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North Carolina "Sealed Corridor" Phase I, II, and III Assessment

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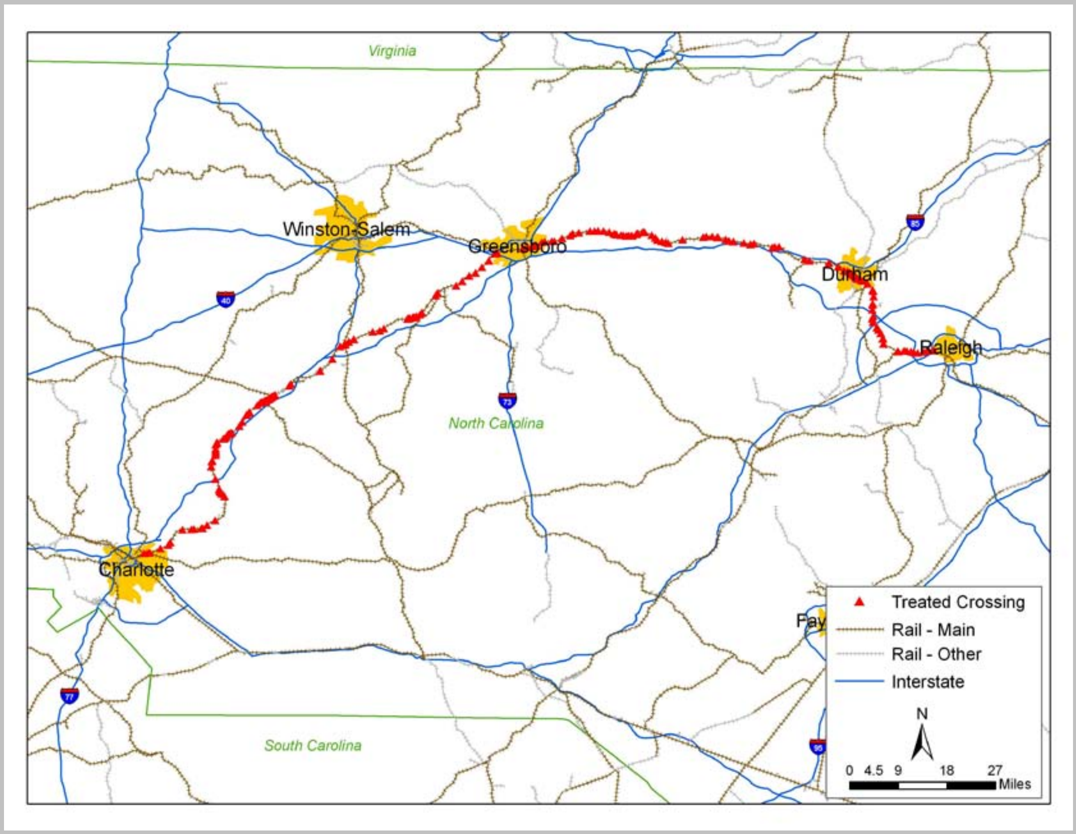

Safety of Highway-Railroad Grade Crossings

DOT/FRA/ORD-09/17

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13. ABSTRACT (Maximum 200 words)

The Federal Railroad Administration (FRA) tasked the John A. Volpe National Transportation Systems Center to document the further success of the North Carolina DOT "Sealed Corridor" project through Phases I, II, and III. The Sealed Corridor is the section of the designated Southeast High Speed Rail (SEHSR) Corridor that runs through North Carolina. The Sealed Corridor program aims at improving or consolidating every highway-rail grade crossing, both public and private, along the Charlotte to Raleigh rail route in North Carolina. The research on the Sealed Corridor assessed the progress made at the 189 crossings that have been treated with improved warning devices or closed between Charlotte and Raleigh, from March 1995 through September 2004. Two approaches were used to describe benefits in terms of lives saved: a fatal crash analysis to derive lives saved, and prediction of lives saved based on the reduction of risk at the treated crossings. Both methods estimated that more than 19 lives have been saved as a result of the 189 improvements implemented through December 2004. Analysis also shows that the resulting reduction in accidents, due to the crossing improvements, is sustainable through 2010, when anticipated exposure and train speeds along the corridor will be increased.

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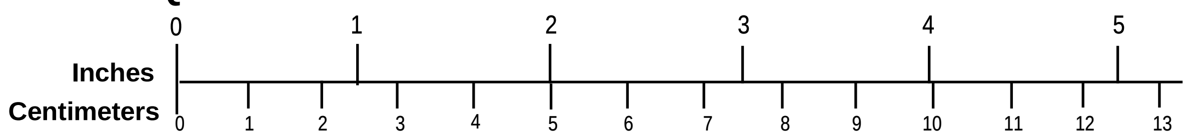

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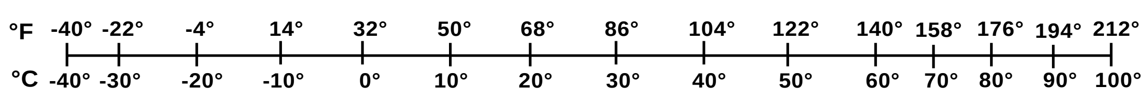

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Executive Summary

In response to a request in the Department of Transportation and Related Agencies Appropriations Act, 2001, P.L. 106-346, this report documents the benefits of the State of North Carolina's Sealed Corridor initiative and the improvements completed at highway-rail grade crossings from March 1995 through September 2004 in terms of lives saved. The analysis concludes that 19 lives were saved during the study period and that this positive benefit of the Sealed Corridor improvements will grow as vehicle volume, train frequency and speeds increase.

High-speed rail passenger service is being encouraged in the United States as evidenced by legislation such as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Swift Rail Development Act of 1994, and the Transportation Equity Act for the 21st Century (TEA-21). High-speed rail operations on corridors designated under TEA-21 could eventually result in train speeds above 110 mph.

The North Carolina Department of Transportation (NC DOT) plays a prominent role among states pursuing high-speed ground transportation development. Part of the Southeast High Speed Rail (SEHSR) Corridor, which connects Washington, DC, through Richmond, VA, to Raleigh and Charlotte, NC, with extensions south to Columbia, SC, Savannah, GA, and southwest to Greenville, SC, Atlanta and Macon, GA, and Jacksonville, FL, runs through the State of North Carolina. Recognizing that improved safety must accompany improved service, the State has instituted an innovative Sealed Corridor program initiative, which aims at improving or closing every grade crossing, both public and private, along the chosen route between Charlotte and Raleigh, NC, via Greensboro on the North Carolina Railroad. The Sealed Corridor initiative is also a model research approach to examine grade crossing issues in other corridors.

The intent of this research is to assess the progress being made at the highway-rail grade crossings that have been treated with improved warning devices or closed between Charlotte and Raleigh. Some of the improvements include nonstandard devices such as traffic channelization and four-quadrant gates. The progress is described in terms of safety benefits. Crash data were examined through December 2004 to ensure any incidents that may have occurred at crossings improved through September 2004 would be included. This report also contains an analysis and evaluation of whether the resulting reduction in incidents is sustainable through the year 2010 when train speeds along the corridor could achieve 110 mph.

Safety benefits are developed through the use of two techniques: (1) a *Fatal Crash Analysis* approach to estimate lives saved through December 2004; and (2) a prediction of lives saved based on the reduction of risk at those treated crossings using a modified United States Department of Transportation (U.S. DOT) Accident Prediction Formula (APF). The resulting risk reduction that can be anticipated through the year 2010 is calculated at operating train speeds of 110 mph along the corridor.

The Sealed Corridor consists of 216 grade crossings, 44 of which are private crossings. Phase I, II, and III of the implementation plan for the corridor addresses 208 crossings between Charlotte and Raleigh. A total of 189 of the 208 crossings have been improved and/or closed. The research documented in this report calculates the number of lives saved based on the improvements made to the highway-rail intersections from March 1995 to September 2004. The results of this research provide a substantive analysis of the Sealed Corridor implementation and provide Federal, State and local organizations a successful model to utilize on their high-speed rail corridor.

Conclusions

At least 19 lives have been saved.

The “fatal crash analysis method” was used to calculate the differences between the annual (or monthly) fatality rates, based on actual experience at the improved crossings, before and after the improvements were made at each crossing. To calculate lives saved, those differences were multiplied by the number of years (or months) that have transpired through December 2004 since each of the respective improvements were made. The sum of these results was then calculated for all of the crossings that were improved. This resulted in an estimate of 19.7, or conservatively, 19 lives saved as a result of the 189 improvements implemented through December 2004.

The “modified U.S.DOT APF” recognizes the probabilistic nature of grade crossing fatalities and relies on a combination of actual experience at the improved crossings and an extensive database of experience at similar crossings nationwide. The formula was used to estimate the annual fatality rates at each crossing before and after each improvement and these were accumulated for corridor-wide results. This method estimated that the improvements implemented through 2004 are reducing fatalities by approximately 2.04 each year, or over two lives saved each year. The Modified U.S.DOT APF predicted 9 fewer lives saved compared to the Fatal Crash Analysis results. This may be due to the fact that the APF contains more variables, and addresses the crossing environment risk.

The accident reduction result is sustainable.

To estimate future incident reduction rates, the second of the above methods was used to ensure increases in train and vehicle exposure over time were considered in the analysis. By the year 2010 it is projected by NC DOT that the vehicle traffic volume and the frequency and speed of trains will increase. The second method is capable of taking these factors into account.

Figure 1 shows the estimated annual fatalities under two conditions: (1) all 208 crossings have been treated (full build, and (2) without any improvements to the 208 crossings (no build). The graph shows a decrease in risk from 1992 to 1996, and an increase in risk with the introduction of the higher train frequency and speed. The graph shows the influence of the improvements, which were initiated in March 1995 on reducing the annual fatalities through 2004. The improvements at the remaining 19 crossings in the corridor were assumed to be implemented in 2008, resulting in a further reduction in annual fatalities. The gradual increase in traffic volume and train frequency from 2004 through 2010 is expected to gradually increase annual fatalities under all conditions. Finally, the increase in train speed to 110 mph, assumed to occur in 2010, would further increase all fatality rates.

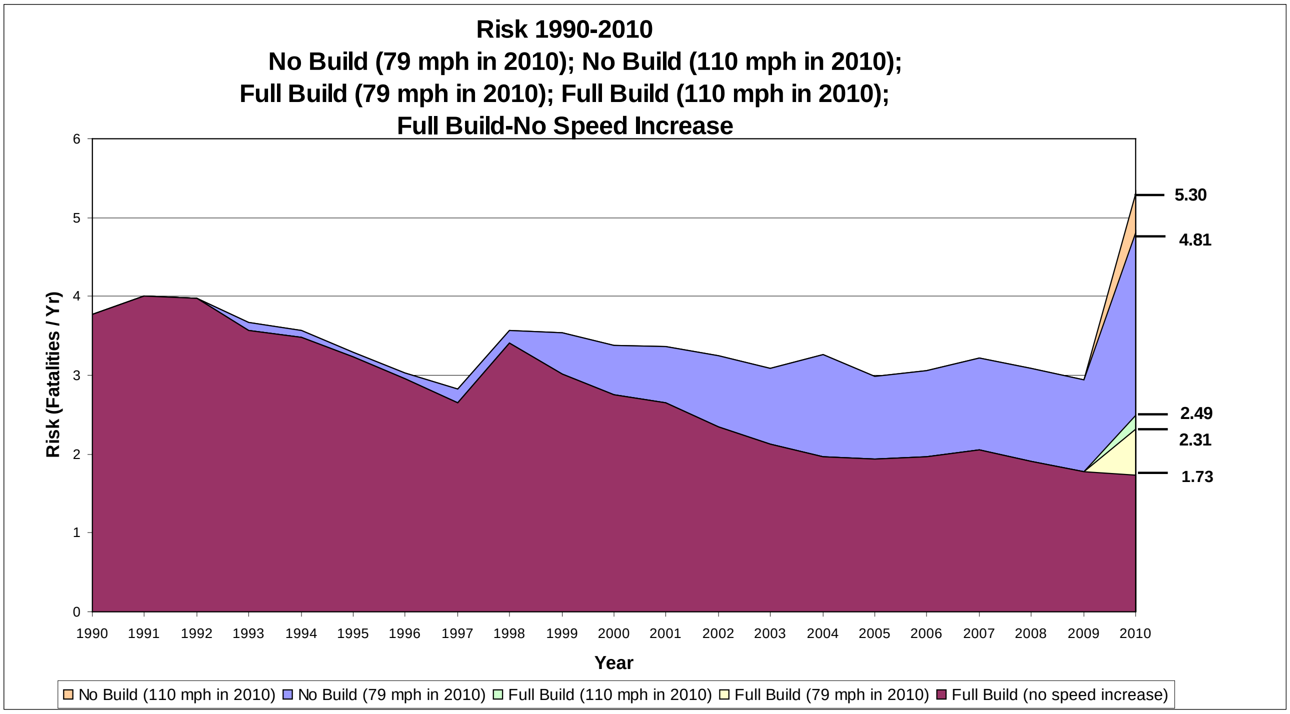

Figure 1. Risk Reduction through 2010 for Phases I, II, and III.

As can be seen in Figure 1, the difference in annual fatalities (the number of lives saved per year) under all conditions (full build, and no build) would continue to increase throughout the period to 2010. By 2010, the fatality rate resulting from the full implementation of the entire Sealed Corridor would be 53 percent lower than if no implementation was executed and train speed increased to 110 mph. Further analysis indicates the fatality rate would be 51.9 percent lower if the speed increased to 79 mph only in 2010 and 46.7 percent lower with no increase in speed in 2010. Discussions with NC DOT Rail Staff indicate train speeds will only increase to 79 mph. Therefore, approximately 52 percent of the risk would be eliminated.

1 Introduction

1.1 Background

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Swift Rail Development Act of 1994, and the Transportation Equity Act for the 21st Century (TEA-21) in 1995, were evidence that high-speed rail passenger service was going to increase in the United States [1]. As a result of this legislation and other initiatives, ten high-speed rail passenger service corridors were designated in the United States. High-speed rail operations on these and other emerging corridors could eventually result in train speeds above 110 mph by the year 2010. Creating a high-speed rail corridor in any growing state will impact safety due to the increase in exposure of vehicles to trains and higher train speeds.

Recognizing that these risks must be addressed if high speed rail service is to be accomplished, the Federal Railroad Administration (FRA) developed guidelines for the installation of motorist warning and train protection devices at grade crossings on the designated high-speed rail corridors. In summary, FRA Guidelines [2] call for the following actions: eliminate all redundant or unnecessary crossings; protect rail movement with full width barriers capable of absorbing the impact of highway vehicles at train operating speeds between 111 and 125 mph; and close or grade separate all highway-rail crossings with train speeds above 125 mph. In 1998, FRA finalized new track safety standards [3]. In these new rules, FRA requires a carrier to submit warning or railroad protection plans for crossings where the speeds are authorized above 110 mph. The new high-speed rail standards prohibit crossings where track speeds exceed 125 mph. FRA published a final rule on passenger equipment safety standards on May 12, 1999 (64 FR 25540). The rule improves the crashworthiness of passenger trains to obtain increases in railroad passenger survivability at higher train speeds.

