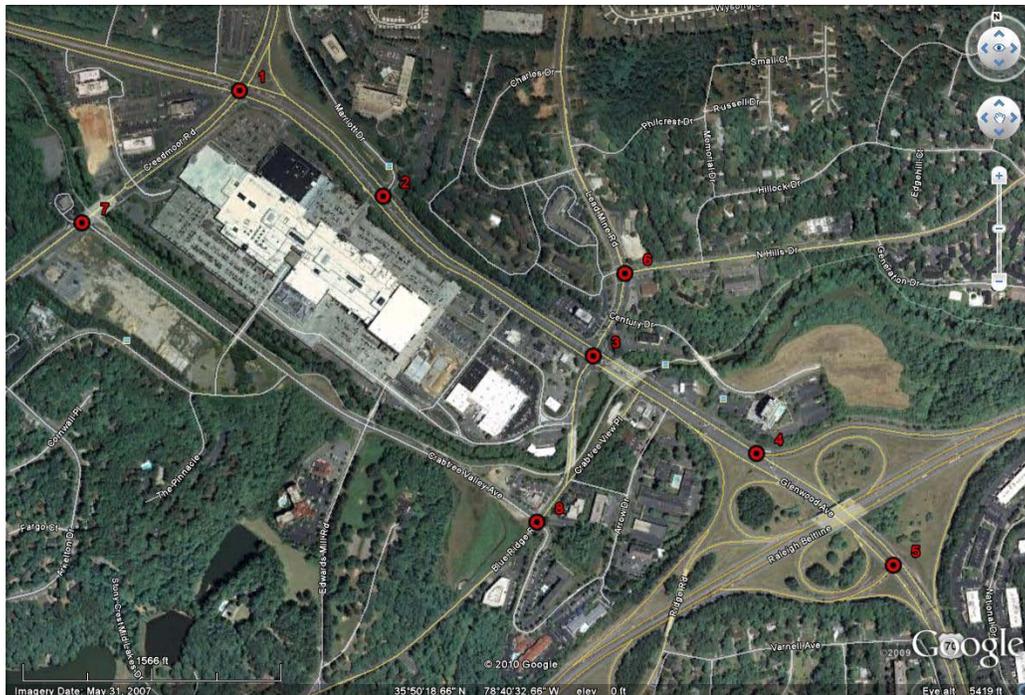
# Accident Analysis



Traffic accident analysis was conducted to evaluate the safety performance at the following eight intersections in the valley:

- |   |                              |
|---|------------------------------|
| 1. Glenwood Avenue & Creedmoor Road             | Signalized intersection      |
| 2. Glenwood Avenue & Marriot Drive              | Signalized intersection      |
| 3. Glenwood Avenue & Lead Mine/ Blue Ridge Road | Signalized intersection      |
| 4. Glenwood Avenue & I-440 WB off ramp/ Outer   | Signalized T- intersection   |
| 5. Glenwood Avenue & I-440 EB off ramp/ Inner   | Signalized T- intersection   |
| 6. Lead Mine Road & North Hills Drive           | Signalized intersection      |
| 7. Creedmoor Road & Crabtree Valley Avenue      | Unsignalized T- intersection |
| 8. Crabtree Valley Avenue & Blue Ridge Road     | Unsignalized T- intersection |

The following figure illustrates the intersection locations.



**Figure 12. Accident Analysis Intersections in Study Area**

Accident data for a three year period (01/01/2007 to 12/31/2009) was obtained using Traffic Engineering Accident Analysis System (TEAAS), accident data software maintained by the North Carolina Department of Transportation

(NCDOT). The data provides information such as location, severity type, accident type, collision type, time of the accident, and weather conditions. A total of 597 accidents were identified for the eight intersections in the valley. Police reports for each accident record were obtained from Department of Motor Vehicles.

According to NCDOT's intersection accident analysis guideline, accident data shall be limited to those crash events that occurred within 150 feet of the intersection. A substantial amount of data screening efforts were made to examine the police reports and organize the raw data into a format that would be useful for the purpose of this analysis. Out of the 597 accident records, 480 accidents occurred within the intersection influence areas. Those accident records were then used for intersection accident analysis.

Two types of accident data analyses were conducted: 1) general assessment of crash pattern and economic cost for the study area, and 2) intersection specific analysis. Accident data is depicted using series of tables and graphs showing comparison among intersections. Collision diagrams were also developed based on the police reports. The collision diagrams illustrate the location of each individual event and areas where these events are clustered.

## Area Accident Data Analysis

### Type of Accidents

Studying what types of crashes are occurring and how often they occur, one may identify patterns in the accidents, possible causal factors and mitigation measures. The following table shows the type of crashes that occurred within the study area from 1/1/2007 to 12/31/2009 and their frequencies.

**Table 6. Accident Type Summary, 1/1/2007 - 12/31/2009**

ACCIDENT TYPE SUMMARY		
Accident Type	Number of Crashes	Probable Cause
Rear End, Slow or Stop	274	Failure to Reduce Speed or Lane Change
Sideswipe, Same Direction	85	Lane Change or Wide Turn
Angle	75	Unsafe Movement or Red Light Violation
Left Turn, Same Roadway	12	Unsafe Movement or Red Light Violation
Ran Off Road	7	Unsafe Speed or Avoid Collision
Backing Up	6	Lane Change or Traffic or Mall Height Restriction
Left Turn, Different Roadway	5	Unsafe Movement or Red Light Violation
Fixed Object	5	Unsafe Driving
Sideswipe	4	Wide Turn or Failure to Yield Right of Way
Right Turn, Different Roadway	3	Wide Turn
Pedestrian	2	Failure to Yield to Pedestrian or Pedestrian Jaywalking
Right Turn, Same Roadway	1	Unsafe Movement
Overturn/Rollover	1	Unsafe Speed

According to the accident data, rear end collisions are the dominant type of crashes in the study area. Rear end collisions are the most common type of crashes at intersections, especially at signalized intersections. Rear end collisions in the study area are often attributed to drivers who are traveling at excessive speed or performing lane change in traffic congestion. Measures to encourage attentive driving and signal timing improvements to maintain proper traffic progression may be able to help reduce the number of rear end collisions in the study area.

Same direction sideswipe is the second most common type of crashes in the study area. Same direction sideswipe crashes are often attributed to lane changes and vehicle making wide turns from dual turn lanes. This type of collision usually results from attempting to pass too closely or making a turn at higher speeds.

Angle collisions are the third most frequent crashes, and are often attributed to unsafe movement and red light violation. To reduce angle collisions, signal timings shall be reviewed to determine if adequate clearance intervals have been provided to minimize vehicles trapped in the “dilemma zone”.

**Time of Accident Occurrence**

When analyzing accident data, it is equally important to examine the time at which crashes occur. The following three figures depict the crash trends that were experienced at the eight intersections in the valley.

As illustrated in the monthly summary figure (Figure 13), the Glenwood Avenue and Lead Mine Road/ Blue Ridge Road intersection has the highest number of accidents in the winter months of October, November and December. Accident data analysis for the study area shows that the months of August, October and December had more crashes than other months of the year. The spike of accident frequency in those three months may be attributed to Crabtree Valley Mall which attracts more shoppers in December for holiday shopping and in August for back to school shopping. An increase in traffic is followed by congestion that often leads to a higher frequency of accidents. The month of February shows the lowest number of crashes in the study area. Limited shopping trips following winter holidays or the cold weather may have reduced the travel demand in the valley.

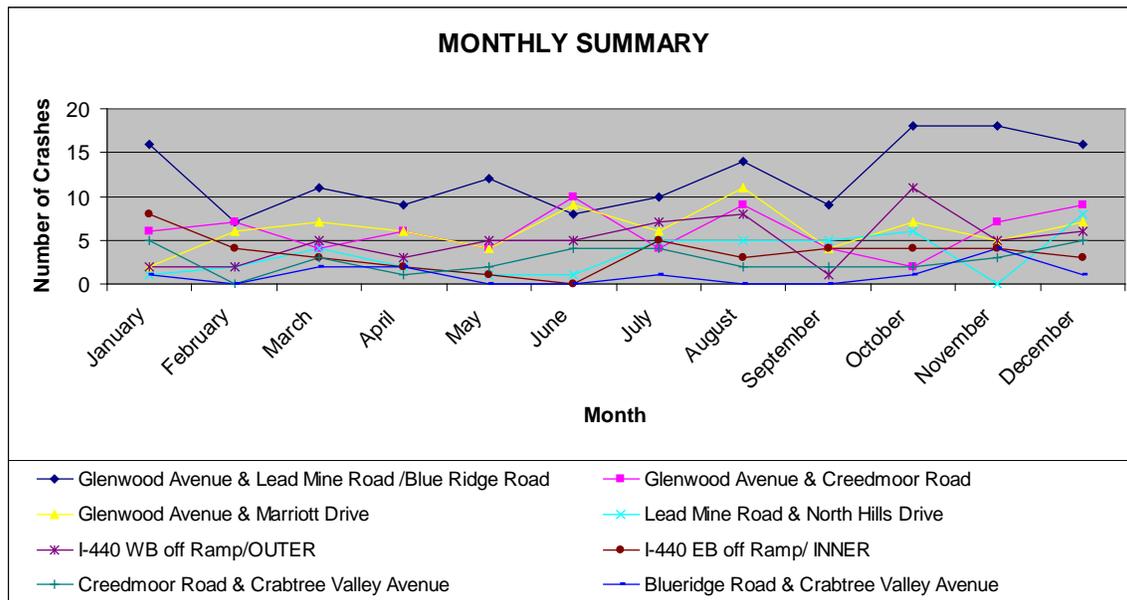


Figure 13. Monthly Accident Summary

The accident daily summary figure (Figure 14), as shown below, illustrates that Tuesdays have the largest number of vehicle crashes followed by Friday and Monday. Sundays have the lowest number of crashes at all the eight intersections. This may be due to the lighter traffic volumes on Sundays.

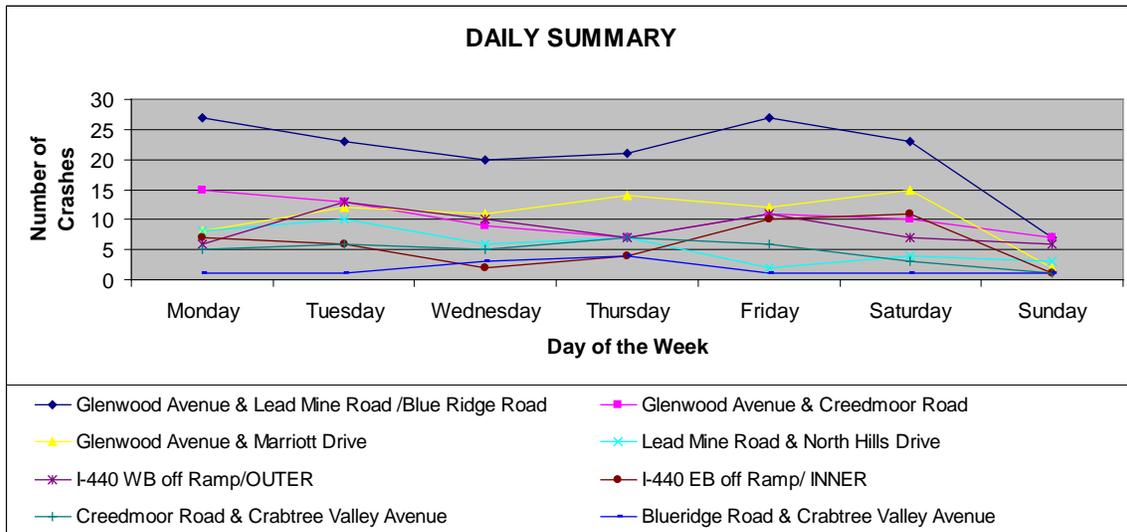


Figure 14. Daily Accident Summary

The accident hourly summary figure (Figure 15) shows that the total number of crashes increases during peak hours. The number of accidents reaches the highest level around 6:00 PM, followed by a mid-day peak around 2:00 PM, and then the AM peak around 10:00 AM. The crash trends illustrated in this figure clearly indicate that peak hour traffic congestion also compromises safety performance.

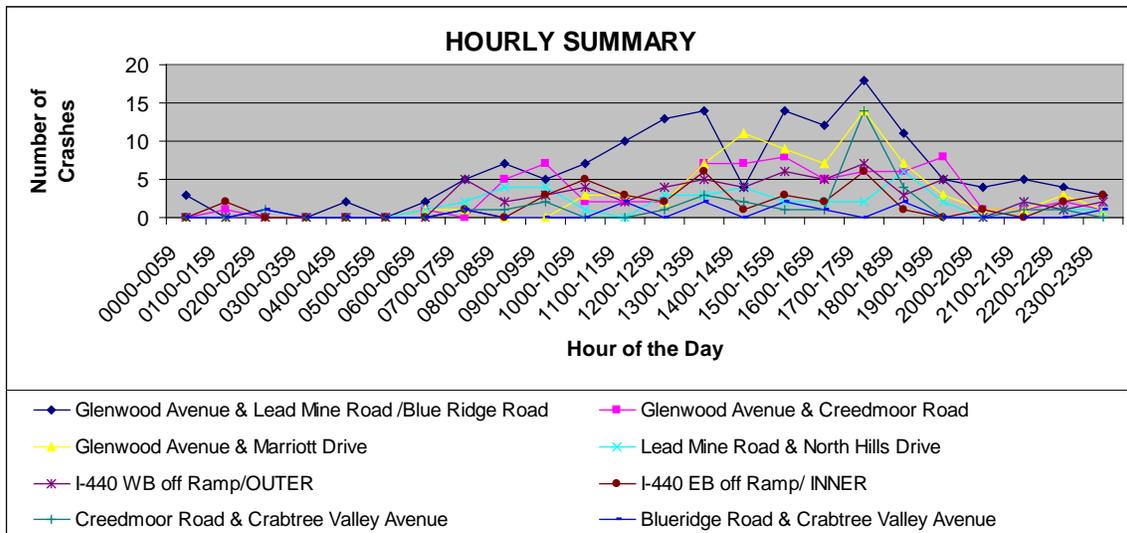


Figure 15. Hourly Accident Summary

### Accident Cost Analysis

Accident costs are calculated based on the severity of personal injury and the amount of property damage sustained in the accident. A traffic crash is rated by the most severe injury involved in the accident. If a crash had eight people involved and six people sustained class C (possible) injuries, one person sustained class B (evident) injuries, and one person sustained class A (disabling) injuries, the crash is recorded as an A injury crash. Property damage only crash is one in which nobody was injured in the accident. In North Carolina, crash costs include the cost associated with the average number of injuries in each crash type. The injury costs include estimates of medical costs, public services, loss of productivity, employer cost, property damage and change in quality of life. The estimated cost of 480 accidents in the study area is approximately \$5.8 million in 2008 dollars. The table below shows accident cost in three year period.

**Table 7. Accident Cost Analysis**

Crash Type	Number of Crashes	NCDOT Cost Per Crash (2008 Dollars)	Estimated Cost of Accidents (2008 Dollars)
Fatal Crashes	0	\$4,400,000	\$0
Class A Injury Crashes	0	\$250,000	\$0
Class B Injury Crashes	13	\$74,000	\$962,000
Class C Injury Crashes	80	\$36,000	\$2,880,000
Property Damage Only Crashes	387	\$5,000	\$1,935,000
<b>TOTAL</b>	<b>480</b>		<b>\$5,777,000</b>

### Intersection Accident Data Analysis

The intersection accident analysis uses several performance measures and analysis techniques recommended by NCDOT's Traffic Safety Unit, including Frequency, Severity Index (SI), Equivalent Property Damage Only (EPDO), Crash Rate and Collision Diagrams. These performance measures allow for a better understanding of the safety problems at the study locations.

#### Frequency

The intersection accident analysis shows that the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection had the highest frequency with an average of 49 accidents per year over the three years. The second most accident prone intersection is Glenwood Avenue and Marriott Drive with an average of 25 accidents per year, followed closely by the Glenwood Avenue and Creedmoor Road intersection with an average of 24 accidents per year. The accident frequency at the other intersections in study area ranges from 4 to 20 accidents per year. Table 8. Annual Accident Frequency ranks the intersections in order of accident frequency. The detailed discussion of accident frequency by crash type for each intersection is presented in collision diagrams later in this report.

Table 8. Annual Accident Frequency

Intersection	Total Number of Crashes	Annual Frequency
Glenwood Avenue & Lead Mine Road/Blue Ridge Road	148	49
Glenwood Avenue & Marriott Drive	74	25
Glenwood Avenue & Creedmoor Road	72	24
Glenwood Avenue & I-440 WB Ramp	60	20
Glenwood Avenue & I-440 EB Ramp	41	14
Lead Mine Road & North Hills Drive	10	13
Creedmoor Road & Crabtree Valley Avenue	33	11
Crabtree Valley Avenue & Blue Ridge Road	12	4

### Severity Index

The severity index (SI), developed by NCDOT is a representative of crash injury severity. There are five types of injuries: K (fatal), A (disabling), B (evident), C (possible), O (none) and U (unknown). The crash severity is equal to the most serious injury sustained by any individual involved in the crash (i.e. a crash that involved one disabling injury and two evident injuries would have a crash severity of 'A'). The SI of a crash is equal to the total Equivalent Property Damage Only (EPDO) divided by the number of crashes, as expressed in the following formula:

$$\text{Severity Index} = (76.8 \times (\text{K+A crashes})) + (8.4 \times (\text{B+C crashes})) + (1.0 \times (\text{O+U crashes})) / \text{total crashes}$$

A severity index of 8.4 is the threshold for locations that have more serious crashes (i.e. a location with an SI = 9.6 would tend to have more severe injuries than other locations).

#### As shown in

Table 9, the Glenwood Avenue and Creedmoor Road intersection has the highest SI of 3.26 with 3 evident injury crashes, 19 possible injury crashes and 50 property damage only crashes. The study area overall tends to have less severe accidents compared to other similar locations in North Carolina.

Table 9. Severity Index

Intersection	Number of Crashes	Crash Type					Severity Index
		Fatal Crashes	Class A Crashes	Class B Crashes	Class C Crashes	PDO Crashes	
Glenwood Avenue & Lead Mine Road/Blue Ridge Road	148	0	0	4	24	120	2.40
Glenwood Avenue & Marriott Drive	74	0	0	2	13	59	2.50
Glenwood Avenue & Creedmoor Road	72	0	0	3	19	50	<b>3.26</b>
Glenwood Avenue & I-440 WB Ramp	60	0	0	1	12	47	2.60
Glenwood Avenue & I-440 EB Ramp	41	0	0	0	4	37	1.72
Lead Mine Road & North Hills Drive	10	0	0	3	2	35	1.93
Creedmoor Road & Crabtree Valley Avenue	33	0	0	0	4	29	1.90
Crabtree Valley Avenue & Blue Ridge Road	12	0	0	0	2	10	2.23

***Equivalent Property Damage Only***

Equivalent Property Damage Only (EPDO) provides a means to compare crashes with different types of injuries. A non-injury crash (O) or an unknown injury crash (U) is equivalent to 1.0 PDO crashes (i.e. EPDO =1.0). An evident injury crash (B) or a possible injury crash (C) is equivalent to 8.4 PDO crashes (EPDO =8.4). A fatal crash (K) or a disabling injury crash (A) is equivalent to 76.8 PDO crashes (i.e. EPDO = 76.8)

As shown in the following table, the Glenwood Avenue and Lead Mine Road/ Blue Ridge Road intersection has the highest EPDO index of 355.20, followed by the Glenwood Avenue and Creedmoor Road intersection with an EPDO crash index of 234.80.

**Table 10. Equivalent Property Damage Only (EPDO) Index**

Intersection	Number of Crashes	Crash Type					EPDO Crash Index
		Fatal Crashes	Class A Crashes	Class B Crashes	Class C Crashes	PDO Crashes	
Glenwood Avenue & Lead Mine Road/Blue Ridge Road	148	0	0	4	24	120	<b>355.20</b>
Glenwood Avenue & Marriott Drive	74	0	0	2	13	59	185.00
Glenwood Avenue & Creedmoor Road	72	0	0	3	19	50	234.80
Glenwood Avenue & I-440 WB Ramp	60	0	0	1	12	47	156.20
Glenwood Avenue & I-440 EB Ramp	41	0	0	0	4	37	70.60
Lead Mine Road & North Hills Drive	10	0	0	3	2	35	77.00
Creedmoor Road & Crabtree Valley Avenue	33	0	0	0	4	29	62.60
Crabtree Valley Avenue & Blue Ridge Road	12	0	0	0	2	10	26.80

### Crash Rate

Crash rate is another safety measure recommended by NCDOT for intersection accident analyses. As expressed in the following formula, the intersection crash rate uses both the number of crashes and intersection Average Daily Traffic (ADT) to calculate a performance measure that's comparable between different intersections.

Intersection Crash Rate = (Number of Crashes X 1,000,000) / (number of analysis years X 365 X total entering ADT at the intersection)

NCDOT's 2007 traffic survey data was used to estimate the ADT volumes on Glenwood Avenue, Creedmoor Road, Lead Mine Road, Blue Ridge Road and North Hills Drive. Since ADT volumes include bi-directional traffic, intersection entering volumes were calculated by adding the ADT volumes on each leg and then dividing by two. For minor roadways such as Crabtree Valley Avenue, Marriott Drive and I-440 ramps, the ADT volumes were estimated from peak hour turning movement counts.

As listed in the following table, the Glenwood Avenue and Lead Mine Road/ Blue Ridge Road intersection has the highest crash rate, at an estimated 1.62 crashes for every million entering vehicles. Unlike roadway segments, currently there is no average intersection crash rate information in North Carolina.

**Table 11. Intersection Crash Rate**

Intersection	Number of Crashes	Intersection ADT	Crash Rate (crashes/ million entering vehicles)
Glenwood Avenue & Lead Mine Road/Blue Ridge Road	148	83,500	<b>1.62</b>
Glenwood Avenue & Marriott Drive	74	43,500	1.55
Glenwood Avenue & Creedmoor Road	72	68,000	0.97
Glenwood Avenue & I-440 WB Ramp	60	58,600	0.94
Glenwood Avenue & I-440 EB Ramp	41	62,000	0.60
Lead Mine Road & North Hills Drive	10	29,250	1.25
Creedmoor Road & Crabtree Valley Avenue	33	25,150	1.20
Crabtree Valley Avenue & Blue Ridge Road	12	11,450	0.96

Crash Diagrams



Figure 16. Glenwood Avenue and Creedmoor Road Crash Diagram

Table 12. Glenwood Avenue/Creedmoor Road Intersection Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	35	Failure to Reduce Speed
Angle	6	Red Light Violation/Unsafe Turn
Sideswipe, same direction	27	Lane Change
Sideswipe, opposite direction	1	Diabetic Crisis
Fixed Object	1	Unsafe Speed
Ran-off Road	1	Unsafe Speed
Overturn/Rollover	1	Unsafe Speed
<b>TOTAL ACCIDENTS</b>	<b>72</b>	

The Glenwood Avenue and Creedmoor Road intersection had a total of 72 accidents over the three-year analysis period. 49% of accidents at this intersection were rear end crashes. The large number of rear end crashes is mainly due to congestion and failure to reduce speed in a timely manner.

The second most common type of crash is same direction sideswipe crashes, comprising of 38% of total crashes at the intersection. The causes of same direction sideswipe crashes are improper lane changes, avoiding stopped vehicle ahead/ accident, turns from wrong lane at this intersection. The single opposite direction sideswipe incident was caused by a diabetic crisis where the driver drove in opposite travel direction.

Angle crashes at this intersection are primarily due to red light running or unsafe turn. Two of the angle crashes and two rear end crashes were caused by emergency vehicle/ police vehicle confusions. Emergency vehicle preemptions may be able to reduce this type of accidents.

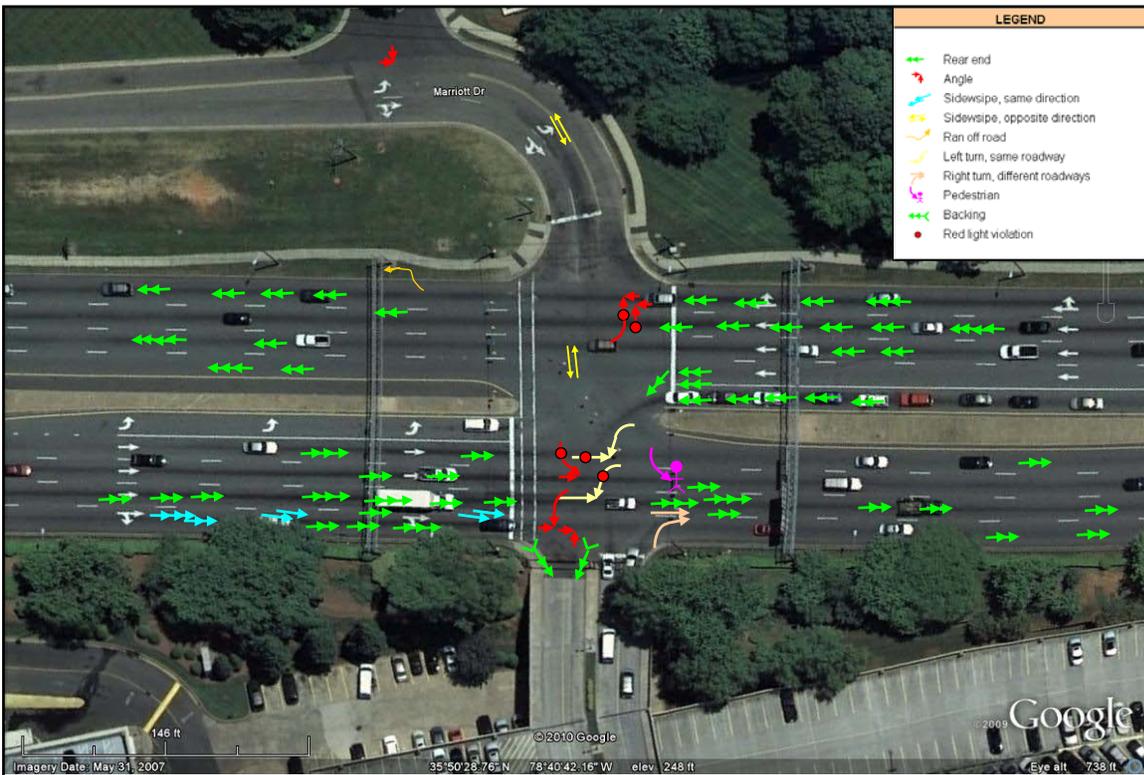


Figure 17. Glenwood Avenue and Mall Entrance/Marriott Drive Crash Diagram

Table 13. Glenwood Avenue and Mall Entrance / Marriott Drive Intersection Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	55	Failure to Reduce Speed
Angle	6	Red Light Violation/Unsafe Movement
Sideswipe, same direction	4	Lane Change
Sideswipe, opposite direction	2	Wide Turn/Failure to Yield ROW
Left Turn, Same Roadway	2	Red Light Violation
Right Turn, Different Roadway	1	Wide Turn
Ran-off Road	1	Avoid accident ahead
Backing	2	Unaware of height restriction to mall
Pedestrian	1	Failure to Yield ROW to Pedestrian
<b>TOTAL ACCIDENTS</b>	<b>74</b>	

The Glenwood Avenue and Marriott Drive intersection had a total of 74 accidents over the three-year analysis period. 74% of accidents at this intersection were rear end crashes. The occurrence of large number of rear end crashes may be attributed to the close spacing of traffic signals, improper signal progression, and the traffic congestion on Glenwood Avenue.