The organization of the report is as follows. Section 1 describes the North Carolina Sealed Corridor, defines the treatment types, and lists crossings by upgrade. Section 2 describes the crash analysis methods used and summarizes all 33 crossings within Phase I, II, and III that had fatal crashes from 1987 through 2004. Section 2 also describes the Fatal Accident Prediction Method and details the findings that determine the pretreatment fatalities and the post-improvement lives saved through December 2004. Section 2 also describes the modified U.S. DOT Accident Prediction Formula (APF) [4, 5, 6], the assumptions used within the formula, and its results through December 2004. Finally, Section 2 describes results if all of the Phase I, II, and III crossings were treated as proposed by the North Carolina Department of Transportation (NC DOT) by the year 2010. For the 2010 analysis, five scenarios are developed and the Sealed Corridor risks are compared. Section 3 compares the Phase I analysis results versus Phase I, II, and III results obtained from this analysis. Section 4 provides findings and conclusions of the assessment of the NC DOT Sealed Corridor Phase I, II, and III program. Specific costs and effectiveness of the warning devices employed are also discussed.

1.2 NC DOT Sealed Corridor Background

North Carolina plays an important role among states pursuing high-speed ground transportation development. Part of the Southeast High Speed Rail (SEHSR) Corridor, which connects

Washington, DC, through Richmond, VA, to Raleigh and Charlotte, NC, with extensions south to Columbia, SC, Savannah, GA, and southwest to Greenville, SC, Atlanta and Macon, GA, and Jacksonville, FL, and runs through the State of North Carolina (see Figure 2). The SEHSR Corridor is approximately 500 miles in length. The segment of the SEHSR corridor from Washington, DC, to Charlotte, NC, was one of the five original national high-speed rail corridors designated for improvements to high-speed status under ISTEA in 1991.

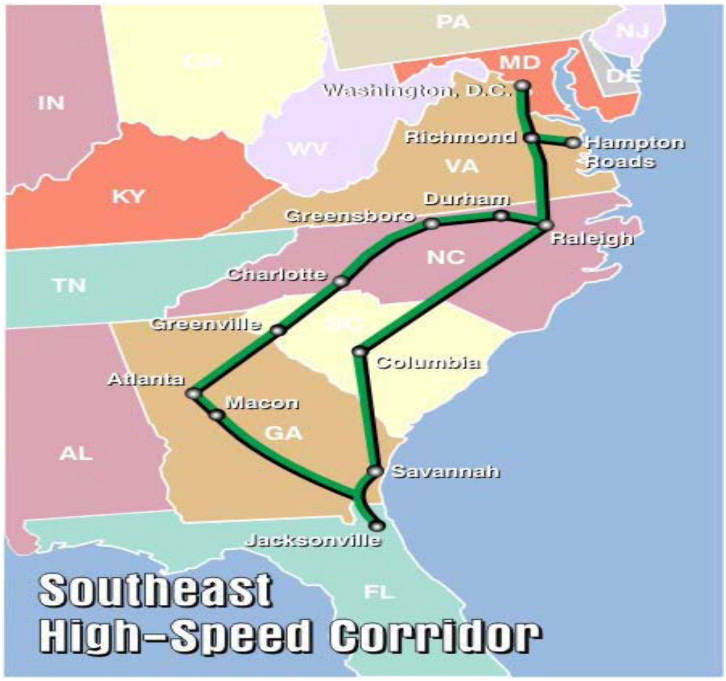

Figure 2. Southeast High Speed Rail Corridor

1.3 Corridor Description

The NC DOT corridor is usually single track including sidings with approximately one crossing per mile. The route carries 35 freight trains per day and approximately six daily passenger trains. It has a mix of public and private crossings and the route contains both urban and rural environs. Future plans for this corridor include operation at speeds up to 110 mph by the year 2010. North Carolina realized the increasing service has the potential of increasing the number of incidents along its high speed rail (HSR) corridor. For safety reasons, North Carolina has organized an innovative sealed corridor program, which aims at improving or closing every grade crossing, public and private along the Charlotte to Raleigh rail route. The warning devices and other improvement type are four-quadrant gates, traffic channelization devices, long gates, closure, video enforcement, grade separation, signs, pavement markings and health monitoring. The NC DOT Sealed Corridor includes 216 grade crossings, 44 of which are private crossings, over a distance of 173.3 miles.

The corridor has been broken into four phases, based on location:

Phase I East 36th Street, Charlotte northeastward to South Elm Street, Greensboro, Phase II Gillespie Street, Greensboro eastward to Academy Street, Cary,

Phase III [1] Reedy Creek Road, Cary eastward to Royal Avenue, Raleigh, and

Phase IV Private Crossing Safety Improvement (PCSI) program, 44 private crossings between Charlotte and Raleigh.

Norfolk Southern Corporation's main railroad line between Greensboro and Charlotte operates over the North Carolina Railroad. It hosts high levels of freight traffic with up to 35 daily freight trains and six passenger trains moving over the corridor daily. Passenger train traffic is projected to increase to 23 daily trains by 2010. Historically, this route has had a high rate of crossing incidents due to the ever-growing highway traffic in the urban areas along the corridor. Between 1987 and 2004, 282 crashes have occurred on the corridor, which involved 74 injuries and 55 fatalities.

1.4 Purpose

The United States Department of Transportation (U.S. DOT) Research and Innovative Technology Administration's Volpe National Transportation Systems Center (Volpe Center) was requested by the FRA Office of Research and Development in 2000 to assess Phase I between Charlotte and Greensboro of North Carolina's Sealed Corridor program for all improvement crossings completed from 1987 to September 2000. Phase I addressed a total of 100 crossings, 52 of which were improved and/ or closed as of September 2000. The objective was to determine the lives saved through December 2000 along the Sealed Corridor Phase I program, and to determine whether the planned treatments for the entire Phase I corridor would provide a sustainable crash reduction condition through 2010.

The purpose of this report is to update the 2001 Report to Congress Phase I [7] and document the benefits of the State of North Carolina's Phase I, II, and III Sealed Corridor Program and the improvements completed through December 2004 at highway-rail grade crossing. A Fatal Crash Analysis method and a modified U.S. DOT APF were employed utilizing crash histories and fatalities from 1987 through December 2004. Benefits were estimated for the treatments used along the Sealed Corridor through December 2004 in terms of lives saved.

This report documents an assessment of the benefits resulting from all 208 crossings of the Phase I, II, and III Sealed Corridor Program that have been improved through September 2004, and also contains an analysis and evaluation of whether the resulting reduction in crashes is sustainable through 2010, when train speeds along the corridor are projected to achieve 110 mph and all 208 crossings have been treated and/or closed. The baseline information for the study was obtained from the FRA Railroad Accident Incident Reporting System (RAIRS) database [8] from October 2000 through September 2004, NC DOT collision reports, police reports, and newspaper articles.

Phase III has two segments. Fetner Junction to Boylan Junction, Cary and Reedy Creek Road, Cary to Royal Avenue, Raleigh.

1.5 Objective

The objectives of this assessment report are twofold:

- Determine the potential lives saved through September 2004 along the NC DOT Sealed Corridor Phase I, II, and III program, by using the Fatal Crash Analysis approach, and

- Determine whether the planned treatments for the entire Phase I, II, and III corridor provide a sustainable crash reduction condition through 2010 with train speeds increase to 110 mph in the year 2010, using a modified United States Department of Transportation (U.S.DOT) APF.

Risk is the product of probability and severity of a crash occurring. If one crossing has one crash per year with one fatality and another crossing has only one crash every 10 years, but there are 10 fatalities in that crash, the statistical risk is the same at each crossing—one fatality per year. Fatalities were chosen as being an essential measure of safety without some of the ambiguity involved in injury counts or other measures.

1.6 Corridor Activities

By using modified standard technologies, the NC DOT makes railroad operations safer by closing redundant crossings, and by using median barriers, long gate arms, four-quadrant gates, health monitoring, and other innovative signage and traffic control devices at the remaining crossings.

Figure 3 shows the locations of the 208 treated crossings through September 2004 of all three phases of the Sealed Corridor from Charlotte to Raleigh. The railroad tracks of the corridor belong to the North Carolina Railroad Company and CSX Transportation, Inc.

Detailed information about each of the 208 treated crossings analyzed in this report, including crossing number, milepost, road name, type of treatment, and the construction date is contained in Appendix A.

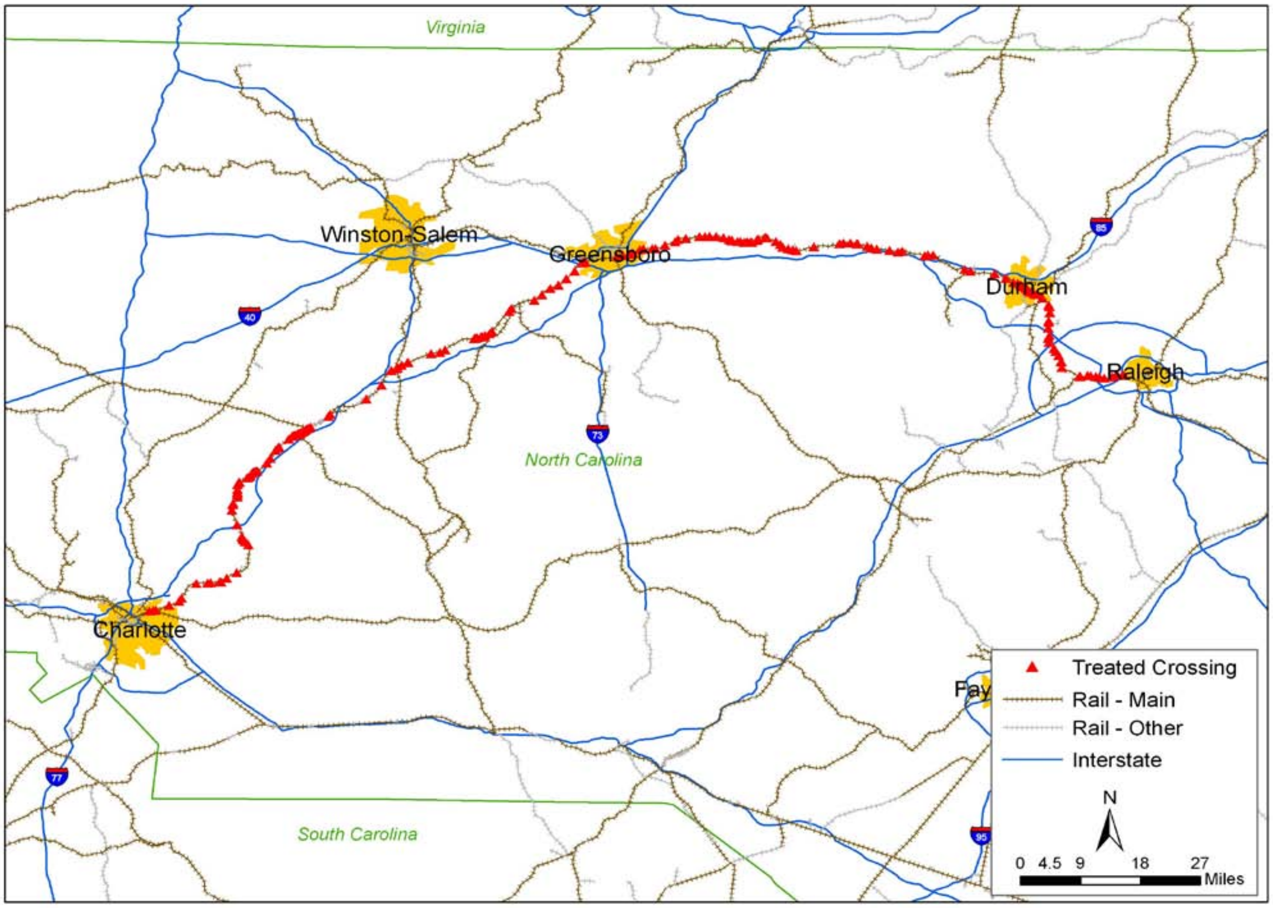

Figure 3. Phase I, II, and III "Sealed Corridor" Treated Crossings through September 2004

1.7 Treatment Description

Closings

A Traffic Separation Study (TSS) [9, 10] process was developed in 1995 by the NC DOT Rail Division to help close more crossings statewide by establishing a series of steps to improve coordination, communication and consistency among all stakeholders across the State. The TSS process helped close more crossings in many communities throughout the State by doing the following: educating the public on railroad crossing safety, identifying specific candidate crossings for closure, prioritizing concerns, and building consensus regarding closures in that community. Studies have also examined other possible safety enhancements to local streets and crossings to further improve public safety while accommodating current and projected highways, school bus routes, and emergency response traffic routes. When considering crossing improvements, it is important to evaluate whether crossing closure or consolidation is feasible and if there are multiple crossings in close proximity that provide access to the same area that could be considered redundant. The NC DOT considers a crossing redundant if it is within a quarter of a mile of another crossing connected to the same street network.

To identify specific candidate crossings for closure, the NC DOT Rail Division conducted a series of TSS to determine the need for improvements and/or elimination of public grade crossings based on specific criteria, which include accident history, existing and projected vehicular and train traffic, types of roadways and crossings, type of property being served, emergency and school bus routes, type of warning devices present, feasibility for improvements, and economic impact on the community if the crossing were to be closed. Figure 4 shows an example of a closure activity. Table 1 describes in detail the milepost, road name, type of crossing, and the construction date for each crossing that was updated with closure.

Figure 4. View of Hackett Street after Closing

Table 1. Closures Completed Through September 2004

Milepost	Road Name	Type Crossing	Upgrade	Construction Date
160.64	Beryl Road Crossover	Public	CL	3/14/2001
163.1	Bashford Road	Public	CL	3/26/2002
68.66	Ashe Street	Public	CL	1/30/1997
63.98	Northern Telecom Road	Public	CL	6/15/2004
33.33	Walton Crossing	Public	CL	6/26/2002
17.05	Antioch Avenue	Public	CL	8/18/2003
16.66	South Holt Avenue	Public	CL	8/11/2000
14.75	Smith Street	Public	CL	8/8/2005
11.97	Bell Road/SR-2764	Public	CL	9/25/2002
5.84	Four Mile Loop/SR-2827	Public	CL	6/1/2001
288.01	Rucker Street	Public	CL	8/16/2004
288.26	Rail Street	Public	CL	8/16/2004
288.47	Boston Road	Public	CL	8/16/2004
293.11	Stanford Drive/ SR-1550	Public	CL	6/1/2006
304.56	Unity Street/ SR-2051	Public	CL	1/13/2003
305.6	College Street	Public	CL	5/24/1996
306.22	Loftin Street	Public	CL	12/15/1995
306.62	Hoover Street	Public	CL	8/15/2005
306.83	Boyles Street	Public	CL	12/15/1995
307	Peace Street	Public	CL	1/2/2004
316.2	Bristol Street	Public	CL	9/10/2001
316.35	Pond Street	Public	CL	9/10/2001
317.84	East 13th Avenue	Public	CL	10/1/2001
329.76	Hackett Street/ SR-2124	Public	CL	3/15/2004
334.45	Knox Street	Public	CL	4/15/1997
334.61	Crawford Street	Public	CL	10/20/1998
335.2	East Harrison Street	Public	CL	8/17/1999
334.85	Lumber Street	Public	CL	11/3/1998
334.91	Mildred Avenue	Public	CL	10/20/1998
334.97	Vance Avenue	Public	CL	10/20/1998
350.28	C Avenue	Public	CL	4/15/1997
335.49	D Avenue	Public	CL	7/7/1998
335.66	Julian Road	Public	CL	11/5/1997
338.19	Peach Orchard Lane/SR2545	Public	CL	1/31/1997
342.67	East Liberty Street	Public	CL	12/28/2004
343.01	Ketchie Street	Public	CL	1/4/1993
343.55	Chapel Street	Public	CL	5/12/2004
344.18	Bostian Rd./ SR-1221	Public	CL	11/8/1999
346.07	East Round Street	Public	CL	10/11/2004
348.1	Ebenezer Road	Public	CL	4/12/1999
349.38	East C Street	Public	CL	4/12/1999
349.1	Plymouth Street	Public	CL	4/12/1999
354.7	Winecoff Avenue	Public	CL	11/4/2001
355.31	Misenheimer Drive	Public	CL	11/8/1999
356.01	Elm Street	Public	CL	11/8/1999
370.21	Turner Road/ SR-2841	Public	CL	3/1/1993

Grade Separation

Grade separation of the highway and the railroad tracks is both the most effective and the most expensive treatment to eliminate risk at a grade crossing. A grade separation project can cost on average $3–5 million dollars per location [7]. Because grade separation is expensive, it is not used as often as closing grade crossings. NC DOT in its TSS for Salisbury identified three crossings for grade separation. In the city of Thomasville, two grade crossings have been selected for grade separation. At the time of documenting the 12 Sealed Corridor improvements, only one crossing had been grade separated, Old Linwood Road in Lexington, NC. The goal of the traffic separation studies performed by NC DOT was to consolidate redundant and/or unsafe grade crossings while identifying ways to improve highway-traffic flow across the rail corridor.