Two backing accidents were reported at the Mall Entrance. The drivers indicated that they had no knowledge of the height restriction at the mall entrance. Proper height restriction signage installed in advance of the Mall Entrance may help to prevent the backing accidents.

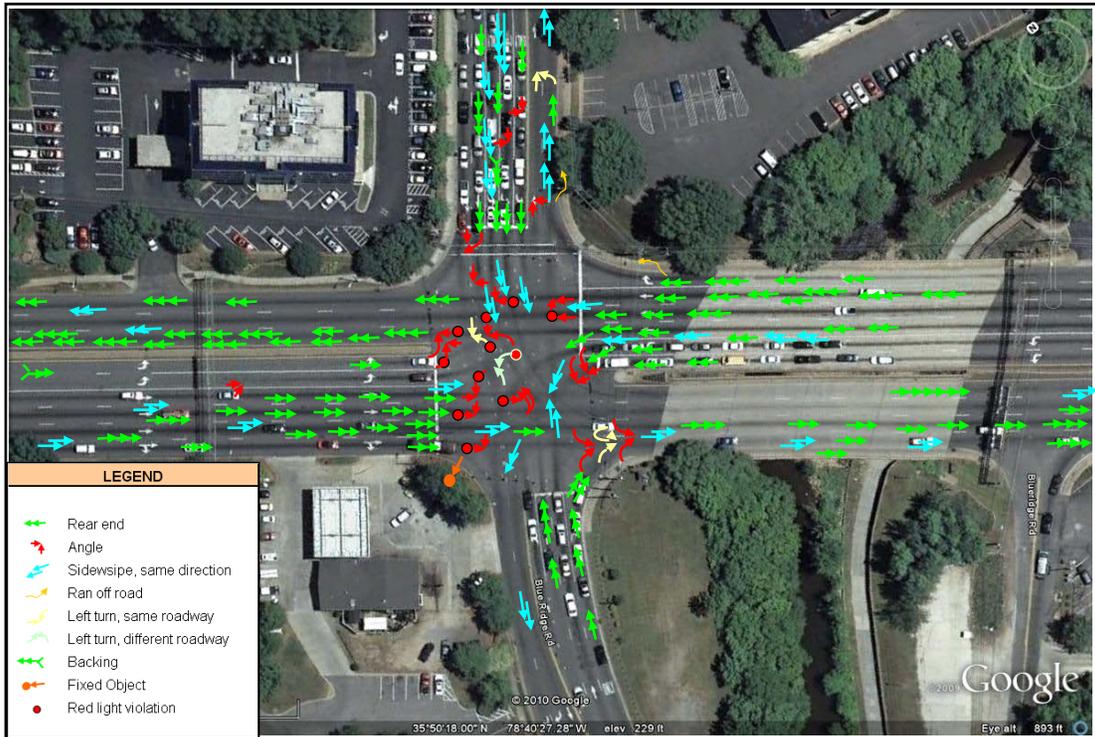


Figure 18. Glenwood Avenue and Lead Mine Road/Blue Ridge Road Crash Diagram

Table 14. Glenwood Avenue and Lead Mine Road/ Blue Ridge Road Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	90	Failure to Reduce Speed
Angle	19	Red Light Violation/Unsafe Movement
Sideswipe, same direction	30	Lane Change/Wide Turn
Left Turn, same roadway	3	Red Light Violation/Unsafe Movement
Left Turn, different roadway	1	Red Light Violation
Ran off Road	2	Avoid Accident Ahead
Backing	2	Unsafe Movement
Fixed Object	1	Careless/Reckless Driving
<b>TOTAL ACCIDENTS</b>	<b>148</b>	

The Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection has a total of 148 accidents over the three-year analysis period. 61% of accidents at this intersection were rear end crashes. The occurrence of large number of rear end crashes is believed to be caused by traffic congestion at this location. The second most common type of crash is same direction sideswipe crashes comprising of 20% of total crashes at this intersection. The causes of same direction sideswipe crashes are improper lane changes and wide turns from the southbound triple left turn lanes.

Another common type of crash experienced at this intersection is angle crashes. 47% of angle crashes were due to red-light running, and the remaining 53% were results of unsafe turning movements.

Three DUI accidents are reported, including one ran off road accident, one angle collision with red light running and one left turn different roadway accident. Four of the rear-end crashes and one same direction sideswipe crash were attributed to emergency vehicle response. Emergency vehicle signal preemptions may help to correct this type of accidents.

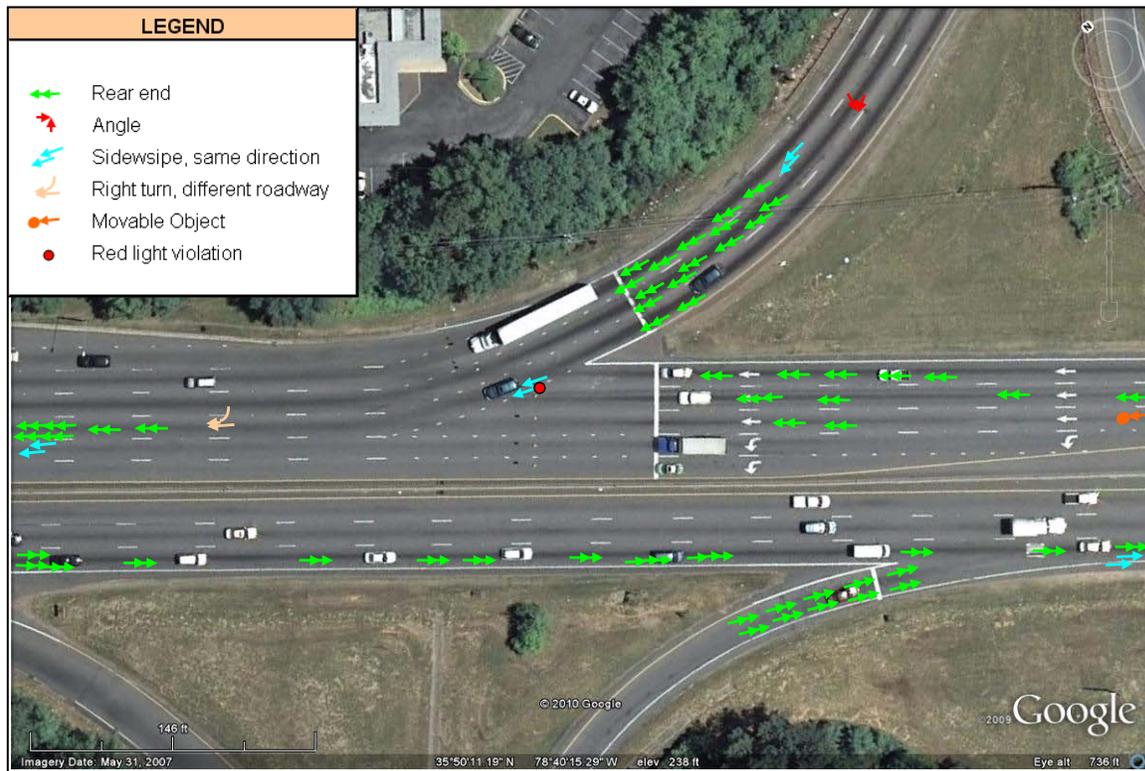


Figure 19. Glenwood Avenue and I-440 WB Ramp Crash Diagram

Table 15. Glenwood Avenue and I-440 WB Ramp Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	53	Failure to Reduce Speed/Lane Change
Angle	1	Unsafe Movement
Sideswipe, same direction	4	Lane Change
Right Turn, different roadway	1	Wide Turn
Movable Object	1	Flying Rock
<b>TOTAL ACCIDENTS</b>	<b>60</b>	

The Glenwood Avenue and I-440 WB ramp intersection experienced 60 accidents over the three-year analysis period. 88% percent of accidents at this intersection were rear end crashes. The occurrence of large number of rear end crashes is mainly due to lane change and failure to reduce speed in a timely manner. The I-440 westbound exit ramp to eastbound Glenwood Avenue is a stop sign controlled approach. Vehicles coming off the exit ramp may not be able to discern well in advance the stopped or slow moving vehicles at the stop line, leading to rear end crashes.

Four same direction sideswipe crashes were reported for this location. Two of the sideswipe accidents, one on the I-440 exit ramp and one on westbound Glenwood Avenue, were caused by unsafe lane changes likely conducted by drivers trying to enter downstream left-turn lanes to access the Mall. The other two sideswipe crashes on Glenwood Avenue were caused by red light running and lane weaving.

The angle crash, different roadway right turn, and movable object accidents at this intersection appear to be isolated occurrences and do not follow any pattern.

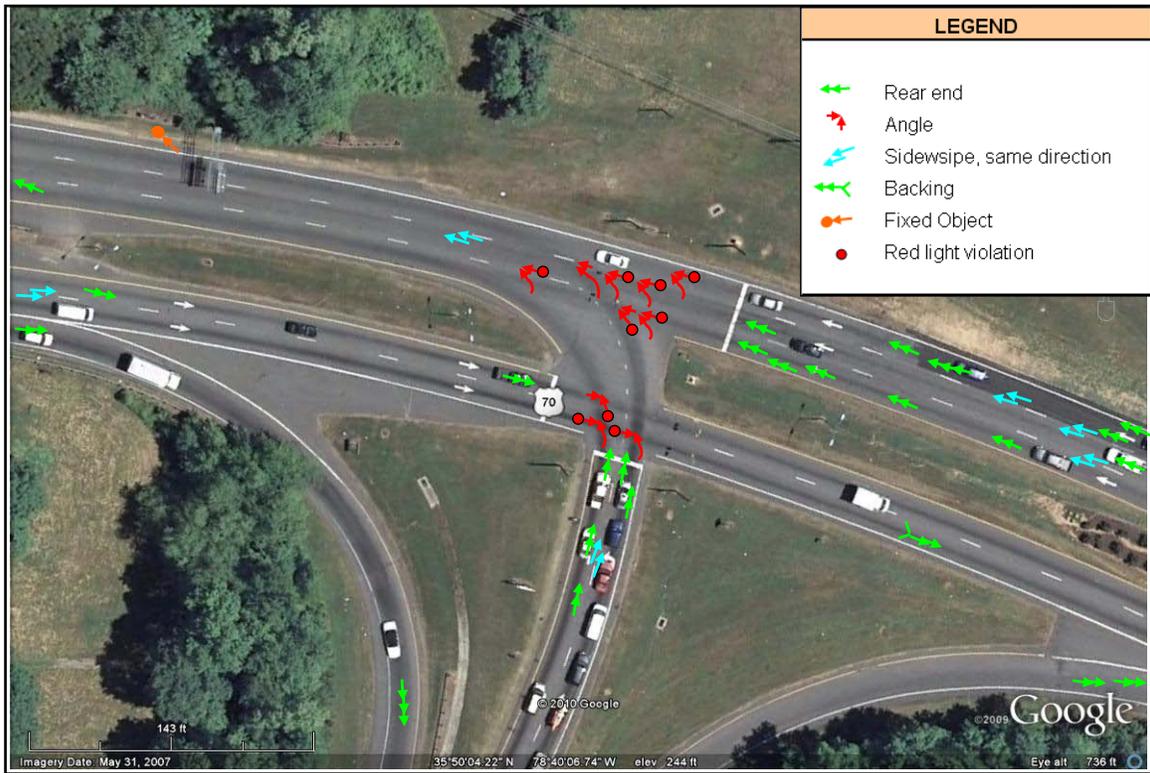


Figure 20. Glenwood Avenue and I-440 EB Ramp Crash Diagram

Table 16. Glenwood Avenue and I-440 EB Ramp Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	23	Failure to Reduce Speed/Lane Change
Angle	10	Red Light Violation/Unsafe Movement
Sideswipe, same direction	6	Lane Change/Wide Turn
Backing	1	Traffic
Fixed Object	1	Ran off Road
<b>TOTAL ACCIDENTS</b>	<b>41</b>	

The Glenwood Avenue and I-440 EB ramp intersection experienced 41 accidents over the three-year analysis period. 56% of accidents at this location were rear end crashes. Almost half of the rear end crashes occurred on westbound Glenwood Avenue approach. The rear end crashes is mainly due to traffic congestion and signal control. The horizontal curve and grade on westbound Glenwood Avenue approach can also be a contributing factor.

Almost all the angle crashes at this intersection involve red light running. Proper traffic signal timing, especially the yellow and all-red change intervals may help to correct this type of accident.

Six same direction sideswipe crashes were reported for this location, comprising of 15% of total crashes. Lane changes by attempting to pass too closely were reported as the main cause of sideswipe accidents.

The backing accident appears to be an isolated incident. The fixed object accident could be attributed to the wet pavement where the driver lost control and hit the object on side of the road on a rainy day.



Figure 21. Lead Mine Road and North Hills Drive

Table 17. Lead Mine Road and North Hills Drive Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End	9	Failure to Reduce Speed/Lane Change
Angle	13	Red Light Violation/Unsafe Movement
Sideswipe, same direction	12	Lane Change/Wide Turn
Left Turn, same roadway	5	Unsafe Movement
Pedestrian	1	Unsafe Movement
<b>TOTAL ACCIDENTS</b>	<b>40</b>	

The intersection of Lead Mine Road and North Hills Drive experienced 40 accidents over the three year analysis period. 75% of the accidents involved vehicles traveling on Lead Mine Road in the southbound direction. The rear end crashes are primarily due to failure to reduce speed and lane changes.

Most of the angle crashes involving red light violating vehicles on the northbound Lead Mine Road approach. Proper signal change intervals may help to reduce the right angle crashes.

The same direction sideswipe crashes were mainly caused by lane changes or wide turns from westbound North Hills Drive to Lead Mine Road. While pavement markings at the intersection provide turning path guidance for the westbound left-turn movements, congestion and queuing at the downstream Glenwood Avenue may affect the en route lane selection decisions, causing sudden lane changes.

The Pedestrian accident was reported involving a pedestrian crossing Lead Mine Road between the subject intersection and the Glenwood Avenue intersection. A pedestrian crosswalk is provided at both intersections.



Figure 22. Creedmoor Road and Crabtree Valley Avenue Crash Diagram

Table 18. Creedmoor Road and Crabtree Valley Avenue Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End, slow or stop	4	Failure to Reduce Speed
Rear End, turn	1	Improper Lane Change
Angle	16	Left Turn from Crabtree Valley Ave (CVA)
Sideswipe, same direction	2	Unsafe Movement
Sideswipe, opposite direction	1	Unsafe Movement/Left Turn from CVA
Left Turn, same roadway	1	Failure to Reduce Speed
Left Turn, different roadway	4	Unsafe Movement
Right Turn, same roadway	1	Unsafe Movement
Right Turn, different roadway	1	Unsafe Movement/Left Turn from CVA
Backing	1	Lane Change
Fixed Object	1	Wide Turn from CVA
<b>TOTAL ACCIDENTS</b>	<b>33</b>	

The intersection of Creedmoor Road and Crabtree Valley Avenue experienced 33 accidents over the three-year analysis period. 48% of the accidents involved vehicles making a left-turn from Crabtree Valley Avenue to southbound Creedmoor Road. Heavy through traffic on Creedmoor Road may have forced left turning vehicles on stop controlled Crabtree Valley Avenue to accept smaller gaps for the turning maneuver. Based on the number and type of crashes experienced at this location, it is recommended that a traffic signal warrant analysis shall be conducted for this location. Relocating Crabtree Valley Avenue to Edwards Mill Road, as recommended in the near term improvement alternative, can increase the intersection / signal spacing.



Figure 23. Blue Ridge Road & Crabtree Valley Avenue Intersection

Table 19. Blue Ridge Road and Crabtree Valley Avenue Accident Data Summary

ACCIDENT DATA SUMMARY		
Collision Type	Number of Crashes	Probable Cause
Rear End, slow or stop	4	Failure to Reduce Speed
Angle	4	Failure to Yield ROW
Run off Road	3	Speed or To Avoid Collision
Left Turn, same roadway	1	Unsafe Movement
TOTAL ACCIDENTS	12	

The Blue Ridge Road and Crabtree Valley Avenue intersection experienced 12 accidents over the three-year analysis period, including four rear end accidents and four angle collisions. The intersection also had three run off road accidents. Two of the run off road accidents were due to traveling at unsafe speed, and one was due to attempting to avoid accident.

## Conclusions and Recommendations

The eight intersections in Crabtree Valley study area experienced a total of 480 accidents in a three year period (from 01/01/2007 to 12/31/2009) causing approximately \$5.8 million worth of property damage in 2008 dollars. The accident data was obtained from North Carolina Department of Transportation (NCDOT) Traffic Engineering Accident Analysis System (TEAAS) database and police reports from Department of Motor Vehicles.

During the three year analysis period, the most common type of crash was the rear end crashes, followed by same direction sideswipe, and then angle collisions. The highest total number of crashes occurred during the months of August, October and December which can be attributed to holiday shopping in December and back to school shopping in August. The accidents also seem to be higher on Tuesdays, followed by Friday and Monday. The analysis shows that the accidents frequency increases as the traffic demand increases which is most noticeable in the PM peak hour, indicating that congestion will compromise intersection safety performance. The accident analysis also reveals that most of the crashes occur during daytime hours with clear weather and dry road conditions. A few accidents involved drivers under the influence of drugs or alcohol.

Per guidelines and recommendations set forth by NCDOT Traffic Safety Unit, the intersections were also analyzed for several performance measures such as frequency, severity index, equivalent property damage only (EPDO) index, crash rate and collision diagram. On reviewing frequency, severity index, EPDO index and crash rate collectively, the intersections of Glenwood Avenue with Lead Mine Road/ Blue Ridge Road and Glenwood Avenue with Creedmoor Road among other intersections have higher chances of severe crashes with more property damage. This may be due to large volume of traffic traversing through these intersections that consequently increases the chances of conflicts between drivers. Intersection analyses also indicate that none of the accidents in study area involved a fatal or disabling (Class A) injury.

Below is a detailed discussion on main type of accidents, possible causes and recommendations for each intersection in the study area.

### *Glenwood Avenue and Creedmoor Road*

#### **Main Accident Type**

The intersection had a total of 72 accidents over the three-year analysis period including 35 rear end crashes, 27 same direction sideswipe direction and 6 angle crashes among others.

#### **Possible Causes**

The large number of rear end crashes is mainly due to congestion and failure to reduce speed in a timely manner. The causes of same direction sideswipe crashes are improper lane changes, avoiding stopped vehicle ahead/ accident, turns from wrong lane at this intersection. Angle crashes at this intersection are primarily due to red light running or unsafe turns. Two of the angle crashes and two rear end crashes were caused by emergency vehicle/ police vehicle confusions.

#### **Recommendations**

Measures to encourage attentive driving and signal timing improvements to maintain proper traffic progression may be able to help reduce the number of rear end collisions and same direction sideswipe crashes. Also, emergency vehicle preemptions may be able to reduce accidents caused by emergency vehicle confusion.

### *Glenwood Avenue and Mall Entrance / Marriott Drive*

#### **Main Accident Type**

The intersection had a total of 74 accidents over the three-year analysis period including 55 rear end crashes, 6 angle crashes, 4 same direction sideswipe crashes and 2 backing crashes reported at the Mall Entrance among others.

#### **Possible Causes**

The occurrence of large number of rear end crashes may be attributed to the close spacing of traffic signals, improper signal progression, and the traffic congestion on Glenwood Avenue. The drivers involved in backing accidents indicated that they had no knowledge of the height restriction at the mall entrance.

#### **Recommendations**

Measures to encourage attentive driving and signal timing improvements may help with rear end crashes and angle crashes. Proper height restriction signage installed in advance of the Mall Entrance may help to prevent the backing accidents.

### *Glenwood Avenue and Lead Mine Road / Blue Ridge Road*

#### **Main Accident Type**

The intersection had a total of 148 accidents over the three-year analysis period including 90 rear end crashes, 30 same direction sideswipe direction and 19 angle crashes among others.

#### **Possible Causes**

The occurrence of large number of rear end crashes is believed to be caused by traffic congestion at this location. The causes of same direction sideswipe crashes are improper lane changes and wide turns from the southbound triple left turn lanes. Angle crashes were due to red-light running and unsafe turning movements. Four of the rear-end crashes and one same direction sideswipe crash were attributed to emergency vehicle response.

#### **Recommendations**

Measures to encourage attentive driving can help reduce rear end crashes, signal timing improvements may lower angle crashes. Emergency vehicle signal preemptions may help to correct accidents caused due to emergency vehicle confusion.

### *Glenwood Avenue and I-440 WB Ramp*

#### **Main Accident Type**

The intersection experienced 60 accidents over the three-year analysis period including 53 rear end crashes and 4 same direction sideswipe crashes among others.

#### **Possible Causes**

The occurrence of large number of rear end crashes is mainly due to lane change and failure to reduce speed in a timely manner. The I-440 westbound exit ramp to eastbound Glenwood Avenue is a stop sign controlled approach. Vehicles coming off the exit ramp may not be able to discern well in advance the stopped or slow moving vehicles at the stop line, leading to rear end crashes.

#### **Recommendations**

Measures to encourage attentive driving can help reduce rear end crashes and same direction sideswipe crashes.

### *Glenwood Avenue and I-440 EB Ramp*

#### **Main Accident Type**

The intersection experienced 41 accidents over the three-year analysis period including 23 rear end crashes, 10 angle crashes and 6 same direction sideswipe crashes among others. Almost half of the rear end crashes occurred on westbound Glenwood Avenue approach.

#### **Possible Causes**

The rear end crashes may be attributed to traffic congestion and signal control. The angle crashes at this intersection involve red light running. Lane changes by attempting to pass too closely were reported as the main cause of sideswipe accidents.

#### **Recommendations**

Measures to encourage attentive driving can help reduce rear end crashes and same direction sideswipe crashes. Proper traffic signal timing, especially the yellow and all-red change intervals may help to correct angle crashes at this intersection.

### *Lead Mine Road and North Hills Drive*

#### **Main Accident Type**

The intersection experienced 40 accidents over the three year analysis period including 13 angle crashes, 12 same direction sideswipe and 9 rear end crashes among others.

#### **Possible Causes**

Most of the angle crashes involve red light violating vehicles on the northbound Lead Mine Road approach. The sideswipe crashes were mainly caused by lane changes or wide turns from westbound North Hills Drive to Lead Mine Road. While pavement markings at the intersection provide turning path guidance for the westbound left-turn movements, congestion and queuing at the downstream Glenwood Avenue may affect the en route lane selection decisions, causing sudden lane changes. The rear end crashes are primarily due to failure to reduce speed and lane changes.

#### **Recommendations**

Proper signal change intervals may help to reduce the right angle crashes. Measures to encourage attentive driving can help reduce rear end crashes and same direction sideswipe crashes.

### *Creedmoor Road and Crabtree Valley Avenue*

#### **Main Accident Type**

The intersection experienced 33 accidents over the three-year analysis period including 16 angle crashes, 5 rear end crashes and 4 left turn different roadways. Almost half of the accidents involved vehicles making a left-turn from Crabtree Valley Avenue to southbound Creedmoor Road.

#### **Possible Causes**

Heavy through traffic on Creedmoor Road may have forced left turning vehicles on the stop sign controlled Crabtree Valley Avenue to accept smaller gaps for the turning maneuver.

#### **Recommendations**

Based on the number and type of crashes experienced at this location, it is recommended that a traffic signal warrant analysis shall be conducted for this location. Relocating Crabtree Valley Avenue to Edwards Mill Road, as recommended in the near term improvement alternative, can increase the intersection / signal spacing.

***Blue Ridge Road and Crabtree Valley Avenue*****Main Accident Type**

The intersection experienced 12 accidents over the three-year analysis period, including four rear end accidents and four angle collisions. The intersection also had three run off road accidents.

**Possible Causes**

Two of the run off road accidents were due to traveling at unsafe speed, and one was due to attempting to avoid accident.

**Recommendations**

The accidents do not indicate an alarming pattern or frequency, hence, no recommendations are made.

# Streets and Highways



## The Challenge

One transportation challenge assigned to the project team was how to address both existing and future traffic issues inside the study area. Current traffic volumes of 40,000 to 70,000 vehicles per day (vpd) exist on the main thoroughfare of US 70, locally known as Glenwood Avenue. Glenwood connects downtown Raleigh with the historic Five Points area; Crabtree Valley; additional, strip commercial development, and then to the Outer Beltline (I-540), and Durham. Additional major thoroughfares such as Creedmoor Road, Lead Mine Road, and Blue Ridge Road also penetrate the study area and provide access from neighboring residential communities. I-440 (Beltline) provides major freeway access from both south and north Raleigh. The roadway system is currently characterized by major turning accommodations on all of the roads mentioned (except I-440), including two triple turning lane configurations from both Lead Mine and from I-440 onto Glenwood Avenue. Accommodating high turning volumes is a particular challenge in this area, and prevents strong signal coordination on US 70 that would otherwise more effectively move the large volume of “through” traffic. Overall, the roadway network is extremely well-developed, and constrained to a large degree by existing built land uses and, to an almost equal extent, topography and floodplain/floodway restrictions. The roadway system is shown at its maximum stress levels from Thanksgiving through the first week of January when additional shoppers arrive from other counties to do their holiday shopping.

## The Response

### *Transportation Design Alternatives*

The following mobility strategies were developed through coordination and input from City staff, community stakeholders, and transportation consultants. Each alternative is a blend of pedestrian, bicycle, transit, and driving improvements providing traffic congestion relief in either the near-term (2010 to 2015), mid-term (2015 to 2020) or long term-time frame (beyond 2020). Pedestrian and transit facility improvements are incorporated into street retrofit design concepts. For the purposes of providing a clear description, Interstate 440, US 70/Glenwood Ave, Arrow Drive, Edwards Mill Road, and Crabtree Valley Avenue are referred to as east-west routes, whereas Creedmoor Road, Blue Ridge Road, and Lead Mine Road are referred to as north-south routes.

#### 1. Initial Improvements

This alternative relates strictly to pedestrian and bicycle facility improvements (see **Pedestrian and Bike** map). The design includes pedestrian refuge islands at the intersections of Glenwood Avenue at Creedmoor Road, Marriott Drive, and Lead Mine Road (west side only). The project may include reconstruction of some existing high-speed I-440 ramp movements (see “remove exist. roadway” on **Crabtree Valley Avenue A1** map) that would incorporate lower design speeds with improved pedestrian crossings. A sidewalk would be constructed on the south side of Glenwood Avenue between Blue Ridge Road and Woman’s Club Drive.

#### 2. Near-Term Improvements on Crabtree Valley Avenue and Ridge Road

As development and/or redevelopment (timetable depends on developers) occurs on Kiddy Hill, the City may partner with private developers to widen Crabtree Valley Avenue to the east between Blue Ridge Road and Homewood Banks Road. The proposed typical section would reflect a median divided four-lane street section (see **Crabtree Valley Avenue B2** map). Between Homewood Banks Road and Edwards Mill Road, the City anticipates

coordination with Crabtree Valley Mall and other private development in the area concerning the relocation of Crabtree Valley Avenue. (See **Crabtree Valley Avenue B4** map). This alternative retains the existing signal on Creedmoor Road at Crabtree Valley Mall and adds an additional signal on Creedmoor Road at the intersection with the relocated extension of Crabtree Valley Avenue.

Intersections on Crabtree Valley Ave will be signalized when the traffic demands meet adopted signal warrants. When the intersection of Crabtree Valley Ave and Blue Ridge Rd becomes signalized, the existing traffic signal at Blue Ridge Road and Crabtree Valley Mall would be removed and concrete islands within the intersection installed to preclude left-turns from the Mall to Blue Ridge Road. Right-turns would be permitted and traffic re-directed to Crabtree Valley Avenue. A new signal on Crabtree Valley Avenue at Homewood Banks Road would induce some Mall traffic to exit at that location to use the new signal. The existing bridge over Crabtree Creek from the Mall to Crabtree Valley Avenue would be widened to accommodate more traffic. Crabtree View Place, a short street segment just east of Blue Ridge Road, would be closed to motorized traffic or converted to one-way toward Glenwood Avenue; but with enhanced pedestrian and bicycle facilities in either case.

In addition to improvements on Crabtree Valley Avenue, the existing Ridge Road interchange and Glenwood Avenue interchange would be modified to increase the weave distance between the Ridge Road entrance to I-440 and the ramp exit to Glenwood Avenue east/west (see **Ridge Road** map). The weaving distance would improve from an existing weave distance of 650 feet to a proposed 2200 feet. The existing Glenwood Avenue exit ramp would be closed and replaced with a loop in the south-east quadrant of the interchange. One important feature of this alternative is that access to I-440 from Ridge Road has been eliminated. Vehicles on Ridge Road wanting to access I-440 will take Ridge Road to Glenwood Avenue where I-440 can be accessed by on ramps. When the Century Drive bridge over Crabtree Creek reaches the end of its service life, this alternative proposes to remove that bridge and replace it with a new bridge over Crabtree Creek with connections to Glenwood Avenue and the ramp from I-440 to Glenwood Avenue west.

### 3. Mid-Term Improvements at I-440 / Ridge Road Interchange (estimated 2020)

This alternative proposes to use potential "Bridge Replacement" funds to build a new bridge over I-440, replacing the Ridge Road bridge with a new connection to Crabtree Valley Avenue from I-440 ramps. The existing movement from I-440 east to Ridge Road will remain and the existing movement from I-440 west to Ridge Road will be modified since the Ridge Road bridge will be removed. Vehicles heading west on I-440 destined for Ridge Road will exit on a modified loop and travel east on Glenwood Avenue to turn right on an extended Ridge Road (see **Crabtree Valley Avenue A1, A3 and A3B** maps). Signage on the freeway will indicate "Crabtree Valley" or "Crabtree Valley Avenue" to reinforce the use of the new interchange for local traffic, freeing up capacity on Glenwood Avenue to carry through traffic as a U.S. route. A sidewalk would be constructed on the east side of the new bridge over I-440 (see "Prop. trail connection" on **Crabtree Valley Avenue A1, A3, and A3B** maps) to connect pedestrians and bicyclists to Crabtree Valley from Ridge Road. The Crabtree Valley Avenue Extension will bridge over Blue Ridge Road, coming back to grade in order to form an at-grade signalized intersection with Homewood Banks (see **Crabtree Valley Avenue A3 and A3B** map). A grade separation at the Crabtree Valley Avenue extension and Blue Ridge Road will enhance motorist and pedestrian safety as well as preclude vehicle queues from extending to the I-440 freeway from ramp traffic stopped at a signalized intersection.

### 4. Long-Term Improvement for Glenwood Avenue/Lead Mine Road/Creedmoor Road

Alternative 1: Using potential State and federal funds, build a new road and bridge extending Crabtree Valley Avenue west from Creedmoor Road to connect with Glenwood Avenue via a partial interchange serving traffic to and from the west on Glenwood Avenue (see **Crabtree Valley Avenue B1** map). The intersection of Creedmoor Road and Crabtree Valley Avenue would be signalized. The existing signal at nearby Creedmoor Road and Crabtree Valley Mall would be removed and the median extended through the intersection to allow only right-in and right-out turn movements. No other signals would be installed in the vicinity of the Creedmoor Road / Crabtree Valley Avenue intersection so that adequate signal spacing is maintained and vehicle queues from adjacent intersections do not overlap. Ramps on Glenwood Avenue / Crabtree Valley Avenue Extension would be designed for free-flow

merging and diverging at speeds that are consistent with Glenwood Avenue traffic. More than 50 percent of the extension will be built on structure over Crabtree Creek and its adjacent floodplain.

Alternative 2: This design proposes to construct a grade separated partial interchange at Glenwood Avenue and Lead Mine Road (see **Crabtree Valley Avenue A4-B** map). This partial interchange, when combined with the Glenwood/Creedmoor interchange will create an expressway through the Crabtree Valley area. As shown on the map, the hatched-red area shows the approximate footprint of the bridge where westbound Glenwood Avenue “through” traffic would travel over Lead Mine Road without stopping. Left turn movements onto Blue Ridge Road from Glenwood Avenue are eliminated in this alternative. Vehicles headed southbound on Lead Mine Road destined for I-440 east will have the option of turning left at the intersection of Glenwood Avenue and Lead Mine Road to access I-440 east via an existing loop, or heading straight through the intersection and utilizing a proposed loop and the Crabtree Valley Avenue interchange. The alternate to this design is to provide a flyover for the left turn movements off of Lead Mine Road heading to I-440 or Glenwood Avenue east (see **Crabtree Valley Avenue A-4** map).

Alternative 3: This design proposes to construct a grade-separated interchange at Glenwood Avenue and Creedmoor Road (see **Creedmoor Road Intersection** map) as an alternative to extending Crabtree Valley Avenue to Glenwood Avenue. Compared with the extension of Crabtree Valley Avenue to Glenwood Avenue, the interchange option would minimize environmental impacts on Crabtree Creek and its floodplain. As shown on the map, the hatched-red area shows the approximate footprint of the bridge where Glenwood Avenue “through” traffic would travel over Creedmoor Road without stopping. Glenwood Avenue “local” traffic would exit and enter via ramps controlled by traffic signals at Creedmoor Road. On the map, the blue lines show the limits of walls and concrete barriers needed to separate “through” lanes from “local” traffic lanes to maintain safe merging and diverging movements. Local traffic would exit in advance and travel through a signalized intersection to move through the area and access right-in, right-out only driveways. A unique feature is proposed for U-turns whereby exiting traffic along Glenwood Avenue remains in the left-lane and uses a dedicated lane in advance of the signalized intersection to travel under the bridge and return to the other side traveling in the opposite direction on Glenwood Avenue (Example: A motorist exiting the Beltline destined for the main entrance of Crabtree Valley Mall would exit I-440, continue through the traffic signal at Lead Mine Road / Blue Ridge Road, then exit westbound Glenwood Avenue at Creedmoor Road, remain in the left-lane and then turn left before the signalized intersection, merging with eastbound Glenwood Avenue “local” traffic.) Based on very conceptual illustrations, it is believed that the entire interchange can be built with minimal impacts to the existing rights-of-way on Glenwood Avenue and Creedmoor Road. However, because of the close proximity of the traffic signals on Glenwood Avenue at Marriott Drive and Crabtree Valley Mall entrance, these intersections would be converted into right-in / right-out only driveways. The existing median would be extended to eliminate left-turn movements. As shown in the illustration (see **Creedmoor Road (CR) Intersection** map) a pedestrian bridge is shown across Glenwood Avenue in the vicinity of Marriott Drive. Due to a number of complexities associated with constructing a pedestrian bridge over US 70, an alternative being considered is to install pedestrian-activated traffic signals and enhance the raised median to safely accommodate pedestrian crossings of Glenwood Avenue under the proposed Creedmoor Road interchange.

The goal when developing the alternatives described above was to create a design which worked in conjunction with each alternative to follow with little or no throw away construction. For example, alternative B2 can be constructed to serve its intended purpose. When the traffic demand is met and funding for alternative A3-B is available, it can be constructed to work with B2. When the traffic demand is met and funding is available, alternative A4-B can be constructed to work with A3-B. The final alternative to be constructed would be the Glenwood Avenue bridge over Creedmoor Road. This series of alternatives will be implemented as the traffic demand grows and funding becomes available in order to provide a master plan for the Crabtree Valley area (see **Crabtree Valley Avenue A5-B** map).

Note: Alternatives **A2**, **A5** and **B3** were removed from further consideration because of lack of support.

### Right-of-Way Impacts

The overlying theme when developing transportation alternatives for the Crabtree Valley area was to create designs which complement the surrounding environment and serve the purpose of relieving traffic congestion in the design year. With this theme in mind, each alternative was designed to require as little additional right-of-way as possible. The table below shows the additional right-of-way requirements for each alternative.

**Table 20. Additional Right-of-Way Requirements**

Alternative	Additional Right-of-Way Required
<b>A1</b>	<b>&lt; 1.5 Acres</b>
<b>A3</b>	<b>&lt; 3.0 Acres</b>
<b>A3-B</b>	<b>&lt; 3.0 Acres</b>
<b>A4</b>	<b>&lt; 3.0 Acres</b>
<b>A4-B</b>	<b>&lt; 3.0 Acres</b>
<b>A5-B</b>	<b>&lt; 3.0 Acres</b>
<b>B1</b>	<b>&lt; 1.5 Acres</b>
<b>B2</b>	<b>&lt; 2.0 Acres</b>
<b>B4</b>	<b>&lt; 1.5 Acres</b>
<b>RR</b>	<b>&lt; 1.0 Acres</b>
<b>CR</b>	<b>&lt; 1.0 Acres</b>

### Environmental Impacts

As work progresses on the Crabtree Valley Transportation Study, it will later be determined which NEPA document would be most appropriate to address environmental impacts. NEPA documentation may consist of a Categorical Exclusion (CE), Environmental Assessment (EA), or an Environmental Impact Statement (EIS). In order to accurately quantify environmental impacts, field investigations for existing natural resources will need to be conducted. A field investigation of jurisdictional streams and wetlands will need to be performed to delineate and survey the location and extent of these features within the project boundary. Appropriate coordination with the US Army Corps of Engineers (USACE) and NC Division of Water Quality (NCDWQ) will be necessary to verify streams and wetland boundaries and discuss Neuse Riparian Buffer Rules. In addition, during field investigations, a threatened and endangered species survey will need to be conducted. Online databases for protected species can be obtained through the NC Natural Heritage Program (NCNHP) and US Fish and Wildlife's (USFWS) websites.

Impacts to waters of the United States fall under the jurisdiction of the USACE through section 404 of the Clean Water Act (33 U.S.C. 1344) and under the jurisdiction of the NCDWQ through the Section 401 Water Quality Certification Process (NC General Statutes Chapter 143 Article 21, Part 1). Any action that proposes to place fill into waters of the United States falls under the jurisdiction of the USACE under Section 404 of the Clean Water Act (33 U.S.C. 1344). A permit is required under the Section 404 permitting process and is required prior to authorization. Depending on the amount of impacts to natural resources, the proposed project would require either an Individual 404 permit or Nationwide Permit (NWP 14). An NWP 14 would apply if wetland impacts do not exceed 0.5 acres or stream impacts do not exceed 300 linear feet per stream. Water Quality Certification pursuant to Section 401 of the Clean Water Act must be obtained from the NCDWQ Water Quality Section. The primary focus of the 401 Water Quality Certification (NC General Statutes Chapter 143 Article 21, Part 1) for impacts to wetlands is on the role wetlands play in the protection of water quality of surface waters and the uses of those waters. Permit requirements vary according to the type of activity proposed and the specific wetland situation. If an Individual Section 404 permit is required by the USACE, an Individual Section 401 Certification will also be required. Because the proposed project falls within the Neuse River basin, impacts to riparian buffer areas would be regulated by NCDWQ under the Neuse Riparian Buffer Rules (15A NCAC 2B .0233). Uses causing impacts to riparian buffers will require written authorization from the NCDWQ and a determination that no practical alternatives exist.

Segments of the proposed project will occur within the Crabtree floodplain. As a result, coordination with the Federal Emergency Management Agency (FEMA) will be necessary to complete a conditional letter of map revision (CLOMR) detailing any change in water surface elevation as a result of the project. Once the project is complete, a letter of map revision (LOMR) will need to be sent to FEMA to detail as-built conditions.

A Natural Resources Technical Report (NRTR) will detail natural resources as observed within the project study area during field investigations and a summary of the proposed project's anticipated effects on these resources under Section 404 of the Clean Water Act and Section 401 Water Quality Certification Process. Topics will include soils, terrestrial ecosystems and aquatic communities, waters of the United States, and rare and protected species. Avoidance, minimization, and mitigation will be discussed as well as permitting requirements.

As the study progresses, funds are secured, and the project area is established, extensive studies will be conducted as well as coordination with federal and state natural resource agencies regarding environmental impacts and permitting.

### **Constructability**

The alternatives described in this report will have a varying degree of difficulty with regards to constructability. Each alternative presented in this report has been evaluated for ease of constructability and it has been determined that none of the alternatives present a constructability challenge beyond what is deemed reasonable for site conditions. The biggest challenge facing any designer and contractor working in an area such as Crabtree Valley is traffic control. The contractor will be tasked with maintaining existing traffic patterns to the greatest extent possible. In order to accomplish this, it is expected that detours, temporary signals, and extensive signage will be utilized. Structures such as Glenwood Avenue over Lead Mine Road and Glenwood Avenue over Creedmoor Road will be built using staged construction or phased construction. This method of construction will allow vehicles to travel across a partially constructed bridge in order to shift traffic so that the remaining half of the bridge can be built.

### **Construction Cost**

The following table details the estimated construction cost of each alternative which were developed using current year dollar values. Cost breakouts are provided for each alternative in Appendix D.

**Table 21. Construction Cost**

<b>Alternative</b>	<b>Construction Cost (millions)</b>
<b>A1</b>	<b>\$ 29.5</b>
<b>A3</b>	<b>\$ 44.3</b>
<b>A3-B</b>	<b>\$ 40.1</b>
<b>A4</b>	<b>\$ 65.7</b>
<b>A4-B</b>	<b>\$ 52.8</b>
<b>A5-B</b>	<b>\$ 90.7</b>
<b>B1</b>	<b>\$ 21.4</b>
<b>B2</b>	<b>\$ 7.9</b>
<b>B4</b>	<b>\$ 10.0</b>
<b>RR</b>	<b>\$ 11.2</b>
<b>CR</b>	<b>\$ 26.1</b>

# Traffic Analysis



## A Historical Review of Study Area Roadways and Traffic Issues

Crabtree Valley is a major regional activity center located at the confluence of heavily traveled arterials, I-440, Crabtree Creek and House Creek. Glenwood Avenue (US 70), a principal arterial running through the valley, at one time was the only highway connecting Durham to the west and Raleigh to the East. Today Glenwood Avenue carries an Average Daily Traffic (ADT) of approximately 70,000 vehicles inside the valley. The traffic volumes drop to 38,000 on the west side of the valley, and 27,000 on the east side of the valley / the beltline.

In the early 1970s, Crabtree Valley Mall was built within the Crabtree Creek floodway. As a result of the mall construction, the Crabtree Creek was rerouted to its current location. The mall, which was later remodeled and expanded in the 1980s and 1990s, has been a major regional traffic generator for the past 38 years.

Lead Mine Road, a major thoroughfare, forms a Y-shaped junction in the valley with North Hills Drive and Blue Ridge Road, two minor thoroughfares. The three thoroughfares collectively carry over 50,000 ADT, channeling traffic from the surrounding residential communities to Glenwood Avenue. The intersection of Glenwood Avenue and Lead Mine Road / Blue Ridge Road is one of the few places in Wake County where triple left-turn lanes are provided.

Creedmoor Road (NC 50) and Edwards Mill Road run across the valley in the north-south direction, serving as secondary arterials for residential communities in the northwest Raleigh area. In 2002, the southern section of Edwards Mill Road was extended to Wade Avenue, providing a new link between Glenwood Avenue and I-40.

Northern Wake Expressway, part of the I-540 loop, is a 30 mile freeway traversing North Raleigh from I-40 near the Raleigh-Durham International Airport (RDU) to US 64 / 264 in Knightdale. Construction of this expressway began in 1997, with the section to US 1 / Capital Boulevard completed in 2002 and the entire length to Knightdale completed in 2007. The Northern Wake Expressway, as well as the Edwards Mill Road extension, has caused some noticeable changes in travel patterns through the valley over the past decade.

While there have been fluctuations in through traffic volumes on Glenwood Avenue, steady population growth in the Raleigh area has exacerbated traffic conflicts at major intersections along the Glenwood Avenue corridor. Traditional roadway widening over the years has reached the maximum roadway width allowable by the natural and built environment. The wide cross sections of Glenwood Avenue make it difficult and unsafe for pedestrians to cross. Traffic signals, already coordinated and optimized for throughputs, have also reached their capacities.

Crabtree Valley has been the subject of many traffic studies over the past 20 years. In a 1988 study conducted by Wilbur Smith Associates, a one-way pair system was proposed where Glenwood Avenue would be serving the westbound traffic only, and Crabtree Valley Avenue would be extended on both ends to Glenwood Avenue serving the eastbound traffic only. In another study conducted in 1994 by Parsons Brinckerhoff, Crabtree Valley Avenue was proposed to be extended to Glenwood Avenue to the west, with Homewood Banks Drive extended to I-440 near Glen Eden Drive Bridge to the east. Due to the construction cost, environmental and economic impacts, access restrictions, and lack of funding, neither study gained enough public support. In 2006, two studies were conducted for the proposed Soleil Center and Kidd's Hill mixed-use developments in the valley, each proposing additional roadway widening and intersection improvements to accommodate the new development traffic. Because of the economic downturn, neither development has been constructed to date.

## Methodology

### Traffic Analysis Procedures

Extensive traffic analyses have been conducted to assess baseline traffic conditions, project future traffic growth, and identify and evaluate various improvement alternatives. The traffic analysis follows the capacity analysis methodologies as defined in the Transportation Research Board's Highway Capacity Manual (HCM) as well as NCDOT Congestion Management's Capacity Analysis Guidelines. The traffic analyses were completed through the use of Synchro/Simtraffic Version 7, and HCS+. Both software packages are based on the HCM methodology and criteria. The following figure illustrates the traffic analysis process used in this study.

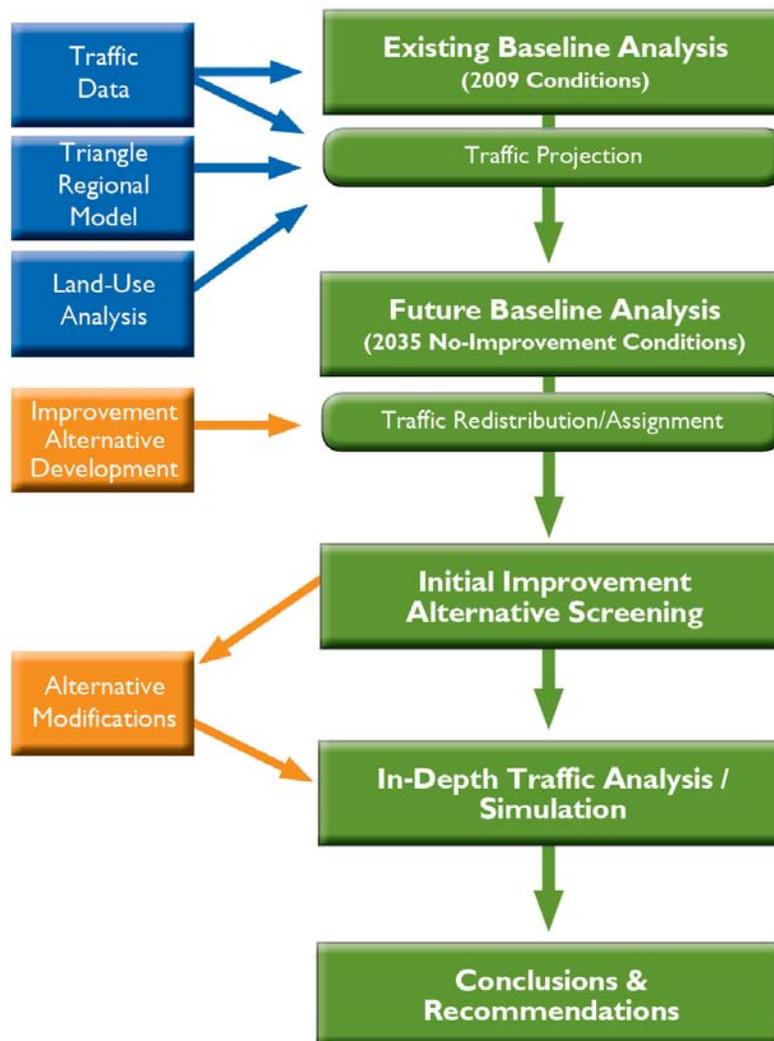


Figure 24. Traffic Analysis Process

### *Measures of Effectiveness*

The following Measures of Effectiveness (MOE) are used to quantify the traffic operational performance:

#### ***Intersection Performance***

- Delays
- Level of Service

#### ***Glenwood Avenue Arterial Performance***

- Travel Time
- Delays
- Average Speed
- Level of Service

#### ***Freeway/Interchange***

- Weaving Segment Speed
- Weaving Segment Density
- Weaving Segment Level of Service
- Ramp Junction Density
- Ramp Junction Level of Service

#### ***Network Performance***

- Performance Index
- Total Delays
- Number of Stops
- Fuel Consumed
- Emissions

The level of service (LOS), defined in HCM, is a quality measure describing traffic operational conditions. It measures delays for at-grade intersections, average travel speeds for arterials, and vehicle densities and speeds for freeway ramp junctions and weaving segments. LOS is graded by letters "A" through "F" representing progressively worsening traffic conditions. According to industry standards, LOS D or better are considered acceptable LOS. LOS E or F is considered substandard and may need solutions to improve the operational performance. It should be noted that the City's 2030 Comprehensive Plan allows for the use of a LOS E standard where necessary for adequate multimodal accommodations.

Performance Index (PI) is a quantity measure used in the traffic capacity analysis software "Synchro". It measures the total delays and stops, thus lower PI numbers indicate better system-wide performance.

## Existing Baseline Analysis (2009 Conditions)

---

### *Traffic Network*

To accurately model the existing traffic conditions in the valley, over 20 intersections and freeway ramp junctions were coded in the traffic network. More specifically the following roadways are included: Glenwood Avenue, Creedmoor Road, Lead Mine Road, North Hill Drive, Blue Ridge Road, Crabtree Valley Avenue, Edwards Mill Road, Homewood Banks Drive, Ridge Road, and I-440.