Video Enforcement

Digital video ticketing system is a photo-based system implemented in conjunction with instrumentation installed at a particular site by NC DOT and the Norfolk Southern Corporation to obtain evidence of violations. In August 1998, a digital video ticketing system was placed in service at the Henderson Street Crossing in Salisbury, NC. The Henderson Street Crossing consists of six tracks, on which operate both freight and passenger service. The frequency of trains at this location is approximately one every 15 minutes. This particular crossing had a history of violations and incidents. In cooperation with local law enforcement and judicial officials, violators were ticketed based on video-recorded evidence in a test that was the first of its kind in North Carolina. The University of North Carolina Highway Safety Research Center conducted comparisons of driver violation records and general users and also administered a survey on drivers' perception of risk at railroad gate crossings.

During the period of the video ticketing study from August to December of 1998 at the Henderson Street, Salisbury location, 64 documented instances were documented where drivers were observed to illegally proceed around the lowered crossing gates as a train was approaching. With the cooperation of local law enforcement, violators were ticketed and fined. This demonstration resulted in a reduction in violations by 72 percent [7], showing that photo-based video enforcement methods combined with a fine/penalty structure are an effective alternative to traditional enforcement.

Four-Quadrant Gate

Four-quadrant gate systems are rising in popularity. These installations add another pair of gates to the conventional gated crossing. This results in a crossing that has gates blocking all lanes of traffic on both sides of the crossing making it very difficult for a motorist to go around them in an attempt to beat an approaching train. Four-quadrant gates may be used where insufficient physical space prevents the installation of traffic channelization devices due to nearby highway intersections or driveways. Many communities seeking to establish quiet zones have chosen to use four-quadrant gate systems, despite their relative high cost, because of their demonstrated effectiveness in preventing train-vehicle collisions.

The NC DOT has authorized engineering and construction of four-quadrant gate systems at several locations along the corridor. “Before” and “after” data on driver behavior at four-quadrant gates was gathered using a video monitoring system to show the effectiveness of the treatment. Sugar Creek Road in Charlotte was selected during the initial tests because it has the highest Average Annual Daily Traffic (AADT) in the corridor and more than 21,000 vehicles per day. The four-quadrant gates were found to improve safety by reducing violations by 86 percent [7]. Figure 5 shows one of the installations of four-quadrant gates. When combined with 50 to 100-foot traffic channelization devices to further deter violations, the combination has been shown to be 98 percent effective in reducing violations [7]. Although the cost of this type of installation is considerably higher than a standard two-gate system, the improved safety benefit is appreciable. Table 2 list each crossing that was upgraded with four-quadrant gates.

Figure 5. 4-Quad Gates at Shamrock Road, Harrisburg, NC

Table 2. Four-Quadrant gates Completed Through September 2004

Milepost	Road Name	Type Crossing	Upgrade	Construction Date
160.77	Blue Ridge Road/SR-3072	Public	4Q	4/7/1999
72.7	Academy Street/SR-1312	Public	4Q	3/15/2004
72.58	North Harrison/SR-1652	Public	4Q	3/15/2004
62.83	Cornwallis Road	Public	4Q	9/9/2002
57.57	Ellis Road/SR-1954	Public	4Q	3/5/2004
55.5	Fayetteville Street/SR-1118	Public	4Q	7/31/2003
55.45	Dillard Street	Public	4Q	3/26/2002
55.09	Blackwell/Corcan Street	Public	4Q	7/31/2003
53.76	Swift Avenue/SR-1322	Public	4Q	7/31/2003
53.21	Anderson Street	Public	4Q	9/16/2003
52.04	North LaSalle Street	Public	4Q	7/31/2003
31.64	Fifth St/NC-119	Public	4Q	3/18/2003
31.46	Third Street/SR-1962	Public	4Q	5/30/2003
29.83	Lake Latham Road/SR-1976	Public	4Q	9/19/2002
23.17	Washington Street/SR-1716	Public	4Q	2/28/2002
22.6	Queen Ann Street	Public	4Q	5/30/2003
21.86	Gilmer Street	Public	4Q	3/10/2003
21.36	Main Street	Public	4Q	11/18/2002
20.63	Elmira Street/SR-1530	Public	4Q	5/28/2003
17.26	Oak Avenue/SR-1323	Public	4Q	5/30/2003
16.73	Williamson Avenue/SR-1301	Public	4Q	8/14/2002
3.01	Franklin Blouvardd/SR-3005	Public	4Q	8/19/2002
2.05	Holts Chapel Road	Public	4Q	3/14/2006
1.83	North English Street	Public	4Q	5/30/2003
0.67	South Dudley Street	Public	4Q	2/25/2003
284.1	South Elm Street	Public	4Q	7/28/2000
300.17	West Point Avenue	Public	4Q	2/28/2006
317.99	East 15th Avenue	Public	4Q	6/25/2002
318.68	Prospect Drive	Public	4Q	2/9/2000
333.28	Henderson Street	Public	4Q	4/5/2004
349.1	East 1st Street/ SR-1706	Public	4Q	2/24/2003
352.72	Winecoff School Road/ SR-1790	Public	4Q	5/27/2003
361.5	Pharr Hill Road/ SR-1158	Public	4Q	1/16/2003
362.88	Shamrock Road/ SR-1160	Public	4Q	10/13/2004
370.71	Hickory Grove Road/ SR-2853	Public	4Q	8/5/1999
374.87	East 36th Street	Public	4Q	5/16/2000

Long Gate Arm

The longer gate arms systems cover at least three quarters of the roadway. Tests at the Orr Road Crossing in Charlotte were conducted by NC DOT to evaluate the effectiveness of longer gate arms to reduce the drivers' ability to run around the gates (see Figure 6). A total of three tests were conducted. The first test gathered driver violation data before treatment was installed. The second test gathered posttreatment violation after data of the effect of long arm gates and showed a 67 percent reduction of crossing violations. A third test gathering "after" data on long gate arms was conducted at Orr Road a year after the first test to determine if the long gate arms retain their effectiveness. The results from the third test showed an even higher reduction of 84 percent in crossing violations compared with pretreatment "before" numbers. Longer gate arms are being used in conjunction with traffic channelization devices, but not where they would block a street or driveway intersection close to the crossing. Table 3 lists each crossing that was upgraded with Long Gate Arm.

Figure 6. Longer Arm Gate at Orr Road, Charlotte, NC

Table 3. Long Gates Arm Completed Through September 2004

Milepost	Road Name	Type Crossing	Upgrade	Construction Date
159.94	Beryl Road	Public	LG	5/24/2001
161.33	Powell Drive	Public	LG	4/19/2001
162.42	Nowell Road/SR-1657	Public	LG	9/10/2001
67.02	McCrimmon PKWY/SR-1635	Public	LG	10/17/2001
66.5	Barbee Road/SR-1706	Public	LG	10/3/2001
65.29	Church Street/SR-1980	Public	LG	10/3/2001
64.57	Hopson Road	Public	LG	10/3/2001
61.8	Lbm Access Road	Public	LG	2/28/2002
59.28	Wrenn Road/SR-1955	Public	LG	10/3/2001
58.98	Glover Road/SR-1940	Public	LG	10/17/2001
56.7	Driver Street	Public	LG	3/1/2004
56.4	Plum Street	Public	LG	3/5/2004
55.9	Ramseur Street	Public	LG	5/20/2004
54.2	Buchanan Road	Public	LG	7/9/2003
50.2	Neal Road	Public	LG	10/17/2001
47.07	Mt. Herman Church/SR-1713	Public	LG	1/8/2002
46.28	University Station/SR-1712	Public	LG	1/8/2002
41.2	Fairbault Lane/SR-1149	Public	LG	1/8/2002
37.31	Mt. Willing Road/SR-1120	Public	LG	1/16/2002
35.69	Redman Crossing/SR-1399	Public	LG	1/9/2002
34.11	Buckhorn Road/SR-1114	Public	LG	3/17/2003
32.79	Mattress Factory/SR-1402	Public	LG	3/17/2003
31.56	Fourth Street	Public	LG	3/13/2003
30.69	Moore Road/SR-1965	Public	LG	3/11/2003
29.36	Gibson Road/SR1940	Public	LG	11/4/2002
26.02	Stone Street/SR-1935	Public	LG	1/9/2002
23.67	Pomeroy Street/SR-1719	Public	LG	12/3/2001
19.43	South Glenn Raven/SR-1523	Public	LG	4/9/2002
19.21	Lakeview Drive/SR-1349	Public	LG	1/9/2002
18.16	Gilliam Road/SR-1342	Public	LG	2/12/2002
16.36	Church Street	Public	LG	8/14/2002
15.87	Cook Road/SR-1311	Public	LG	1/23/2002
15.51	Huffines Street/SR-1310	Public	LG	1/23/2002
14.87	Springwood Avenue/SR-2748	Public	LG	5/30/2003
14.42	East Joyner Street	Public	LG	5/30/2003
13.67	Power Line Road/SR-2763	Public	LG	1/23/2002
12.81	Wagoner Road/SR-2724	Public	LG	3/3/2003
11.44	Cullen Road/SR-2801	Public	LG	2/26/2003
9.09	Carmon Road/SR-2755	Public	LG	11/5/2001
8.02	McLeansville Road/SR-2819	Public	LG	5/30/2003
7.6	Frieden Church/SR-2746	Public	LG	11/5/2001
4.92	Wagoner Bend Road/SR-3040	Public	LG	9/26/2001
4.54	Buchanan Church Road/SR-3028	Public	LG	11/5/2001
3.49	O'Ferrell Street/SR-3022	Public	LG	6/27/2006
1.45	Gillespie Street	Public	LG	11/4/2002

335.2	Klumac Road/ SR-2541	Public	LG	9/13/2000
346.82	East 29th Street	Public	LG	10/8/2001
367	Stroup Farm Road	Public	LG	10/28/1997
372.19	Orr Road	Public	LG	10/28/1997

Traffic Channelization Devices

Although the installation of flashing lights and gates reduces the likelihood of a collision by 75 percent [7], it does not eliminate them. Because the deployment of these devices does not necessarily prevent all crossing collisions, FRA and its departmental partners are pursuing alternative means and innovative methods to improve their effectiveness. The use of traffic channelization devices or medians in advance of a gated crossing makes it much more difficult for a motorist to go around lowered gates. Traffic channelization devices consist of a prefabricated mountable island made of a composite material painted yellow. Reflectorized paddle delineators or tubes, 24-inches high with yellow and black stripes, are mounted on the curb barrier. To accommodate wide loads, such as mobile homes, all delineators are required to bend and return to their upright position. The paddle delineators are mounted on a flexible rubber boot, which allows them to return to their original vertical position after being impacted by vehicles. Concrete island median barriers are also used with the yellow striped delineators mounted to them.

NC DOT believes that traffic channelization devices, which cost on average about $10,000 per location, have proven to be a low-cost investment with a high rate of return in safety at crossings [7] (see Figure 7). Considering their low maintenance cost and high effectiveness, traffic channelization devices are preferred by NC DOT to deter violators at crossings. On average, such treatments reduce the number of motorist violations by an additional 75 percent [7]. Table 4 list each crossing that was upgraded with traffic channelization and median barrier devices.

Figure 7. Traffic Channelization Device at Turner Road, Charlotte, NC

Table 4. Traffic Channelization Completed Through September 2004

Milepost	Road Name	Type Crossing	Upgrade	Construction Date
164.47	Ready Creek Road	Public	MB	4/24/2001
60.27	Ellis Road/SR-1954	Public	MB	5/14/2002
17.91	York Road	Public	MB	5/30/2003
10.74	Colony Road/SR-2800	Public	MB	1/9/2002
296.99	Pendleton Street	Public	MB	8/7/1997
311.18	Upper Lake Road./ SR-2024	Public	MB	2/12/2002
313.09	Turner Road/ SR-2005	Public	MB	2/12/2002
317.21	East 7th Avenue	Public	MB	6/13/2001
332.94	East 11th Street	Public	MB	9/19/2000
333.77	East Council Street	Public	MB	3/17/2004
334.2	East Monroe Street/ SR-1703	Public	MB	9/19/2000
338.66	Peeler Road/ SR-2538	Public	MB	2/11/2002
340.07	Webb Road/ SR-3490 (SR-1500)	Public	MB	2/11/2002
347.28	East 22nd Street/ SR-1254	Public	MB	10/11/2000
356.3	Corban Avenue	Public	MB	2/11/2002
363.95	Hickory Ridge Road/ SR-1138	Public	MB	5/17/2000
365.24	Caldwell Road/ SR-1173	Public	MB	6/1/1998
374.02	Sugar Creek Road	Public	MB	2/11/2002

Signs, Pavement Markings and Health Monitoring

Sign and pavement marking upgrades were determined based on the condition of the existing markings at crossings. Signs advising the motorist where to stop for activated crossing signals, such as in Figure 8, were placed on all crossings receiving treatment. Another sign placed at all crossings that receive treatment on the Sealed Corridor program provided a 1-800 emergency phone number that motorists can use to call the railroad to report any malfunctions of the crossing signals.

An intelligent signal monitoring system was placed at some treated public crossing to notify railroad personnel about malfunctions, and to improve the reliability of warning devices. A roadway equipped with four-quadrant gates is very hard to go around when the gates are activated; therefore, the devices have a very high level of reliability and performance. Table 5 lists each crossing that was upgraded with health monitoring devices.