### *Traffic Data Collection*

Peak hour traffic counts were collected at seven major intersections during weekdays in the third week of December, 2009. Traffic demands in the valley are believed to reach the peak level during this period because of the combination of holiday shopping traffic and regular commuter traffic. These traffic counts were supplemented by additional traffic counts provided by the City of Raleigh, NCDOT, as well as those traffic counts used in recent traffic studies. Volume discrepancies between intersections naturally exist due to the day to day traffic variations. Base year traffic volumes were balanced using the following information:

- Intersection Turning Movement Counts
- NCDOT AADT Data
- NCDOT Continuous Traffic Counts on I-440
- Triangle Regional Model 2009 Volume Output
- Engineering judgments

Figures 1 and 2 in Appendix G summarize the existing peak hour traffic volumes. In addition to the traffic counts, traffic signal plans and signal timing schedules for the existing signalized intersections were obtained from the City of Raleigh and NCDOT. This information ensures that signal timing parameters used in the analyses, such as cycle lengths, offsets, splits, minimum initials, yellow and all-red times, are consistent with current field operations.

Several field visits were conducted to verify the intersection geometry and signal operation schemes. Preliminary Origin-Destination (O-D) information in the Valley was also gathered by observing several CCTV traffic cameras simultaneously inside the City's Traffic Operations Center.

In April 2010, the City's engineering staff conducted real time travel time data collection along the Glenwood Avenue arterial during weekday peak hours. The travel time data was used to compare and calibrate the traffic simulation models.

### *2009 Base Condition Analysis Results*

The two figures in the following pages illustrate the traffic volumes and operational conditions at signalized intersections during weekday peak hours in December, 2009, the existing baseline conditions. In the AM peak hour, the intersection of Glenwood Avenue and Lead Mine Road / Blue Ridge Road is the worst intersection in the valley. Vehicles entering this intersection experience an average delay of 85.8 seconds (LOS F). The heavy triple left-turn movement from southbound Lead Mine Road to eastbound Glenwood Avenue has an average delay of 138.4 seconds (LOS F), and consumes over 30% of the signal green time. The analysis shows, as confirmed by field observations, that the queue on the southbound Lead Mine Road frequently spills back beyond the North Hills Drive intersection.

The intersection of Glenwood Avenue and Creedmoor Road, operating at LOS E with an average delay of 66.3 seconds, is another location causing AM commuter delays. Similar to the Lead Mine Road intersection, the heavy southbound left-turn movement on Creedmoor Road has an average delay of 84.1 seconds (LOS F), and consumes 30% of the green time.

In the PM peak hour, approximately 34% more traffic enters the Valley on Glenwood Avenue compared to the AM peak hour. Both the Lead Mine Road intersection and the Creedmoor Road intersection operate at LOS F with an average delay of 135.2 seconds and 89.5 seconds respectively.

Traffic volumes on westbound I-440 off ramp to westbound Glenwood Avenue (Exit 7B) increase nearly 50% in the PM peak hour. As a result, the average delay at this signalized ramp intersection increases to 144.3 seconds (LOS F). This signal currently is the only location on Glenwood Avenue that operates at half of the network cycle length (200 seconds). Future review of the current signal timing schedules indicates that the delays experienced by vehicles on the exit ramp are partially caused by the needs to maintain proper traffic progressions on westbound Glenwood Avenue. With the eastbound I-440 off ramp intersection (Exit 7) located less than 1,000 feet away, excessive queuing on westbound Glenwood Avenue would adversely affect the eastbound I-440 off ramp operations.

Traffic simulations indicate that, in the week before Christmas 2009, the average travel speed on Glenwood Avenue was 17 mph in the eastbound direction and 11 mph in the westbound direction in the AM peak hour, and 13 mph in the eastbound direction and 12 mph in the westbound direction in the PM peak hour. Travel time data collected by the City's engineering staff in April 2010 shows similar speeds for the westbound arterial, at 13.4 mph in the AM peak hour and 12.2 mph in the PM peak hour. The eastbound arterial however has significantly higher operation speeds in April, 2010, at approximately 30.5 mph during both AM and PM peak hours. As the Crabtree Valley Mall is located on the south side of the Glenwood Avenue arterial, it is estimated that the difference in eastbound arterial speeds was largely caused by the spike of ingressing holiday shopping traffic which tends to create more conflicts for the westbound arterial, especially in the PM peak hour.

Ramps and weaving segments on I-440 between Exit 6 (Ridge Road) and Exit 7B were analyzed using the latest Highway Capacity Software (HCS Version 5.5). The analysis results, as summarized in Appendix H, show that all the ramps and weaving segments are operating at LOS D or better.

While the capacity analysis shows acceptable LOS, it is worthy to note that there are two short weaving areas on I-440 where the weaving maneuver is perceived by drivers as a challenging task. The first weaving segment is located on eastbound I-440 between the Ridge Road on ramp and the Glenwood Avenue off ramp (Exit 7). I-440 Ingressing traffic from Ridge Road needs to cross the Glenwood Avenue exit traffic and merge to the I-440 through traffic within a 700-foot weaving distance. The second weaving segment is located on westbound I-440 between the on ramp from westbound Glenwood Avenue and the off ramp to eastbound Glenwood Avenue and Ridge Road. The weaving segment is approximately 630 feet in length. As the on ramp volumes at both locations are relatively low during the peak hours, the capacity analysis shows no deficiencies for the 2009 Baseline Conditions. It is anticipated that the weaving LOS will degrade as the on ramp volumes increase in the future.

Table 22. 2009 Baseline Traffic Condition

Intersection	Approach	2009 Base Conditions				
		AM		PM		
Glenwood Ave/ Creedmoor Rd	Intersection	66.3	E	89.5	F	
	EB	70.5	E	74.3	E	
	WB	50.9	D	62.8	E	
	NB	78.0	E	106.1	F	
	SB	76.0	E	152.7	F	
Glenwood Ave/ Marriott Dr	Intersection	18.0	B	30.5	C	
	EB	11.5	B	11.8	B	
	WB	21.2	C	39.9	D	
	NB	74.6	E	61.7	E	
	SB	85.9	F	99.1	F	
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	Intersection	85.8	F	135.2	F	
	EB	82.7	F	147.1	F	
	WB	69.7	E	106.9	F	
	NB	98.6	F	199.5	F	
	SB	114.9	F	165.4	F	
Glenwood Ave/ I-440 WB Ramp	Intersection	14.7	B	144.3	F	
	EB	0.2	A	0.0	A	
	WB	21.8	C	20.8	C	
	NB	--	--	--	--	
	SB	33.7	C	450.6	F	
Glenwood Ave/ I-440 EB Ramp	Intersection	23.4	C	48.4	D	
	EB	7.7	A	41.0	D	
	WB	9.5	A	26.8	C	
	NB	84.8	F	86.5	F	
	SB	--	--	--	--	
Lead Mine Rd/ North Hills Dr	Intersection	19.2	B	24.2	C	
	EB	31.3	C	81.4	F	
	WB	51.2	D	101.9	F	
	NB	15.7	B	19.6	B	
	SB	13.1	B	10.0	B	
Creedmoor Rd/ Mall Entr	Intersection	8.9	A	15.8	B	
	EB	83.0	F	44.5	D	
	WB	80.4	F	35.9	D	
	NB	5.2	A	12.3	B	
	SB	8.5	A	13.9	B	
Blue Ridge Rd/ Mall Entr	Intersection	8.2	A	16.1	B	
	EB	38.7	D	33.3	C	
	NB	2.3	A	9.8	A	
	SB	6.1	A	8.8	A	
	SB	0.9	A	3.1	C	
Creedmoor Rd/ Crabtree Valley Ave	Intersection	--	--	--	--	
	EB	--	--	--	--	
	WB	67.1	F	--	F	
	NB	--	--	--	--	
	SB	0.9	A	3.1	C	
Crabtree Valley Ave/ Blue Ridge Rd	Intersection	--	--	--	--	
	EB	123.1	F	423.2	F	
	WB	14.5	B	27.7	D	
	NB	1.7	A	3.0	A	
	SB	0.5	A	1.2	A	
Crabtree Valley Ave/ Edwards Mill Rd	WB	2.8	A	4.0	A	
	NB	10.6	B	29.6	D	
	SB	--	--	--	--	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	Intersection	--	--	--	--	
	EB	1.4	A	2.0	A	
	WB	0.5	A	0.8	A	
	NB	12.0	B	30.1	D	
	SB	11.3	B	22.6	C	
Performance Index		550.4		2,218.9		
Glenwood Ave Arterial	EB	Speed (mph)	17 (16-18)	E	13 (9-17)	F
		Travel Time (sec)	426.6 (406.6-453.2)		561.0 (476.3-755.1)	
		Delays(sec/veh)	262.7 (242.7-289.3)		396.9 (273.0-640.0)	
	WB	Speed (mph)	11 (10-15)	F	12 (9-14)	F
		Travel Time (sec)	511 (422.2-533.4)		510.9 (424.8-895.4)	
		Delays (sec/veh)	380.2 (250.7-448.5)		379.5 (293.4-764.0)	
Network Performance	Total Delay (hr)	2,189.4 (1,848.5-2,408.9)		3,737.2 (3,341.6-4,020.4)		
	Stops (#)	41,572.0		50,886.0		
	Fuel Consumed (gal)	1,313.1		1,663.1		
	HC Emmissions (g)	13,615.0		14,460.0		
	CO Emissions (g)	592,226.0		605,867.0		
	NOx Emissions (g)	45,002.0		45,673.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

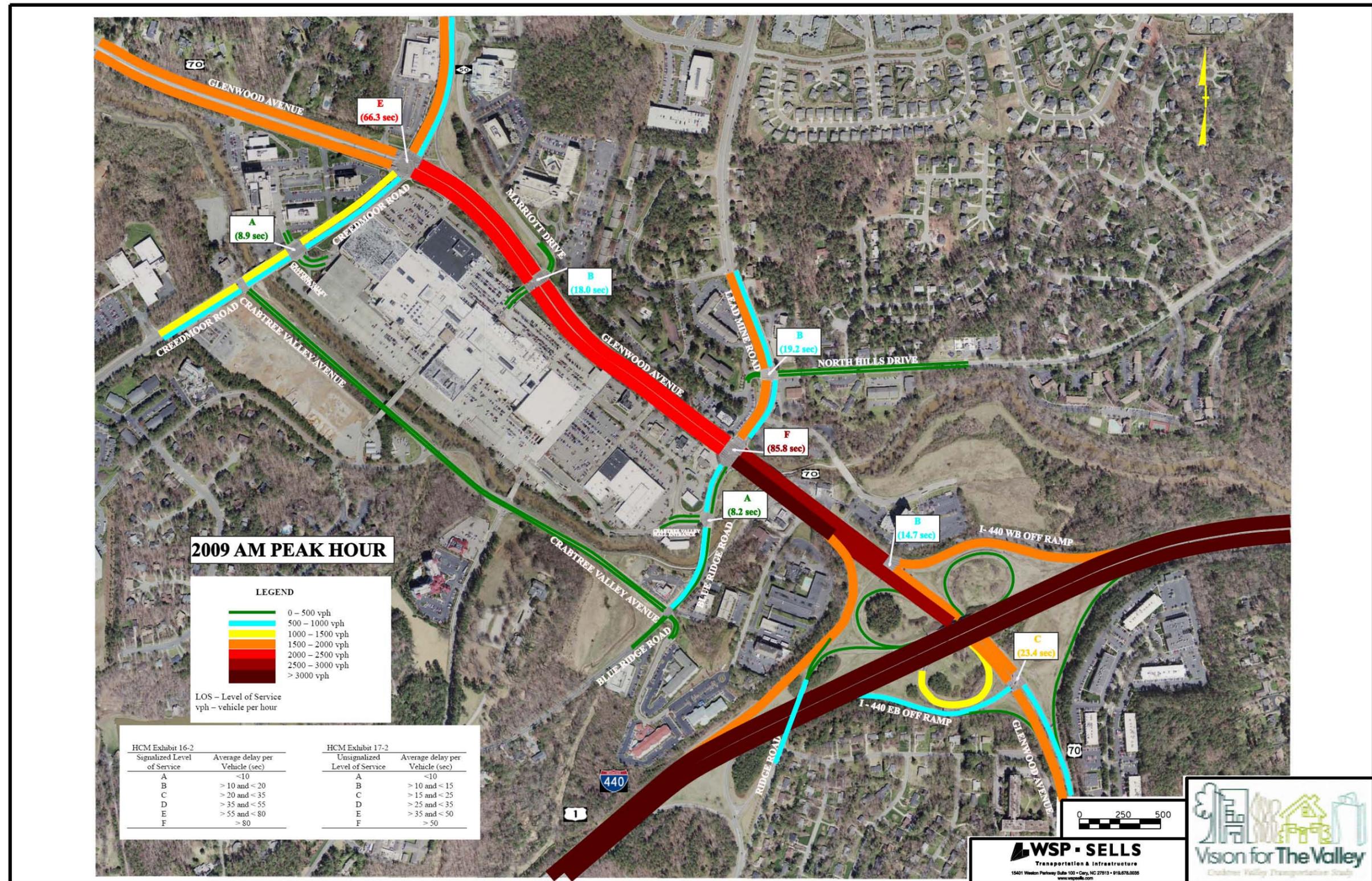


Figure 25. 2009 Morning Peak Hour Traffic Volumes

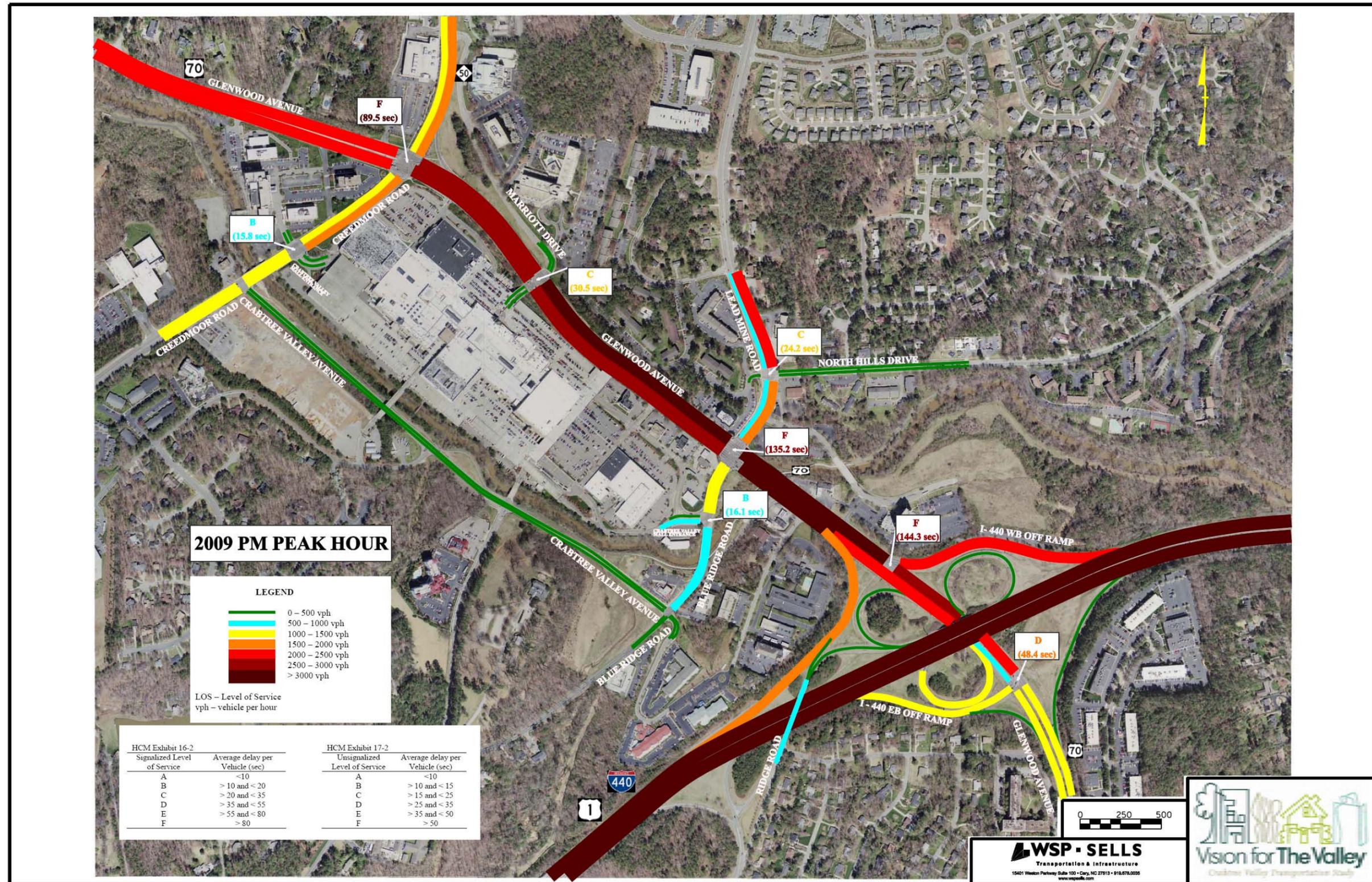


Figure 26. 2009 Evening Peak Hour Traffic Volumes

## Future Traffic Projection (2035 No Improvement Conditions)

### Traffic Projection

While the land use analyses were performed for 2020 and 2030 to be consistent with the City's Comprehensive Plan, the study steering committee decided that 2035 should be used as the design year for future traffic analyses. Three different sources of data were used to estimate the 2035 no improvement volumes, as follows:

#### 1. Growth Factor

An annual growth factor of 2.5% is typically used in traffic studies in the Raleigh area. While the 2.5% growth factor might seem a bit high given the recent economic recession and slow recovery, the growth factor is roughly consistent with the 2010 census data which shows that the Raleigh population has grown 40%, or at an annual rate of 3.4%, for the past decade. Assuming the same turning movement splits at intersections, the 2.5% growth factor is applied to the 2009 base year roadway link volume inputs to estimate the 2035 volumes. This approach will increase the background volumes by 90% over 26 years. Figures 3 and 4 in Appendix G summarize the estimated 2035 background traffic volumes.

#### 2. Triangle Regional Model (TRM)

The TRM is a transportation planning tool designed to evaluate how future growth impacts transportation facilities. The TRM covers approximately 2,600 square miles in the triangle region which is further divided into 2,317 Traffic Analysis Zones (TAZs). The model uses socio-economic data, traffic and roadway network information, going through a four step travel demand forecasting process, to estimate and evaluate future traffic conditions. 2009 and 2035 volume outputs were obtained from the TRM Service Bureau for the study area. Comparing the 2009 and 2035 TRM volume outputs, growth factors were calculated for each roadway link. Those factors were then applied to the base year volume inputs to estimate 2035 volumes. This process essentially calibrates the 2035 TRM volume outputs with the 2009 traffic counts. Except for Blue Ridge Road, this approach estimates lower volumes on the study area roadway network compared with the growth factor approach. Figures 5 and 6 in Appendix G summarize the calibrated 2035 TRM traffic volumes.

#### 3. Land Use Analyses

As summarized in Appendix A, trip generations were conducted for the parcels that most likely will be developed or redeveloped in the valley over the next 20 years. The parcels were then grouped to form the same TAZs used in the TRM. There are a total of 14 TAZs affected by the new developments or redevelopments. Comparing the Average Daily Traffic (ADT) growth estimated by the TRM and the growth estimated through the land use analyses, eight TAZs will experience higher growth according to the land use traffic estimates. The other six TAZs will either have less growth or a relative growth of less than 200 vehicles per day which is unlikely to cause any noticeable difference in peak hour traffic operations. For those eight TAZs, the additional growth volumes were redistributed to the TRM traffic volume network, based on the Institute of Traffic Engineers' (ITE) recommended trip distribution procedures. Figures 7 and 8 in Appendix G summarize the 2035 traffic volumes based on the land use analysis.

The 2035 no improvement condition volume estimates, as summarized in Figures 9 and 10 in Appendix G, is a synthesis of the volume outputs from the three sources discussed above, where the highest volume estimates were adopted for both the roadway link volume inputs and intersection turning movement volumes. While being a relatively conservative approach, this traffic projection method ensures that the developments and redevelopments in the valley are fully accounted for when developing and evaluating future improvement alternatives.

### *Traffic Growth Analysis*

Comparing the 2035 no improvement volumes with the volumes estimated from the 2.5% annual growth factor, the growth caused by the developments and redevelopments can be separated from the background traffic growth. The figure in the following page shows the traffic growth projection for the valley, via a screenline analysis approach.

The following four screenlines are used in the analysis.

- Screenline A crosses Glenwood Avenue on the west side of Creedmoor Road
- Screenline B crosses Creedmoor Road, Lead Mine Road and North Hills Road on the north side of Glenwood Avenue
- Screenline C crosses Glenwood Avenue on the west side of I-440
- Screenline D crosses Creedmoor Road, Edwards Mill Road, Homewood Banks Drive and Blue Ridge Road on the south side of Crabtree Valley Avenue

The analysis indicates that, except for the south side of the valley, the overwhelming majority of the traffic growth is caused by the background traffic growth. Due to several major projected new developments and redevelopments near Crabtree Valley Avenue, the development related trips account for 33% of the net traffic growth along the southern edge of the valley (Screenline D) in the AM peak hour, and 25% of the net growth in the PM peak hour.

The analysis also reveals that the projected new developments and redevelopments in the valley will reduce the traffic crossing screenlines A and B in the AM peak hour, although by a small amount of trips. This seemingly odd result actually makes logical sense, considering the steps taken to estimate the 2035 traffic volumes.

As discussed in the previous section, the highest entering volumes from the growth factor, triangle regional model, and the land use model were adopted as the roadway link input volumes. The trips were then redistributed at certain intersections to account for the developments and redeployments. At the screenline crossings, the entering volumes are always equal to or higher than the projected background traffic volumes. Since the screenline traffic volumes include traffic both entering and leaving the valley, the trip reductions indicate that, in the morning because of the commercial and office portions of the new developments or redevelopments, the valley becomes slightly more of a destination than an origination.

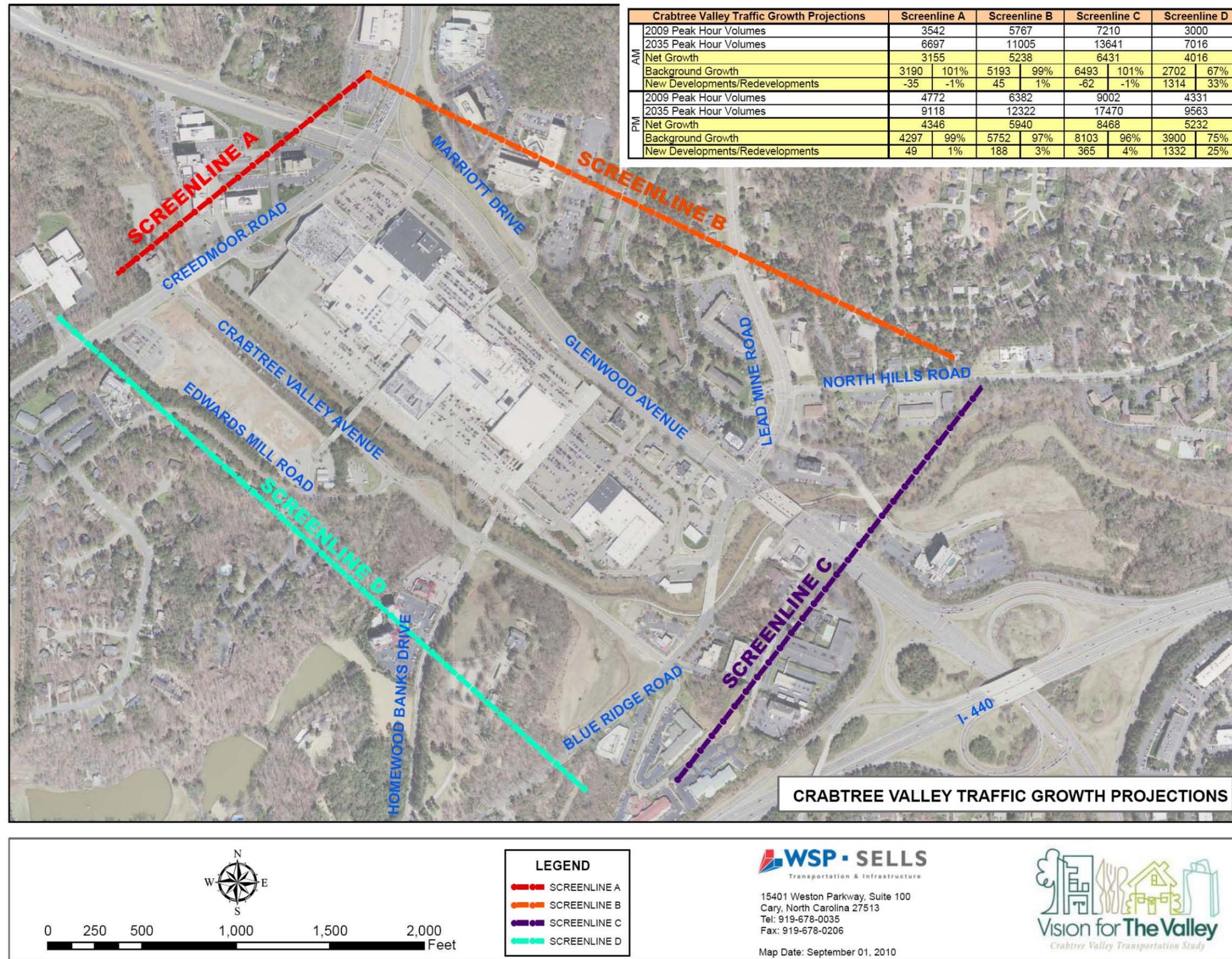


Figure 27. Crabtree Valley Traffic Growth Projections

## Future Baseline Analysis (2035 No Improvement Conditions)

### *Assumptions on “2035 No Improvement Conditions”*

The future baseline conditions, while named as “No Improvement Conditions” as in contrast to the proposed improvement alternatives, include the following planned improvement measures.

- Traffic signal timing optimization
- Crabtree Valley Avenue will be widened to a four-lane median divided facility as per the City’s thoroughfare plan.
- Three new traffic signals will be installed on Crabtree Valley Avenue at Creedmoor Road, Homewood Banks Drive / Mall Entrance, and Blue Ridge Road.
- A left-turn lane will be installed on both Blue Ridge Road approaches at its intersection with Crabtree Valley Avenue.

### *2035 No Improvement Condition Analysis Results*

When the traffic volumes exceed the roadway capacities, vehicle delays increase dramatically, as is in the case of the 2035 No Improvement scenario. With almost twice as much traffic entering the valley, most of the intersections in the study area will be operating with excessive delays (LOS F) during peak hours. The capacity analysis results, as summarized in the following table, indicate that the average PM peak hour delays will increase to 422.8 seconds at the Glenwood Avenue / Creedmoor Road intersection, 632.9 seconds at the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection, and 360.2 seconds at the Glenwood Avenue / Westbound I-440 off ramp intersection. The average AM peak hour delays at the three intersections will increase to 259.5 seconds, 384.9 seconds, and 193.6 seconds respectively.

Traffic simulations show that the average travel speed on Glenwood Avenue will be reduced to 3 to 4 mph in the eastbound direction, and 5 to 7 mph in the westbound direction during peak hours. The total traffic delays for the valley are estimated to be 6.5 times worse in the AM peak hour and 4.1 times worse in the PM peak hour.

Freeway capacity analyses show that, except for the eastbound I-440 off-ramp to Ridge Road Exit 6 (AM LOS E), the eastbound I-440 on-ramp from westbound Glenwood Avenue (AM LOS C), and the westbound I-440 off-ramp to westbound Glenwood Avenue Exit 7B (AM LOS D/ PM LOS C), all the ramp junctions and weaving segments will be operating at LOS F. The westbound I-440 off-ramp to westbound Glenwood Avenue was analyzed as a major diverge area (lane drops) following the Highway Capacity Manual (HCM) methodology. The formula provided in HCM (Equation 25-12) estimates the density across all freeway lanes for the ramp influence area. While the estimated average densities are within acceptable ranges, the freeway through traffic demand, when separated from the off-ramp traffic, will exceed the capacity. In addition, the off-ramp performance will be largely determined by the signal operations at the off-ramp intersection on Glenwood Avenue. The results of the freeway capacity analyses, as summarized in Appendix H, indicates that the westbound I-440 capacity will be exceeded in both AM and PM peak hours, and the eastbound I-440 capacity will be exceeded in the PM peak hour.

Table 23. Crabtree Valley Area with No Improvements Performance Index (2035)

Intersection	Approach	2035 No Improvements			
		AM		PM	
Glenwood Ave/ Creedmoor Rd	Intersection	259.5	F	422.8	F
	EB	270.6	F	426.6	F
	WB	189.5	F	451.3	F
	NB	202.5	F	297.0	F
	SB	346.9	F	508.0	F
Glenwood Ave/ Marriott Dr	Intersection	39.2	D	220.6	F
	EB	49.7	D	259.3	F
	WB	22.2	C	201.7	F
	NB	78.2	E	54.0	D
	SB	141.5	F	202.8	F
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	Intersection	384.9	F	632.9	F
	EB	421.8	F	674.2	F
	WB	365.4	F	722.4	F
	NB	229.0	F	417.9	F
	SB	409.0	F	409.9	F
Glenwood Ave/ I-440 WB Ramp	Intersection	193.6	F	360.2	F
	EB	233.7	F	200.8	F
	WB	150.3	F	385.7	F
	NB	--	--	--	--
	SB	166.5	F	517.1	F
Glenwood Ave/ I-440 EB Ramp	Intersection	148.4	F	185.0	F
	EB	202.2	F	194.8	F
	WB	16.4	B	174.8	F
	NB	216.6	F	189.5	F
	SB	--	--	--	--
Lead Mine Rd/ North Hills Dr	Intersection	77.2	E	173.5	F
	EB	104.5	F	63.6	E
	WB	112.2	F	126.6	F
	NB	56.9	E	269.4	F
	SB	79.7	E	24.9	C
Creedmoor Rd/ Mall Entr	Intersection	121.7	F	70.8	E
	EB	170.0	F	98.8	F
	WB	69.5	E	76.0	E
	NB	30.7	C	81.7	F
	SB	158.4	F	54.2	D
Blue Ridge Rd/ Mall Entr	Intersection	139.7	F	133.4	F
	EB	120.7	F	274.0	F
	NB	2.0	A	15.7	B
	SB	203.8	F	129.5	F
	SB	--	--	--	--
Creedmoor Rd/ Crabtree Valley Ave	Intersection	48.7	D	97.1	F
	EB	--	--	79.3	E
	WB	46.8	D	75.3	E
	NB	38.3	D	122.5	F
	SB	53.8	D	71.8	E
Crabtree Valley Ave/ Blue Ridge Rd	Intersection	238.6	F	239.4	F
	EB	197.2	F	125.0	F
	WB	245.1	F	241.2	F
	NB	105.2	F	260.0	F
	SB	312.8	F	267.7	F
Crabtree Valley Ave/ Edwards Mill Rd	WB	6.3	A	6.0	A
	NB	56.1	F	--	F
	SB	--	--	--	--
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	Intersection	11.6	B	21.2	C
	EB	4.9	A	9.4	A
	WB	5.5	A	8.7	A
	NB	37.2	D	57.1	E
	SB	30.9	C	30.8	C
Performance Index		6,549.3		12,596.3	
Glenwood Ave Arterial	EB	Speed (mph)	4 (4-4)	3 (3-3)	
		Travel Time (sec)	2,805.3 (2,467.6-3,171.4)	4,893.8 (4,530.0-5,493.5)	
		Delays(sec/veh)	2,638.2 (2,300.5-3,004.3)	4,726.2 (4,362.4-5,325.9)	
	WB	Speed (mph)	7 (6-7)	5 (3-5)	
		Travel Time (sec)	1,141.4 (930.3-1,589.6)	5,875.6 (4,932.8-10,417.3)	
		Delays (sec/veh)	1,007.7 (796.6-1,455.9)	5,742.1 (4,799.3-10,283.8)	
Network Performance	Total Delay (hr)	14,237.3 (13,714.1-14,695.0)		15,350.3 (15,085.0-15,601.8)	
	Stops (#)	72,973.0		76,420.0	
	Fuel Consumed (gal)	3,945.6		4,207.9	
	HC Emissions (g)	18,208.0		19,383.0	
	CO Emissions (g)	671,004.0		727,244.0	
	NOx Emissions (g)	42,317.0		44,038.0	

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

## Improvement Alternative Development

A series of alternatives have been proposed to improve the mobility, accessibility, and safety for both vehicular and pedestrian traffic in the valley. As discussed in the “Roadways” section, each alternative has its pedestrian, bicycle, and transit service improvement elements which are incorporated in the traffic analyses where applicable. Since the heavy vehicular traffic demands are the primary cause of congestion and delays, the proposed alternatives can be grouped into the following two categories based on the problem solving approach. Some alternatives listed below have several versions with varying roadway configurations.

### A. *Apply Directly Where It Hurts!*

The alternatives in this category are designed to mitigate congestion by removing specific traffic conflicts with grade-separated structures.

#### 1. Creedmoor Road Interchange

This alternative provides an overpass for Glenwood Avenue through traffic at the Creedmoor Road intersection.

#### 2. Lead Mine Road Flyover

This alternative provides an overpass for the southbound Lead Mine Road left-turn movements to eastbound Glenwood Avenue. Some versions of this alternative also have direct ramp connections to I-440.

#### 3. Lead Mine Road Interchange

This alternative provides an overpass for Glenwood Avenue through traffic at the Lead Mine Road intersection. One version of this alternative provides the overpass only for the westbound Glenwood Avenue approach. Another interchange alternative consists of an overpass for the Lead Mine Road / Blue Ridge Road traffic.

### B. *Let's Drill A Relief Well!*

The alternatives in this category are designed to mitigate congestion by diverting traffic to use an improved existing route, or providing new access route(s) to the valley.

#### 1. Crabtree Valley Avenue Improvements

This alternative will widen and reroute the current lightly traveled Crabtree Valley Avenue. With new signals installed at the Mall entrances, the improved Crabtree Valley Avenue will become an appealing alternative route for the retail traffic.

#### 2. Ridge Road Improvements

This alternative is designed to improve the weaving on eastbound I-440 between Ridge Road on ramp and Glenwood Avenue off ramp by (A) rerouting the eastbound I-440 on ramp traffic from eastbound Glenwood Avenue to the existing Ridge Road bridge over I-440 and an improved Ridge Road on ramp, (B) rerouting the Glenwood Avenue exit traffic to use a new loop ramp in the northeastern quadrant of the existing interchange, and (C) rerouting the current Ridge Road on ramp traffic to access I-440 via an extension of Ridge Road to a modified I-440 eastbound on/off ramp intersection on Glenwood Avenue.

#### 3. Crabtree Valley Avenue Extension to I-440

This alternative provides direct access between Crabtree Valley Avenue and I-440.

#### 4. Crabtree Valley Avenue Extension to Glenwood Avenue

This alternative provides direct access between Crabtree Valley Avenue and Glenwood Avenue

## Initial Improvement Alternative Screening

### *Types of Traffic Analysis*

As briefly mentioned early in the Methodology section, the following two types of traffic analysis were conducted to effectively evaluate the various alternatives.

The **initial screening** focuses exclusively on traffic capacity analyses. Using performance measures such as intersection delays, weaving speed, ramp junction densities, LOS, and system performance index, the initial screening is designed to quickly identify if the proposed alternative can provide adequate capacity for the traffic it intends to serve.

The **in-depth traffic analysis** is built upon the initial analysis, and includes both traffic capacity analyses and traffic simulations to better quantify and evaluate the operational performance improvements. Some additional performance measures used in this analysis include arterial speeds and LOS, network delays, total stops, and emissions. Both the “Existing Baseline Analysis” and the “Future Baseline Analysis” can be considered in-depth traffic analysis.

### *Alternatives (Not) Included in Initial Screening*

Among the proposed improvement alternatives, the “Crabtree Valley Avenue Improvements” alternative follows most closely with the City’s current thoroughfare plan, receives favorable feedback from the stakeholders, and is widely believed by the study steering committee that it can be implemented in the near future. With less uncertainty on its viability, this alternative skips the initial traffic analysis screening and directly proceeds to the in-depth traffic analysis which will be discussed later in this report.

The Lead Mine Road Interchange alternative, also referred to as the *Glenwood Avenue Overpass* later in this report, was developed at a late stage of this study after most of the initial screening analysis was completed. This alternative was believed to have several merits and was automatically included in the in-depth traffic analysis.

It should be noted that, although the two alternatives discussed above are not “included” in initial screening for *comparison purpose*, they do go through the same type of screening, as the in-depth analysis also includes the traffic capacity analysis.

While the alternatives were developed, it became clear that certain combinations of the alternatives may deliver a much greater traffic improvement benefit for the valley. The initial traffic analysis screening includes the following alternatives and combination of alternatives.

#### Near Term Improvement

- Ridge Road Improvements

#### Mid / Long Term Improvements

- Creedmoor Road Interchange
- Lead Mine Road Flyover
- Crabtree Valley Avenue Extensions (to Glenwood Avenue and to I-440)
- Crabtree Valley Avenue Extension to I-440

### *Traffic Distribution/Assignment for Proposed Alternatives*

Most of the proposed alternatives will cause traffic diversions or shifts, because new road connectors are added or certain existing movements are prohibited. Based on the 2035 No Improvements link input volumes and intersection turning movement percentages, traffic volumes were estimated for various Origin-Destination (O-D) pairs that will be affected by individual improvement alternatives or combination of alternatives. Those volumes were redistributed to the network based on the shortest-route assumptions in terms of travel times or travel distances, as well as engineering judgments. The 2035 no improvement volumes were thus adjusted for each alternative to account for the redistribution of those trips. The OD matrixes used in the trip redistributions are included in Appendix G.

### *Initial Screening Results*

#### **Ridge Road Improvements**

As the primary goal of this alternative is to, in the near term, improve the weaving performance on eastbound I-440 between Ridge Road on ramp and Glenwood Avenue off ramp, freeway weaving segment analysis was conducted with 2009 base year traffic volumes. The analysis shows that, although the weaving segment length will be increased from 700 feet to 2,100 feet, the Ridge Road on ramp volume will also increase by over 1,000 vehicles per hour during both AM and PM peak hours. As a result, this alternative will cause the weaving segment LOS to degrade from "D" to "E" in the PM peak hour. In the AM peak hour, while the LOS would remain at "C", the analysis shows increased vehicle density in the weaving segment, which indicates inferior performance. Based on the weaving segment analysis results, as summarized in Appendix H, this alternative is removed from further consideration.

#### **Creedmoor Road Interchange**

The traffic model used in this analysis was created for an early version of the alternative where the interchange does not have U-turns underneath, and this version of the alternative retains the traffic signal on Glenwood Avenue at the Mall / Marriott Entrance. The table in the following page summarizes the capacity analysis results.

Comparing this alternative with the Future Baseline Conditions, the analysis shows that the average delays at the Glenwood Avenue / Creedmoor Road intersection will be reduced by 42% from 259.5 seconds to 151.2 seconds in the AM peak hour, and by 54% from 422.8 seconds to 192.9 seconds in the PM peak hour. The intersection of Glenwood Avenue and Lead Mine Road / Blue Ridge Road, as well as the intersection of Glenwood Avenue and Westbound I-440 off ramp, will also benefit from this improvement, especially in the PM peak hour although at a lesser degree. The average PM peak hour delays at the two intersections will be decreased from 632.9 seconds to 528 seconds, and from 360.2 seconds to 310.8 seconds respectively.

The system performance index also indicates that the proposed alternative may bring system wide delay reductions. Since this proposed alternative will not affect the ramp volumes on I-440, the ramp junction and weaving segment performance will be the same as in the Future Baseline Conditions.

While the capacity analysis shows positive results, the signal at the Mall / Marriott entrance presents potential operational problems because of the close proximity to the overpass structure. Based on the findings discussed above, it is determined that in-depth traffic analysis shall be performed for a refined version of this alternative where the traffic signal at the Mall / Marriott Entrance will be removed, and U-turns will be provided under the interchange to maintain access to the Mall Entrance from westbound Glenwood Avenue..

Table 24. 2035 Creedmoor Road Interchange System Performance

Intersection	Approach	2035 Creedmoor Rd Interchange (without U-Turns on Glenwood Ave)			
		AM		PM	
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>151.2</b>	<b>F</b>	<b>192.9</b>	<b>F</b>
	EB	105.3	F	213.8	F
	WB	79.2	E	94.5	F
	NB	138.6	F	261.4	F
	SB	196.5	F	196.6	F
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	<b>33.5</b>	<b>C</b>	<b>220.5</b>	<b>F</b>
	EB	46.3	D	258.0	F
	WB	16.7	B	202.2	F
	NB	50.0	D	49.3	D
	SB	91.4	F	217.7	F
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	<b>Intersection</b>	<b>384.0</b>	<b>F</b>	<b>528.0</b>	<b>F</b>
	EB	419.4	F	531.6	F
	WB	378.1	F	546.9	F
	NB	236.2	F	566.7	F
	SB	386.1	F	398.1	F
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>158.5</b>	<b>F</b>	<b>310.8</b>	<b>F</b>
	EB	156.3	F	26.5	C
	WB	153.6	F	421.8	F
	NB	--	--	--	--
	SB	167.5	F	513.3	F
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>156.4</b>	<b>F</b>	<b>185.5</b>	<b>F</b>
	EB	216.3	F	201.7	F
	WB	13.8	B	155.3	F
	NB	226.0	F	212.1	F
	SB				
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>52.0</b>	<b>D</b>	<b>208.1</b>	<b>F</b>
	EB	64.2	E	62.4	E
	WB	125.3	F	131.3	F
	NB	21.3	C	330.2	F
	SB	51.5	D	23.6	C
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	<b>112.0</b>	<b>F</b>	<b>39.1</b>	<b>D</b>
	EB	268.5	F	93.0	F
	WB	57.3	E	70.1	E
	NB	16.8	B	55.3	E
	SB	142.6	F	11.0	B
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	<b>133.7</b>	<b>F</b>	<b>151.2</b>	<b>F</b>
	EB	97.6	F	301.0	F
	NB	1.5	A	17.2	B
	SB	197.0	F	152.9	F
	SB				
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>30.6</b>	<b>C</b>	<b>77.5</b>	<b>E</b>
	EB	--	--	73.0	E
	WB	45.2	D	88.2	F
	NB	36.6	D	80.3	F
	SB	26.0	C	70.6	E
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>242.4</b>	<b>F</b>	<b>267.1</b>	<b>F</b>
	EB	209.4	F	135.2	F
	WB	245.2	F	268.9	F
	NB	92.3	F	286.3	F
	SB	322.8	F	305.1	F
Crabtree Valley Ave/ Edwards Mill Rd	WB	6.3	A	6.0	A
	NB	56.1	F	--	F
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>9.1</b>	<b>A</b>	<b>19.9</b>	<b>B</b>
	EB	5.0	A	10.3	B
	WB	3.4	A	14.1	B
	NB	28.0	C	35.8	D
	SB	23.2	C	33.4	C
<b>Performance Index</b>		5,749.2		10,465.7	

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

### Lead Mine Road Flyover

Comparing this alternative with the Future Baseline Conditions, the analysis shows that the average delays at the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection will be reduced from 384.9 seconds to 258.4 seconds in the AM peak hour, and from 632.9 seconds to 466.5 seconds in the PM peak hour. The percentage reductions are 33% and 26% respectively. The table in the following page summarizes the intersection capacity analysis results.

While the proposed alternative removes the heaviest turning movement in the AM peak hour from the at-grade intersection, it does not address the dominant PM peak hour turning movement - the westbound left-turn movement from Glenwood Avenue to Blue Ridge Road. The westbound Glenwood Avenue will continue to operate with over 500 seconds of delay in the PM peak hour. In addition, the proposed alternative will require the closure of two existing T-intersections on Glenwood Avenue at Crabtree View Place and Arrow Drive, two collector streets located on the east side of Blue Ridge Road. Local residents have voiced their objections because of the access restrictions.

Since this proposed alternative will not affect the ramp volumes on I-440, the ramp junction and weaving segment performance will be the same as in the Future Baseline Conditions. Given the results of the analyses, as well as the cost, environmental and access impacts, this alternative is removed from further consideration.

Table 25. 2035 Lead Mine Road Flyover System Performance

Intersection	Approach	2035 Lead Mine Flyover			
		AM		PM	
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>262.5</b>	<b>F</b>	<b>384.3</b>	<b>F</b>
	EB	292.7	F	352.9	F
	WB	190.3	F	362.1	F
	NB	177.7	F	461.0	F
	SB	344.7	F	389.2	F
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	<b>41.6</b>	<b>D</b>	<b>298.3</b>	<b>F</b>
	EB	54.7	D	381.1	F
	WB	21.3	C	228.8	F
	NB	71.3	E	311.9	F
	SB	135.2	F	243.7	F
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	<b>Intersection</b>	<b>258.4</b>	<b>F</b>	<b>466.5</b>	<b>F</b>
	EB	298.7	F	467.4	F
	WB	263.8	F	533.9	F
	NB	37.9	D	186.1	F
	SB	281.8	F	283.8	F
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>90.6</b>	<b>F</b>	<b>289.8</b>	<b>F</b>
	EB	9.8	A	9.7	A
	WB	162.4	F	357.0	F
	NB	--	--	--	--
	SB	161.9	F	538.7	F
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>148.3</b>	<b>F</b>	<b>186.2</b>	<b>F</b>
	EB	205.5	F	203.9	F
	WB	16.4	B	155.3	F
	NB	207.7	F	212.1	F
	SB				
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>51.1</b>	<b>D</b>	<b>58.3</b>	<b>E</b>
	EB	77.1	E	71.0	E
	WB	97.0	F	135.2	F
	NB	34.3	C	66.5	E
	SB	49.0	D	23.7	C
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	<b>121.7</b>	<b>F</b>	<b>66.1</b>	<b>E</b>
	EB	187.1	F	140.3	F
	WB	66.6	E	78.3	E
	NB	33.1	C	83.8	F
	SB	156.3	F	35.4	D
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
	EB	270.8	F	332.6	F
	NB	--	A	--	A
	SB	--	--	--	--
	SB				
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>47.3</b>	<b>D</b>	<b>71.8</b>	<b>E</b>
	EB	--	--	72.6	E
	WB	44.9	D	138.4	F
	NB	37.4	D	68.0	E
	SB	52.3	D	55.1	E
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>220.9</b>	<b>F</b>	<b>246.6</b>	<b>F</b>
	EB	239.1	F	151.6	F
	WB	238.3	F	241.9	F
	NB	132.4	F	268.0	F
	SB	253.2	F	267.2	F
Crabtree Valley Ave/ Edwards Mill Rd	WB	6.3	A	6.0	A
	NB	56.1	F	--	F
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>12.8</b>	<b>B</b>	<b>18.8</b>	<b>B</b>
	EB	10.2	B	11.4	B
	WB	3.3	A	9.5	A
	NB	35.8	D	36.1	D
	SB	29.6	C	33.6	C
<b>Performance Index</b>		5,349.6		11,014.5	

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

### Crabtree Valley Avenue Extensions

The scenario modeled in this analysis is a combination of two alternatives, the Crabtree Valley Avenue extension on the western end to Glenwood Avenue and the Crabtree Valley Avenue extension on the eastern end to I-440. The two alternatives collectively create a “Glenwood Avenue by-pass” through the valley, and thus have a great potential to relieve the congestion on Glenwood Avenue. This scenario will also encourage shoppers to use Crabtree Valley Avenue to access the Mall.

The traffic analysis results, as summarized in the table on the following page, indicate that the combined alternative can provide significant system-wide performance improvements. On the Glenwood Avenue arterial, the average intersection delays at the Creedmoor Road intersection will be reduced by 38% to 161.1 seconds in the AM peak hour, and by 41% to 248.7 seconds in the PM peak hour. The average delays at the Lead Mine Road / Blue Ridge Road intersection will be reduced by 32% to 260 seconds in the AM peak hour, and by 42% to 362.5 seconds in the PM peak hour. The westbound I-440 off ramp intersection will also experience a 36% delay reduction in the PM peak hour.

The freeway ramp junction and weaving segment analyses, as documented in Appendix H, show that on the eastbound I-440 approach, the combined alternative will improve the ramp performance at the Ridge Road / Crabtree Valley Avenue / Glenwood Avenue exit, by increasing the ramp capacity and removing a significant amount of traffic off I-440 so that it will operate under capacity in the PM peak hour. The LOS for this exit ramp is expected to improve from E to C in the AM peak hour, and remain at LOS F in the PM peak hour with an improved vehicle density / performance at the exit ramp. This combined alternative will also remove the existing weaving segment between Ridge Road and Glenwood Avenue. Because the existing Ridge Road on ramp traffic will access I-440 at a modified eastbound ramp intersection on Glenwood Avenue, the eastbound on ramp from westbound Glenwood Avenue will have higher volumes while the freeway volumes will decrease at the on ramp junction. The analysis shows the combined alternative will increase the vehicle density from 26.5 pc/mil/ln (LOS C) to 28.9 pc/mil/ln (LOS D) in the AM peak hour, and from 29.9 pc/mil/ln (LOS F) to 32.4 pc/mil/ln (LOS F) in the PM peak hour.

At the westbound I-440 exit ramp to westbound Glenwood Avenue, the freeway capacity will be exceeded although the estimated average densities are still within acceptable ranges. As discussed earlier in the Future Baseline Condition Analysis, the average densities were calculated for all the freeway lanes including the exit lanes. When separated from the exit traffic, the freeway through traffic demand will exceed the capacity during both AM and PM peak hours. The new westbound on ramp from Crabtree Valley Avenue will operate at LOS F in the AM peak hour, because the I-440 capacity will be exceeded even with an additional through lane added at the on ramp junction. In the PM peak hour, the additional through lane will provide enough capacity to serve the through traffic, and this on ramp junction will operate at LOS D. The traffic model in this analysis was developed for a version of the Crabtree Valley Avenue interchange where the westbound I-440 on ramp traffic from westbound Glenwood Avenue is diverted to use a modified on ramp from eastbound Glenwood Avenue via a signalized at-grade intersection. This version of the alternative eliminates the weaving on westbound I-440 between the Glenwood Avenue on and off ramps. The introduction of a new signal on eastbound Glenwood Avenue, however, proves to be a less effective solution.

While overall this combined alternative appears to be able to provide system-wide improvements, it also has several disadvantages. As discussed in the *Roadway* section, over 50% of the extension to Glenwood Avenue will need to be built on structures over Crabtree Creek and its floodplain. Also when compared with the Creedmoor Road Interchange alternative, the extension to Glenwood Avenue is less effective at mitigating congestion for the Glenwood Avenue / Creedmoor Road intersection. The construction cost, environmental impact, as well as the long term structure maintenance makes the extension to Glenwood Avenue a less desirable solution. A decision is thus made to remove the extension to Glenwood Avenue from further consideration.

The Crabtree Valley Avenue extension to I-440, on the other hand, would still be able to relieve the congestion on Glenwood Avenue by providing an alternate route between the valley and I-440. A modified version of this alternative, as discussed in the following section, is recommended for further evaluation.