Figure 8. Grade Crossing Sign and Emergency Number

Table 5. Health Monitoring Completed Through September 2004

Milepost	Road Name	Type Crossing	Upgrade	Construction Date
294.25	Oakdale Mill Road./ SR-1352	Public	HM	1/10/2001
295.76	Scientific Street/ SR-1332	Public	HM	8/8/2000
296.99	Pendleton Street	Public	HM	8/7/1997
300.73	Prospect Avenue	Public	HM	11/4/1999
305	Turner Street/ SR-2165	Public	HM	3/15/2001
305.97	Salem Street/ NC-109	Public	HM	4/12/2000
306.11	Fisher Ferry Road	Public	HM	2/3/2000
311.18	Upper Lake Road/ SR-2024	Public	HM	2/12/2002
311.99	Lower Lake Road/ SR-2020	Public	HM	10/12/2000
317.21	East 7th Avenue	Public	HM	6/13/2001
324.29	SR-1135	Public	HM	2/12/2002
330.18	Long Ferry Rd/SR-2120	Public	HM	10/11/2000
332.94	East 11th Street	Public	HM	9/19/2000
333.57	East Kerr Street/ SR-2052	Public	HM	2/22/2002
333.77	East Council Street	Public	HM	3/17/2004
334.11	East Horah Street	Public	HM	1/21/2002
334.2	East Monroe Street/ SR-1703	Public	HM	9/19/2000
336.24	Henderson Grove Road./ SR-1526	Public	HM	11/8/2000
337.98	Peach Orchard Road./ SR-2539	Public	HM	3/13/2001
338.66	Peeler Road./ SR-2538	Public	HM	2/11/2002
340.07	Webb Road./ SR-3490 (SR-1500)	Public	HM	2/11/2002
340.96	Mt. Hope Church Road./ SR-1505	Public	HM	10/24/2001
342.86	East Church Street/ SR-1337	Public	HM	2/21/2001
343.2	East Centerview Drive	Public	HM	2/26/2001
343.94	West Thom Street/ SR-1232	Public	HM	2/26/2001
344.44	Eudy Road./ SR-1220	Public	HM	2/26/2001
345.61	East Ryder Avenue/ SR-1210	Public	HM	4/16/2003
345.69	East Mills Street	Public	HM	6/12/2001
347.28	East 22nd St./ SR-1254	Public	HM	10/11/2000
347.55	East 18th Street	Public	HM	7/23/2001
355.12	McGill Avenue	Public	HM	2/22/2000
356.3	Corban Avenue	Public	HM	2/11/2002
363.95	Hickory Ridge Road./ SR-1138	Public	HM	5/17/2000
364.12	Robinson Church Road./ SR-1166	Public	HM	5/17/2000
365.62	Milbrook Road./ SR-1182	Public	HM	10/29/2001
374.02	Sugar Creek Road.	Public	HM	2/11/2002
374.39	West Craighead Road.	Public	HM	3/17/1995

2 Method and Results

The Volpe Center conducted a site visit along the corridor to captured pictures of all crossings with or without treatment and also examined various databases including the FRA RAIRS update database, NC DOT Collision reports, police reports, and newspaper articles by using two different methods to estimate the number of lives saved and the potential for sustainability of a reduction in collisions through 2010. The Volpe Center teams created a database with the following categories for each crossing: crossing ID, milepost, road name, location, county, phase, public versus private crossings, gated versus passive crossings, type of treatment, status of treatment, and the completion date.

The first method used by the Volpe Center was the fatal crash analysis to calculate the differences between the annual/monthly fatality rates, based on actual experience at the improved crossings, before and after the improvements at each crossing. The differences were multiplied by the number of years/months that transpired through December 2004 since each improvement was made. The sum of these results was then calculated over all of the crossings that were improved.

The second method used was the modified U.S. DOT APF, which recognizes the probabilistic nature of grade crossing fatalities and relies on a combination of actual experience at the improved crossings and an extensive database of experience at similar crossings nationwide. The formula was used to estimate the annual fatality rate at each crossing before and after each improvement.

To estimate future accident reduction rates, the second of the stated methods was used to ensure increases in train and vehicle exposure over time and were considered in the analysis. By 2010, it is projected by NC DOT that the vehicle traffic volume and the frequency and speed of trains will increase. The second method is capable of taking these factors into account under full build, and no build conditions.

2.1 Crash Analysis Method and Result

The ability to review the before and after conditions of highway-rail grade crossings with fatal crashes is very useful in determining the benefits of the treatment used. Thirty-three grade crossings were analyzed to assess the number of fatalities that occurred in the pretreatment conditions and lives saved under the posttreatment condition through December 2004 along the Sealed Corridor. All crashes from 1987 through December 2004 were considered for the Fatal Crash analysis, but only crossings with fatal crashes were selected. From 1987 to the time the treatment took place, a fatality-rate was calculated by using the crash history for each of the crossings by holding the warning device constant for pretreatment period. From the time of the Sealed Corridor treatment through December 2004, actual experience was compared with the pretreatment fatality rate to determine the potential lives saved. Between 1987 and 2004, 282 crashes occurred on the corridor resulting in 74 injuries and 55 fatalities. Table 6 shows the historical fatalities for 5 years before treatment and illustrates an average of 2.75 fatalities per year during the pretreatment condition.

Table 6. Five-Year Fatal Crash Analysis Pretreatment Fatalities

Improvement	Crossing Name	Mile Post	Historical Fatalities (five years prior to Treatment)
MB/HM	Hickory Ridge Road	370.71	0
MB/HM	Corban Avenue	356.30	1
MB/HM	Ellis Road	57.57	1
LG/MB/HM	E. 22nd St./ SR-1254	347.28	1
LG/MB/HM	East Council Street	333.77	0
LG/HM	East Centerview Drive	343.2	0
LG/HM	East Mills Street	345.69	1
LG/HM	East 18th Street	347.55	0
LG	Lower Lake Road	311.99	0
LG	Powell Drive	161.33	0
LG	Hopson Road	64.57	0
LG	Plum Street	56.4	0
LG	Mt. Herman Church Road	47.07	0
LG	Fairbault Lane	41.20	0
LG	Randhurst Road	7.60	0
CL	C Avenue	335.40	1
CL	East 13th Avenue	317.84	0
CL	Ebenezer Road	348.06	0
CL	Lumber Street	334.85	2
CL	Knox Street	334.45	0
CL	Bashford Road	163.10	4
CL	Ashe Street	68.66	0
CL	Turner Crossing(SR-2841)	370.21	1
4Q/MB/HM	Sugar Creek Street	374.02	0
4Q/MB/HM	East 11th Street	332.94	0
4Q/HM	Salem Street/ NC-109	305.97	0
4Q/HM	West Craighead Road	374.39	0
4Q/HM	East Kerr Street/ SR-2052	333.57	0
4Q	Henderson Street	336.24	0
4Q	Winecoff School Road	352.72	0
4Q	Main Street	21.36	0
4Q	Fifth Street	31.64	0
4Q	Gilmer Street	21.86	0
Average Fatalities per year			2.75

Table 7 shows the summary results of potential lives saved Analysis by warning device type. It also illustrates the development of the fatal crash rate and the distribution of that rate over the posttreatment time period to obtain the number of lives saved as a result of the treatment. The fatality rate was calculated by dividing the number of pretreatment fatalities for each crossing from 1987 through when it was treated by the pretreatment time period. The fatal crash rate for each crossing was then multiplied by the posttreatment time period. Any posttreatment fatalities were subtracted from the estimated lives saved. The final calculation determined the lives saved through December 2004 for each crossing.

As shown in Table 7, crossings with closure for treatment had a total of 15 fatalities before the crossing was closed during in average time of 142 months and no fatalities after treatment during in average time of 68 months. Crossings equipped with four-quadrant gates, median barriers, and health monitoring had a total of 14 fatalities before treatment and 2 fatalities after treatment. Crossings treated with long gates, median barriers, and health monitoring had a total of 16 fatalities before treatment and only one fatality after treatment. Finally, crossings with median barriers and health monitoring had only three fatalities before treatment and no fatalities after treatment. Closure and grade separation were shown to be the most effective treatments at grade crossings, each with 100 percent effectiveness. Four-quadrant gates with median barriers showed 92 percent effectiveness, median barriers an 80 percent effectiveness, and long gate arm showed a 75 percent effectiveness. Overall, the analysis estimated a total of 19 lives potentially saved.

Tables 8–15 summarize the results broken down by warning device type for each crossing in this case study. Figure 9 illustrates the fatal crash analysis of lives saved per crossing through December 2004. As previously documented, the Sealed Corridor project Phase I, II, and III encompassed a total of 208 crossings. At the time of this study, 189 had been treated and the remaining 19 were in the design stage or awaiting construction.

Table 7. Summary of Lives Saved Analysis Results by Warning Device Type

Phase I, II and III	Pretreatment		Posttreatment		
Warning Device Improvement	Fatalities	Ave Time Frame (Months)	Fatalities	Ave Time Frame (Months)	Analysis of Lives Saved
Closure Subtotal	15	142	0	68	8.727
4-Quadrant Gate Subtotal	14	139	2	49	6.013
Long Gate Subtotal	16	135	1	36	4.012
Median Barrier Subtotal	3	157	0	51	0.988
Totals	48		3		19.74

Table 8. Fatal Crash Analysis Results for Closure

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
CL	C Avenue	335.40	1	116	0	88	0.759
CL	E. 13th Ave	317.84	1	166	0	38	0.229
CL	Ebenezer Rd	348.06	1	159	0	57	0.358
CL	Lumber Street	334.85	3	145	0	71	1.469
CL	Knox Street	334.45	3	124	0	92	2.226
CL	Bashford Rd	163.10	4	172	0	33	0.767
CL	Ashe Street	68.66	1	109	0	95	0.872
CL	Turner Xing(SR-2841)	370.21	1	63	0	129	2.048
Subtotal			15		0		8.727

Table 9. Fatal Crash Analysis Results for 4-Quandrant gate

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
4Q	Henderson St	336.24	4	93	0	49	2.108
4Q	Winecoff School Rd	352.72	1	185	0	17	0.092
4Q	Main St	21.36	1	179	0	25	0.140
4Q	Fifth St	31.64	0	147	1	21	-1.000
4Q	Gilmer St	21.86	1	185	0	19	0.103
Subtotal			7		1		1.442

Table 10. Fatal Crash Analysis Results for 4-Quad, Median Barrier and Health Monitoring

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
4Q/MB/HM	Sugar Creek St	374.02	1	104	0	112	1.077
4Q/MB/HM	E. 11th St.	332.94	1	153	0	39	0.255
Subtotal			2		0		1.332

Table 11. Fatal Crash Analysis Results for 4-Quadrant and Median Barrier

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
4Q/HM	Salem St./ NC-109	305.97	0	148	1	56	-1.000
4Q/HM	W. Craighead Rd	374.39	3	99	0	117	3.545
4Q/HM	E. Kerr St./ SR-2052	333.57	2	98	0	34	0.694
Subtotal			5				3.239

Table 12. Fatal Crash Analysis Results for Long Gate and Health Monitoring

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
LG/HM	E. Centerview Dr.	343.2	1	159	0	46	0.289
LG/HM	E. Mills St.	345.69	2	159	0	42	0.528
LG/HM	E. 18th St.	347.55	1	163	0	41	0.252
Subtotal			4				1.069

Table 13. Fatal Crash Analysis Results for Long Gate

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
CL	C Avenue	335.40	1	116	0	88	0.759
CL	E. 13th Ave	317.84	1	166	0	38	0.229
CL	Ebenezer Rd	348.06	1	159	0	57	0.358
CL	Lumber Street	334.85	3	145	0	71	1.469
CL	Knox Street	334.45	3	124	0	92	2.226
CL	Bashford Rd	163.10	4	172	0	33	0.767
CL	Ashe Street	68.66	1	109	0	95	0.872
CL	Turner Xing(SR-2841)	370.21	1	63	0	129	2.048
Subtotal			15		0		8.727

Table 14. Fatal Crash Analysis Results for Median Barrier and Health Monitoring

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	
MB/HM	Hickory Ridge Rd	370.71	1	149	0	55	0.369
MB/HM	Corban Avenue	356.30	1	150	0	66	0.440
MB/HM	Ellis Rd	57.57	1	173	0	31	0.179
subtotal			3		0		0.988

Table 15. Fatal Crash Analysis Results for Long Gate, Median Barrier, and Heath Monitoring

Phase I, II, and III			Pre-Treatment		Post-Treatment		
Improvement	Crossing Name	Mile Post	Fatalities	Time Frame (Months)	Fatalities	Time Frame (Months)	Analysis of Lives Saved
LG/MB/HM	E. 22nd St./ SR-1254	347.28	1	147	0	50	0.340
LG/MB/HM	E. Council St.	333.77	1	111	0	9	0.081
Subtotal			2				0.421

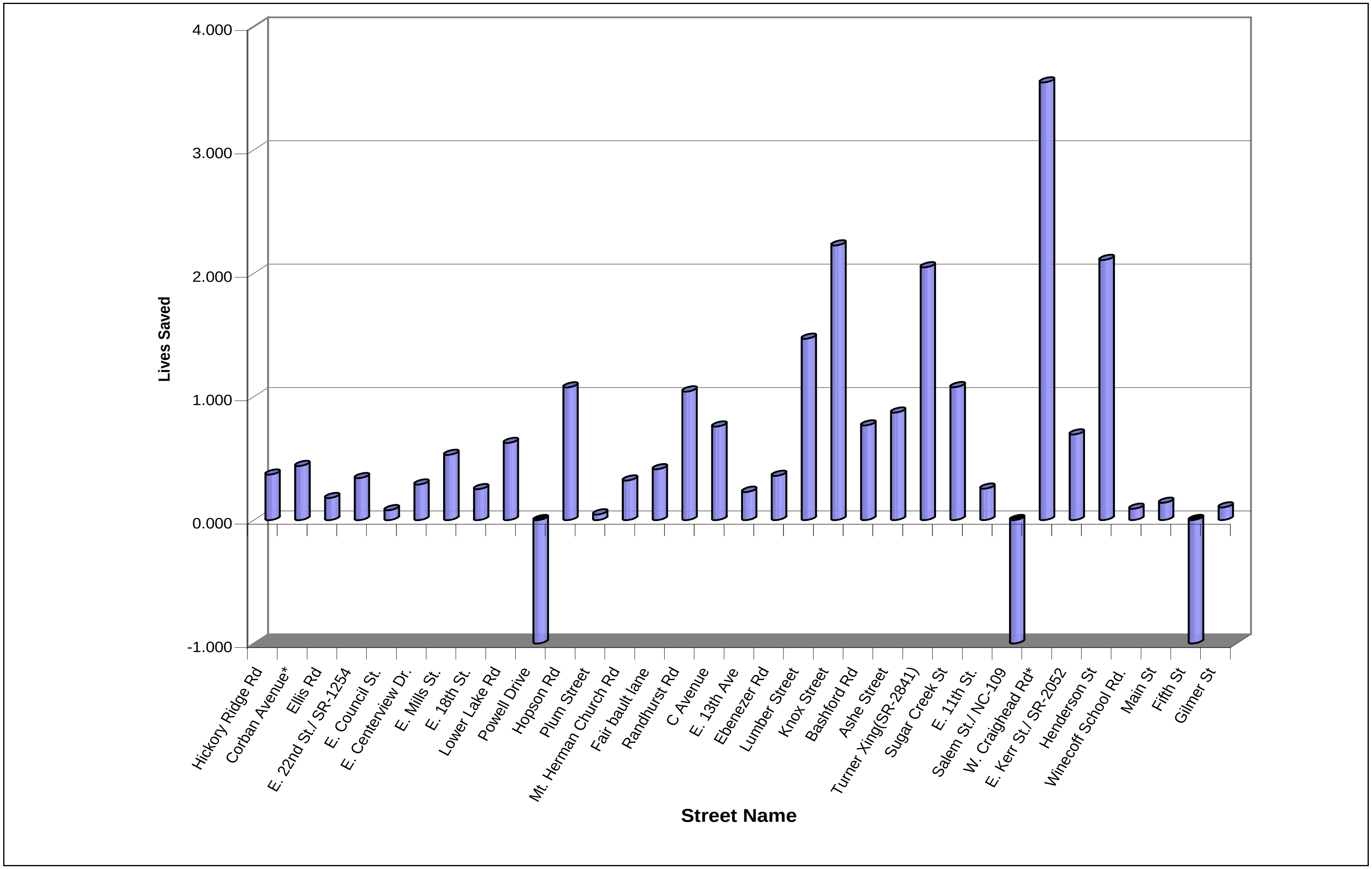

Figure 9. Fatal Crash Analysis of Lives Saved Per Crossing

2.2 Fatal Accident Prediction Method and Result

The U.S. DOT Fatal APF was used as the baseline to calculate risk in the corridor. The DOT standard formula developed by the Volpe Center has many variables to predict the severity of a crash at a grade crossing. The formula handles high-speed rail and additional enhancements and is based on the U.S. DOT Fatal APF with updates to the collision severity portion [4, 5, 6]. To determine accident probability, the study used the standard U.S. DOT APF weighted with actual crash history. To obtain accident rate estimates for improved crossings, an effectiveness rate was applied to the baseline accident prediction result. To differentiate between freight and passenger train operations and to account for higher train speeds, the severity calculation from the APF was not used. Instead, the independent severity model described in the Empire Corridor Risk Assessment Study was used. This severity model includes the use of vehicle mix in the determination of severity in passenger train operations as one of its attributes.