Table 26. 2035 Crabtree Valley Avenue Extensions System Performance

Intersection	Approach	2035 Crabtree Valley Ave (CVA) Extensions			
		AM		PM	
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>161.1</b>	<b>F</b>	<b>248.7</b>	<b>F</b>
	EB	94.9	F	131.8	F
	WB	152.3	F	250.7	F
	NB	132.8	F	357.6	F
	SB	214.4	F	266.8	F
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	<b>20.4</b>	<b>C</b>	<b>160.0</b>	<b>F</b>
	EB	26.3	C	245.5	F
	WB	9.1	A	91.5	F
	NB	45.7	D	107.2	F
	SB	77.8	E	224.5	F
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	<b>Intersection</b>	<b>260.0</b>	<b>F</b>	<b>362.5</b>	<b>F</b>
	EB	220.3	F	249.5	F
	WB	263.5	F	433.2	F
	NB	215.3	F	304.7	F
	SB	314.1	F	432.6	F
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>166.4</b>	<b>F</b>	<b>227.2</b>	<b>F</b>
	EB	225.8	F	139.4	F
	WB	40.0	D	254.8	F
	NB	271.5	F	294.0	F
	SB	60.0	E	320.7	F
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>113.9</b>	<b>F</b>	<b>51.3</b>	<b>D</b>
	EB	160.1	F	73.8	E
	WB	7.2	A	17.8	B
	NB	160.7	F	85.8	F
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>54.7</b>	<b>D</b>	<b>155.7</b>	<b>F</b>
	EB	52.6	D	77.9	E
	WB	157.6	F	127.6	F
	NB	28.8	C	237.2	F
	SB	44.4	D	25.6	C
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	--	--	--	--
	EB	11.0	B	9.5	A
	WB	8.9	A	25.6	D
	NB	--	--	--	--
	SB	--	--	--	--
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	--	--	--	--
	EB	--	F	--	F
	NB	--	--	--	--
	SB	--	--	--	--
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>95.4</b>	<b>F</b>	<b>121.6</b>	<b>F</b>
	EB	104.3	F	147.5	F
	WB	89.5	F	92.3	F
	NB	82.2	F	139.2	F
	SB	102.6	F	107.1	F
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>104.2</b>	<b>F</b>	<b>149.3</b>	<b>F</b>
	EB	86.2	F	140.3	F
	WB	110.3	F	106.9	F
	NB	78.4	E	168.8	F
	SB	132.3	F	221.7	F
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--
	NB	22.8	C	91.5	F
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>19.5</b>	<b>B</b>	<b>76.2</b>	<b>E</b>
	EB	18.2	B	47.7	D
	WB	9.6	A	75.2	E
	NB	58.5	E	106.5	F
	SB	50.9	D	148.9	F
Crabtree Valley Ave/ Summit Park Ln	NB	10.1	B	22.1	C
Blue Ridge Rd/ Crabtree View Pl	WB	17.2	C	12.5	B
<b>Performance Index</b>		3,260.3		7,118.0	

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

### Crabtree Valley Avenue Extension to I-440

Based on the previous analyses and public inputs, several elements of this alternative have been subsequently revised, including:

- The section of Crabtree Valley Avenue between Creedmoor Road and Edwards Mill Road is rerouted to Edwards Mill Road, as proposed in the “Crabtree Valley Avenue Improvements” alternative. This revision increases the intersection spacing on Creedmoor Road so that the existing traffic signal at the Mall Entrance can be retained.
- Instead of providing a right-in/ right-out entrance on the extended Crabtree Valley Avenue, next to its intersection with Blue Ridge Road, to provide access to Summit Park Lane, Summit Park Lane will be closed and replaced with a new access point on Blue Ridge Road by extending Arrow Drive. The new T-intersection will also be signalized.
- The new ramp signal discussed in the previous section on eastbound Glenwood Avenue will be removed. A new Collector / Distributor (C/D) road will be created on westbound I-440 to improve the weaving performance.
- The shoulder area on eastbound Glenwood Avenue under the I-440 bridge will be converted to a fourth lane so that the westbound I-440 exit traffic, after yielding for pedestrians if present, can enter its receiving lane instead of waiting for gaps to merge into the eastbound Glenwood Avenue through traffic.
- A southbound overpass will be provided on the proposed Ridge Road Extension at its intersection with the westbound I-440 off ramp. This grade separation will resolve the traffic conflicts between the I-440 exit traffic and ingressing Ridge Road traffic.

The analysis results, as summarized in the following table, show that the revised alternative can also provide system-wide improvement, although at a lesser degree when compared with the combined alternatives discussed earlier. The average PM peak hour intersection delays, typically the worst delays, will be reduced by 14% to 362.5 seconds at the Glenwood Avenue / Creedmoor Road intersection, and by 26% to 466.6 seconds at the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection. The two ramp intersections will benefit the most from this alternative, with the averaging PM peak hour delays reduced by 48% to 186.1 seconds at the westbound ramp intersection, and by 71 % to 53.7 seconds (LOS D) at the eastbound ramp intersection. The improvements at the ramp intersections can be directly contributed to the traffic diversions.

Similar to the freeway analysis results discussed in the previous section, the alternative will eliminate the weaving section of eastbound I-440. In the AM peak hour, the eastbound I-440 off ramp to Ridge Road / Crabtree Valley Avenue / Glenwood Avenue and the eastbound on ramp from Crabtree Valley Avenue will operate at LOS C. The eastbound on ramp from westbound Glenwood Avenue will operate at LOS D. In the PM peak hour, the eastbound off ramp to Ridge Road / Crabtree Valley Avenue / Glenwood Avenue and the eastbound on ramp from westbound Glenwood Avenue will operate at LOS F due to capacity deficiencies on I-440. The eastbound on ramp from Crabtree Valley Avenue will operate at LOS D in the PM peak hour, as the freeway through traffic will be under capacity once the Ridge Road / Crabtree Valley Avenue / Glenwood Avenue exit traffic is removed. On westbound I-440, the proposed Collector Distributor (C/D) road will improve the weaving LOS from F to C. The other westbound on and off ramp junction capacity analysis results are similar to those discussed in the previous section. The results of the freeway analyses are included in Appendix H.

A closer examination of the capacity analysis results, however, reveals that the intersection of Crabtree Valley Avenue and Blue Ridge Road will have significant queuing, particularly on the southbound Blue Ridge Road approach and the westbound Crabtree Valley Avenue approach coming off the I-440 exit ramps. The queue on the southbound approach is estimated to fill the entire length of Blue Ridge Road between Glenwood Avenue and Crabtree Valley Avenue during peak hours. On the westbound approach, the queue length is estimated to be longer than 822 feet in the PM peak hour, which indicates that the queues may very likely spill back to I-440. This alternative is thus revised to elevate the proposed Crabtree Valley Avenue extension over the Blue Ridge Road intersection. As part of the overpass structure, a loop ramp will be provided in the southwestern quadrant of the intersection for the southbound left-turn traffic destined for I-440. The revised alternative will be evaluated in the in-depth traffic analysis.

Table 27. 2035 Crabtree Valley Avenue Extension to I-440 System Performance

Intersection	Approach	2035 CVA Extension to I-440 (with an at-grade intersection at CVA and Blue Ridge Rd)			
		AM		PM	
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>234.0</b>	<b>F</b>	<b>362.5</b>	<b>F</b>
	EB	224.0	F	296.8	F
	WB	197.6	F	336.6	F
	NB	185.5	F	476.6	F
	SB	295.4	F	388.0	F
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	<b>58.3</b>	<b>E</b>	<b>248.5</b>	<b>F</b>
	EB	57.9	E	279.0	F
	WB	56.5	E	248.4	F
	NB	65.2	E	101.9	F
	SB	95.6	F	214.9	F
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	<b>Intersection</b>	<b>305.8</b>	<b>F</b>	<b>466.6</b>	<b>F</b>
	EB	302.4	F	357.0	F
	WB	324.6	F	648.4	F
	NB	52.3	D	138.9	F
	SB	337.2	F	290.6	F
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>57.7</b>	<b>E</b>	<b>186.1</b>	<b>F</b>
	EB	66.7	E	34.7	C
	WB	58.5	E	312.1	F
	NB	5.7	A	2.1	A
	SB	60.3	E	346.1	F
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>68.5</b>	<b>E</b>	<b>53.7</b>	<b>D</b>
	EB	82.3	F	40.5	D
	WB	20.3	C	51.9	D
	NB	99.5	F	73.2	E
	SB	69.6	E	26.4	C
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>69.0</b>	<b>E</b>	<b>143.6</b>	<b>F</b>
	EB	75.3	E	75.1	E
	WB	143.1	F	121.0	F
	NB	36.4	D	216.6	F
	SB	69.6	E	26.4	C
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	<b>126.4</b>	<b>F</b>	<b>80.2</b>	<b>F</b>
	EB	92.5	F	92.1	F
	WB	48.2	D	53.6	D
	NB	37.2	D	124.2	F
	SB	171.5	F	35.5	D
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	--	--	--	--
	EB	--	F	956.6	F
	NB	--	--	--	--
	SB	--	--	--	--
	SB	--	--	--	--
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>32.7</b>	<b>C</b>	<b>50.1</b>	<b>D</b>
	EB	--	--	--	--
	WB	50.1	D	81.3	F
	NB	33.6	C	53.1	D
	SB	26.4	C	30.8	C
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>111.0</b>	<b>F</b>	<b>108.0</b>	<b>F</b>
	EB	77.8	E	52.2	D
	WB	68.1	E	106.7	F
	NB	102.6	F	118.5	F
	SB	149.3	F	136.8	F
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--
	NB	12.8	B	14.6	B
Crabtree Valley Ave/ Mall Parking Deck	<b>Intersection</b>	<b>9.3</b>	<b>A</b>	<b>18.1</b>	<b>B</b>
	EB	7.8	A	10.0	B
	WB	5.1	A	7.3	A
	NB	81.6	F	73.2	E
	SB	88.1	F	97.4	F
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>24.0</b>	<b>C</b>	<b>53.4</b>	<b>D</b>
	EB	11.9	B	52.1	D
	WB	12.5	B	33.1	C
	NB	79.9	E	94.7	F
	SB	94.5	F	65.3	E
Crabtree Valley Ave/ Summit Park Ln	NB	--	--	--	--
Blue Ridge Rd/ Crabtree View Pl	WB	--	--	--	--
Arrow Dr Extension/ Blue Ridge Rd	<b>Intersection</b>	<b>26.5</b>	<b>C</b>	<b>34.0</b>	<b>C</b>
	WB	63.5	E	87.9	F
	NB	21.4	C	30.2	C
	SB	19.5	B	21.6	C
	<b>Performance Index</b>		3,582.1		6,875.7

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

## In-Depth Traffic Analysis / Simulation

### *Traffic Simulations*

Through the initial alternative screening process, several alternatives have been identified as candidates for implementation. In-depth traffic analyses are conducted to further evaluate the traffic operational performance and finalize an implementation strategy. Extensive traffic simulations were conducted at this stage to evaluate the proposed alternatives. Because of the stochastic nature of traffic flows, 10 one-hour traffic simulations were conducted for each alternative or combination of alternatives. Based on the traffic simulation results, the traffic models were calibrated and refined several times to better represent the "real world" conditions. The findings presented in this report are based on over 400 hours of traffic simulations which generated over one terabyte (TB) of data.

### *Alternatives and Possible Implementation Schedules*

Based on the initial screening traffic analyses, the following alternatives or combinations of alternatives emerge as candidates for implementations.

#### **Near Term Improvement Candidate**

- Crabtree Valley Avenue Improvements

#### **Mid Term Improvement Candidate**

- Crabtree Valley Avenue Extension to I-440

#### **Long Term Improvements Candidate**

- Creedmoor Road Interchange
- Lead Mine Road Interchange

Due to its conformity with the City's current thoroughfare plan and the support from stakeholders, the "Crabtree Valley Avenue Improvements" alternative is believed to be the first major mitigation measure, other than the bike and pedestrian improvements, that can be implemented in the valley.

The Crabtree Valley Avenue Extension to I-440 alternative is believed to be implemented when the existing Ridge Road Bridge over I-440 is replaced. The Ridge Road Bridge was constructed in 1960. Bridges today are typically designed for a 50- year lifespan. According to the most recent NCDOT bridge inspection report completed in September 2008, this bridge is "structurally deficient" and "functional obsolete". It is expected that the bridge will be replaced when funding becomes available, possibly before the interchange improvements on Glenwood Avenue can be funded.

In addition, the Creedmoor Road Interchange and Lead Mine Road Interchange alternatives both are primarily local mitigation measures designed to address specific traffic flow conflicts, whereas the Crabtree Valley Avenue Extension to I-440 alternative is a system-wide improvement measure designed to relieve the traffic congestion for the whole valley. Implementing the system-wide improvement measure first will likely postpone the need for interchange improvements on Glenwood Avenue. Based on the considerations discussed above, it is determined that the Crabtree Valley Avenue Extension to I-440 alternative shall be the candidate for the mid-term improvement.

The initial screening analysis did not include the Lead Mine Road interchange alternative. Both interchange improvement alternatives on Glenwood Avenue were evaluated in the in-depth analysis.

### *In-Depth Analysis / Simulation Results*

#### **Crabtree Valley Avenue Improvements**

The proposed alternative will widen Crabtree Valley Avenue between Blue Ridge Road and Homewood Banks Road to a four-lane divided facility, and widen and relocate Crabtree Valley Avenue to Edwards Mill Road on the western section of the street. The improvements will also include turn lanes, pedestrian and bicycle facilities, and new traffic signals at Creedmoor Road, the entrance to the Mall parking deck, Homewood Banks Drive / Mall Entrance, and Blue Ridge Road. Traffic signals will be installed when the traffic volumes meet the signal warrants. The signal at Blue Ridge Road is proposed to replace the existing signal at the intersection of Blue Ridge Road and Mall Entrance which will become a right-in / right-out entrance. The traffic model developed for this alternative also includes a one-way Crabtree View Place towards Glenwood Avenue. Since this alternative is expected to be implemented in the near future, 2009 base year traffic volumes and projected pedestrian volumes are used in the analyses.

The analysis results, as summarized in the following table, show that the proposed improvements, if implemented today, can significantly improve the roadway and intersection capacity on Crabtree Valley Avenue. The coordinated traffic signals on Crabtree Valley Avenue will operate at LOS B at the Creedmoor Road intersection, at LOS C at the Blue Ridge Road intersection during both AM and PM peak hours. The new signal at the Homewood Banks Drive / Mall Entrance will operate at LOS C in the AM peak hour, and LOS D in the PM peak hour. With the 2009 traffic volumes, the intersection of Crabtree Valley Avenue and Mall Parking Deck Entrance would not meet the signal warrants. Therefore it was analyzed as an unsignalized intersection. Both stop sign controlled approaches to the intersection will operate at LOS C or better during peak hours.

The analysis also shows that system-wide signal timing improvement may reduce the total delays by up to 11% in the AM peak hour, and 3% in the PM peak hour. It shall be noted that many factors will need to be considered for signal system timing improvements, and that the optimized timing plans generated from capacity analysis programs may not be best plans for field implementations. With the optimized signal timing plans, traffic simulation results indicate that the eastbound Glenwood Avenue average travel speed may be improved by 1 mph in the AM peak hour. In the PM peak hour, the results show a 2 mph speed increase in the eastbound direction, and a decrease of 3 mph in the westbound direction, which indicates that the current signal timing schedules has been adjusted to provide a more balanced arterial performance.

Since the proposed alternative will not affect the ramp volumes on I-440, the ramp junction and weaving segment performance will be the same as in the 2009 Existing Baseline Conditions.

Table 28. Crabtree Valley Avenue Improvements Performance Index(2009).

Intersection	Approach	Crabtree Valley Avenue Improvements (2009)				
		AM		PM		
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>54.8</b>	<b>D</b>	<b>91.0</b>	<b>F</b>	
	EB	61.3	E	79.2	E	
	WB	35.1	D	80.5	F	
	NB	69.6	E	108.3	F	
	SB	66.6	E	112.3	F	
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	<b>5.9</b>	<b>A</b>	<b>25.1</b>	<b>C</b>	
	EB	3.3	A	16.0	B	
	WB	3.5	A	19.4	B	
	NB	71.7	E	95.6	F	
	SB	78.3	E	65.2	E	
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	<b>Intersection</b>	<b>68.6</b>	<b>E</b>	<b>107.7</b>	<b>F</b>	
	EB	49.3	D	67.9	E	
	WB	60.0	E	120.4	F	
	NB	73.3	E	167.1	F	
	SB	110.1	F	117.4	F	
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>9.8</b>	<b>A</b>	<b>113.4</b>	<b>F</b>	
	EB	0.2	A	0.0	A	
	WB	17.8	B	25.7	C	
	NB	--	--	--	--	
	SB	19.2	B	343.0	F	
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>21.2</b>	<b>C</b>	<b>47.0</b>	<b>D</b>	
	EB	20.5	C	44.0	D	
	WB	7.4	A	30.5	C	
	NB	44.3	D	73.7	E	
	SB	--	--	--	--	
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>22.0</b>	<b>C</b>	<b>19.9</b>	<b>B</b>	
	EB	78.4	E	81.3	F	
	WB	86.1	F	105.7	F	
	NB	8.0	A	11.2	B	
	SB	13.1	B	10.2	B	
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	<b>9.1</b>	<b>A</b>	<b>24.4</b>	<b>C</b>	
	EB	63.0	E	83.5	F	
	WB	46.8	D	71.3	E	
	NB	16.1	B	18.3	B	
	SB	4.6	A	17.5	B	
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	--	--	--	--	
	EB	15.4	C	14.7	B	
	NB	--	--	--	--	
	SB	--	--	--	--	
	SB	--	--	--	--	
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>11.7</b>	<b>B</b>	<b>12.5</b>	<b>B</b>	
	EB	--	--	--	--	
	WB	71.1	E	31.1	C	
	NB	6.8	A	13.2	B	
	SB	6.2	A	6.4	A	
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>23.4</b>	<b>C</b>	<b>26.4</b>	<b>C</b>	
	EB	61.0	E	44.5	D	
	WB	82.7	F	100.7	F	
	NB	9.1	A	18.5	B	
	SB	8.4	A	7.8	A	
Crabtree Valley Ave/ Mall Parking Deck	<b>Intersection</b>	--	--	--	--	
	EB	0.3	A	0.9	A	
	WB	0.2	A	0.3	A	
	NB	11.3	B	15.2	C	
	SB	11.6	B	14.2	B	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>24.8</b>	<b>C</b>	<b>54.3</b>	<b>D</b>	
	EB	2.4	A	13.4	B	
	WB	5.6	A	19.7	B	
	NB	82.8	F	90.5	F	
	SB	81.8	F	88.2	F	
<b>Performance Index</b>		463.7		1,859.0		
Glenwood Ave Arterial	EB	Speed (mph)	18 (16-21)	E	15 (13-18)	E
		Travel Time (sec)	402.7 (352.2-457.7)		500.1 (416.2-554.1)	
		Delays(sec/veh)	238.6 (188.1-293.6)		335.7 (251.8-389.7)	
	WB	Speed (mph)	11 (8-13)	F	9 (8-10)	F
		Travel Time (sec)	539.4 (442.6-772.5)		816.8 (596.4-1,152.3)	
		Delays (sec/veh)	408.5 (311.7-641.6)		684.9 (464.5-1,020.4)	
Network Performance	Total Delay (hr)	1,944.5 (1,663.8-2,136.5)		3,630.0 (3,523.6-3,961.9)		
	Stops (#)	38,978.0		61,137.0		
	Fuel Consumed (gal)	1,297.0		1,695.2		
	HC Emissions (g)	14,095.0		14,647.0		
	CO Emissions (g)	616,524.0		619,746.0		
	NOx Emissions (g)	47,233.0		47,487.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

***Crabtree Valley Avenue Extension to I-440***

The traffic models used in the initial traffic analysis were revised to include the grade-separated structure at the intersection of Crabtree Valley Avenue and Blue Ridge Road. Traffic signal timings for the at-grade intersection were also calibrated to prevent the queues on the eastbound Crabtree Valley Avenue approach from blocking the I-440 on ramp.

The analysis results, as summarized in the following table, show similar levels of delays on the Glenwood Avenue as in the initial traffic analysis. At the intersection of Crabtree Valley Avenue and Blue Ridge Road, the proposed grade-separation will reduce the average delays from 111 seconds (LOS F) to 20.8 seconds (LOS C) in the AM peak hour, and from 108 seconds (LOS F) to 31.3 seconds (LOS C) in the PM peak hour.

While the analysis estimates high delays at the right-in/ right-out Mall Entrance on Blue Ridge Road, the signal on Glenwood Avenue will create gaps in the southbound Blue Ridge Road traffic stream for the right- turn exit traffic. Traffic assumed to exit at this location may also be diverted to the Crabtree Valley Avenue and Homewood Banks Drive / Mall Entrance intersection, where the signal is estimated to be operating at LOS D in the AM peak hour, and at LOS E in the PM peak hour with much lower delays.

As the grade separation at Crabtree Valley Avenue / Blue Ridge Road intersection will not affect the ramp volumes on I-440, the freeway ramp junction and weaving segment analysis results are identical to those discussed earlier in the initial traffic analysis section.

Traffic simulations indicate that the proposed alternative will increase the westbound Glenwood Avenue arterial average travel speed by 5 mph to 12 mph in the AM peak hour, and by 6 mph to 11 mph in the PM peak hour. The eastbound average travel speed will remain at 4 mph in the AM peak hour, and improve by 2 mph to 5 mph in the PM peak hour. The Performance Index measure shows the alternative will deliver significant system performance improvements. It is interesting to note that total delays estimated from traffic simulations did not show significant difference (2% delay reduction in the AM peak hour, and less than 1% delay increase in the PM peak hour) from the Future Baseline Conditions. The signal timing adjustments and extensive calibrations made for this model may have skewed the estimated total delays. As the traffic capacity analyses show almost all the intersections in the valley will experience lower delays, it is reasonable to believe that this alternative, with proper signal coordination strategy, will improve the traffic conditions in the Valley.

Table 29. Crabtree Valley Avenue Extension to I-440 System Performance (2035)

Intersection	Approach	2035 CVA Extension to I-440 (with a grade separation at CVA and Blue Ridge Rd)				
		AM		PM		
		Delay (sec)	LOS	Delay (sec)	LOS	
Glenwood Ave/ Creedmoor Rd	Intersection	236.9	F	355.4	F	
	EB	216.9	F	291.8	F	
	WB	208.6	F	330.6	F	
	NB	209.3	F	371.4	F	
	SB	292.2	F	490.7	F	
Glenwood Ave/ Marriott Dr	Intersection	53.1	D	240.0	F	
	EB	50.0	D	281.8	F	
	WB	53.6	D	228.7	F	
	NB	69.5	E	101.6	F	
	SB	100.7	F	213.8	F	
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	Intersection	330.5	F	479.4	F	
	EB	291.6	F	376.7	F	
	WB	330.1	F	668.5	F	
	NB	77.4	E	113.0	F	
	SB	428.6	F	229.7	F	
Glenwood Ave/ I-440 WB Ramp	Intersection	61.0	E	205.9	F	
	EB	70.4	E	40.5	D	
	WB	60.1	E	354.5	F	
	NB	5.7	A	2.3	A	
	SB	66.2	E	359.3	F	
Glenwood Ave/ I-440 EB Ramp	Intersection	73.5	E	62.8	E	
	EB	83.8	F	45.1	D	
	WB	22.2	C	66.8	E	
	NB	114.1	F	76.2	E	
Lead Mine Rd/ North Hills Dr	Intersection	60.9	E	152.9	F	
	EB	112.8	F	78.8	E	
	WB	100.1	F	123.2	F	
	NB	27.9	C	232.6	F	
	SB	69.2	E	26.4	C	
Creedmoor Rd/ Mall Entr	Intersection	71.6	E	55.9	E	
	EB	97.5	F	95.9	F	
	WB	65.3	E	78.9	E	
	NB	39.5	D	51.8	D	
	SB	83.8	F	49.5	D	
Blue Ridge Rd/ Mall Entr	Intersection	--	--	--	--	
	EB	--	F	957.7	F	
	NB	--	--	--	--	
	SB	--	--	--	--	
Creedmoor Rd/ Crabtree Valley Ave	Intersection	28.2	D	51.9	D	
	EB	--	--	--	--	
	WB	42.7	D	71.5	E	
	NB	33.0	C	64.5	E	
	SB	20.8	C	24.0	C	
Crabtree Valley Ave/ Blue Ridge Rd	Intersection	20.8	C	31.3	C	
	EB	72.7	E	52.9	D	
	WB	--	--	--	--	
	NB	26.7	C	30.3	C	
	SB	8.9	A	23.5	C	
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--	
	NB	12.8	B	14.6	B	
	SB	--	--	--	--	
Crabtree Valley Ave/ Mall Parking Deck	Intersection	7.6	A	20.4	C	
	EB	7.1	A	11.4	B	
	WB	2.0	A	10.3	B	
	NB	84.7	F	75.8	E	
	SB	91.9	F	100.9	F	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	Intersection	40.6	D	62.8	E	
	EB	19.8	B	57.8	E	
	WB	48.6	D	52.1	D	
	NB	41.9	D	69.1	E	
	SB	97.0	F	84.2	F	
Crabtree Valley Ave/ Summit Park Ln	NB	--	--	--	--	
Blue Ridge Rd/ Crabtree View Pl	WB	--	--	--	--	
Arrow Dr Extension/ Blue Ridge Rd	Intersection	33.1	C	36.4	D	
	WB	70.0	E	70.3	E	
	NB	19.5	B	28.2	C	
	SB	27.8	C	30.8	C	
Performance Index		3,525.6		8,969.8		
Glenwood Ave Arterial	EB	Speed (mph)	4 (4-4)		5 (5-5)	
		Travel Time (sec)	2,334.0 (2,136.6-2,783.0)		2,188.0 (2,041.2-2,458.9)	
		Delays(sec/veh)	2,174.0 (1,976.6-2,623.0)		2,026.6 (1,879.8-2,297.5)	
	WB	Speed (mph)	12 (12-13)		11 (10-11)	
		Travel Time (sec)	1,190.3 (1,019.7-1,252.7)		3,273.6 (3,048.4-3,459.5)	
		Delays (sec/veh)	1,038.7 (868.1-1,101.1)		3,121.6 (2,896.4-3,307.5)	
Network Performance	Total Delay (hr)	13,898.2 (13,618.7-14,163.9)		15,459.7 (15,315.6-15,785.4)		
	Stops (#)	65,098.0		86,597.0		
	Fuel Consumed (gal)	4,018.2		4,371.9		
	HC Emmissions (g)	20,590.0		21,035.0		
	CO Emissions (g)	809,989.0		791,693.0		
	NOx Emissions (g)	50,308.0		50,234.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

***Crabtree Valley Avenue Extension to I-440 and Creedmoor Road Interchange***

Traffic models were developed to test the scenario where the Creedmoor Road interchange will be constructed before the Lead Mine Road Interchange. The proposed interchange has two major revisions to the previous version, including:

- A. U-turns will be allowed underneath the interchange to access to the Mall from westbound Glenwood Avenue.
- B. The Mall / Marriott Entrances will be converted to right-in /right-out entrances with median installed on Glenwood Avenue.

The traffic capacity analysis results, as summarized in the following table, show that most of the intersections in the valley will experience delay reductions. The intersection of Glenwood Avenue and Creedmoor Road will benefit most from this improvement. The average delays at this intersection are expected to be reduced from 236.9 seconds to 100.8 seconds in the AM peak hour, and from 355.4 seconds to 184 seconds in the PM peak hour. The right-in / right-out Mall Entrance on Glenwood Avenue, similar to the one on Blue Ridge Road, is projected to have high PM peak hour delays. Gaps created by adjacent signals will provide opportunities for the exit traffic to enter Glenwood Avenue. Traffic may also be diverted to exit the Mall at signalized entrance intersections which are expected to operate at much lower delays. Since the new interchange will not change the ramp volumes on I-440, the ramp junction and weaving performance will not be affected.

Traffic simulations show that in the AM peak hour, the westbound Glenwood Avenue arterial speed may increase by 1 mph to 13 mph. In the PM peak hour, however, the westbound average speed may be reduced by 3 mph to 8 mph. The traffic simulations reveal that, even with the new I-440 / Crabtree Valley Avenue interchange improvement, the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection will continue to be the worst bottleneck on the Glenwood Avenue arterial. The interchange improvement at Creedmoor Road will not help to reduce delays at the Lead Mine Road intersection. As excessive queues develop on the eastbound Glenwood Avenue approach at the Lead Mine Road intersection, the westbound U-turn movements underneath the proposed Creedmoor Road interchange will be adversely affected, which eventually will block the westbound through traffic and cause the arterial travel speed to decrease. It was decided that the Creedmoor Road interchange improvement shall be implemented after mitigations at the Lead Mine Road / Blue Ridge Road intersection.

Table 30. Crabtree Valley Avenue Extension and Creedmoor Road SPUI (2035)

Intersection	Approach	2035 CVA Extension to I-440 and Creedmoor Rd SPUI				
		AM		PM		
Glenwood Ave/ Creedmoor Rd	<b>Intersection</b>	<b>100.8</b>	<b>F</b>	<b>184.0</b>	<b>F</b>	
	EB	107.0	F	137.6	F	
	WB	42.5	D	86.3	F	
	NB	119.1	F	261.2	F	
	SB	115.0	F	188.6	F	
Glenwood Ave/ Marriott Dr	<b>Intersection</b>	--	--	--	--	
	EB	--	--	--	--	
	WB	--	--	--	--	
	NB	57.0	F	676.6	F	
	SB	16.8	C	46.9	E	
Glenwood Ave/ Lead Mine Rd/ Blue Ridge Rd	<b>Intersection</b>	<b>316.5</b>	<b>F</b>	<b>470.7</b>	<b>F</b>	
	EB	329.9	F	364.4	F	
	WB	353.4	F	654.4	F	
	NB	72.8	E	113.4	F	
	SB	292.1	F	245.3	F	
Glenwood Ave/ I-440 WB Ramp	<b>Intersection</b>	<b>54.0</b>	<b>D</b>	<b>205.3</b>	<b>F</b>	
	EB	57.6	E	39.4	D	
	WB	61.2	E	353.6	F	
	NB	5.3	A	2.3	A	
	SB	62.0	E	359.6	F	
Glenwood Ave/ I-440 EB Ramp	<b>Intersection</b>	<b>66.7</b>	<b>E</b>	<b>62.2</b>	<b>E</b>	
	EB	73.5	E	44.4	D	
	WB	20.5	C	68.0	E	
	NB	108.3	F	76.3	E	
	SB	62.0	E	359.6	F	
Lead Mine Rd/ North Hills Dr	<b>Intersection</b>	<b>75.2</b>	<b>E</b>	<b>152.6</b>	<b>F</b>	
	EB	219.3	F	77.5	E	
	WB	89.2	F	122.5	F	
	NB	77.4	E	232.2	F	
	SB	66.5	E	26.3	C	
Creedmoor Rd/ Mall Entr	<b>Intersection</b>	<b>87.0</b>	<b>F</b>	<b>73.4</b>	<b>E</b>	
	EB	83.1	F	99.3	F	
	WB	62.8	E	199.7	F	
	NB	40.4	D	43.6	D	
	SB	109.2	F	52.8	D	
Blue Ridge Rd/ Mall Entr	<b>Intersection</b>	--	--	--	--	
	EB	--	F	956.4	F	
	NB	--	--	--	--	
	SB	--	--	--	--	
	SB	--	--	--	--	
Creedmoor Rd/ Crabtree Valley Ave	<b>Intersection</b>	<b>25.2</b>	<b>C</b>	<b>50.1</b>	<b>D</b>	
	EB	--	--	--	--	
	WB	35.9	D	80.2	F	
	NB	31.5	C	55.1	E	
	SB	18.3	B	28.4	C	
Crabtree Valley Ave/ Blue Ridge Rd	<b>Intersection</b>	<b>19.6</b>	<b>B</b>	<b>30.3</b>	<b>C</b>	
	EB	74.8	E	50.9	D	
	WB	--	--	--	--	
	NB	27.1	C	29.8	C	
	SB	6.4	A	22.5	C	
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--	
	NB	12.8	B	14.6	B	
	SB	12.8	B	14.6	B	
Crabtree Valley Ave/ Mall Parking Deck	<b>Intersection</b>	<b>7.5</b>	<b>A</b>	<b>21.3</b>	<b>C</b>	
	EB	5.9	A	13.9	B	
	WB	3.8	B	10.1	B	
	NB	73.3	E	74.9	E	
	SB	79.0	E	99.6	F	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	<b>Intersection</b>	<b>36.6</b>	<b>D</b>	<b>60.7</b>	<b>E</b>	
	EB	17.9	B	48.8	D	
	WB	43.6	D	48.3	D	
	NB	38.6	D	75.4	E	
	SB	85.1	F	85.3	F	
Crabtree Valley Ave/ Summit Park Ln	NB	--	--	--	--	
Blue Ridge Rd/ Crabtree View Pl	WB	--	--	--	--	
Arrow Dr Extension/ Blue Ridge Rd	<b>Intersection</b>	<b>28.5</b>	<b>C</b>	<b>36.4</b>	<b>D</b>	
	WB	60.2	E	69.5	E	
	NB	19.2	B	28.1	C	
	SB	22.4	C	31.1	C	
<b>Performance Index</b>		2,704.0		7,047.0		
Glenwood Ave Arterial	EB	Speed (mph)	4 (2-4)		5 (5-5)	
		Travel Time (sec)	3,478.1 (2,882.3-5,221.1)		2,337.9 (2,042.0-2,608.2)	
		Delays(sec/veh)	3,316.8 (2,721.0-5,095.8)		2,176.3 (1,880.4-2,446.6)	
	WB	Speed (mph)	13 (9-14)		8 (7-8)	
		Travel Time (sec)	1,366.4 (1,180.8-1,682.4)		7,515.8 (6,660.0-8,938.3)	
		Delays (sec/veh)	1,214.1 (1,028.5-1,530.1)		7,363.2 (6,507.4-8,785.7)	
Network Performance	Total Delay (hr)	14,051.0 (13,631.4-14,618.0)		15,117.3 (14,802.6-15,588.0)		
	Stops (#)	60,306.0		84,028.0		
	Fuel Consumed (gal)	4,023.5		4,335.4		
	HC Emmissions (g)	20,624.0		21,397.0		
	CO Emissions (g)	815,153.0		819,278.0		
	NOx Emissions (g)	49,584.0		51,808.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

## ***Crabtree Valley Avenue Extension to I-440 and Lead Mine Road Interchange /Glenwood Avenue Overpass***

### ***Alternative Developments***

Several interchange improvement alternatives have been developed for the Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection, in addition to the Lead Mine Flyover alternative discussed earlier. One version of the interchange consists of a Single Point Urban Interchange (SPUI) similar to the one proposed for the Creedmoor Road Interchange. However, due to the close spacing between the intersection and the I-440 ramps, heavy weaving traffic is expected over a short distance on eastbound Glenwood Avenue between the overpass and the westbound I-440 on ramp. While some versions of this alternative have direct ramp connections between the two interchanges, the cost associated with those ramps and the environmental and business impact prove to be prohibitive.

Another version of the interchange consists of a Lead Mine Road Overpass. In this scenario, the southbound Lead Mine Road through and left-turn traffic will use the overpass to enter the intersection of Crabtree Valley Avenue and Blue Ridge Road, which as discussed earlier has a loop ramp to access I-440. At the at-grade intersection of Glenwood Avenue and Lead Mine Road / Blue Ridge Road, medians will be installed on Glenwood Avenue to preclude left-turn movements. Westbound left-turn traffic will be diverted to use the Crabtree Valley Avenue exit on I-440. The eastbound left-turn traffic will be routed to Crabtree View Place to access the Lead Mine Road Overpass. This alternative completely separates the conflicting traffic flows, but it also has two major disadvantages. Because of the Crabtree Creek and its floodplain, the overpass will be an expensive, long structure. And secondly, traffic from southbound Lead Mine Road destined to eastbound Glenwood Avenue is not properly served. While a revised version of this alternative has a new ramp added to the outside of westbound I-440 Crabtree Valley Avenue Exit ramp to bring the left-turn traffic from the Crabtree Valley Avenue / Blue Ridge Road intersection to the westbound I-440 ramp intersection on Glenwood Avenue, the route diversion may be perceived as confusing because of the additional travel length and turning movement.

A more practical alternative, modified from the SPUI, includes an overpass only for the westbound Glenwood Avenue. In this alternative, hereafter referred to as Westbound Glenwood Avenue Overpass, the westbound left-turn movement on Glenwood Avenue will also be diverted to use the Crabtree Valley Avenue exit on I-440. The westbound through traffic movement will also be prohibited at the at grade intersection, by installing right-turn only channelizing devices.

To ensure that the westbound right-turn and eastbound left-turn traffic can be adequately served, this alternative also proposed to remove the eastbound signal phase at the adjacent Lead Mine Road and North Hills Drive intersection. The signal at the North Hills Drive intersection currently has a split phasing, meaning that the eastbound and westbound approach each has its own signal phase. The removal of the signal phase for the low-volume eastbound approach can increase the throughput for the northbound Lead Mine Road approach, and help to discharge traffic from the valley. Traffic on the eastbound approach of the North Hills Drive intersection may be routed to the Charles Drive / Lead Mine Road intersections via existing internal roads.

At the intersection of westbound Glenwood Avenue and westbound I-440 exit ramp, this alternative will install medians and a two-lane slip ramp. On the westbound Glenwood Avenue approach, the inside two lanes will become “express lanes”, only traffic destined to Lead Mine Road will need to stop at the signal. On the westbound I-440 exit ramp approach, traffic in the inside two lanes will use the slip ramp to enter westbound Glenwood Avenue, when given the green light. Traffic in the right lane can only make a right-turn to go to Lead Mine Road.

This alternative also includes modifications at the Glenwood Avenue and Mall / Marriott Entrance Intersection. Left-turns from the Mall or Marriott will be prohibited. The eastbound left-turn movement to Marriott will also be prohibited, and rerouted to the Marriott entrance on Creedmoor Road. On the westbound approach, dual left-turn lanes will be provided to maintain access to the Mall. Westbound through traffic will travel through the intersection without stopping. The Mall Entrance will be reconfigured to provide dual right turn lanes. A traffic signal will be installed to protect the westbound left-turn and northbound right-turn movements which will run concurrently.

### ***Analysis Results***

The traffic capacity analysis results, as summarized in the following table, show that the Westbound Glenwood Avenue Overpass alternative can reduce delays at most of the major intersections, except for the intersection of Glenwood Avenue and Creedmoor Road where the average delays will increase by 14.3 seconds in the AM peak hour, and by 42.3 seconds in the PM peak hour. At the intersection of Glenwood Avenue and Lead Mine Road / Blue Ridge Road, the average intersection delays will be reduced by 36% to 212.7 seconds in the AM peak hour, and by 62% to 184.5 seconds in the PM peak hour. The Glenwood Avenue and Westbound I-440 exit ramp intersection LOS will improve from E (61 seconds) to B (15.6 seconds) in the AM peak hour, and from F (205.9 seconds) to E (64.8 seconds) in the PM peak hour. At the Lead Mine Road and North Hills Drive intersection, the PM peak hour delays will be reduced by 29% to 108.1 seconds because of the removal of the eastbound signal phase.

Traffic simulations show that the alternative can improve the westbound Glenwood Avenue arterial speed by 4 mph to 16 mph in the AM peak hour. In the PM peak hour, there is no noticeable change as the arterial performance is limited by the Creedmoor Road intersection capacity. The simulations show a 5% reduction in total delays in the AM peak hour, and a 3% reduction in the PM peak hour.

The proposed alternative will not significantly affect the travel pattern on eastbound I-440. The ramp junction and weaving performance will be similar to the Crabtree Valley Avenue Extension to I-440 alternative. On westbound I-440, because of the Blue Ridge Road traffic diversion, the C/D road weaving area between the Glenwood Avenue on and off ramps is expected to have higher vehicle densities. The weaving section will operate at LOS D in the AM peak hour, and LOS F in the PM peak hour. The freeway analysis results are summarized in Appendix H.

The analyses indicate that the improvements delivered by this alternative outweigh the localized performance reductions. Thus this alternative is recommended to be implemented before the Creedmoor Road interchange improvement.

Table 31. Crabtree Valley Avenue Extension and Westbound Glenwood Avenue (2035)

Intersection	Approach	2035 CVA Extension to I-440 and WB Glenwood Ave Overpass				
		AM		PM		
Glenwood Ave/ Creedmoor Rd	Intersection	251.2	F	397.7	F	
	EB	233.4	F	327.4	F	
	WB	220.9	F	335.0	F	
	NB	216.0	F	534.9	F	
	SB	306.5	F	457.4	F	
Glenwood Ave/ Marriott Dr	Intersection	9.5	A	85.3	F	
	EB	10.7	B	108.6	F	
	WB	5.7	A	59.5	E	
	NB	101.1	F	145.3	F	
	SB	--	--	--	--	
Glenwood Ave/ Lead Mine RD/ Blue Ridge Rd	Intersection	212.7	F	184.5	F	
	EB	134.8	F	225.6	F	
	WB	43.1	D	96.3	F	
	NB	209.3	F	94.2	F	
	SB	358.4	F	198.2	F	
Glenwood Ave/ I-440 WB Ramp	Intersection	15.6	B	64.8	E	
	EB	--	--	--	--	
	WB	38.9	D	92.1	F	
	NB	--	--	--	--	
	SB	10.7	B	56.8	E	
Glenwood Ave/ I-440 EB Ramp	Intersection	58.5	E	60.8	E	
	EB	55.4	E	45.3	D	
	WB	22.3	C	64.9	E	
	NB	108.9	F	74.3	E	
	SB	--	--	--	--	
Lead Mine Rd/ North Hills Dr	Intersection	57.2	E	108.1	F	
	EB	128.9	F	52.2	D	
	WB	197.8	F	109.7	F	
	NB	21.6	C	147.2	F	
	SB	41.5	D	41.7	D	
Creedmoor Rd/ Mall Entr	Intersection	86.2	F	55.7	E	
	EB	168.6	F	152.5	F	
	WB	75.0	E	148.2	F	
	NB	18.2	B	31.0	C	
	SB	109.9	F	36.0	D	
Blue Ridge Rd/ Mall Entr	Intersection	--	--	--	--	
	EB	10.8	B	16.5	C	
	NB	--	--	--	--	
	SB	--	--	--	--	
	SB	--	--	--	--	
Creedmoor Rd/ Crabtree Valley Ave	Intersection	27.2	C	44.0	D	
	EB	--	--	--	--	
	WB	39.1	D	40.9	D	
	NB	32.7	C	55.6	E	
	SB	20.3	C	28.8	C	
Crabtree Valley Ave/ Blue Ridge Rd	Intersection	23.7	C	32.3	C	
	EB	80.0	E	64.0	E	
	WB	--	--	--	--	
	NB	34.6	C	30.2	C	
	SB	6.7	A	19.5	B	
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--	
	NB	12.8	B	14.6	B	
	SB	--	--	--	--	
Crabtree Valley Ave/ Mall Parking Deck	Intersection	8.2	A	18.9	B	
	EB	6.2	A	11.0	B	
	WB	4.1	A	10.6	B	
	NB	83.7	F	67.1	E	
	SB	90.5	F	89.6	F	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	Intersection	43.1	D	66.5	E	
	EB	21.2	C	52.2	D	
	WB	52.3	D	74.5	E	
	NB	39.7	D	59.6	F	
	SB	96.4	F	73.2	E	
Crabtree Valley Ave/ Summit Park Ln	NB	--	--	--	--	
Blue Ridge Rd/ Crabtree View Pl	WB	--	--	--	--	
Arrow Dr Extension/ Blue Ridge Rd	Intersection	32.7	C	35.8	D	
	WB	70.7	E	65.0	E	
	NB	17.1	B	24.3	C	
	SB	28.0	C	36.4	D	
Performance Index		2,186.2		5,941.9		
Glenwood Ave Arterial	EB	Speed (mph)	5 (5-6)		5 (5-6)	
		Travel Time (sec)	1,700.7 (1,383.7-2,255.3)		2,161.7 (1,966.4-2,257.2)	
		Delays(sec/veh)	1,539.1 (1,222.1-2,093.7)		1,999.9 (1,798.6-2,089.4)	
	WB	Speed (mph)	16 (12-22)		11 (9-13)	
		Travel Time (sec)	790.8 (633.1-918.0)		1,524.5 (1,404.8-1,655.7)	
		Delays (sec/veh)	638.3 (510.6-765.5)		1,372.0 (1,252.3-1,503.2)	
Network Performance	Total Delay (hr)	13,172.9 (12,872.2-13,532.2)		14,921.7 (14,296.5-15,545.2)		
	Stops (#)	62,738.0		89,583.0		
	Fuel Consumed (gal)	3,933.9		4,309.8		
	HC Emmissions (g)	21,421.0		21,731.0		
	CO Emissions (g)	847,514.0		822,943.0		
	NOx Emissions (g)	54,221.0		52,967.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.

***Crabtree Valley Avenue Extension to I-440, Westbound Glenwood Avenue Overpass, and Creedmoor Road Interchange***

The last traffic analysis was conducted to quantify the traffic operational performance when all the proposed improvement alternatives are implemented. The traffic models employed in the previous analyses were revised to include the Creedmoor Road interchange. The intersection of Glenwood Avenue and Mall / Marriott Entrance was revised to remove the westbound left-turn which would become the U-turn movement under the proposed interchange. The westbound Glenwood Avenue would have a two-lane expressway running through the valley.

The traffic capacity analysis results, as summarized in the following table, show that once the Creedmoor Road Interchange is implemented, the average delay at the at-grade intersection will be reduced by 60% to 99.3 seconds in the AM peak hour, and by 55% to 180.4 seconds in the PM peak hour. The Glenwood Avenue and Lead Mine Road / Blue Ridge Road intersection will experience a small delay increase, 10.5 seconds in the AM peak hour, and 24.2 seconds in the PM peak hour.

While the intersection capacity analyses project high delays for the Mall Entrance on Glenwood Avenue, gaps in the traffic stream created by the Creedmoor Road signal will provide opportunities for the exit traffic to merge into Glenwood Avenue. Traffic may also be diverted to exit the Mall at signalized entrance intersections which are expected to operate at much lower delays. If the actual right-turn traffic volumes warrant signalization, a two phase signal at this location will reduce the PM peak hour northbound delays to 70.2 seconds (LOS E). The average intersection delays and eastbound approach delays are 28.2 seconds (LOS C) and 16.3 seconds (LOS B) respectively. The signal will need to be coordinated with other signals on Glenwood Avenue, and the right turn phase will run concurrently with the northbound Creedmoor Road through movement signal phase.

Traffic simulations show that the westbound Glenwood Avenue arterial performance will be improved to LOS B, operating at an average speed of 34 mph in the AM peak hour, and 28 mph in the PM peak hour. The eastbound arterial average travel speed will be improved by 1 mph to 7 mph in the AM peak hour, and 6 mph in the PM peak hour.

The proposed Creedmoor Road interchange will not affect the travel pattern on eastbound I-440. The ramp junction and weaving performance will be identical to the previous alternative. On westbound I-440, as some Mall traffic will be diverted to use the Crabtree Valley Avenue exit instead of making a U-turn under the proposed Creedmoor Road Interchange in the PM peak hour, the C/D road weaving area between the Glenwood Avenue on and off ramps is expected to operate at LOS F with an increased vehicle density. With an additional lane added to the C/D road, the weaving section is expected to operate at LOS D in the PM peak hour. The freeway analysis results are summarized in Appendix H.

When compared with the 2035 Future Baseline Conditions, the proposed improvement alternatives can significantly improve the intersection performance at the three most congested intersections on Glenwood Avenue, namely Creedmoor Road, Lead Mine Road/ Blue Ridge Road, and Westbound I-440 exit ramp. The average peak hour delay reductions are approximately 60%, 55% and 88% respectively.

Table 32. Crabtree Valley Avenue Extension with Glenwood Avenue Overpass and Creedmoor Road Improvements (2035)

Intersection	Approach	2035 CVA Extension to I-440, WB Glenwood Ave Overpass, and Creedmoor Rd SPUJ				
		AM		PM		
		Intersection		Intersection		
Glenwood Ave/ Creedmoor Rd	Intersection	99.3	F	180.4	F	
	EB	119.2	F	134.4	F	
	WB	55.7	E	75.3	E	
	NB	123.1	F	255.9	F	
	SB	103.9	F	192.7	F	
Glenwood Ave/ Marriott Dr	Intersection	--	--	--	--	
	EB	--	--	--	--	
	WB	--	--	--	--	
	NB	58.8	F	676.6 *	F	
	SB	15.7	C	46.9	E	
Glenwood Ave/ Lead Mine Rd/ Blue Ridge Rd	Intersection	223.2	F	208.7	F	
	EB	159.6	F	245.6	F	
	WB	15.1	B	87.4	F	
	NB	148.7	F	184.2	F	
	SB	373.5	F	229.7	F	
Glenwood Ave/ I-440 WB Ramp	Intersection	15.2	B	57.3	E	
	EB	--	--	--	--	
	WB	36.6	D	74.7	E	
	NB	--	--	--	--	
	SB	10.7	B	52.1	D	
Glenwood Ave/ I-440 EB Ramp	Intersection	57.5	E	54.4	D	
	EB	65.1	E	25.1	C	
	WB	28.7	C	66.7	E	
	NB	76.5	E	73.9	E	
	SB	--	--	--	--	
Lead Mine Rd/ North Hills Dr	Intersection	53.8	D	102.4	F	
	EB	134.6	F	88.1	F	
	WB	153.5	F	110.2	F	
	NB	30.8	C	149.2	F	
	SB	40.6	D	19.8	B	
Creedmoor Rd/ Mall Entr	Intersection	67.8	E	56.3	E	
	EB	175.0	F	160.1	F	
	WB	28.5	C	123.1	F	
	NB	57.4	E	41.5	D	
	SB	65.7	E	35.0	C	
Blue Ridge Rd/ Mall Entr	Intersection	--	--	--	--	
	EB	10.6	B	15.9	C	
	NB	--	--	--	--	
	SB	--	--	--	--	
	SB	--	--	--	--	
Creedmoor Rd/ Crabtree Valley Ave	Intersection	29.7	C	45.2	D	
	EB	--	--	--	--	
	WB	41.4	D	43.7	D	
	NB	54.2	D	60.4	E	
	SB	13.0	B	23.6	C	
Crabtree Valley Ave/ Blue Ridge Rd	Intersection	18.2	B	33.0	C	
	EB	67.1	E	44.0	D	
	WB	--	--	--	--	
	NB	26.6	C	25.4	C	
	SB	4.0	A	36.2	D	
Crabtree Valley Ave/ Edwards Mill Rd	WB	--	--	--	--	
	NB	12.8	B	14.6	B	
	SB	6.9	A	18.8	B	
Crabtree Valley Ave/ Mall Parking Deck	Intersection	6.9	A	18.8	B	
	EB	5.0	A	11.3	B	
	WB	2.5	A	10.2	B	
	NB	85.7	F	68.9	E	
	SB	92.9	F	91.8	F	
Crabtree Valley Ave/ Homewood Banks Dr _Mall Entr	Intersection	46.2	D	70.7	E	
	EB	30.0	C	63.3	E	
	WB	53.3	D	73.7	E	
	NB	40.6	D	71.8	E	
	SB	98.6	F	71.2	E	
Crabtree Valley Ave/ Summit Park Ln	NB	--	--	--	--	
Blue Ridge Rd/ Crabtree View Pl	WB	--	--	--	--	
Arrow Dr Extension/ Blue Ridge Rd	Intersection	33.5	C	34.4	C	
	WB	72.5	E	66.8	E	
	NB	17.2	B	24.4	C	
	SB	29.1	C	31.4	C	
	SB	29.1	C	31.4	C	
Performance Index		1,426.3		4,394.8		
Glenwood Ave Arterial	EB	Speed (mph)	7 (5-8)	6 (4-6)		
		Travel Time (sec)	1,148.1 (833.2-1,807.8)	F	1,960.3 (1,727.8-2,372.3)	F
		Delays(sec/veh)	988.6 (673.7-1,648.3)		1,800.7 (1,568.2-2,212.7)	
	WB	Speed (mph)	34 (30-37)	28 (19-33)		
		Travel Time (sec)	522.5 (407.7-615.7)	B	984.1 (821.6-1,054.9)	B
		Delays (sec/veh)	384.7 (269.9-477.9)		847.2 (684.7-918.0)	
Network Performance	Total Delay (hr)	11,050.3 (10,733.4-11,417.8)		13,107.6 (12,843.8-13,385.8)		
	Stops (#)	64,264.0		85,695.0		
	Fuel Consumed (gal)	3,521.3		4,050.3		
	HC Emissions (g)	20,897.0		23,247.0		
	CO Emissions (g)	843,673.0		894,515.0		
	NOx Emissions (g)	56,847.0		61,130.0		

-- Not applicable or estimated delays over 1,000 seconds if LOS "F" is listed.  
 \* Signalization may reduce the northbound delays to 70.2 seconds (LOS E). The average intersection delays and eastbound approach delays are 28.2 seconds (LOS C) and 16.3 seconds (LOS B) respectively.