A few variables used the crossing’s characteristics obtained from the FRA AAR Crossing Inventory and NC DOT inventory files such as number of tracks, number of train movements, and types of crossing warning devices. Other variables used the FRA Highway-Rail Grade Crossing Accident/Incident Reports for crossing crash history. Individual crossing information was used to help determine the final risk at each crossing.

The APF is dominated by the exposure index term that combines the average daily traffic count and the number of trains. Risk is the product of the probability of an event occurring and the severity of the event. Probability is defined as the predicted number of grade crossing crashes along a set of crossings per year. Severity is defined in this report in terms of fatalities per collision, either to train or motor vehicle occupants. Risk is presented as the number of predicted fatalities per year at the set of crossings.

The crash history factor is the collision history of the crossing of the previous 5-year period of time. Many states regularly use the APF to help prioritize grade crossings for improvements. The validity of the APF is very reliant on the previous 5-year collision history. Changes in crossing characteristics can affect the result of the modeled prediction, so the most accurate data available is used. The Rail-Highway Crossing Resource Allocation Procedure User’s Guide recommends that data older than 5 years may be misleading because of physical changes that could have occurred at the crossing. Therefore, each year’s calculated risk is influenced by only the past 5 years of crash history. The risk is a weighted average of the crossing characteristics and the historical crashes at the crossing. This factor adjusts the final probability of a fatal crash based on historical collision information at the crossing.

A modified APF was developed to predict the future fatalities of the treated crossings through 2010. To be consistent with the fatal crash analysis, the modified APF estimated the risk for 5-year intervals for both pre- and posttreatment time periods for warning device effectiveness calculations. It is populated with year-by-year input variables from both the FRA Inventory and NC DOT data. The model then calculates the effect of the 5-year actual incident history for prediction of future incidents. A 2 percent per year growth in annual average daily traffic (AADT) and train frequency was assumed in the model after the year 2004, and train speeds were assumed to increase to 110 mph for the year 2010 only.

2.2.1 Risk Formula Result with Fatal Incidents

The risk-based fatalities for the pretreatment condition were calculated for the 33 grade crossings analyzed with fatal crash histories and are shown in Table 16. The pretreatment risk in fatalities was determined by summing the annual risk for the 5 years before the date of the grade crossing treatment. As shown in Table 16, the risk-based methodology calculated the total number of fatalities in the 5-year pretreatment condition to be 4.07 fatalities, or a rate of 0.81 fatalities per year.

The lives saved for the same set of crossings was determined from formula predictions. The posttreatment risk was calculated by using the 5-future years from the date of the grade crossing improvement. The risk-based lives saved for the posttreatment condition for the 33 crossings are shown in Table 17. The posttreatment risk in fatalities was determined by summing the annual risk for the 5 years after the date of the grade crossing treatment. As shown in Table 17, the risk-based methodology calculated total fatalities in the 5-year posttreatment condition of 1.94, or a rate of 0.39 fatalities per year. The difference between the pre- and posttreatment risk also provided in Table 17 and illustrates the yearly lives saved at each crossing.

Therefore, the calculated lives saved using the risk-based 5-year before and after condition indicate that approximately 2.13 lives have been saved, which is equivalent to 0.43 lives saved per year. The results for both methods, the fatal crash analysis and the modified U.S. DOT formula, have trend results indicating a reduction of risk.

Table 16. Risk-Based – Predicted "Lives Lost" Under Pretreatment Conditions

Improvement	Crossing Name	Mile Post	Pre-treatment Risk (Fatalities / 5 yrs)
MB/HM	Hickory Ridge Rd	370.71	0.08
MB/HM	Corban Avenue	356.30	0.13
MB/HM	Ellis Rd	57.57	0.21
LG/MB/HM	E. 22nd St./ SR-1254	347.28	0.07
LG/MB/HM	E. Council St.	333.77	0.03
LG/HM	E. Centerview Dr.	343.2	0.07
LG/HM	E. Mills St.	345.69	0.15
LG/HM	E. 18th St.	347.55	0.15
LG	Lower Lake Rd	311.99	0.10
LG	Powell Drive	161.33	0.08
LG	Hopson Rd	64.57	0.02
LG	Plum Street	56.4	0.12
LG	Mt. Herman Church Rd	47.07	0.04
LG	Fair bault lane	41.20	0.02
LG	Randhurst Rd	7.60	0.06
CL	C Avenue	335.40	0.21
CL	E. 13th Ave	317.84	0.02
CL	Ebenezer Rd	348.06	0.05
CL	Lumber Street	334.85	0.38
CL	Knox Street	334.45	0.05
CL	Bashford Rd	163.10	0.41
CL	Ashe Street	68.66	0.11
CL	Turner Xing(SR-2841)	370.21	0.14
4Q/MB/HM	Sugar Creek St	374.02	0.15
4Q/MB/HM	E. 11th St.	332.94	0.04
4Q/HM	Salem St./ NC-109	305.97	0.04
4Q/HM	W. Craighead Rd	374.39	0.35
4Q/HM	E. Kerr St./ SR-2052	333.57	0.10
4Q	Henderson St	336.24	0.17
4Q	Winecoff School Rd.	352.72	0.34
4Q	Main St	21.36	0.07
4Q	Fifth St	31.64	0.05
4Q	Gilmer St	21.86	0.06
Total 5 yr Pre-treatment Fatalities			**4.07**
Total Pre-treatment Fatalities / Yr			**0.81**

Table 17. Predicted Lives Saved for treated Crossings over the Posttreatment 5-Year Period

Improvement	Crossing Name	Pre-treatment Risk (Fatalities / 5 yrs)	Post-treatment Risk (Fatalities / 5 yrs)	Predicted "Lives Saved" for five years After Treatment
MB/HM	Hickory Ridge Rd	0.08	0.05	0.03
MB/HM	Corban Avenue	0.13	0.10	0.03
MB/HM	Ellis Rd	0.21	0.14	0.07
LG/MB/HM	E. 22nd St./ SR-1254	0.07	0.05	0.02
LG/MB/HM	E. Council St.	0.03	0.03	0.00
LG/HM	E. Centerview Dr.	0.07	0.05	0.02
LG/HM	E. Mills St.	0.15	0.05	0.10
LG/HM	E. 18th St.	0.15	0.07	0.08
LG	Lower Lake Rd	0.10	0.02	0.08
LG	Powell Drive	0.08	0.11	-0.03
LG	Hopson Rd	0.02	0.01	0.01
LG	Plum Street	0.12	0.04	0.08
LG	Mt. Herman Church Rd	0.04	0.03	0.01
LG	Fair bault lane	0.02	0.02	0.00
LG	Randhurst Rd	0.06	0.02	0.04
CL	C Avenue	0.21	0.00	0.21
CL	E. 13th Ave	0.02	0.00	0.02
CL	Ebenezer Rd	0.05	0.00	0.05
CL	Lumber Street	0.38	0.00	0.38
CL	Knox Street	0.05	0.00	0.05
CL	Bashford Rd	0.41	0.00	0.41
CL	Ashe Street	0.11	0.00	0.11
CL	Turner Xing(SR-2841)	0.14	0.00	0.14
4Q/MB/HM	Sugar Creek St	0.15	0.19	-0.04
4Q/MB/HM	E. 11th St.	0.04	0.02	0.02
4Q/HM	Salem St./ NC-109	0.04	0.06	-0.02
4Q/HM	W. Craighead Rd	0.35	0.25	0.10
4Q/HM	E. Kerr St./ SR-2052	0.10	0.08	0.02
4Q	Henderson St	0.17	0.14	0.03
4Q	Winecoff School Rd.	0.34	0.13	0.21
4Q	Main St	0.07	0.11	-0.04
4Q	Fifth St	0.05	0.12	-0.07
4Q	Gilmer St	0.06	0.05	0.01
		4.07	**1.94**	
		Predicted Average 5 Yr "Lives Saved"		**2.13**
		Pridicted Average "Lives Saved" / Yr		**0.43**

2.2.2 Total Sealed Corridor Risk Formula Result

Figure 10 compares the risk along the Sealed Corridor for 1991 before any type of treatment was in place for all 208 crossings, and for 2004 for the entire Sealed Corridor (189 treated plus the 19 untreated crossings). The results show that between 1991 and 2004 the risk for the Sealed Corridor crossings was reduced by 50.9 percent, which is equivalent to 2.04 lives saved per year. The entire corridor risk, had it been completed by 2004, would have been reduced by an additional 6.4 percent.

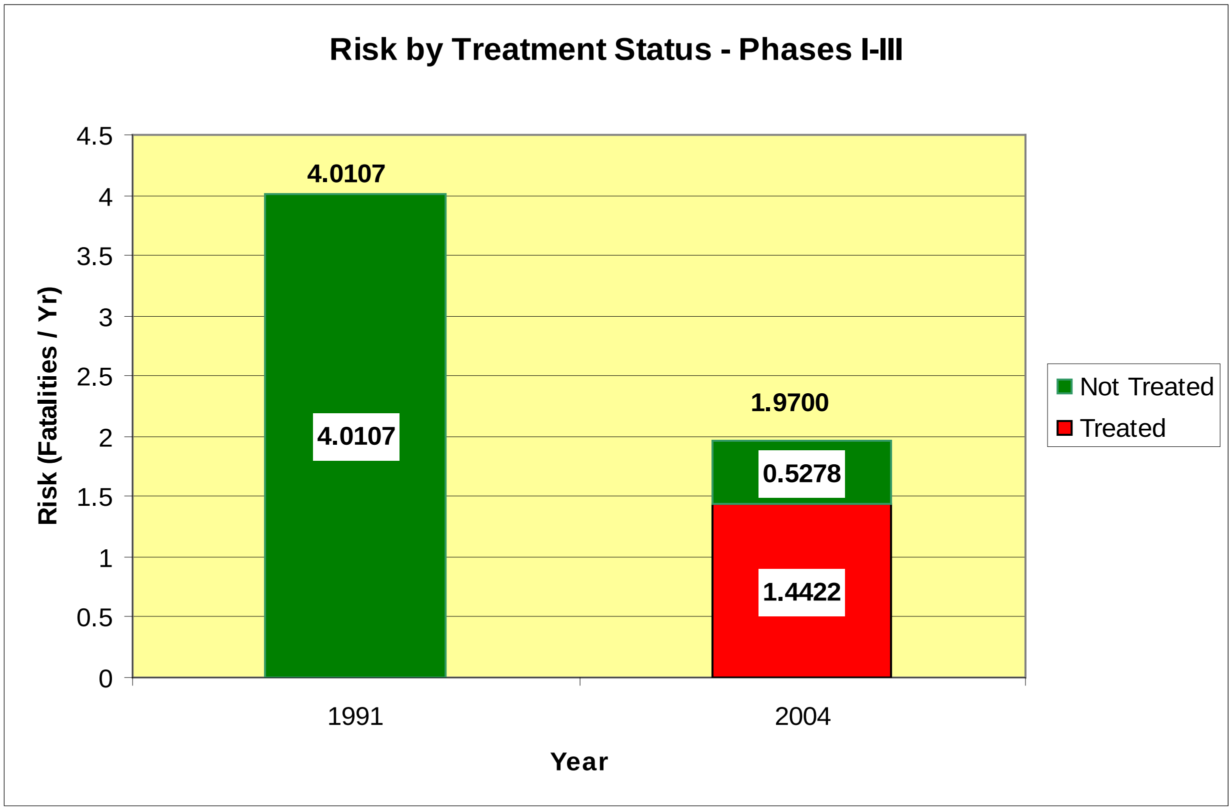

Figure 10. Corridor Risk for Phases I, II, and III

2.2.3 Projected Sealed Corridor Risk Formula Result in 2010

Figure 11 shows the projected risk for the entire Sealed Corridor in 2010 using the U.S. DOT fatal APF. The projected 2010 risk is 2.3 fatalities per year. The figure also indicates that the greatest proportion of this risk is to highway vehicle occupants. The change in risk of fatality to highway occupants from 1991 to 2004 is decreased by a substantial 51 percent and 43 percent from 1991 to 2010, even with increases in vehicle and train traffic.

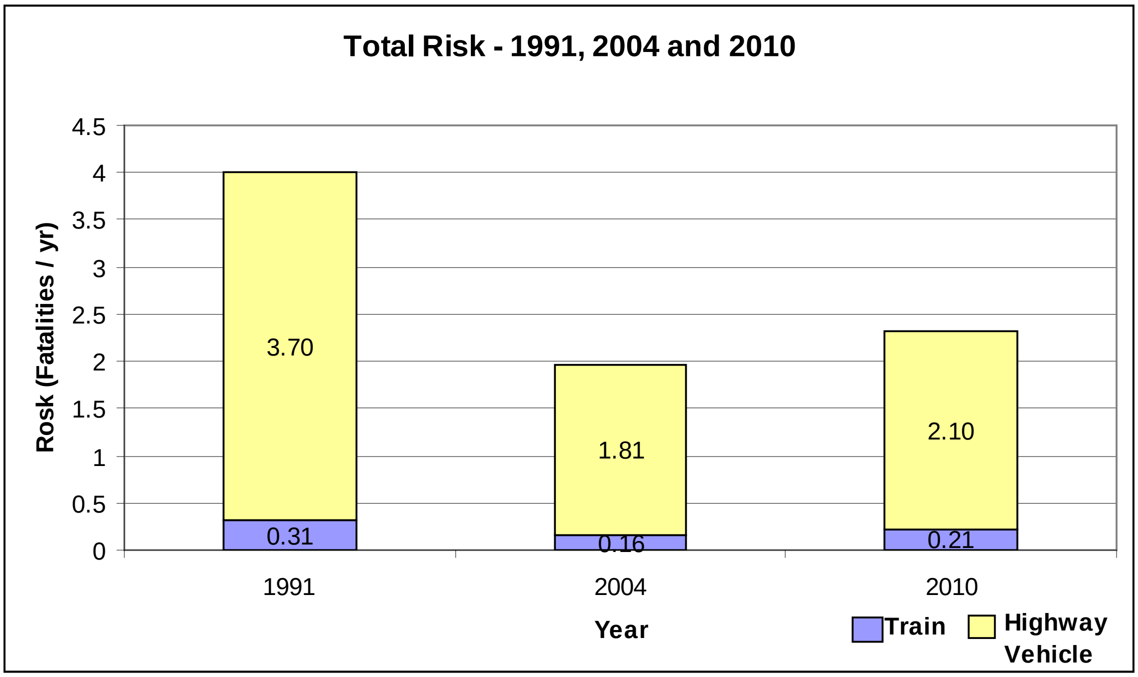

Figure 11. 1991, 2004, and 2010 Corridor Risk for Phases I, II, and III

2.2.4 Year 2010 Build and No-Build Results

Figure 12 shows the risk reduction through the year 2010 if no treatments were implemented on the Sealed Corridor with the speed increased to 110 mph and the risk reduction through the year 2010 for all treated crossings with speed increased to 110 mph.

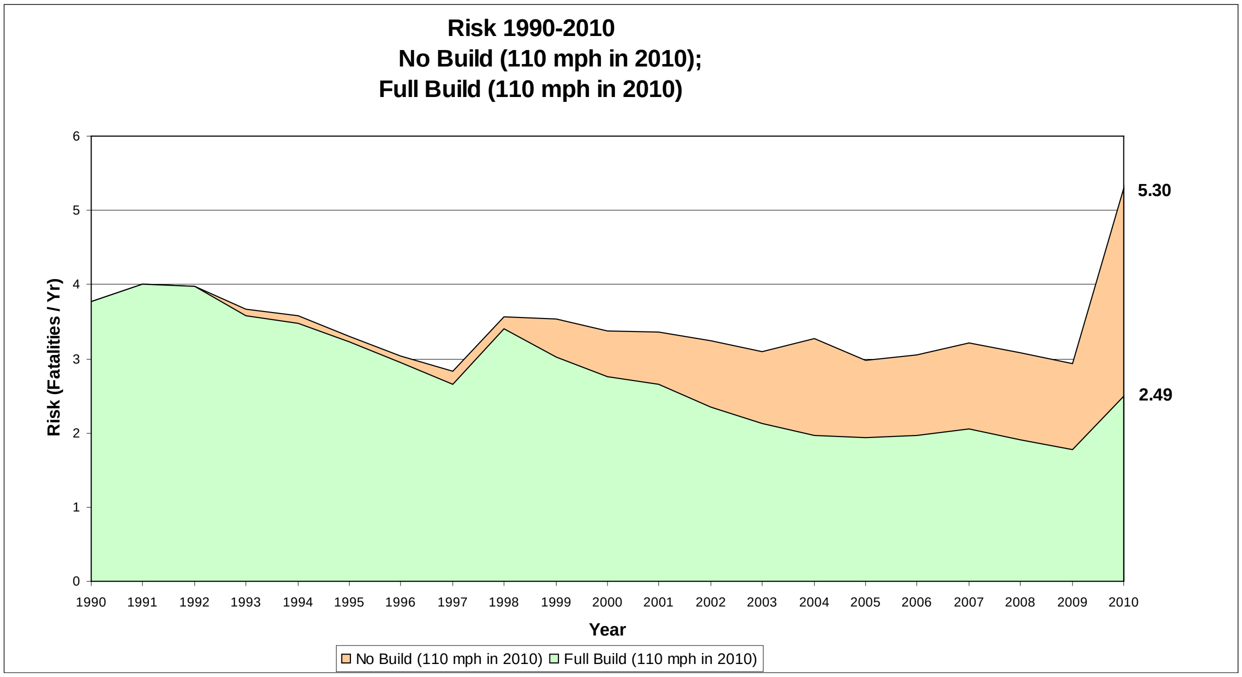

Figure 12. Risk Reduction through 2010 with Speed Increased to 110 mph

Figure 13 shows the risk reduction through the year 2010 if no treatments were implemented on the “Sealed” corridor with the speed increased to 79 mph, the risk reduction through the year 2010 for all treated crossings with speed increased to 79 mph, and the risk reduction through the year 2010 for all treated crossings with no speed increase.

For the treated crossings (Full Build 79 in 2010, and Full Build 110 in 2010) condition assumed all of the crossing treatments and enhancements were implemented as planned. For the 2010 all-treated crossings risk factor, the condition of the corridor in 2004 was projected for 2010 after application of modest growth factors. Because information about future trends and collision statistics were not available, certain assumptions were made. Year 2004 train volumes in the corridor were assumed to grow by two percent per year through 2010 and the train operating speed for 2010 for the corridor was assumed to increase to 79 mph and 110 mph respectively, year 2004 AADT was assumed to grow by a factor of two percent per year through 2010, and the Full Build scenario assumes a 2008 implementation date for all the grade crossing safety improvements. Closed and grade separated crossings had zero AADT growth applied. For collisions, the 2004 collision data were applied as a constant to the 2010 scenario. In 2010, two main tracks were used for the entire corridor as projected by the NC DOT.

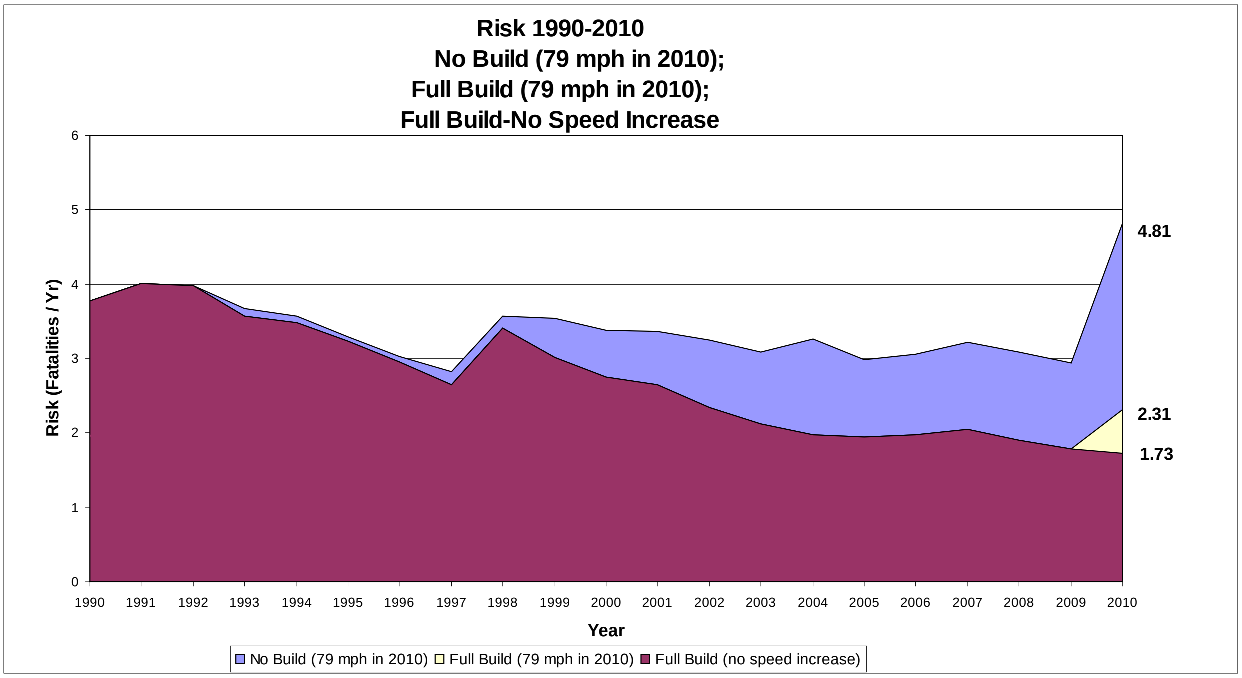

Figure 13. Risk Reduction through 2010 with Speed Increased to 79 mph and No Speed Increased

For the no-treatment (No Build 79 in 2010 and No Build 110 in 2010) condition, pre-implementation crossing warning devices were assumed to remain in place through 2010—no treatment or enhancements were applied to the crossing. The 2010 No Build scenario used pre-implementation AADT with a two-percent growth factor applied through 2010, and train speed for 2010 was assumed to increase to 79 mph and 110 mph respectively. The number of train movements was increased by two percent annually. For collision data, the last pre-implementation collision rate was used.

With the assumption of speed increase to 110 mph in the year 2010, the no build (without the application of enhanced grade crossing devices) condition shows an increase in risk of 2.8 fatalities per year more than the 2010 full build (all treated crossings) condition (5.30 versus 2.49). If speeds were increased to only 79 mph, the no build condition shows an increase in risk of 2.5 fatalities per year more than the full build (4.81 versus 2.31). Further analysis indicates an increase of 1.52 fatalities per year more than the 2010 full build condition, if no speed increase was to occur. By 2010, the fatality rate resulting from the full implementation of the entire Sealed Corridor would be 53 percent lower than if no implementation was executed and speed increase to 110 mph. The fatality rate would be 51.9 percent lower if the speeds increased to only 79 mph in 2010, and 46.7 percent lower with no increase in speed in 2010. This risk assessment, therefore, illustrates that the treatments and crossing enhancements made in the Sealed Corridor program have resulted in a benefit in lives saved through 2010 and will save even more lives for years thereafter.

3 Comparative Analysis (Old Versus New Results)

3.1 Phase I 2001 results

The Sealed Corridor project Phase I had a total of 100 crossings, but only 52 were treated and/or closed at the time of the first report [1]. The remaining 48 were in the design stage or were waiting for construction at the time. There were 154 crashes for all of the Phase I crossings from 1987 through December 2000. Ten grade crossings with fatal crashes were analyzed to assess the number of fatalities that occurred in the pretreatment conditions and to estimate lives saved under the posttreatment condition through December 2000. The results yielded an estimate of 5.8, or conservatively, five lives saved as a result of the 52 improvements implemented through December 2000. The risk-based fatalities for the pretreatment condition were calculated for the 10 grade crossings analyzed with fatal crash histories. The pretreatment risk in fatalities was determined by summing the annual risk for the 5 years before the date of the grade crossing treatment. The risk-based methodology calculated the total number of fatalities in the 5 year pretreatment condition to be 2.65 fatalities, or a rate of 0.53 fatalities per year.

The lives saved for the same set of crossings was determined from formula predictions. The posttreatment risk was calculated by using the 5-future years from the date of the grade crossing improvement. The posttreatment risk in fatalities was determined by summing the annual risk for the 5 years after the date of the grade crossing treatment. The risk-based methodology calculated the total number of fatalities in the 5-year posttreatment condition to be 0.72, or a rate of 0.14 fatalities per year. The calculated lives saved using the risk-based five year "before and after" conditions indicated approximately 1.95 lives have been saved. Therefore, the rate of lives saved is equivalent to 0.39 lives per year. The results for both methods, the fatal crash analysis and the modified U.S. DOT formula, have trend results indicating a reduction of risk.

Phase I risk for 1991 and 2000 for the 52 treated crossings and for the entire Phase I corridor (100 crossings) were compared. The results showed that between 1991 and 2000 the risk for the treated crossings was reduced by 84 percent or 1.3 lives saved per year. The entire Phase I risk, had it been completed by September 2000, would have been reduced by 80 percent for the same time period. This showed that a significant potential existed to reduce risk in the corridor even though the crossings with the highest risk were addressed first. The projected 2010 risk for Phase I was 1.8 fatalities per year. The change of risk to highway occupants from 1991 to 2000 would decreased by a substantial 43 percent even with increases in vehicle and train traffic.

3.2 Phase I, II, and III Results

The second part of the Sealed Corridor project which included the remaining 48 crossings from Phase I, and all the crossings from phase II and III, covered a total of 208 crossings, 189 of which had been treated and 19 were in the process of being treated at the time of this report. There were 282 crashes for all of the Phase I, II, and II crossings from 1987 through December 2004. A total of 33 grade crossings with fatal crashes were analyzed to assess the number of fatalities that occurred in the pretreatment conditions and to estimate lives saved under the posttreatment condition through December 2004. The results yielded an estimate of 19.7, or, conservatively, 19 lives saved as a result of the 189 improvements implemented through

December 2004. The risk-based fatalities for the pretreatment condition were calculated for the 33 grade crossings analyzed with fatal crash histories. The pretreatment risk in fatalities was determined by summing the annual risk for the 5 years before the date of the grade crossing treatment. The risk-based methodology calculated the total number of fatalities in the 5-year pretreatment condition to be 4.07 fatalities, or a rate of 0.81 fatalities per year.

The lives saved for the same set of crossings was determined from formula predictions. The posttreatment risk was calculated using the 5-future years from the date of the grade crossing improvement. The posttreatment risk in fatalities was determined by summing the annual risk for the five years after the date of the grade crossing treatment. The risk-based methodology calculated the total number of fatalities in the five-year posttreatment condition to be 1.94, or a rate of 0.39 fatalities per year. The calculated lives saved using the risk-based 5-year "before and after" conditions indicated that approximately 2.13 lives have been saved. Therefore, the rate of lives saved is equivalent to 0.43 lives per year. The results for both methods, the fatal crash analysis and the modified U.S. DOT formula, have trend results indicating a reduction of risk.

Phase I, II, and III risk for 1991 (before any treatments) and 2004 for the 189 treated crossings plus the 19 untreated crossings were compared. The results showed that between 1991 and 2004 the risk for the treated crossings was reduced by 50.9 percent or 2.04 lives saved per year. The entire corridor Phase I, II, and III risk, had it been completed by September 2004, would have been reduced by 57.3 percent for the same time period. The projected 2010 risk for Phase I, II, and III was 2.3 fatalities per year. The change of risk to highway occupants from 1991 to 2004 decreased by a substantial 51 percent and estimated to decrease 43 percent from 1991 to 2010, even with increases in vehicle and train traffic.

4 Lessons Learned

4.1 Findings Summary

The Sealed Corridor project employed several grade crossing warning technologies and techniques, each with varying degrees of effectiveness. These treatments were four-quadrant gates, long-arm gates, traffic channelization devices, video enforcement, crossing closures, grade separations, and health monitoring. These treatments were used individually and in combination to reduce risk of human injury and fatality resulting from grade crossing crashes.

The Sealed Corridor consists of 208 crossings, 189 of which have been upgraded and 19 are in the process of being upgraded. Before the project was started 85 gated crossings, four crossings with flashing lights, and 11 passive crossings existed. The most employed method of treatment was Long-arm gates, which occurred at 77 crossings. Long-arm gates solo were installed at 49 crossings, long-arm gates with heath monitoring were installed at 22 crossings, long-arm gates with median barrier at 3 crossings, and long-arm gates with median barrier and health monitoring at 3 crossings. The next most frequent grade crossing treatment was composed of four-quadrant gates, which were installed at 49 crossings. Four-quadrant gates solo were installed at 37 crossings, four-quadrant gates and health monitoring at 10 crossings, and four-quadrant gates, health monitoring and median barrier at two crossings. Grade separation occurred at one crossing and median barrier with health monitoring at seven crossings. Figure 14 shows the Sealed Corridor project crossing upgrade implementation schedule. Most of the upgrades were installed between 1998 and 2004.

Future activities include the installation of four-quadrant gates at four locations, median barriers at two locations, health monitoring at two locations, crossings closures at three locations, and eight remaining crossings with treatments yet to be determined. Completion of all pending crossing treatments will further reduce risk of human injury and fatality in the Sealed Corridor. Completion of the whole Sealed Corridor is scheduled for late 2008. Upon completion of the project, the most numerous treatments deployed will be crossings with longer arm gates, and crossings with four-quadrant gates.

Private crossings still need to be assessed. Predictions indicate that additional lives will be saved with the implementation of Phase IV, Private Crossing Safety Initiative (PCSI) [11].