## Recommendations

---

Based on the traffic analyses, the following improvements are recommended:

### Initial Improvements

- Signage Improvements
- Bike/Pedestrian improvements.
- Initialize an interchange modification study to keep NCDOT/FHWA engaged

### Near Term Improvement

- Crabtree Valley Avenue Improvements

### Mid Term Improvement

- Crabtree Valley Avenue Extension to I-440

### Long Term Improvements

- Phase I: Westbound Glenwood Avenue Overpass at Lead Mine Road
- Phase II: Creedmoor Road Interchange (SPUI)

### Ongoing Improvements

- Improve Transit Service and Facilities
- Traffic signal Improvements ( including timing and transit signal preemptions)
- Land use planning modifications to better control the traffic growth

# Public Transportation



## The Challenge

The existing public transportation service in the study area is relatively high, with Crabtree Valley Mall serving as one of eight key bus transfer locations within the Capital Area Transit (CAT) route network. The five routes that serve the area carry about 17% of CAT's total daily ridership. Areas of need in the arena of public transportation services include better coordination of available resources, since the numerous hotels in the area each have individual shuttle services linking their patrons directly to Crabtree Valley Mall, downtown, and RDU International Airport. The existing transit transfer center is located optimally near a main rear entrance of the Mall in a covered area. However, the design of this location could be improved to interfere less with other patrons of this regional shopping center, and made to accommodate more transit vehicles as well for future expansion. Internal circulation in the Crabtree Valley area by public transportation is sparse, since the Crabtree hub is designed to serve cross-town and downtown routes today. Although there is strong service between Crabtree Valley and downtown now, services could be dramatically improved with higher frequencies, which would be especially beneficial for both the hotels and businesses in Crabtree Valley and downtown convention-related events. The same is true for event-related connectivity to the RBC Center and, eventually, planned passenger rail service in the vicinity of Hillsborough Street.

There are three primary goals for public transportation in the Crabtree Valley, each of which calls for a different type and level of service.

These goals are:

- To relieve some traffic congestion during peak periods in the Crabtree Valley.
- To offer reasonable travel choice to anyone who is not interested in driving.
- To connect Crabtree Valley with other activity centers in the region, such as the Convention Center, downtown, and the airport.



### Public Transportation Service in Crabtree Valley

**Route 16 (Oberlin):** Connecting Crabtree Valley Mall to Cameron Village and Raleigh's downtown. This route winds through mostly retail districts, but serves the employees of those districts as well as shoppers and student (students of what school?) populations.

**Route 6 (Glenwood):** Connecting the Mall to the Five Points area and downtown Raleigh; the most direct connection between downtown and Crabtree Valley

This route takes hotel guests from Crabtree Valley to popular tourist destinations downtown as well as provide access to the shopping opportunities for people staying in downtown Raleigh.

**Route 4 (Rex Hospital):** Connecting downtown Raleigh, Rex Hospital, Crabtree Valley and Towne North Shopping Center; this is the most heavily traveled route serving the Crabtree Valley.

**Route 23C (Millbrook Cross-town Connector):** Provides service from the Crabtree Valley Mall to New Hope Road and Capital Boulevard, serving the Millbrook Road Corridor.

**Route 70E (Brier Creek Express):** Provides limited stop service between Crabtree Valley Mall and the Brier Creek retail area during typical retail commute hours only. This route offers a transfer opportunity with the Durham Area Transit Authority (DATA).

## The Response

The framework for implementing public transportation improvements to address transit goals in the Crabtree Valley proposes both institutional and operational recommendations. The latter are organized into short (2010 to 2015), medium (2015 to 2020), and long-term concepts (beyond 2020) that mesh with each other and other recommendations contained in this report.



### Institutional Recommendations

#### Business Improvement District (BID)

Like the Downtown Raleigh Alliance and the Hillsborough Street Community Service Corporation, Raleigh's only BIDs, Crabtree Valley could benefit from a non-profit, member-controlled organization that receives what could be a supplemental ad valorem tax on property in a designated study area. Revenue would be collected by Wake County and distributed through an agreement with the City of Raleigh. Funds could be used for collective branding, marketing, advertising, enhanced security, and transportation options. North Carolina statutes provide for the formation of Municipal Service Districts (MSD) including taxes to generate operating revenue for such organizations.

#### Transportation Management Association

A different institutional option for Crabtree Valley is the formation of a Transportation Management Association (TMA), which is a non-profit, member-controlled organization that supports a range of transportation alternatives in a particular area, such as a commercial district, mall, medical center, or industrial park. Transportation Management Associations (TMAs) typically offer an array of services with the goal of encouraging more efficient use of transportation and parking resources. The following are some examples of services offered by TMAs:<sup>1</sup>

- Access Management
- Commute Trip Reduction
- Commuter Financial Incentives
- Flextime Support
- Guaranteed Ride Home Services
- Marketing and Promotion
- Parking Management and Brokerage
- Pedestrian and Bicycle Planning
- Rideshare Matching and Vanpool Coordination
- Shared Parking Coordination
- Shuttle Services
- Special Event Transportation Management
- Telework Support
- Tourist Transportation Management
- Transit Improvements
- Transportation Access Guides
- Wayfinding and Multi-modal Navigation Tools

TMAs are classified under the broad category of transportation demand management (TDM). There are currently a number of TDM programs operating in the Triangle region, with the Triangle J Council of Governments (COG) serving as the regional TDM Coordinator, linking state policy and funding to local and regional service providers.

<sup>1</sup> Victoria Transport Policy Institute, Online TDM Encyclopedia, updated January 26, 2010.

The Triangle Transit Authority (TTA) serves as the regional TDM service provider, directing services and outreach to specific employers and travelers in the region. TTA provides support for employers, commuters, and TMAs.

SmartCommute@RTP is the only TMA currently operating in the Triangle region. SmartCommute@RTP has 24 members representing between 80 - 90% of the employees in the Research Triangle Park.<sup>2</sup> The primary activities of SmartCommute include promotion of transportation alternatives, administration of transit incentives, and marketing and outreach efforts that enhance the use of alternative commuting practices. SmartComute@RTP is funded through statewide funding and service district funding.

The I-440 North area, including Crabtree Valley was identified as a TDM target area in the Triangle Region 7-Year Long Range Travel Demand Management Plan.<sup>3</sup>

Funds to help support TMAs are available through NCDOT (50% match for administrative expenses). Special TDM projects are also supported through the statewide Congestion Mitigation and Air Quality Program (CMAQ).

An example of a TMA operating in a similar environment to the Crabtree Valley is the North Bethesda Transportation Center (NBTC) (Maryland), operating in an area that is home to a major regional mall, several office campuses and buildings, and multi-family residential areas. The NBTC has an advisory committee made up of representatives from businesses, civic associations, chambers of commerce and local government. Funding for the NBTC comes from grants, parking meter fees and fines, park and ride lot fees and permit revenue, and fees from new commercial and multi-family residential development. Participation in NBTCs programs is voluntary and typically comes from employers with more than 25 employees and owners of office buildings or retail complexes.

The NBTC provides assistance to to employers and employees, including the following:

- On-site employee outreach promotions;
- Centralized information for bus schedules, shuttle schedules, carpool and vanpool information, and telework information, including customized transit itineraries;
- Rideshare-matching services;
- Guaranteed ride home, via a large regional program (Commuter Connections);
- Parking management; and
- Advocacy of bicycle, shuttle, and public transportation services.

A TMA in the Crabtree Valley could serve to help oversee transportation improvements in the area. This arrangement would foster buy-in from area businesses and residents, as they could be involved either on an advisory committee or as a member. A TMA would in essence be an extension of the focus given to the area via the Crabtree Valley Transportation Study.

A TMA could promote transit, encourage local employers to participate in the Go Pass, encourage ride-sharing, flex-schedules, bike/ped options, and potentially manage a hotel and business-oriented shuttle. The TMA would work closely with and coordinate different destination agencies (hotels, offices, Mall) to create a coordinated response to peak, seasonal, and holiday traffic pressures.

#### Hotel Shuttle Coordination

There are several hotels in the Crabtree Valley, many of which have vans that they use to transport guests to local attractions and the airport. Anecdotal observations show that these vans are often idle, while at other times may not be able to meet the demand. Developing a regularly scheduled shuttle operation for the hotels and businesses in the Crabtree Valley may be a way to improve circulation using existing resources. The first step in this process is to start a dialogue with area hotels to create partnerships for financing and optimizing the routes and services. The dialogue would include: a discussion of the current hotel fleet; the service characteristics of the shuttles that

---

<sup>2</sup> Triangle Region 7-Year Long Range Travel Demand Management Plan, UrbanTrans Consultants and Texas Transportation Institute, June 2007, prepared for the Triangle Regional TDP Advisory Committee.

<sup>3</sup> Triangle Region 7-Year Long Range Travel Demand Management Plan, UrbanTrans Consultants and Texas Transportation Institute, June 2007, prepared for the Triangle Regional TDP Advisory Committee.

are currently in service, including the current level of demand; the costs incurred to operate the fleet; the ability of the hotel operators to re-direct the resources to a high-quality consolidated operation; and the willingness of the hotel operators to coordinate/consolidate services to provide a higher level of service that would provide circulation throughout the Crabtree Valley and to the airport.

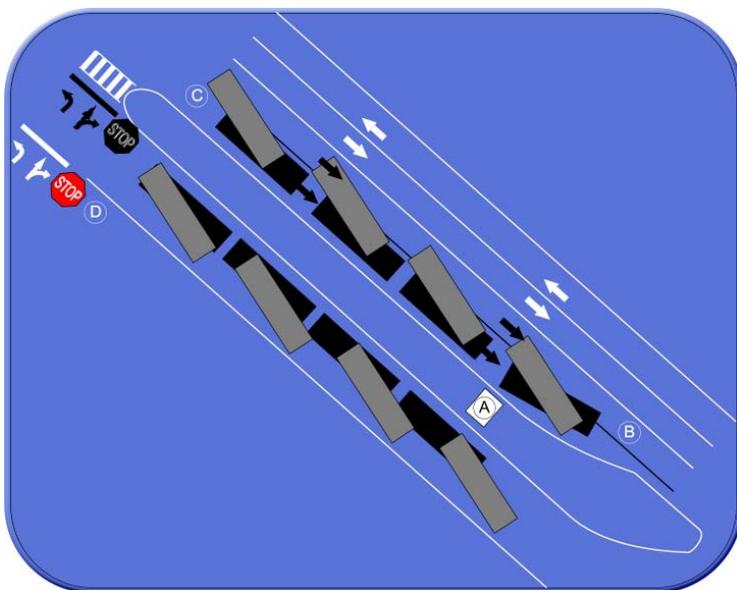
An example of a consolidated hotel/business shuttle has been implemented in the resort area of North Lake Tahoe (California/Nevada). The shuttle, termed Truckee Transit, works in concert with several other public and private transportation providers in the region. The Truckee-North Lake Tahoe Transportation Management Association coordinates and advocates for public and private transportation solutions in the region.

### *Operational Recommendations*

The transit operational strategies are best suited to short, mid, and long-term scenarios. In all three time frames, some common themes should be strongly present:

- The Crabtree Valley area should feature real-time transit information and themed signage at well-marked stops (i.e., hotels, area office buildings, Crabtree Valley Mall).
- Pedestrian improvements around Mall and throughout the Crabtree Valley area so that people will be safe walking to and from their bus stops.
- The recommendations need to be compatible with the pedestrian-oriented streetscape environments of the Glenwood South district and neighborhoods; and work collaboratively with businesses and hotels to generate the maximum exposure and use of these services.
- Generally, multi-way financing partnerships that would improve service frequency and quality should be an underlying goal to reduce the public burden

Project Type	Description
<b>Short-Range (2010 - 2015):</b>	
Improve Transfer Center in Crabtree Valley Mall	<ul style="list-style-type: none"> <li>Better signage to direct people to where the bus stop and transfer area is located.</li> <li>Post a large system map at the site. The route numbers are posted on the flags and there is real-time arrival information, but no map to show where the routes go.</li> <li>Move the stop sign back, closer to the mall entrance off of Crabtree Valley, so that cars do not block the bus exit from the inbound bays or the existing pedestrian crossing.</li> <li>Move to a four-line AVL display board instead of the current single-line AVL display at the transit transfer center.</li> </ul>
Basemap	Create a basemap of the current area, destinations/origins, and service profiles that could be handed out to hotels and offices to make them more aware of current public transportation opportunities.
Stop Amenities	Improve stop amenities at Crabtree Valley Avenue/Creedmoor Road intersection. This is the second-busiest location in the study area.
Circulator Service	Develop an internal circulation route that would serve area hotels, retail establishments, and offices. (sample routing and option service extension map at: <a href="http://maps.google.com/maps/ms?ie=UTF&amp;msa=0&amp;msid=106739957128633862425.0004782d1676e52bd7d26">http://maps.google.com/maps/ms?ie=UTF&amp;msa=0&amp;msid=106739957128633862425.0004782d1676e52bd7d26</a> )
<b>Mid-Range (2-5 years):</b>	
Shuttle Service	Create a branded concept with interesting vehicles, one-seat ride, high-frequency, and promoted through a strong marketing campaign. Any circulator or dedicated service should feature vehicles branded with a Crabtree-area scheme; be comfortable, environmentally sensitive (hybrid), and smaller in size than the typical 40' configuration for internal circulation through tight parking garages, steep grades, and other physically constrained areas.
Signal Preemption	Signal preemption where needed, especially Creedmoor/US 70 and Lead Mine/US 70 intersections, to ensure on-time performance, reduce headway times, and increase reliability.



**Mall Transfer Center Short- and Mid-Term Recommendations**

- A. Replace single-line AVL reader with four-line display
- B. Remove one lane eastbound in front of transfer center to allow more room for bus operations
- C. Modified “saw tooth” parking
- D. Move stop bar and signage back away from existing pedestrian crosswalk to reduce interference with bus and pedestrian movements

Note: All transfer center improvements shall consider future relocation scenario prior to short term capital improvements.

Figure 28. Existing Transit Hub Modifications

*Long-Range (more than 5 years):*

Connections to Future Rail Service	Depending on location of rail stops in vicinity, connect the Crabtree Valley area with express transit buses (e.g., state fairgrounds).
Fixed Route Connections	If demand is strong on service to downtown and buses are not meeting the need, look at a fixed option such as trolley services connecting Crabtree, Cameron Village/NCSU, and Downtown Raleigh/Glenwood South.
Reassess Central Transfer Facility	<p>Reassess the relocation of the central transit transfer center from its current location underneath the parking deck to the south side of Crabtree Valley Avenue. Conditions that may trigger such a reassessment must include the following, at a minimum:</p> <ul style="list-style-type: none"><li>■ The ability to integrate the station waiting, ticketing, and other areas into a comprehensive, mixed use development that includes office, residential and perhaps retail functions. “Integration” in this sense means that common walls are shared with the station facilities and other uses such that the provision of transit services and land use are complimentary to both functions – transport and destination activities.</li><li>■ The ability of passengers boarding and alighting at a relocated station to enjoy direct, separated-grade accessibility onto the Mall properties. Full shelter from inclement weather, lighting, and a design integrated with that of the Mall and the new properties should ensure a level of Mall accessibility at least equal to that now offered by the current transfer center location.</li></ul>

# Cycling and Walking



## The Challenge

As Crabtree Valley developed and grew more houses, shops, and offices, the transportation network grew with it. In the most dynamic period of the area's history, from the middle of the previous century to its end, the standard pattern of growth applied high design standards for roadways with the intent of maximizing automobile throughput. The result is the image of Crabtree Valley as it is today: congested, high volumes of automobiles, and a separated patchwork of land uses accessible only by car, and much less simply, by bus. Pedestrians scramble across busy, major thoroughfares and are confronted by frustrating gaps in sidewalk linking adjacent neighborhoods to the popular destination that is close by but hardly accessible thanks to high-speed ramp exits, lack of pedestrian signal crossings (or lack of them in locations that are accessible to mobility challenged people), and a general design feel that clearly favors motorists in nearly every instance. In recent years, the City of Raleigh has made strides to reconnect this study area together through a system of greenways, separated paved paths that accommodate both casual cyclists and walkers. Grade-separated crossings of the greenway under Creedmoor Road and US 70 provide relief from otherwise daunting roadway crossings. Sidewalks have been constructed as well, and more are planned, as are new greenways such as House Creek, which will begin construction this year (2010) and will connect the west side of the Crabtree Valley Mall property to residential neighborhoods, future business locations, and the North Carolina Museum of Art. Cycling on-road is less well accommodated, with no dedicated bicycle lanes in the area, and relatively narrow outside lane widths and shoulders. With the exception of the Crabtree Creek and other greenway connections existing and proposed, the message to cyclists is fairly clear: only the most confident and experienced on-road cyclists need apply.

An important note about the relationship between land use, building/site design, and patterns of development is appropriate here. If land uses are complimentary, buildings sited closer together, sites more accommodating of property access on foot, bicycle parking made safer and more obvious, and connections between sites made more accessible, then walking and cycling will happen more frequently. While considerable research has yielded few concrete, predictable results, our recent assessment indicates that more connectivity of roadways, more greenways, and more sidewalks has a noticeable impact on the way people choose to travel by as much as ten percent; that is, ten percent of all trips would occur on foot, bicycle or bus. National studies have indicated similar, and even greater – as much as a 25% or more – mode shift when environments are well-lit, well-connected, and designed to accommodate walking. The importance of this fact as it relates to human health, facilitating active lifestyles, decreasing dependence on private automobiles, and improving public transportation options is hard to overstate.

## The Response

While enforcement, education, and encouragement are important components of a comprehensive plan to induce safe, frequent walking and cycling behavior, the current study is focused on a set of physical improvements that will directly facilitate pedestrian and cycling. These recommendations are in concert with those provided by pre-existing, city-wide bicycle and pedestrian plans, and borrow from them freely. The response provided here was also facilitated by comments and concerns expressed by participants in the planning process through direct, email, and workshop contacts.

Project Type	Location
Create a New Walking/Biking/Transit Map Product	Generate an attractive folding map that indicates major destinations, structures, and foot, bike, and transit connections between them; these should be made available at retailers, hotels, and business centers inside the Study Area
Monitor and Repair Gaps between bridges and paving on greenway	Over time, gaps may grow between the edge of the pedestrian bridge and the greenway; repairing this will help make the pathways continue to be safe for cyclists, particularly those on road bikes
Re-Paint Center Stripe separating two directions of traffic	Crabtree Greenway, northeast of Glenwood/Lead Mine Road intersection
Label Overpasses of Greenways to aid in wayfinding	Various, including overpasses at Glenwood Avenue and Creedmoor Road
Install In-Pavement Pedestrian Crossing Signage and Automated Flashing Equipment at Greenway Crossing at Mall's rear (south) entrance	Several people in our survey noted the difficulty of getting cars to obey pedestrian-first right of way rules at this location. Automated crossing equipment that senses the presence of bikers/walkers on the greenway would trigger a flashing response; the in-pavement signing would be a shorter-term measure
Remove debris	Remove trash and debris that have accumulated in locations along the greenway system due to storm deposition
Utilize Light-Sensitive Switching to activate lighting under overpass locations	This particularly includes the Glenwood overpass area
Improve the Alleyway leading from Blue Ridge Road to Hotels	Pedestrians were observed using this private alleyway (approximately 12 feet wide), which could be improved with a formalized repaving and clearing at the edges
Develop Unique Wayfinding Program	A deviation from the new Raleigh wayfinding system using the same general color, font, and design schemes but embossed with a Crabtree Valley "logo" could help reinforce this as a unique, mid-town community still in development
Repair and Reuse the Abandoned Steel Trestle Bridge	The City is currently evaluating the usefulness of reusing this structure, which is remarkable for its aesthetic value
Promote Cycling on Park Lake Avenue	This relatively new addition is four lanes, undivided and heavily unused by automobile traffic; reassess the traffic need for a four-lane roadway without cross-streets that could be re-stripped to provide a scenic connection to neighboring areas to the northwest perimeter of the study area
<b>Pedestrian Crosswalks</b>	
Remove Slip-Ramp; Add Pedestrian Crossing Markings	In various locations, especially at the "nose" end of exit/entrance ramps but also on some surface streets, curb radii favor automobile traffic unnecessarily to the detriment of bicycle and pedestrian crossings (refer to map for locations)
Complete Sidewalks on Blue Ridge Road (both sides) and install bicycle lanes	This is currently called-for in the pedestrian and bicycle plans for the City, and should be an important priority to connect the many neighborhoods and hotels to the south
Improve the Homewood Banks / Blue Ridge Road Intersection	This improvement would facilitate safer bicycle, walking and motorized vehicle traffic, and would principally feature realigning the intersection and removing the wide turning radii currently present to shorten crossing distances and improve sight lines
Complete Sidewalks on Edwards Mill Road (East Side)	This pedestrian connection would safely tie the residential communities behind the Crabtree Valley Mall to the Mall property, public transportation, and future developments
Complete the Homewood Banks Greenway	This important link is set to go to construction in 2010, and would also provide connections to the neighborhoods to the south with the Mall properties
Install ADA Ramp from Parkng Area	While very few sidewalk connections lacked ADA compliance, the small parking area in the northeast corner of Lead Mine / Glenwood is never used and could supply an important access point for those wishing to use the trail below
Install Pedestrian Signals, Crosswalks, and Wider Median at Glennwood and Lead Mine Road/Blue Ridge Road	Navigating this intersection is challenging due to nine lanes of traffic and high traffic volumes; coupled with installing sidewalk on the southwest corner of Blue Ridge Road would make an important contribution to the safety of this

	area (note: also, reevaluating the need for the through-right instead of a dedicated through lane is recommended)
Relocate Existing Pedestrian Signals at Creedmoor and Blue Ridge Road	The two pedestrian crossing signals on the south side of Glenwood are not in ADA-accessible locations; pedestrian signals and a wider median should be implemented in the short-term as well until a major redesign of the intersection takes place
Re-paint Crosswalk and Add West Leg Crosswalk at west side Mall entrance	The current crosswalk is fading, and the west leg of this intersection is missing a crosswalk marking entirely
Install Missing Sidewalk Segments	<ol style="list-style-type: none"> <li>(1) Glenwood Avenue from Creedmoor Road to Lead Mine Road / Blue Ridge Road. This segment is the most challenging, and perhaps the most needed, in the pedestrian system to complete connectivity in front of the Mall properties, including connecting several outparcels. Retaining walls and improved lighting could be utilized to dramatically alter this “no-man’s land” between the parking deck and the busy major thoroughfare</li> <li>(2) Southwest corner of Creedmoor at Crabtree Valley Avenue. This is the only missing piece of sidewalk on Creedmoor Road inside the Study Area.</li> <li>(3) Edwards Mill Road, from existing sidewalk just south of Arkelton Drive to Crabtree Valley Avenue. This segment provides current internal connectivity and future connections to still-developing properties in the Kids’ Hill and Parkside Avenue areas.</li> <li>(4) Blue Ridge Road (both sides; west side especially if funds are not available for both sides). Two small gaps exist in the vicinity of Glen Eden Drive at the perimeter of the Study Area; additional sidewalk would greatly facilitate travel from the current neighborhoods to the Mall properties and public transportation.</li> <li>(5) Glenwood Avenue, from Marriott Drive to Brookhaven Drive. This short segment would connect the large Brookhaven neighborhood to the corner of Crabtree Valley Mall; additional improvements already discussed are required to make the crossing of Glenwood Avenue more safe and convenient</li> <li>(6) Lead Mine Road, from Charles Drive to Sugar Bush Road. The latter already has good sidewalks; this segment would connect businesses to hotels to shopping opportunities.</li> </ol>

**Long-Range (beyond 2020):**

Connect Pedestrian Overpass of Glenwood Avenue from Marriott Drive to Parking Structure at Crabtree Valley Mall	While costly, this improvement could provide the single, most long-term benefit to pedestrian and casual bicycle users of the transportation network in this area. A signature structure should be carefully designed to take advantage of the favorable topography, as well as connecting the Marriott Hotel with the main Mall structure.
---	---



**Changing the Focus**

The intersection of Homewood Banks and Blue Ridge Road today (left) is typically oriented towards high-speed turning movements, disfavoring non-motorized travel. An alternative (right) is to redesign the road with bicycle lanes, sidewalks, crosswalks, and a more calming, lower-speed turning geometry. This will also allow better visibility for turning traffic to improve safety for auto users.