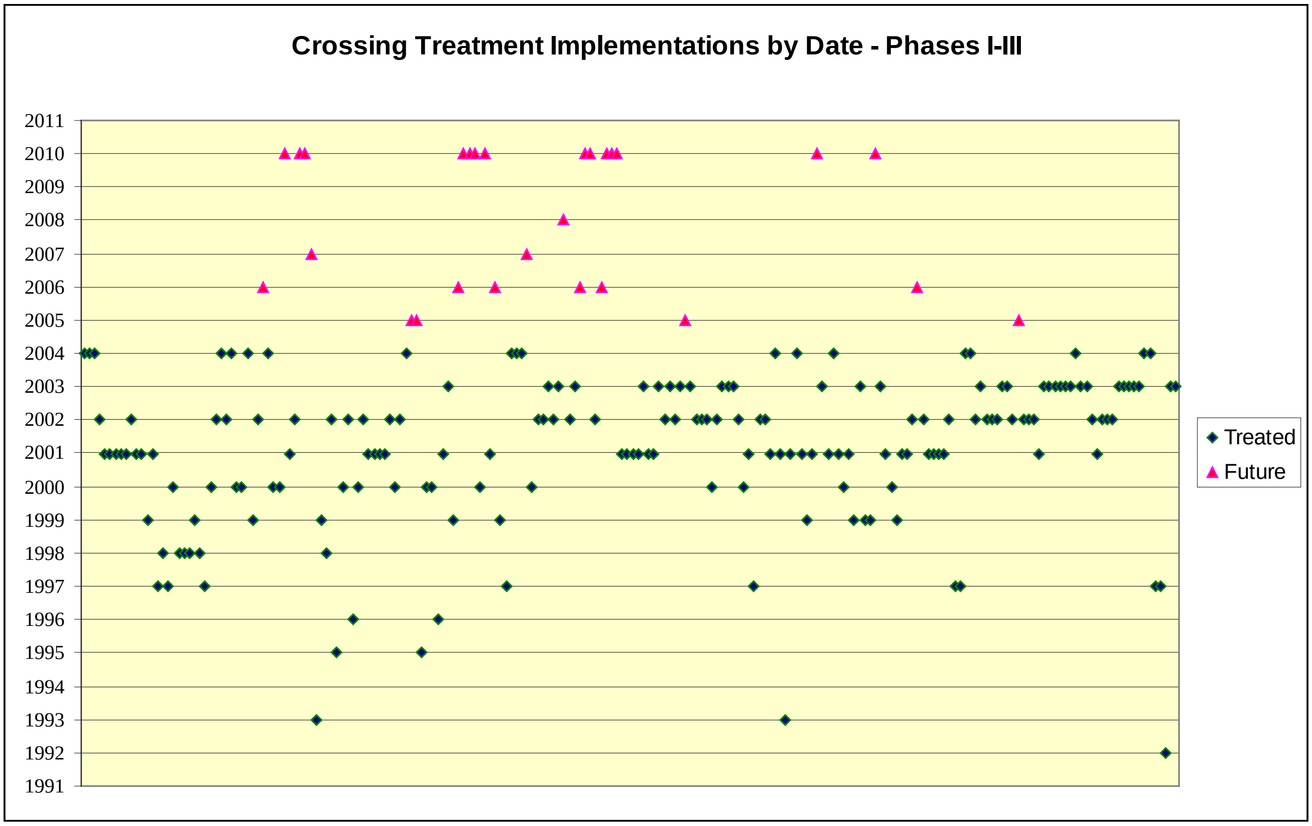

Figure 14. Project Implementations by Date

4.2 Effectiveness and Cost

The Sealed Corridor assessment study utilized information from FRA's Notice of Proposed Rulemaking on Railroad Horn Systems to determine the effectiveness of the devices employed. Although the results are preliminary, they provide a reasonable approximation of the effectiveness of such systems. Note that the cost estimated is based on the assumption that all warning device types can be installed at all crossings and that the average cost is the same at each crossing, regardless of crossing geometry. No extensive increase in maintenance costs is anticipated by NC DOT for the treatments used.

The numbers shown in Table 18 represent the effectiveness of the treatment in terms of expected risk reduction above the two-quadrant gate system. However, the actual change in risk at any particular crossing might be different depending on changes in variables such as AADT, train movements, or train speed.

Table 18. Effectiveness and Cost of Crossing Improvements

	Closure	Long Gate Arm	Traffic Channelization Devices	Video Enforce ment	4-Quad Gates	4-Quad Gates with Channelization	Grade Separation
Effectiveness *	100%	75%**	80%	72%	82%	92%	100%
Cost Estimate	$15K	$5K	$10K	$55K	$125K	$135K	$4M

*** Effectiveness over standard gates in reducing crashes taken from the FRA NPRM on Railroad Horns**
**** Volpe estimate based on FRA NPRM estimates of other supplemental safety devices**

Table 18 demonstrates grade separation and closure are the most effective applications at grade crossings, each with 100 percent effectiveness over and above gates. Once the crossing does not exist for highway vehicle travel the risk is reduced to zero. The cost of grade separation, however, is the most expensive while crossing closures is one of the least expensive measures to implement once local and community agreement have been reached.

Longer arm gates have proven to be a low-cost investment with a high rate of return in safety at crossings. An upgrade to longer arm gates achieved an almost comparable effectiveness to four-quadrant gates. A 75 percent reduction in crashes is assumed, but with an average cost of $5,000 per application which is 96 percent less in cost than four-quadrant gates. Considering the low installation cost, they are a cost-effective deterrence for violators at crossings.

Four-quadrant gates as an upgrade to two-quadrant gates have been proven to be an effective tool to reduce risky behavior at highway-rail intersections. This technique has been proven successful in Connecticut as well as North Carolina. As an upgrade to the standard two-quadrant gate system, the average cost per installation is $125,000. To install four-quadrant gates on passive crossings, the cost was estimated at $250,000.

Traffic channelization devices have proven to be a low-cost investment with a high rate of return in safety at crossings. These devices will cost an average of $10,000 per location and achieve 80 percent effectiveness in reducing crashes at grade crossings. They are the second least expensive of the applications to implement. The low maintenance cost of this device is also very attractive.

Video enforcement has the lowest effectiveness rate of the methods described here at reducing crashes over conventional gates at 72 percent based on highway-highway and highway-rail applications nationwide. The range of costs of the video enforcement system, when used at highway-highway intersections, is $40,000 to $70,000 per installation based on the ITS benefits/cost database. A midrange cost of $55,000 is used for this analysis.

The costs of grade separation, four-quadrant gates, and four-quadrant gates with channelization are the most expensive and effective applications deployed along the Sealed Corridor project.

4.3 Conclusions and Recommendations

This report documents the benefits of North Carolina's Sealed Corridor Program at highway-rail grade crossings. The specific route encompassing the Sealed Corridor consists of 173.3 miles of Norfolk Southern track that runs through Raleigh, Cary, Durham, Hillsborough, Burlington, Greensboro, High Point, Salisbury, Kannapolis, and Charlotte.

The total Sealed Corridor includes 216 crossings, 172 of which are public crossings and 44 are private crossings. This report assesses Phase I, II, and III of the Sealed Corridor program that encompasses rail lines that run between Charlotte and Greensboro with future predictions for reductions in fatalities through 2010. Several types of grade crossing treatments to reduce the risk of fatality were investigated by NC DOT. These grade crossing improvements included video monitoring and enforcement, four-quadrant gate systems, long arm gate systems, traffic channelization devices, health monitoring, and combinations thereof.

The North Carolina Sealed Corridor architecture is typical of the five originally designated high-speed rail corridors nationwide. The NC DOT corridor is typically single track including sidings and approximately one crossing per mile. The route carries 35 freight trains per day and approximately six daily passenger trains. It has a mix of public and private crossings, and the route contains both urban as well as rural environs and the railroad operating speeds fall within the track Class 4 category. Future plans for this corridor include operation at speeds up to 110 mph.

A review was conducted of the 189 treated crossings along the Sealed Corridor. The Sealed Corridor consists of 208 crossings, but 19 crossings have not been treated. The crash history for the Sealed Corridor indicates 282 crashes occurred between 1987 and September 2004. A total of 55 fatalities were reported for those 282 highway vehicle-train crashes. Examination of the accident reports of the 33 treated crossings with fatal accident histories was conducted. A total of 51 fatalities resulting from 40 crashes occurred among the treated crossings. Ninety percent of the crashes resulted from the driver of the vehicle driving around or through the grade crossing gates.

A fatal crash rate was determined for each of the 33 crossings that had a fatal crash history from 1987 through December 2004. The crash rate was distributed over the posttreatment period to obtain a value for lives saved in the posttreatment period through December 2004. The treatments to improve grade crossing safety at the treated crossings resulted in 19.7 lives saved through December 2004.

At least 19 lives have been saved

The fatal crash analysis method resulted in an estimate of 19.7, or, conservatively, 19 lives saved as a result of the Sealed Corridor improvements implemented through December 2004. The Modified USDOT APF estimated that the improvements implemented through 2004 are reducing fatalities by approximately 2.04 each year, or over two lives saved each year. The Modified USDOT APF predicted 9 fewer lives saved compared to the Fatal Crash Analysis results. This may be due to the fact that the APF contains more variables, and addresses the crossing environment risk.

The accident reduction result is sustainable

To estimate future accident reduction rates, the second of the above methods was used to ensure increases in train and vehicle exposure over time were considered in the analysis. Because vehicle traffic volume and frequency and speed of trains are expected to increase, the second method was used because it is capable of taking these factors into account.

Figure 15 shows the estimated annual fatalities under two conditions: (1) all 208 crossings have been treated (full build), and (2) without any improvements to the 208 crossings (no build). The graph shows a decrease in risk from 1992 to 1996 and an increasing risk with the introduction of the HSR. The graph shows the influence of the improvements, which were initiated in March 1995, on reducing the annual fatalities through the year 2004. The improvements at the remaining 19 crossings in the corridor were assumed to be implemented in 2008, resulting in a further reduction in annual fatalities. The gradual increase in traffic volume and train frequency from 2004 through 2010 is expected to gradually increase annual fatalities under all conditions. Finally, the increase in train speed to 110 mph, assumed to occur in 2010, would further increase all fatality rates.

The analysis of the NC DOT project provides support to the following recommendations**:**

- The crossings along the Sealed Corridor are also typical of conditions on the ten other high speed rail corridors designated under Section 104 (d) (2) of Title 23 U.S. Code. This suggests that similar plans for corridor grade crossing improvements be given serious consideration with high-speed rail upgrades in these corridors.

- The implementation of the North Carolina Sealed Corridor initiative is a demonstration of nonstandard corridor highway-railroad grade crossing improvements. The Sealed Corridor should be monitored to serve as a basis for assessing the potential impact of similar programs in other corridors.

- Assessment of Phase IV PCSI.

- Enhancement and implement the Volpe Center methodologies to additional high-speed rail corridors nationwide.

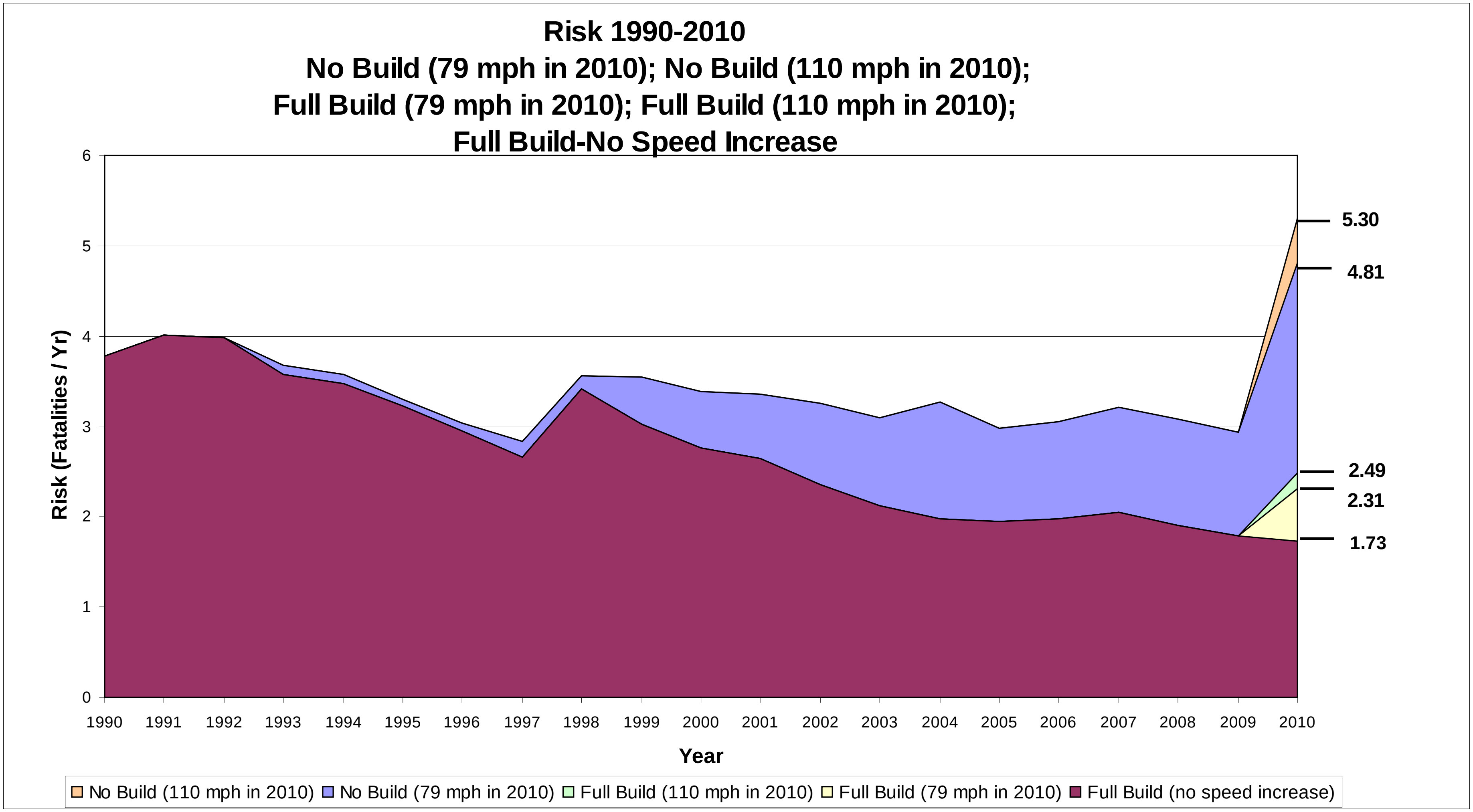

Figure 15. Risk Reduction through 2010 for Phases I, II, and III

5 Appendix A

Table A1. Phase I, II, and III Completed Treatments through September 2004

Crossing Number	Milepost	Road Name	Type Crossing	Upgrade*	Upgrade Date
630471D	56.7	Driver Street	Public	LG	3/1/2004
630472K	56.4	Plum Street	Public	LG	3/5/2004
630474Y	55.9	Ramseur Street	Public	LG/TS	5/20/2004
630477U	55.45	Dillard Street	Public	4Q/TS	3/26/2002
630646E	159.73	Royal Street	Public	LG/HM	5/22/2001
630647L	159.94	Beryl Road	Public	LG/TS	5/24/2001
630649A	160.64	Beryl Road Crossover	Public	CL	3/14/2001
630650U	161.33	Powell Drive	Public	LG	4/19/2001
630654W	162.42	Nowell Road (SR-1657)	Public	LG	9/10/2001
630655D	163.01	Bashford Road	Private	CL	3/26/2002
630657S	163.43	Old Trinity Road (SR-1655)	Public	3Q	8/13/2001
630662N	164.47	Ready Creek Road	Public	LG/MB	4/24/2001
633973A	160.77	Blue Ridge Road (SR-3072)	Public	4Q/TS	4/7/1999
643351A	164.2	NE Maynard Road	Public	4Q/TS	5/23/2001
715269G	335.8	Julian Road	Public	CL	11/5/1997
715270B	335.49	D Avenue	Public	CL	7/7/1998
715272P	335.4	C Avenue	Public	CL	4/15/1997
715273W	335.2	Klumac Road (SR-2541)	Public	LG	9/13/2000
715276S	334.97	Vance Avenue	Public	CL	10/20/1998
715277Y	334.91	Mildred Street Avenue	Public	CL	10/20/1998
715278F	334.85	Lumber Street	Public	CL	11/3/1998
715279M	334.72	East Harrison Street	Public	CL	8/17/1999
715280G	334.7	Crawford Street	Public	CL	10/20/1998
715282V	334.45	Knox Street	Public	CL	4/15/1997
715284J	334.2	East Monroe Street (SR-1703)	Public	LG/HM	9/19/2000
715285R	334.11	East Horah Street	Public	LG/HM	1/21/2002
715289T	333.77	East Council Street	Public	LG/MB/HM	3/17/2004
715290M	333.57	East Kerr Street (SR-2052)	Public	4Q/HM	2/22/2002
715301X	333.28	East Henderson Street	Public	4Q	4/5/2004
715302E	332.94	East 11th Street	Public	4Q/MB/HM	9/19/2000
715307N	330.18	Long Ferry Road (SR-2120)	Public	LG/HM	10/11/2000
715308V	329.76	Hackett Street (SR-2124)	Public	CL	3/15/2004
715312K	356.01	Elm Street	Public	CL	11/8/1999
715319H	356.3	Corban Avenue	Public	G/MB/HM	2/11/2002
715328G	362.97	Shamrock Road (SR-1160)	Public	4Q/MB	10/13/2004
715330H	363.95	Hickory Ridge Road (SR-1138)	Public	G/MB/HM	5/17/2000
715331P	364.12	Robinson Church Road (SR-1166)	Public	LG/HM	5/17/2000
715334K	365.62	Milbrook Road (SR-1182)	Public	LG/HM	10/29/2001
715338M	367.00	Stroup Farm Road	Public	LG	5/28/2002
715347L	370.21	Turner Crossing (SR-2841)	Public	CL	3/1/1993
715348T	370.71	Newell-Hickory Grove Rd (SR-2853)	Public	4Q	8/5/1999

Crossing Number	Milepost	Road Name	Type Crossing	Upgrade*	Upgrade Date
715350U	372.19	Orr Road	Public	LG	8/27/1998
715352H	374.02	East Sugar Creek Road (SR-2975)	Public	4Q/MB/HM	2/11/2002
715355D	374.3	West Craighead Road	Public	4Q/HM	3/27/1995
715356K	374.87	East 36th Street	Public	4Q	5/16/2000
722197X	324.29	Southern Railroad Rd (SR-1135)	Public	LG/HM	2/12/2002
722301P	321.3	Old Linwood Road (SR-1104)	Public	CL	4/1/1996
722302W	318.68	Prospect Drive	Public	4Q	2/9/2000
722303D	317.99	East 15th Avenue	Public	4Q	6/25/2002
722304K	317.84	East 13th Avenue	Public	CL	10/1/2001
722306Y	317.21	East 7th Avenue	Public	LG/MB/HM	6/13/2001
722309U	316.35	Pond Street	Public	CL	9/10/2001
722310N	316.2	Bristol Street	Public	CL	9/10/2001
722314R	313.09	Turner Road (SR-2005)	Public	G/MB	2/12/2002
722315X	311.99	Lower Lake Road (SR-2020)	Public	LG/HM	10/12/2000
722316E	311.18	Upper Lake Road (SR-2024)	Public	G/MB/HM	2/12/2002
722319A	307	Peace Street	Public	CL	1/2/2004
722320U	306.83	Boyles Street	Public	CL	12/15/1995
722322H	306.22	Loftin Street	Public	CL	12/15/1995
722323P	306.11	Fisher Ferry Street	Public	4Q/HM	2/3/2000
722324W	305.97	Salem Street (NC-109)	Public	4Q/HM	4/12/2000
722325D	305.6	College Street	Public	CL	5/24/1996
722327S	305	Turner Street (SR-2165)	Public	LG/HM	3/15/2001
722328Y	304.56	Unity Street (SR-2051)	Public	CL	1/13/2003
722332N	300.73	Prospect Avenue Street	Public	4Q/HM	11/4/1999
722352A	295.76	South Scientific St (SR-1332)	Public	LG/HM	8/8/2000
722355V	294.25	Oakdale Mill Road (SR-1352)	Public	4Q/HM	1/10/2001
722359X	291.67	MacKay Road (SR-1549)	Public	4Q/HM	2/10/1999
722362F	288.47	Boston Road	Public	CL	8/16/2004
722364U	288.26	Rail Street	Public	CL	8/16/2004
722365B	288.01	Rucker Street	Public	CL	8/16/2004
722374A	284.1	South Elm Street	Public	4G	7/28/2000
722812A	19.21	Lakeview Drive (SR-1349)	Public	LG	1/9/2002
722813G	19.43	South Glenn Raven Rd (SR-1523)	Public	LG	4/9/2002
722814N	20.63	Elmira Street (SR-1530)	Public	4Q	5/28/2003
722817J	21.36	Main Street	Public	4Q	11/18/2002
722906B	0.67	South Dudley Street	Public	4Q	2/25/2003
722954R	1.45	Gillespie Street	Public	LG	11/4/2002
722955X	1.83	North English Street	Public	4Q	5/30/2003
722959A	3.01	Franklin Boulevard (SR-3005)	Public	4Q	8/19/2002
722965D	4.54	Buchanan Church Road (SR-3028)	Public	LG	11/5/2001
722966K	4.92	Wagoner Bend Road (SR-3040)	Public	LG	9/26/2001
722970A	5.84	Four Mile Loop (SR-2827)	Public	CL	6/1/2001
722975J	7.6	Frieden Church Road (SR-2746)	Public	LG	10/24/2001
722976R	8.02	McLeansville Road (SR-2819)	Public	LG	5/30/2003
722978E	9.09	Carmon Road (SR-2755)	Public	LG	10/30/2001
722981M	10.74	Colony Road (SR-2800)	Public	MB	10/24/2001

Crossing Number	Milepost	Road Name	Type Crossing	Upgrade*	Upgrade Date
722982U	11.44	Cullen Road (SR-2801)	Public	LG	2/26/2003
722983B	11.97	Bell Road (SR-2764)	Public	CL	9/25/2002
722984H	12.81	Wagoner Road (SR-2724)	Public	LG	3/3/2003
722986W	13.67	Power Line Road (SR-2763)	Public	LG	1/23/2002
722987D	14.42	East Joyner Street	Public	LG	5/30/2003
722990L	14.87	Springwood Avenue (SR-2748)	Public	LG	5/30/2003
722991T	15.51	Huffines Street (SR-1310)	Public	LG	1/23/2002
722992A	15.87	Cook Road (SR-1311)	Public	LG	1/23/2002
722993G	16.36	Church Street	Public	LG	8/14/2002
722994N	16.66	South Holt Avenue	Public	CL	8/11/2000
722995V	16.73	Williamson Avenue (SR-1301)	Public	4Q	8/14/2002
722996C	17.05	Antioch Avenue	Public	CL	8/18/2003
722997J	17.26	Oak Avenue (SR-1323)	Public	4Q	5/30/2003
722998R	17.91	York Road	Public	LG/MB	5/30/2003
723001E	18.16	Gilliam Road (SR-1342)	Public	LG	2/12/2002
724362M	336.24	Henderson Grove Road (SR-1526)	Public	LG/HM	11/8/2000
724367W	337.98	Peach Orchard Road (SR-2539)	Public	LG/HM	3/13/2001
724368D	338.19	Peach Orchard Lane (SR-2545)	Public	CL	1/31/1997
724369K	338.4	Peeler Road (SR-2538)	Public	G/MB/HM	2/11/2002
724374G	340.07	Webb Road / SR-3490 (SR-1500)	Public	G/MB/HM	2/11/2002
724376V	340.96	Mt. Hope Church Road (SR-1505)	Public	LG/HM	10/24/2001
724381S	342.67	East Liberty Street	Public	CL	12/28/2004
724382Y	342.86	East Church Street (SR-1337)	Public	LG/HM	2/21/2001
724383F	343.01	Ketchie Street	Public	CL	1/4/1993
724384M	343.2	East Centerview Drive	Public	LG/HM	2/26/2001
724386B	343.55	Chapel Street	Public	CL	5/12/2004
724388P	343.94	West Thom Street (SR-1232)	Public	LG/HM	2/26/2001
724389W	344.18	Bostian Road (SR-1221) (Elm St)	Public	CL	11/8/1999
724390R	344.44	Eudy Road (SR-1220)	Public	LG/HM	2/26/2001
724394T	345.61	East Ryder Avenue (SR-1210)	Public	LG/HM	4/16/2003
724395A	345.69	East Mills Street	Public	LG/HM	6/12/2001
724396G	346.07	East Round Street	Public	CL	10/11/2004
724397N	346.82	East 29th Street	Public	LG	10/8/2001
724398V	347.28	East 22nd Street (SR-1254)	Public	LG/MB/HM	10/11/2000
724399C	347.55	East 18th Street	Public	LG/HM	7/23/2001
724400U	348.1	Ebenezer Road (SR-1267)	Public	CL	4/12/1999
724404W	349.1	East 1st Street (SR-1706)	Public	4Q	2/24/2003
724405D	349.38	East C Street	Public	CL	4/12/1999
724407S	350.28	Plymouth Street (SR-2048)	Public	CL	4/12/1999
724410A	352.72	Winecoff School Road (SR-1790)	Public	4Q	5/27/2003
724415J	354.7	Winecoff Avenue (SR-1397)	Public	CL	11/4/2001
724418E	355.12	McGill Avene (SR-1394)	Public	4Q/HM	2/22/2000
724419L	355.35	Misenheimer Drive	Public	CL	11/8/1999
734735L	58.98	Glover Road (SR-1940)	Public	LG	10/17/2001
734736T	59.28	Wrenn Road (SR-1955)	Public	LG	10/3/2001
734737A	60.27	Ellis Road (SR-1954)	Public	G/MB	5/14/2002

Crossing Number	Milepost	Road Name	Type Crossing	Upgrade*	Upgrade Date
734740H	61.58	IBM Driveway (SR-2029)	Public	G/LGC	1/1/2006
734742W	62.83	Cornwallis Road	Public	4Q	9/9/2002
734746Y	64.57	Hopson Road	Public	LG	10/3/2001
734748M	65.29	Church Street (SR-1980)	Public	LG	10/3/2001
734749U	66.5	Barbee Road (SR-1706)	Public	LG	10/3/2001
734750N	67.02	McCrimmon Parkway (SR-1635)	Public	LG	10/17/2001
734751V	67.75	Long Beverage Road	Private	LG	4/30/2002
734752C	68.66	Ashe Street	Public	CL	1/30/1997
734753J	68.78	Morrissville Carpenter Road	Public	4Q/HM	1/23/1997
734755X	72.58	North Harrison Street (SR-1652)	Public	4Q	3/15/2004
734756E	72.7	Academy Street (SR-1312)	Public	4Q	3/15/2004
735138H	33.33	Walton Crossing	Public	CL	6/26/2002
735141R	34.11	Buckhorn Road (SR-1114)	Public	LG	3/17/2003
735142X	35.69	Redman Crossing (SR-1399)	Public	LG	1/9/2002
735143E	36.71	Grimes Chapel Road (SR-1316)	Public	LG/HM	1/8/2002
735145T	37.31	Mt. Willing Road (SR-1120)	Public	LG	1/16/2002
735151W	40.36	West Hill Avenue (SR-1161)	Public	LG/HM	2/11/2003
735152D	40.61	Bellevue Street (SR-1172)	Public	LG/HM	2/11/2003
735157M	41.2	Fairbault Lane (SR-1149)	Public	LG	1/8/2002
735189T	43.89	Byrdsville Road	Public	LG	9/16/2002
735191U	46.28	University Station (SR-1712)	Public	LG	1/8/2002
735192B	47.07	Mt. Herman Church Rd (SR-1713)	Public	LG	1/8/2002
735202E	50.2	Neal Road	Public	LG	10/17/2001
735205A	52.04	North LaSalle Street	Public	4Q	7/31/2003
735223X	53.76	Swift Avenue (SR-1322)	Public	4Q	7/31/2003
735225L	54.2	Buchanan Boulevard	Public	LG	7/9/2003
735227A	54.6	South Duke Street (SR-1445)	Public	2G	7/31/2003
735229N	55.09	Blackwell/Corcan Street	Public	4Q	7/31/2003
735231P	55.14	Mangum Street (US-15)	Public	2G	7/31/2003
735236Y	57.57	Ellis Road (SR-1954)	Public	4Q	3/5/2004
735443T	21.86	Gilmer Street	Public	4Q	3/10/2003
735445G	22.6	Queen Ann Street	Public	4Q	5/30/2003
735448C	23.17	Washington Street (SR-1716)	Public	4Q	2/28/2002
735456U	23.67	Pomeroy Street (SR-1719)	Public	LG	12/3/2001
735462X	26.02	Stone Street (SR-1935)	Public	LG	1/9/2002
735464L	29.36	Gibson Road (SR-1940)	Public	LG	11/4/2002
735465T	29.83	Lake Latham Road (SR-1976)	Public	4Q	9/19/2002
735468N	30.69	Moore Road (SR-1965)	Public	LG	3/11/2003
735469V	31.46	Third Street (SR-1962)	Public	4Q	5/30/2003
735471W	31.56	Fourth Street	Public	LG	3/13/2003
735472D	31.64	Fifth Street (NC-119)	Public	4Q	3/18/2003
735474S	32.79	Mattress Factory Road? (SR-1402)	Public	LG	3/17/2003
736173A	63.98	Northern Telecom Road	Private	CL	6/15/2004
736223B	61.8	IBM Access Road	Private	CL	1/6/2004
736238R	297	North Pendleton Street	Public	G/MB	8/7/1997
904436A	69.7	Morrisville Parkway	Public	G/MB	1/15/1997

Crossing Number	Milepost	Road Name	Type Crossing	Upgrade*	Upgrade Date
910579L	52.56	West Durham Lumber Company	Private	LG	10/7/1992
910594N	53.21	Anderson Street	Public	4Q/TS	9/16/2003
910605Y	55.5	Fayetteville Street (SR-1118)	Public	4Q	7/31/2003

*Note: 4Q – Four quadrant gates, TCD – Traffic Channelization Devices, LG – Long gates, CL – Closure, GS – Grade Separation, VE – video Enforcement, HM – Health Monitoring.

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Acronyms

AADT	Annual Average Daily Traffic
APF	Accident Prediction Formula
CSX	CSX Corporation
DOT	Department of Transportation
FRA	Federal Railroad Administration
HSR	High-Speed Rail
ISTEA	Intermodal Surface Transportation Efficiency Act
NC DOT	North Carolina Department of Transportation
PCSI	Private Crossing Safety Initiative
RAIRS	Railroad Accident Incident Reporting System
SEHSR	Southeast High-Speed Rail Corridor"
TSS	Traffic Separation Study
TEA-21	Transportation Equity Act for the 21st Century
U.S. DOT	United States Department of Transportation
Volpe Center	John A. Volpe National Transportation Systems Center